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ТЕМАТИЧЕСКИЙ РЕФЕРАТИВНЫЙ СБОРНИК № 21-2

“Radar Waveform Processing”
(«Обработка РЛ сигналов»)

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"Waveform-agile mimo radar for urban terrain tracking"

We investigate the problem of tracking a moving target in urban terrain using a multiple-input and multiple-output (MIMO) radar system. Our proposed method aims to maximize the target information using an optimal configuration of MIMO widely-separated radar sensors while exploiting multipath returns from all the sensors. Furthermore, we adaptively configure the parameters of the transmit waveforms of the MIMO system at each time step in order to minimize the overall mean-squared tracking error. We demonstrate our results using a realistic urban environment, by varying the regions of obscuration and the number of bounce path returns. An important advantage of the MIMO system is that, based on the radar configuration, it is possible to completely eliminate the obscuration regions. [C1]

"Stepped delay noise radar with high dynamic range"

In the paper we propose and analyze an alternative approach to evaluation of cross correlation function in Noise Radar enabling drastically enhance dynamic range of wideband noise radar with digital signal processing. The approach is based upon digital generation of both sounding and reference signals using fast enough Arbitrary Waveform Generator (AWG) with the required delay and coherent analog reception of the radar returns. Both signals may be up converted to the required carrier frequency. Cross-correlation between the reference and radar returns is to be realized at the carrier frequency using analog mixer and low pass filter. In the paper we describe the new approach and compare it with the conventional one. [C2]

"Noise Waveform SAR for 2D and 3D imaging"

Generation of high resolution two-dimensional (2D) and three-dimensional (3D) images in short range applications with the help of coherent radar is the main objective of the paper. Conventional SAR generates 2D image using combination of range compression and 1D aperture synthesis via azimuth (cross-range) compression. The range resolution is limited by the signal spectrum width, while cross-range resolution is defined by the signal wavelength to synthetic aperture length ratio. We suggest applying 2D aperture synthesis that implies cross-range compression technique in both dimensions to generate 2D coherent images. Application of noise waveform with wide enough power spectrum bandwidth enables generation of 3D images of radiotransparent objects, such as trees, bushes, interior of rooms, etc. We present results of modelling of noise waveform radar with 1D and 2D aperture synthesis having various configurations of planar 2D synthetic aperture and results of experiments aimed on SAR imaging with continuous noise waveform and 2D synthetic aperture. [C3]

"Classification of LFM radar signals based on the wavelet decomposition and the neural LVQ classifier"

The paper presents a novel approach, based on wavelet decomposition, to automatic classification of signals with the linear frequency modulation (LFM), generated by a radar emitter. The goal of radar transmitter classification is to determine the particular transmitter from which a signal originated, using only the received waveform. To categorise a current signal to the particular transmitter, the discrete wavelet decomposition of the signal is accomplished. The Learning Vector Quantisation (LVQ) algorithm is proposed as the intelligent classification algorithm. [C4]

"Design and implementation of a highly configurable low power robust signal processor for portable ground based "multiple scan rate" surveillance radar"

FPGA based realization of a highly configurable low-power robust signal processor for a portable ground-based multiple scan ratesurveillance radar is presented. Portability feature of the radar demands a compact radar system which should be able to detect low flying aerial targets against clutter/interference background. All

requirements could be met in a FPGA-based design of a multi-channel signal processor to cater for low peak power large bandwidth waveforms, separate processing for special targets and an embedded softcore processor. Reliable self-test mechanisms-external as well as internal have been built into the signal processor for functional verification of entire radar system. [C5]

"A MIMO radar for Sense and Avoid function: A fully static solution for UAV"

Up to now, UAV are employed in crisis or war times. For training purposes, some areas are especially attributed for UAV deployment in a limited space area and in a limited time slot. In the future, both for emerging civilian applications and for training purpose, these limitations will no longer be acceptable and UAV will have to be inserted in the general air traffic. Thus, "Sense and Avoid" systems will be mandatory. The radar is the most pertinent non-cooperative "all-weather" sensor because it provides, by essence, accurate ranging, direction and closing speed. In this paper, we propose a low cost radar solution based on the coherent "MIMO" principles. This design allows the implementation of the radar within the UAV airframe without any moving part. [C6]

"Development milestones in 24 GHz automotive radar systems"

Driving a car means a dangerous task! There are about 5000 fatalities on German streets every year, which are absolutely too many. Drivers have strong limitations in the ability to measure precisely the distance and the speed difference between cars, which is the reason for several accidents. Therefore some assistance is needed. There is large progress in waveform and system design as well as in MMIC chip development for 24 GHz radar sensor technology [4]. [C7]

"Stepped-frequency noise radar with short switching time and high dynamic range"

Stepped frequency technique is in wide use in radar. Narrow frequency bandwidth of the transmitted signal is an attractive feature of this technique which enables application of rather slow sampling rate. In this case, high-bit and cost effective ADCs are readily availability. However, this technique also has some drawbacks, such as: (a) Ambiguity in range measurements; (b) High level of range side lobes; (c) Low resistance against narrowband coherent interferences. To go around these drawbacks we suggest application of random waveforms with synthesized spectrum. In this case the ensemble of the probing signals realizations can be produced in different ways: (1) Stepped variation of a single frequency signal over a discrete frequency mesh according to a random law, i.e. frequency hopping with random frequency hops; (2) Step-like increase of the central frequency of a narrow band random signal over a discrete mesh of frequencies; (3) Frequency hopping of a narrow band random signal according to a random law, i.e. random frequency hopping of random signals. [C8]

"Designing sparse frequency waveform using iterative algorithm"

Sparse frequency waveform with stopbands sparsely distributed over a larger spectrum band is desired in many radar and communication systems operated in a highly congested spectrum environment. In this paper, a new method for designing sparse frequency waveform with sidelobe constraint is proposed. The basic idea is to construct a penalty function based on both the Power Spectrum Density requirement and the sidelobe requirement and then minimize it through an iterative algorithm. The proposed new method is efficient in computation and can design sparse frequency waveform with large dimensions. Numerical studies with design examples illustrated the efficiency of the proposed method. [C9]

"Weak signal detection using compressive receiver"

Nowadays modern radar uses more and more complex waveforms. Some waveforms are developed intentionally to make their intercept almost impossible. The main distinctive features of modern radar signal are hidden in its time-frequency structure. In the near past the problem of radar signal feature extraction was considered in time or frequency domain separately, because radar waveforms were relatively simple. Today, however, the signals should be observed simultaneously in both domains. Time-frequency distribution concept offers a new approach in radar signals classification/identification. The paper presents some results of weak, pulsed and continuous radar signals detection by the use of compressive receiver. [C10]

"Admittance inversion of crosshole radar data"

In this paper, a new inversion approach has been proposed using the ratio of two mutually orthogonal components of recorded electric and magnetic fields: apparent admittance. This study aims at the development of a full waveform inversion algorithm in two-dimension (2D) without the precise knowledge of source functions and without any compensations of 3D nature of radar wave propagation. To alleviate local minima problems, we developed a data weighting method based on the data misfits. The developed inversion approach was firstly

demonstrated through inverting 2D FDTD simulation data of crosshole radar survey with false source signatures. Further demonstrated was that the numerical data simulated in the 3D space could be inverted by the proposed 2D algorithm with the 2D FDTD forward modeling. All numerical experiments showed that the material property distribution with remarkably high accuracy can be calculated in spite of the lack of the accurate source information and no compensations of the characteristics of radar wave propagation in 3D space. [C11]

"Symmetry based 3D GPR feature enhancement and extraction"

The efficient analysis of high-resolution 3D GPR data sets is of increasing importance given todays possibilities to acquire large and dense data volumes. In order to reduce data complexity and enhance the features of interest, attribute based analysis, a well-established field in reflection seismology, has received growing interest also in the GPR community. Here, we present a novel GPR attribute called phase symmetry, which is adapted from image processing. We believe that this attribute is well-suited for analyzing 3D GPR data sets. In this study, we introduce the basic concepts of phase symmetry. Using two synthetic examples and comparing phase symmetry to the well- known Canny edge detector, we illustrate that phase symmetry also provides high quality results in the presence of significant noise and smoothly varying anomalies. Using two 3D GPR field examples collected to detect buried utilities and archaeologically relevant features, respectively, demonstrates the applicability of phase symmetry to real GPR data and illustrates that this attribute is an effective tool in order to extract symmetric features embedded within a heterogeneous background. Additionally, we show that phase symmetry can be combined with the similarity attribute to jointly emphasize event symmetry and waveform similarity. [C12]

"Recent advances in RF tomography for underground imaging"

Underground imaging for tunnel detection is proposed using the principles of radio frequency (RF) tomography. In RF tomography, a set of distributed transmitters and receivers are deployed arbitrarily above the ground, or slightly buried. These transmitters radiate suitable narrowband, low-frequency waveforms into the ground. The resulting wavefront impinges upon underground objects, scattering electromagnetic energy in all directions. Receivers sample the scattered signal, mitigate direct-path leakage, retrieve the phasor of the scattered signals, and relay this information to a base station. After adaptive processing of measured data, an image of the underground facilities is achieved. [C13]

"Petroleum industry techniques yield new insights into 3D GPR data"

We have adapted petroleum industry technologies to 3D GPR datasets from a variety of geological and archaeological settings. Seismic attribute analysis designed for 3D seismic volumes of oil fields has been used to map a 19thcentury cemetery and to prepare a Roman archaeological site for detailed study by mapping the prior disturbances of the site. Specific seismic attributes that we have successfully applied include connectedness ("geoanomalies"), semblance (or dissimilarity), volume rendering (transparency visualization), and waveform classification. An especially powerful strategy is to use two or more attributes simultaneously via volume rendering that allows multiple visualizations. [C14]

"High-resolution imaging of a vineyard in south of France using ground penetrating radar and electromagnetic induction"

GPR and EMI surveys were carried out in a vineyard in southern France in order to produce high-resolution maps of soil stratigraphy and to retrieve soil hydrogeophysical properties of the different soil layers. The preliminary results presented in this paper show large spatial variations of the vineyard soil properties, which are in accordance with the distribution of the different soil types within the study area. This is particularly observable from soil electrical conductivity data, which show strong spatial correlation with large areas of comparable values delimited by well-defined discontinuities, revealing sharp variations of soil characteristics over short distances. These discontinuities almost systematically correspond to the limits of the vineyard plots, though areas of contrasted soil electrical conductivity values are also found within some plots. Furthermore, the patterns of soil electrical conductivity are in good agreement with soil stratigraphy observed from GPR measurements. Finally, these results also highlighted compaction as a likely explanation to vine vigour problems observed locally in the vineyard. Future work will focus on the full-waveform inversion of GPR and EMI data to retrieve the properties of the different soil layers and to investigate the spatial variation of soil water availability in the study area, and provide on this basis recommendations for the vineyard management. [C15]

"The use of high speed FIFO chips for implementation of a noise radar"

An ultra wide band spread spectrum radar (a noise radar) can be built using a system that generates two wide band spread spectrum (pseudo-random) waveforms. One waveform is transmitted by the system and one

waveform is used to correlate against the received signals. Because of system dispersion, propagation channel dispersion and radar target dispersion, it is often appropriate for the receive correlation waveform to be of a different form than that of the transmitted waveform. Thus a noise radar often needs to be able to generate two different wide band waveforms with controlled differential delay time. This paper will discuss the implementation of such a system using commercially available FIFO microchips. [C16]

"Investigation of the frequency dependent antenna transfer functions and phase center position for modeling off-ground GPR"

We compared different methods to estimate the phase center of an ultra wideband ground penetrating radar (GPR) horn antenna operating off-ground, namely, (1) extrapolation of peak-to-peak reflection values in the time domain and assuming a fixed phase center, and (2), frequency-domain full-waveform inversion assuming a frequency dependent phase center. For that purpose, we performed radar measurements at different heights above a perfect electrical conductor (PEC). A double ridged horn antenna operating in the frequency range 0.8-5.2 GHz was used. In the limits of the antenna geometry, we observed that antenna modeling results were not significantly affected by the position of the phase center, even when considering frequency dependence. This implies that the transfer function model used to model the antenna inherently accounts for the phase center position. This analysis showed that the proposed antenna model avoids the need for the frequency dependent phase center determination and is valid for any applications where the field measured by the antenna can be considered as coming from a distance larger than the antenna aperture itself, such as for off-ground GPR or telecommunications. [C17]

"Full-waveform modeling of ground-coupled GPR antennas for wave propagation in multilayered media: The problem solved?"

We propose a full-waveform approach for modeling time and frequency domain, off-ground and on-ground radars for wave propagation in multilayered media. The radar antennas are modeled using an equivalent set of infinitesimal electric dipoles placed over the antenna aperture. The linear relations between the fields in the transmission line, the sources, and the backscattered fields over the antenna aperture are expressed in terms of frequency dependent, global reflection and transmission coefficients, which are characteristic to the antenna. The interactions between the antenna and the layered medium are thereby accounted for. Far-field and near-field measurements are used to determine these antenna coefficients. The fields over the antenna aperture are calculated using three-dimensional Green's functions. We validated the approach using measurements with a 900 MHz centre frequency transmitting and receiving antenna situated at different heights above a copper plane. For heights larger than the antenna, a single point source and receiver was sufficient for accurately modeling the radar data. For smaller distances, using six sources and receivers provided remarkably good results. Although some simplifications were made in this paper, the proposed method shows great promise for characterizing multilayered media using full-waveform inversion, with very limited computation time compared to numerical methods. [C18]

"A novel analytical method and error criterion of the synthetic range profile"

In this paper, a novel method to analyze the distortion of a synthetic range profile (SRP) is put forward, which is simpler and more effective, and more importantly it can be available for the present existing any synthetic wideband waveform (SWW) forms. At the same time, since the traditional error criterion of the SRP for the stepped frequency waveform (SFW) is the quadratic phase error criterion, which has some inherent faults for any synthetic wideband waveforms, a modified error criterion is proposed to overcome such shortcomings. Specific conclusions are investigated with some simulations. [C19]

"Time-domain calibration technique for ultra-wide instantaneous-bandwidth vector waveform generation using parallel I/Q channels"

An architecture for generating ultra-wide instantaneous-bandwidth vector waveforms by combining the spectra of multiple I/Q sub-channels is described. Each sub-channel consists of an I/Q modulator driven by a pair of digital-to-analog converters. A time-domain calibration technique is described that uses the measured channel response to equalize the sub-channels. The overall response of the combined system is realized by properly controlling the phases of the corrected I/Q sub-channels. Examples of wideband vector waveforms generated using the combined system will be given. [C20]

"Active beamforming with interpolated FIR filterin"

The interpolated FIR (IFIR) radar was recently introduced in the context of MIMO radar theory. It was shown that

this system has a signal to clutter ratio intermediate between those of the SIMO and MIMO radars. This paper considers the optimal design of the active IFIR beamformer in presence of jammers. It is shown that this beamformer can achieve beamwidths as sharp as those of colocated MIMO radars with full-length virtual arrays. At the same time, the extra complexity of MIMO radars, which arises from use of multiple transmitter waveforms and several sets of receiver matched filter banks, is not present in the IFIR realization. Design examples for IFIR radars which optimize the receiver beamforming weights in presence of jammers for fixed transmitter are also presented. [C21]

"High-repetition and -stability all-solid state pulsers based on avalanche transistor Marx circuit"

Ultra-wide spectrum (UWS) pulser, in which avalanche transistor is used as its switch, can generate high-repetition and -stability short-pulse, but its power is sharply lower than that of SOS and Tesla generators. Marx circuit is used to increase the power of this type of pulser. Different charged-capacitance and class of Marx circuit determines different waveform and peak-power of output pulse. 20-class and 30-class avalanche transistor Marx circuit pulsers are designed, and the charged-capacitance is 100 pF and 470 pF, then 4 types of waveform are get. The highest output peak-voltage is 2.9 kV, the highest repetition can reach 70 kHz, and keep a better pulse stability, jitter is less than 40 ps. [C22]

"Human detection and tracking via Ultra-Wideband (UWB) radar"

This paper presents an algorithm for human presence detection and tracking using an Ultra-Wideband (UWB) impulse-based mono-static radar. UWB radar can complement other human tracking technologies, as it works well in poor visibility conditions. UWB electromagnetic wave scattering from moving humans forms a complex returned signal structure which can be approximated to a specular multi-path scattering model (SMPM). The key technical challenge is to simultaneously track multiple humans (and non-humans) using the complex scattered waveform observations. We develop a multiple-hypothesis tracking (MHT) framework that solves the complicated data association and tracking problem for an SMPM of moving objects/targets. Human presence detection utilizes SMPM signal features, which are tested in a classical likelihood ratio (LR) detector framework. The process of human detection and tracking is a combination of the MHT method and the LR human detector. We present experimental results in which a mono-static UWB radar tracks human and non-human targets, and detects human presence by discerning human from moving non-human objects. [C23]

"A communication waveform for radar"

This paper discusses some opportunities created by using Orthogonal Frequency Division Multiplexing signals for radar and communication at the same time. Two examples of opportunities in radar are proposed, i.e. solving the unambiguous radial speed in a single transmission and improving the signal-to-background contrast. The performance of the data link is analyzed and shown to be useful. [C24]

"Research of Portable Community-Oriented Health Monitoring"

A new kind of wrist-worn health monitoring terminal is developed to realize multi-parameter measurement, wearing facilitates and reliable data transmission. The physiological parameters includes body temperature, pulse rate, breath rate and waveform, blood pressure, electrocardiograph(ECG), electroencephalogram(EEG) and the level of blood glucose real-timely. This terminal is designed by modules, which includes intelligent processing module based on MSP430, electrodes for collecting the physiological signals and electric circuit module for signal preprocessing, wireless data transmission module based on GPRS. The terminal is able to analyze the above signal. The terminals can be formed as a network based on wireless transmission. Credible and portable terminal for life indication is realized by developing micro-sensor and integrated modules for signal detecting and processing. Amounts of clinic tests have been done and the results have been approved by the doctors in hospitals and patients. [C25]

"Robust waveform design for MIMO radars"

The problem of robust waveform design for multiple-input, multiple-output radars equipped with widely-spaced antennas is addressed here. Robust design is needed as a number of parameters are unknown, e.g., the target scattering covariance matrix and, possibly, the clutter covariance matrix. A min-max approach is proposed, so that the code matrix is designed to minimize the worst-case cost (or equivalently maximize the corresponding figure of merit) under all possible target (or target and clutter) covariance matrices. Surprisingly, the same min-max solution applies to many commonly adopted performance measures, such as the average signal-to-clutter-plus-noise ratio, the mutual information between the received signal echoes and the unknown target response, and the approximation of the detection probability in the high- and low-signal regimes. [C26]

"Ambiguity function analysis for MCPC radar signal"

The MCPC signal using Orthogonal Frequency-Division Multiplexing structure has caught much attention of researchers recently since it has good anti-jamming capability, high spectrum efficiency and simple digital processing. This paper deduces ambiguity function expression of MCPC radar signal analyses its performance and discuss the influence of individual parameter on ambiguity function in both range and Doppler domain. Derived conclusion can provide theoretical basis for the waveform design and signal processing of the MCPC signal. [C27]

"Design of prospective spaceborne multi-aperture UWB polarimetric high performance SAR system"

Multi-aperture synthetic aperture radar (SAR) systems ensure high performance SAR imaging that is unachievable for conventional SAR. Application of modern technological capabilities in ultra-wide-band radar signals digital forming and processing (including optional modulation modes) enables realizing high performance characteristics and using operational flexibility of the SAR system. This report presents technical pattern and characteristics of the SAR, that is based on segmented polarimetric wide-band active phased array and multichannel digital subsystem for signal parameters control. The system uses technologies of 'multidimensional waveform encoding' for transmitted signal and 'digital beam forming' (DBF) for echoed signal receiving. The design main qualitative characteristics are estimated for multichannel remote sensing modes. [C28]

"Comparison of classical and orthogonal UWB waveforms for radar applications"

In this paper, classical UltraWideband (UWB) waveforms and orthogonal functions (Hermite and Gegenbauer) for radar applications are proposed. The use of this emergent technology in radar applications domains allows the development of compact and low-cost radars with multiple fields of application in daily life. In many classical UWB radar systems, only Gaussian and monocycle pulses are used. UWB waveforms based on orthogonal functions (Hermite and Gegenbauer) are proposed for there good resolution adapted more to radar detection function. There multiple access capacity due to their orthogonality presents an important advantage of these waveforms. This study proposes to compare these waveforms to Gaussian and monocycle pulses with simulations for short range avoidance collision radar application. [C29]

"A software defined UMTS passive radar demonstrator"

Passive radar systems, also referred to as Passive Coherent Location systems (PCL), exploit non-cooperative illuminators of opportunity (IO) in order to detect and track targets. Some of the main advantages of such systems with respect to conventional radars include low cost architectures, low energy requirements, the capability of operating without any spectrum resource allocation and a potentially null probability of intercept. In this paper, we introduce a passive radar demonstrator based on the use of UMTS (Universal Mobile Telecommunications System) signals as a source of opportunity. An overview of the UMTS standard and some preliminary measurements are firstly presented in order to verify the suitability of the UMTS waveform for radar applications. Secondly, a low cost software defined experimental radar system is introduced together with a measurement scenario. Finally, some live data detection results are presented and discussed in order to demonstrate the capability of this passive radar system. [C30]

"New challenges for PCL system: 3D requirements and "Optimal" resources management for PCL air traffic survey"

For more than 15 years, the interest for PCL (Passive Coherent Location) system has been growing. It began with the analog waveforms like TV [1] and FM [2, 3], nevertheless it quickly appears that the recent digital waveforms (using COFDM modulation) could offer new interesting capabilities especially for range resolution. Despite the interesting recent progress related to these digital waveforms like the compulsory development of a specific zero-Doppler path cancellation filter [2, 4] especially for SFN mode, some new additional requirements mentioned by several potential users [5, 6] of such PCL system have appeared: • Such PCL systems are generally considered as complementary sensors for low altitude coverage. As a consequence, these systems should provide an altitude estimation and especially for these low altitude targets. • On other hand, it is also important to manage and chose the most suitable donors in a given area in order to "optimise" the system definition according to our objectives. This paper will illustrate some experimental results for site estimation using DVB-T transmitters in SFN mode. The signals are received on a 2D array. Then a brief comparison of the mutual and specific benefits expected for the main civilian broadcasters (FM, DAB, DVB-T) will be provided. [C31]

"A Comparative analysis of two wide-band rational approximations for input impedance of antennas"

Asymptotic waveform evaluation technique and the Neville-type Stoer-Bulirsch algorithm are investigated and compared as the tools for efficient performance evaluation of antennas with emphasis placed on their input impedance over a wide frequency band. Numerical results are given for a helical antenna with a truncated-cone reflector. [C32]

"3 GS/s S-Band 12 bit MuxDAC on SiGeC technology"

In advanced applications such as digital radar, Ultra Wide Bandwidth communications and software defined radio, the need for instantaneous bandwidth often drives system design decisions. Access to high speed data converters enabling up and down conversion directly in the L Band and S Band removes the limit imposed by bandwidth scarcity and allows the design of flexible and simplified system architectures. Broadband DAC's (Digital to Analogue Converters) are key enabling components which open up new design opportunities for digital Synthesizer systems. In this regard, this paper describes a new 12 Bit 3GS/s DAC, based on a 200 GHz SiGeC bipolar Technology, which enables direct synthesing of 1GHz arbitrary waveforms directly in the high IF (S_Band) region closer to the Antenna. [C33]

"Complex radar signal source for radar receivers testing"

This paper presents a design of a Radar Signal Generator (RSG) for radar receivers testing and development (i.e. receiver dynamic measurement, pulse compression modules). RSG is a multifunction flexible radar signal source generating multichannel coherent signals with reference signal for radar station and the other auxiliary signals and noise signal. The presented design is based on digital synthesizers with high flexibility in radar signal intrapulse modulation schemes. The architecture of RSG allows complex signals generating with bandwidth up to 150MHz (the frequency range is limited with proper filters due to most used frequency ranges). Phase stability of the output signal is less 1є deviation RMS and phase noise performance of reference signals is -134dBc/Hz@1kHz for 10MHz. [C34]

"PARSAX: High-resolution Doppler-polarimetric FMCW radar with dual-orthogonal signals"

The article describes the IRCTR PARSAX radar system. It is an S-band high-resolution Doppler polarimetric FMCW radar utilizing dual-orthogonal sounding signals. The signals allow for measuring in one sweep all elements of the radar targets polarization scattering matrix simultaneously. PARSAX characteristics are: modular system set-up, highly-optimised linearity and sensitivity of the RF front-end receiver, use of a flexible multi-channel arbitrary waveform generator as sounding waveforms source, high-resolution analogue to digital conversion of the received signals at sufficiently high intermediate frequency and FPGA-based programmable digital multi-channel receiver. The paper shows that PARSAX is a unique radar research platform for studying arbitrary sounding waveforms with bandwidth up to 50 MHz and processing algorithms in Doppler-polarimetric radar. [C35]

"Coherent MIMO radar"

Multiple-input multiple-output (MIMO) extensions to radar systems enable a number of advantages compared to traditional approaches. These advantages include improved angle estimation and target detection. In this tutorial, an overview of MIMO radar is provided, and the concept of coherent MIMO radar is defined. In addition, two topics are addressed more thoroughly: MIMO waveform/array geometry optimization for target tracking, and MIMO ground moving target indication (GMTI). [C36]

"Waveform diversity & knowledge based systems"

Summary form only given. Waveform diversity is an emerging technology that has dramatically altered the development of futuristic radar systems, as has knowledge based processing and control. With increasing numbers of radio frequency sensors and communications systems, battlefield scenarios have become more complex and continuously redefined. Our challenge will be to effectively use this technology to enhance overall performance of advanced radar systems operating within available spectrum in these battlefield environments. Technologies essential to this goal include cognition and knowledge based systems for waveform generation timing and control, and intelligent radar signal/data processing for detection, parameter estimation and track processing. Cognition is defined as the act or process of knowing, including both awareness and judgment. Awareness of the dynamically changing spectral environment and judgment for the selection of optimal waveform parameters and sensor placement will enable dramatically improved performance for target surveillance/reconnaissance in addition to enhanced interference mitigation. A confluence of factors and

technologies now makes waveform diverse knowledge based systems a logical and affordable alternative to classically designed radars. [C37]

"OFDM radar waveform design for sparsity-based multi-target tracking"

We propose a sparsity-based approach to track multiple targets using an orthogonal frequency division multiplexing (OFDM) radar. The use of an OFDM signal increases the frequency diversity of our system as different scattering centers of a target resonate variably at different frequencies. We observe that in a particular pulse interval the targets lie at a few points on the delay-Doppler plane. Hence, we exploit that inherent sparsity to develop a tracking procedure. The nonzero entries of the sparse vector in our model correspond to the target scattering coefficients at different OFDM subcarriers. Therefore, the sparse vector and associated sparse measurement model exhibit block-sparsity property. We design the spectral weights of the transmitting OFDM waveform to minimize the block-coherence measure of the sparse model. In the tracking filter, we develop a block version of the compressive sampling matching pursuit (CoSaMP) algorithm. We present numerical examples to show the performance of our sparsity-based tracking approach and compare with that of a particle filter (PF). The proposed sparsity-based tracking algorithm takes significantly less computational time and provides equivalent, and sometimes better, tracking performance in comparison with the PF-based tracking. [C38]

"Wideband MIMO waveform design for transmit beampattern synthesis"

The usage of multi-input-multi-output (MIMO) systems such as a MIMO radar allows the array elements to transmit different waveforms freely. This waveform diversity can lead to flexible transmit beampattern synthesis, which is useful in many applications such as radar/sonar and biomedical imaging. In the past literature most attention was paid to receive beampattern design due to the stringent constraints on waveforms in the transmit beampattern case. Recently progress has been made on MIMO transmit beampattern synthesis but mainly only for narrowband signals. In this paper we propose a new approach that can be used to efficiently synthesize MIMO waveforms in order to match a given wideband transmit beampattern, i.e. to match a transmit energy distribution in both space and frequency. The synthesized waveforms satisfy the unit-modulus or low peak-to-average power ratio (PAR) constraints that are highly desirable in practice. Several examples are provided to investigate the performance of the proposed approach. [C39]

"Implementation of a low cost synthetic aperture radar using Software Defined Radio"

GNU radio is a free open-source software toolkit for building software radios, in which software defines the transmitted waveforms and demodulates the received waveforms. In this paper an attempt has been made to explore the means to use a Software Defined Radio (SDR) to implement a basic radar system and then synthetic aperture radar. An experiment where in readings at two different scenarios (free environment and metal object) are taken into account and their plots are also given. This has been attempted keeping in mind the exponential increase in chip computing power and the ability to upgrade a radio transceiver via software updates with a marginal investment, the two features which makes such a foray attractive, technology wise and cost wise. This attempt also takes us a step closer to establishing the concept of a Cognitive radar which is software signal processing intensive. [C40]

"Side lobe control of UWB antenna array for real beam radar imaging"

The ultra wideband (UWB) array waveform is essential to the improving of resolution for microwave imaging. Large antenna arrays provide high angular resolution microwave images. These images are plagued with artifacts caused by high side lobes. Specifically, these artifacts are false targets and target break-up or speckle. In this paper, an UWB comb taper slot antenna array with large element spacing and impulse excitation is studied. The four-element UWB array system with uniform and non-uniform element spacings in the broadside direction is analyzed by energy pattern for side lobe control. A technique for beam scanning with a time delay technique is developed for UWB arrays. Different excitation pulse width is studied for peak side lobe that is far away from the designed beam direction of UWB array with uniform element spacings of 8.5 and 18 cm. Energy patterns for simulation and measurement are in good agreement. The periodic grating lobes of the UWB antenna array do not occur in the energy pattern, even if the element spacing and scan angle are large. In general, the optimum design of array element spacing is required for special applications. [C41]

"Pulse Doppler radar waveforms"

Modern military airborne radars are highly sophisticated, multi-mode systems which are required to detect difficult targets in all aspects and over a large range/velocity detection space. There are particular difficulties associated with the airborne case such as the limited antenna aperture, high platform velocity and severe clutter levels

which present difficult waveform design challenges. This tutorial will consider the design parameters of high pulse repetition frequency (PRF) and medium PRF waveforms commonly used in airborne pulse Doppler radar modes. The majority of this tutorial will be devoted to the issues concerning the selection of the number of PRFs and of the PRF values used in the medium PRF mode. PRF optimisation methods using evolutionary algorithms used by the author and his colleagues in a number of recent studies will be described. Examples will be given of airborne fire control radars, airborne early warning systems and active radar seekers used in anti-aircraft missiles. [C42]

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The following topics are dealt with: MIMO, radar, imaging techniques, spectral cohabitation, adaptive waveforms, modulation techniques, and spectrum management. [C43]

"Deisgn of look-up table based architecture for wideband beamforming"

Wideband beamforming with a real-time array testbed will be studied in this paper. The algorithm and implementation architecture on wideband beamforming will be the main focus. The contribution of this paper can be summarized in the following three aspects. First, the channel imbalances among different RF chains will be taken into account. The equivalent complex baseband impulse responses of RF chains are measured from the AFRL TELA testbed. The second contribution is that the novel architecture of wideband beamforming is proposed. Look-up table (LUT) based architecture is exploited to replace the pre-steering delay component to avoid fractional delay-one implementation bottleneck. In addition, the general optimization issue for wideband beamforming is formulated as semi-definite programing (SDP), which can be efficiently solved by the convex optimization tool, e.g. CVX. [C44]

"Reduced rank detection algorithms for distributed array sensors"

Distributed sensing systems provide an inherent spatial diversity by viewing a potential target from different aspect angles. Even though the centralized fully adapted processing scheme provides optimum performance, it is impractical for reasons of computational complexity and the sample support required for weight training. This paper presents two decentralized reduced rank STAP algorithms to overcome the drawbacks of centralized fully adapted processing. [C45]

"The metrication of low probability of intercept waveforms"

In recent years, military radar operators have been concerned that the transmitted radar signals will beacon the presence of the radar to an enemy. If intercepted, the radar signals alert a target to an attack which could prompt evasive measures or countermeasures to be taken by the target including the possibility of a reprisal attack using an antiradiation missile. Furthermore, intercepted signals can divulge operating parameters of the radar to the enemy. In response to this low probability of intercept (LPI) requirement, waveforms have been designed to minimize the probability of intercept by an enemy receiver. These are largely based on the use of low peak powers and spread spectrum waveforms offering large processing gains. The interception of signals is a function of both the transmitted radar waveform and the intercept receiver. The aim of this work is to deduce a metric which may be used to quantify and hence compare how "discrete" many of the commonly used LPI radar waveforms actually are. This study considers the following LPI waveforms: Linear Frequency Modulation (LFM), Sinusoidal Frequency Modulation (Sin FM), PolyPhase Shift Keying (PPSK) techniques including Frank, P1, P2, P3, and P4 codes Costas code Frequency Shift Keying (FSK), and Costas-Barker Hybrid (FSK/PSK). This work represents the first attempt to be published in the open literature to quantify the LPI properties of transmitted radar waveforms. Secure waveform coding strategies to minimize the risk of divulging radar capabilities is known as low probability of exploitation (LPE) and is not considered here. [C46]

"Phase-modulated waveform design for the target detection in the presence of signal-dependent clutter"

The problem to be considered is a phase-modulated waveform design for detection of extended targets contaminated by signal-dependent clutter returns and additive channel noise in practical radar systems. We first introduce an optimal waveform design algorithm for extended target detection in a band-limited radar system by maximizing the signal-to-clutter-and-noise ratio (SCNR) at the output of the receiver, and give the analytical solution of the optimal signal energy spectral density (ESD). In order to make full use of the transmission power, a phase iterative algorithm to design the phase-modulated waveform with constant envelop is proposed, which is proven to be able to achieve a small SCNR loss by minimizing the mean-square spectral distance between the optimal waveform and the designed one. The results of extensive simulations illustrate that our approach provides less than 1 dB SCNR loss when the signal duration is greater than 1 μs. [C47]

"Compressive radar imaging using white stochastic waveforms"

In this paper, we apply the principles of compressive sampling to ultra-wideband (UWB) stochastic waveform radar. The theory of compressive sampling says that it is possible to recover a signal that is parsimonious when represented in a particular basis, by acquiring few projections on to an appropriate basis set. Drawing on literature in compressive sampling, we develop the theory behind stochastic waveform-based compressive imaging. We show that using stochastic waveforms for radar imaging, it is possible to estimate target parameters and detect targets by sampling at a rate that is considerably slower than the Nyquist rate and recovering using compressive sensing algorithms. Thus, it is theoretically possible to increase the bandwidth (and hence the spatial resolution) of an ultra-wideband radar system using stochastic waveforms, without significant additions to the data acquisition system. Further, there is virtually no degradation in the performance of a UWB stochastic waveform radar system that employs compressive sampling. We present numerical simulations to show that the performance guarantees provided by theoretical results are achieved in realistic scenarios. [C48]

"Mismatched filtering of chaotic codes"

Low Probability of Intercept (LPI) pulse compression waveforms find applications in secure communications. Conventional waveforms with good correlation properties fail to satisfy requirements in presence of unintentional interference. Chaotic pulse compression codes combined with mismatched sidelobe suppression filters are proposed to simultaneously improve LPI performance and meet low sidelobe level requirements of secure communications. [C49]

"Adaptive design for distributed MIMO radar using sparse modeling"

Multiple Input Multiple Output (MIMO) radar systems with widely separated antennas provide spatial diversity gain by viewing the targets from different angles. In this paper, we propose an approach to accurately estimate the properties (position, velocity) of multiple targets using such systems by employing sparse modeling. We also propose a new metric to analyze the performance of the radar system. We develop an adaptive mechanism for optimal energy allocation at different transmitters. We show that this adaptive mechanism outperforms MIMO radar systems that transmit fixed equal energy across all the antennas. [C50]

"Design of an optimal radar signal waveform for a range-doppler spreading channel"

This paper deals with the optimal radar waveform design problem using the quadratically constraint quadratic programing (QCQP) in the narrowband signal echo to range-doppler extended target regime. The solution is obtained in the sense of signal to interference plus noise ratio(SINR) maximization with resolution and fixed transmit power constraints. The performance is compared with other conventional waveforms such as continuous wave (CW) pulse and linearly frequency modulated (LFM) pulse, in terms of resolution through ambiguity function. [C51]

"Waveform-diverse moving-target spotlight SAR"

This paper develops the theory for waveform-diverse moving-target synthetic-aperture radar. We assume that the targets are moving linearly, but we allow an arbitrary flight path and (almost) arbitrary waveforms. We consider the monostatic case, in which a single antenna phase center is used for both transmitting and receiving. We include the case of waveforms whose duration is sufficiently long that the targets and/or platform move appreciably while the data is being collected. [C52]

"Inverse frequency scaling algorithm (IFSA) for SAR raw data simulation"

This paper presents a SAR raw data simulation approach using the inverse frequency scaling algorithm (IFSA) based on deramp processing. It is time-saving and can take motion error into account. The limitation of the inverse chirp scaling algorithm (ICSA) on transmitted waveforms is also overcome. Simulated results show the validity of the algorithm. [C53]

"Design and implementation of a dual-interface radar data recorder"

This paper analyses the design and implementation of a small-scale dual-interface radar data recorder based on DSP+FPGA. It has two types of interfaces: solid-state IDE hard disk and RJ45. The recorder can save sampling data of original radar waveforms in real time for further analysis and validation. It adapts to a variety of application environments and has a high storage speed and reliable operation performance. It can be widely used in radar testing and flight experiments. [C54]

"Stepped-Frequency waveform processing for moving target based on genetic-CLEAN algorithm"

Stepped-Frequency waveform (SFW) is a very important type of high range resolution radar signal. A novel processing method for SFW based on genetic algorithm and CLEAN technique is proposed in this paper. The parameters (i.e., position, amplitude and velocity) of a point scatterer can be found by global searching with genetic algorithm. And an iterative CLEAN processing is used to eliminate the extracted point from the received data of one SFW burst. Then the high range resolution profile (HRRP) of the target can be reconstructed with the estimated parameters. Finally the effectiveness of the algorithm is verified by the simulation results. [C55]

"A new waveform for range-velocity decoupling in automotive radar"

Radar sensors for automotive applications require extremely high performance figures in terms of measurement accuracy and time. LFMCW radar sensors have the advantages of high range resolution, but it will bring out ghost targets and missed targets in multi-target detection. This paper describes a new waveform combining LFMCW with SFCW pairing is proposed and discusses in detail to demonstrate the technical differences and advantages. [C56]

"Tackling the non-linearity problem in GPR waveform inversion"

Crosshole radar tomography is a non-invasive tool used in diverse geological, hydrogeological and engineering investigations. Conventional tomograms provided by standard ray-based techniques have limited resolution. Higher resolution radar tomograms can be derived by using full-waveform inversion schemes. However, despite the theoretical improvement in resolution, convergence problems can arise in the application of full-waveform schemes due to the ill-posed nature of the inverse problem and the high non-linearity of the relationship between the model parameters and the scattered fields (i.e. the forward problem). We present here a new inversion scheme that starts with a low-pass filtered version of the radargrams and progressively expands the frequency bandwidth as the iterations proceed, thus reducing the likelihood of the inversion getting trapped in a local minimum. The benefits over standard full-waveform time- domain inversion are demonstrated by means of three synthetic examples. [C57]

"Tests of sommerfeld ground wave theory using ground-penetrating radar pulses"

We have used ground-penetrating radar pulse waveforms within moveout profiles that we recorded over dielectric ground, to test the geometric amplitude attenuation rates of interfacial surface air waves predicted by classic Sommerfeld theory. The pulses allow separation of interfacial wave modes. We used horizontally polarized pulses centered from 37-390 MHz, frozen ground, and an intermediate range of tens of wavelengths over which radial polarization is predicted to exhibit anomalously low rates. As predicted, azimuthal broadside polarization at 37-45 MHz attenuated in proportion to the square of range, but the radial endfire rate was closer to the 1.6 power of range. At 360-390 MHz, both rates exhibited predicted range-squared amplitude attenuation. Not readily extractable from the theory are the rates for subsurface direct waves, for which we found, from numerical experiments, that both polarizations attenuate in proportion to the square of range. This suggests that geometric rates for all types of subsurface interfacial waves attenuate in proportion to range squared and could be subtracted from actual rates to determine material loss rates. [C58]

"Full-waveform inversion of multi-offset surface GPR data"

Common ray-based techniques for analysing common midpoint (CMP) ground penetrating radar (GPR) data use only part of the measured traces and return results with limited resolution and non-quantitative values for conductivity. Due to the fact that full-waveform inversion uses all information of the measured traces, a higher resolution image of the subsurface and quantitative conductivity values can be obtained. Using an experimental dispersive CMP dataset, the results of dispersion analysis, i.e. permittivity and thickness, define the start model parameters for full-waveform inversion. After estimating an effective source wavelet, the full-waveform inversion based on a simplex search algorithm returns reliable permittivity and conductivity values of the subsurface. [C59]

"Full-waveform inversion of crosshole ground penetrating radar data to characterize a gravel aquifer close to the Thur River, Switzerland"

Imaging results of crosshole GPR can be significantly improved by using full-waveform inversion compared to conventional ray-based inversion schemes. A recently developed 2D finite difference time domain (FDTD) vectorial full-waveform crosshole radar inversion method was made more flexible to allow using an optimized acquisition setup that reduces the measurement speed and the computational cost. This improved algorithm was used to invert crosshole GPR data acquired within a gravel aquifer in northern Switzerland. Compared to the

ray-based inversion, the results from the full-waveform inversion show significantly higher resolution images in the depth range of 6m-10m. Comparison of the inversion results with borehole logs shows that porosity estimates obtained from Neutron-Neutron data correspond well with the GPR porosities derived from the permittivity distribution in the depth range 6 m-10 m and that the trends are in good qualitative agreement. Furthermore, there is a good correspondence between the conductivity tomograms and natural Gamma logs at the boundary between the gravel layer and the underlying lacustrine clay sediments. [C60]

"An approach for extracting the transmitted waveforms based on compound filter for MIMO radar"

Extracting the transmitted waveforms is crucial for MIMO radar. A new eatracting approach is proposed in this paper based on the compound filter. The proposed method can compress the input pulse width to a narrower one and suppress range sidelobe level lower than a matched filter. The computer simulation proves the efficiency of the method. [C61]

"A system demonstrator for the performance evaluation of a 24 GHz ISM band radar operating with OFDM waveforms"

OFDM signals possess a high flexibility, which, besides their typical employment for wireless digital communications, makes them also suitable for radar applications. In this paper an OFDM system will be presented that offers communication and radar functions in parallel based on one joint transmit signal. A typical application area would be intelligent transportation systems, which require the ability for vehicle-to-vehicle communication as well as the need for reliable environment sensing. A system demonstrator based on commercial equipment has been set up that allows for the transmission of an OFDM signal carrying arbitrary user information. From the reflected signal radar images resolving the distances of multiple reflecting objects can be calculated. In this paper, first the employed waveform and the detailed system setup will be discussed. Then, measurement results will be shown that prove the operability of the developed system concept and its performance. [C62]

"Design of a pseudorandom reference codes for reduced sidelobes and spectrally clean out-of-band emissions using an extended optimal filtering approach"

In this paper we propose an extended version of the classical optimal filtering techniques to be used with binary noise codes, called m-sequences, and complementary codes. We introduce here extended optimal filters to achieve lower ACF sidelobe levels and spectrally clean waveforms with out-of-band suppression (OBS) levels directly proportional to the filter length. [C63]

"A new ground penetrating radar signal analysis method based on S transform"

The paper discussed the characteristics of GPR signals of one object and two objects respectively, and studied the rule of extracting twin-peak attribute when the size of object or the distance of two objects was changing through GST. For one object, the two reflections can't be resolved in time when the diameter of object is less than or equal to 1/3 dominant wavelength within object medium, but the twin-peak attribute can resolve the reflections when the diameter is as small as 1/7 dominant wavelength, so the size can be estimated combining the attribute with time-domain waveform and the definition of a small object can be given. For two objects that each is a small object in time-frequency domain, we considered the situations where the permittivity were same or different, and it is pointed out that the attribute can improve the resolution of two objects and can estimate the distance combined with time-domain waveform. The selection rule of parameter and frequency point of twin-peak attribute was given as well so the unsystematic problem was solved. [C64]

"On orthogonal waveform design for MIMO sonar"

MIMO sonar that transmits orthogonal waveforms via transmitter sensors is an emerging technology that has significant application potential. Compared to standard phased array sonar, orthogonal transform waveform can bring many advantages including improved angular resolution and multi-target detection ability. We derive in this paper a novel binary-phase waveform design coded by Gold sequences. This phase code is computationally efficient compared to other codes previously proposed in the literature. We provide some numerical examples to demonstrate the performances of the new code sequence. [C65]

"A novel design of SAR scattering signal simulator based on AWG"

Synthetic Aperture Radar (SAR) raw signal simulation is crucial for SAR system design and processing algorithms. This paper proposes the simulation method of SAR RF signal via utilizing Arbitrary Waveform Generation (AWG). At first, the SAR imaging principle is analyzed. Then, the space-borne SAR scenario model

is constructed. The echoes of point target are calculated, which is impulse response of the SAR signal acquisition. At the end, based on the scattering model expressions of a random roughness surface and the electromagnetic wave shadow theory, the Radar Cross Section (RCS) simulation parameters of terrain target is calculated. 2D-FFT method is utilized to improve simulation efficiency significantly. [C66]

"Millimeterwave radar high-resolution imaging via OFDM waveforms"

A novel combination of millimeterwave linearly frequency modulated (LFM) technology and new radar imaging techniques can provide a good high-resolution imaging sensor that can be inboard in unmanned vehicles, in which stringent limitations of size, weight and power consumption are required. This paper presents an approach of multiple transmission and multiple reception in elevation for vehicle-borne millimeterwave radar high-resolution imaging. This radar employs orthogonal frequency diversity modulated (OFDM)-LFM waveforms, so as to obtain a high-resolution imagery over a wide swath coverage. The system concepts, geometry relations and signal models are provided. Computer simulation examples are also performed. Additionally, the generation of the OFDM waveforms with parallel direct digital synthesizer (DDS)-driven phase locked loop (PLL) synthesizer is discussed, and the block diagram of the synthesizer is provided. [C67]

"Transmit beamforming for colocated MIMO radar"

MIMO radar has seen growing interest in recent years owing to the many advantages that it offers over conventional radar, including spatial diversity and enhanced target direction resolution. Unlike standard phased array (SIMO) radar that transmits scaled versions of a single waveform from its many transmit antennas, a MIMO radar can transmit distinct waveforms from each antenna. Such an increase in the number of degrees of freedom for waveform design can potentially be used to obtain beamforming performance similar to SIMO radars with a far fewer total number of transmit and receive antennas. In recent literature, the problem of finding a signal correlation matrix that achieves a desired transmit beam pattern has been addressed, but a closed form solution for this problem has been lacking. In this paper, we first formulate a new spatial ambiguity function that simultaneously specifies the transmit beam pattern as well as the cross-correlation beam pattern. We then provide a closed form solution for the signal correlation matrix whose spatial ambiguity function is closest to a desired function (in the mean square sense), when using colocated uniform linear arrays. Further, we show how a suitable tapering window could be applied on the signal correlation matrix to tradeoff sidelobe levels for mainlobe width in the spatial ambiguity function. [C68]

"Radar echo signal detection with sparse representations"

Sparse decomposition can explore the most important or interesting features of a signal, thus it is very favorable in data compression, noise reduction, signal analysis, correction and other applications. In this paper, we propose a method of radar echo signal detection with sparse representations. In the proposed method, we first design a waveform-matched dictionary according to the a priori knowledge of the transmitted signal to sparsely represent the radar echo signal. The components in the dictionary have exactly the same waveform as the transmitted signal. With this dictionary, the echo signals of a given radar system have very sparse representation. Using the sparse representation based on the waveform-matched dictionary, the radar echo detection can bi achieved. Simulation results show that the proposed method is effective and has the high anti-noise ability. [C69]

"Optimal waveform selection for software defined data acquisition system"

This paper describes specific digital beamforming methods and prototype of the data acquisition system. Moreover, the detailed description of the beamforming and reception algorithms would explain the possible estimation criteria for given system. The modelling results and software radar prototype performance are presented. Concerning the use of spread spectrum waveforms with wideband beamforming methods, possible modes of data acquisition applications will be discussed. [C70]

"On the design of mismatched filters with an adjustable matched filtering loss"

We present a method for the design of mismatched filters minimizing the interference from unwanted targets (point target or clutter) under the constraint of matched filtering loss. The method method seeks to find the optimum filter minimizing the interference and having a desired cross-correlation with a given transmitter waveform. The method is applied to get the minimum integrated side-lobe level filters and to optimize the receivers of the pulse diversity systems. [C71]

"Preliminary results of ultra-wideband through-the-wall life-detecting radar"

It is often a difficult task of knowing the location or movement of people behind barriers. To address this problem, we develop a through-the-wall life-detecting radar (TWLDR) prototype. It is a kind of ultra-wideband (UWB) radar using impulse waveform, which can penetrate non-metallic walls to detect static and moving targets behind walls. We first introduce configurations of the radar system, then describe signal processing techniques, and present experimental results in different situations at last. Results indicate that the UWB TWLDR can penetrate non-metallic walls to detect people with different locomotion states such as standing, walking along cross-range direction, walking along range direction, and the signal processing algorithm could be applied to other complex environments. [C72]

"Waveform agile sensing for tracking with collaborative radar networks"

In this paper we consider the problem of waveform scheduling for multiple Range-Doppler radars operating collaboratively for target tracking. First, we consider the canonical cases of collocated radar platforms, each capable of choosing a waveform at every PRI from a fixed chirp waveform library. We assume the radars fuse the information that they obtain from their measurements after each chirp pulse in a Kalman Filter tracking framework to obtain posterior distribution of the target state. The radars then use the resulting distribution to jointly select their next waveform set. Our results extend previous work on information theoretic waveform-scheduling proposed for single range-doppler radar to multiple radars interrogating the same target. We show that the radar platforms have to employ a mixture of minimum and maximum chirp-rates supported by the radar hardware to maximize mutual information between the target state and measurements. For the case of two identical radars we completely characterize the optimal combination of chirp waveforms with minimum and maximum chirp-rates as a function of prior target state covariance, carrier frequency, width of transmitting pulse and allowable chirp rates. Finally, the results are extended to arbitrary number of radars at arbitrary geometry. [C73]

"Design alternatives for Foliage Penetration SAR ultra wideband waveforms"

Foliage Penetration SAR has achieved significant operational attention from both military and civilian applications. To achieve the spatial resolution desired, the waveform must occupy fractional bandwidths near 100 percent, and integration angles on the order of π/2. Both design objectives are classified as ultra-wideband, and require special constraints to allow operation in the crowded radio frequency spectrum. This effort examines the SAR waveform design approaches, given the recent advances in digital waveform synthesis, to satisfy frequency allocation constraints. [C74]

"Removing autocorrelation sidelobes of phase-coded waveforms"

This paper studies autocorrelation properties of a train of identical signals overlaid with a phase coding in the case when the uncoded signal forming the train consists of several groups of identical bits. It is shown that, if the coding patterns are the rows of a mutually orthogonal complementary set matrix, the waveform's autocorrelation sidelobes around the main lobe area can be completely removed. At the same time, repetition of some bits of the uncoded signal can be used to achieve a low sidelobe level in the close vicinity of the main lobe. [C75]

"The instagram: A novel sounding technique for enhanced HF propagation advice"

Modern OTHR systems make extensive use of propagation support information for parameter setup advice. A novel method for increasing dimensionality and temporal resolution of this advice is demonstrated here using an instantaneously wideband waveform on a one-way path. A composite of pseudo-randomly phased, discretized, massively multi-channel signals is synthesized through a simple summing scheme. Upon reception the composite is rapidly processed in the frequency domain to produce channel scattering information simultaneously across the band. The channels may be collapsed in the Doppler domain to reduce to conventional oblique ionograms. Total integration time required to produce the full Doppler ionograms, even with low transmit powers, is reduced over conventional methods by up to three orders of magnitude leading to the term `Instagram'. The technique is implemented on an oblique sounding system that provides the necessary direct digital arbitrary waveform generation and reception capability. A result from the initial field trial is provided. [C76]

"Airborne GMTI using MIMO techniques"

The performance of a ground moving target indicator (GMTI) radar is strongly driven by the length of the radar aperture, as longer apertures enable lower minimum detectable velocity (MDV) and better target geolocation. Multiple-input multiple-output (MIMO) techniques can enable the use of long sparse array geometries while avoiding the adverse sidelobe effects typical of such arrays. In 2009 an experiment was conducted at Ft. Devens, MA to collect MIMO GMTI data on instrumented ground targets. A reconfigurable S-band antenna array was programmed to transmit both conventional single-input multiple-output (SIMO) and MIMO waveforms.

Analysis of the data indicates improved detection performance with the MIMO techniques compared to the conventional SIMO approach. [C77]

"Waveform interference mitigation for a shared spectrum MIMO radar system"

MIMO radars may outperform conventional ones as regards target detection, parameter estimation and classification via spatial and waveform diversities. MIMO radar is a kind of shared spectrum system: the mutual interference among the waveforms may lead to considerable performance degradation, especially with multiple targets. As a result, preserving MIMO radar performance under such conditions via waveform design becomes an interesting research topic. In this paper, we consider the marriage of space time coding (STC) and Golay complementary pairs to mitigate both waveform autocorrelation and cross-correlation effects, and hence to enhance range resolution. The implementation is discussed, and an application for instantaneous polarization is briefly introduced. [C78]

"OFDM waveforms for multistatic radars"

In this paper, the benefits of OFDM waveforms are analyzed for multistatic radar systems, where several radar stations cooperate in the same frequency band. The signal is coded over a 2D pattern, in the time and the frequency domains, using orthogonal Golay complementary sets derived from Reed-Muller codes. Binary data are also encoded in the signal. The obtained ambiguity and cross-ambiguity functions show that the OFDM signal structure is well adapted for radar applications. Transmitted waveforms have relatively low interference and sidelobe levels in the range and Doppler axis. [C79]

"Passive synthetic aperture radar imaging with single frequency sources of opportunity"

In this paper we consider passive airborne receivers that use backscattered signals from sources of opportunity transmitting fixed-frequency waveforms. Due to its combined passive synthetic aperture and the fixed-frequency nature of the transmitted waveforms, we refer to the system under consideration as Doppler Synthetic Aperture Hitchhiker (DSAH). We present a novel image formation method for DSAH. Our method first correlates the windowed signal obtained from one receiver with the windowed, filtered, scaled and translated version of the received signal from another receiver. This processing removes the transmitter related variables from the phase of the Fourier integral operator that maps the radiance of the scene to the correlated signal. We next use the microlocal analysis to reconstruct the scene radiance by the weighted-backprojection of the correlated signal. This imaging algorithm can put the visible edges of the scene radiance at the correct location, and under appropriate conditions, with correct strength. Additionally, it is an analytic reconstruction technique which can be made computationally efficient. We show that the resolution of the image is directly related to the length of the support of the windowing function and the frequency of the transmitted waveform. The image reconstruction method is applicable with both cooperative and non-cooperative sources of opportunity using one or more airborne receivers. We present numerical simulations to demonstrate the performance of the image reconstruction method and to verify the theoretical results. [C80]

"Resolution of two point targets using sub-arrayed MIMO radar"

Recent works on MIMO radar have shown benefits in optimising the signal covariance matrix for estimation of target parameters, over the performance of conventional radar and the orthogonal waveform approach used in much of the MIMO radar literature to date. The full diversity approach requires a large amount of flexibility at the transmitter and computation prior to transmission. In this work, we study the performance of a sub-arrayed transmit beamforming approach for MIMO Radar, which greatly reduces the requirements of the transmitter, for the important case of resolving two point targets. [C81]

"Evaluation of modulus-constrained matched illumination waveforms for target identification"

In prior work, we have applied matched illumination strategies to target identification by a closed-loop radar system. In the closed-loop system, multiple waveforms are transmitted in succession, but each is customized based on the returns from prior transmissions. In this prior work, however, the matched waveforms were not constrained to be constant modulus. This current paper evaluates the performance of closed-loop radar with constant-modulus matched illumination. We also compare the performance of non-constant-modulus illumination under a peak power constraint. Finally, we use simple target models and assume unknown orientation, rather than the deterministic or Gaussian target models used in earlier work. [C82]

"Compressed Sampling for pulse Doppler radar"

This paper presents a study of how the Analogue to Digital Converter (ADC) sampling rate in a digital radar can

be reduced-without reduction in waveform bandwidth-through the use of Compressed Sampling (CS). Real radar data is used to show that through use of chirp or Gabor dictionaries and Basis Pursuit (BP) the ADC sampling frequency can be reduced by a factor of 128, to under 1 mega sample per second, while the waveform bandwidth remains 40 MHz. The error on the reconstructed fast-time samples is small enough that accurate range-profiles and range-frequency surfaces can be produced. [C83]

"Phase-coded-linear-frequency-modulated waveform for low cost marine radar system"

This paper proposes a continuous waveform to realize low transmitted power in a Radar system. The proposed waveform utilizes a pulsed compression scheme based on phase-coded modulation and linear FM which combines the desirable properties of both types of modulation. This paper also verifies waveform operation under channel effects such as multipath and noise. We determine power optimization due to waveform compression gain for given system specifications and use correlation values to detect both unambiguous range and Doppler shift. With a pre-determined noise and Doppler threshold, we can distinguish targets from sea clutter. Finally, we show the improvement in accuracy of elevation measurements by simulation when auto-correlation instead of signal strength ratios are used to determine target height. [C84]

"Scaling radar measurements for advanced algorithms"

This paper describes waveform diverse signal measurements using a two channel laboratory radar system. Using a combination of a Lab-Volt™ radar training system, Tektronix™ arbitrary waveform generator (AWG), Tektronix™ digital oscilloscope (DSO), and Tektronix™ real-time spectrum analyzer (RSA), a two channel, waveform diverse, multiple-input, multiple-output (MIMO) system is configured to collect both MIMO and bistatic radar measurements. In the experiments, the radar operates at X-band and samples the echoes at radio frequency (RF) before down-conversion into in-phase and quadrature (I/Q) channels. The laboratory environment does not need any special treatment as an anechoic chamber because the system uses very short duration and low power waveforms. Measured data for the MIMO radar is presented along with discussion of the bistatic configuration. [C85]

"Detection and estimation of multi-pulse LFMCW radar signals"

The Wigner-Ville Hough transform (WVHT) has been applied to detect and estimate the parameters of linear frequency-modulated continuous-wave (LFMCW) low probability of intercept (LPI) radar waveforms. The WVHT, which is optimal for a single linear frequency modulated (LFM) signal, becomes sub-optimal when applied to LFMCW signals since the observed waveform is composed of concatenated LFM pulses. We formulate the detection and estimation problem to take into account the multiple pulses that are available in an observation interval at the intercept receiver. The new algorithm, called the periodic WVHT (PWVHT), is shown to significantly outperform the WVHT for LFMCW signals. [C86]

"Range profile specific optimal waveforms for minimum mean square error estimation"

Optimal waveforms for minimum mean square error range profile estimation are investigated. An idealized measurement and waveform adaptation process is developed that yields optimal scene and range specific waveforms. This process is idealized in that during each cycle of the process, a large number of dwells are required. As part of our method, a modified version of the Adaptive Pulse Compression (APC) estimation method is used to estimate the range profile after each dwell cycle. The proposed method is analogous to the APC method in that it yields a set of range specific optimal waveforms, while the APC method yields a set of range specific optimal pulse compression filters. In certain scenarios, the measurement and waveform adaptation process yields range profile estimates that are significantly better than those derived by the APC method alone. [C87]

"Nanosecond Pulser Based on Serial Connection of Avalanche Transistors"

Generation and measure of nanosecond pulse with large amplitude are difficult problems in the field of exploration. The principle of avalanche transistor is analyised and four-stage serial connection of avalanche transistors is designed. Experimental results show that across the 50Г‚Вї load the amplitude of the output pulse can reach 666V and half-width is 3.4 nanosecond. Repeat frequency of the pulse can reach 10KHz. Time-domain waveforms of the pulse and the measure data are shown in the paper. The pulser and the RL-loaded bowtie antenna get matched. The pulser can be fabricated easily and works well. It can be used in UWB Ground Penetrating Radar to improve its validity. [C88]

"Automatic Measurement of Radar Receiver Sensitivity"

This paper puts forward a method to measure the receiver sensitivity automatically. Taking an airborne radar as example, the method utilizes signal integration to improve the accuracy of the measurement. The implementation circuitry and experimental waveforms are given to demonstrate the utility of the method. [C89]

"Transmit policies for MIMO radar detection and time-delay estimation"

This paper is aimed at investigating the role of Space-Time Coding (STC) for target detection and time-delay estimation through MIMO radars with widely spaced antennas. To this end we formulate the waveform optimization problem as a constrained maximization of some detection-oriented figures of merit under an accuracy constraint. Interestingly, such an additional constraint deeply modifies the optimal transmit policy. We also offer closed-form formulas of the Fisher Information in target delay estimation as a function of the singular values of the code matrix. Numerical results validating the theoretical findings are also given. [C90]

"Stochastic dynamic programming model of adaptive waveform selection"

In cognitive radar, it is very important to select proper waveform to transmit according to different environment. The adaptivity of waveform corresponding to environment can be realized in many ways. In this paper, stochastic dynamic programming model of adaptive waveform selection is proposed. With this model, dynamic programming algorithms can be used to solve the problems of adaptive waveform selection. The necessity of adaptive waveform selection has been shown with simulations. Finally, the whole paper is summarized. [C91]

"Analysis of induced surface currents on high velocity target using a relativistic approach"

Radar is an electromagnetic system used for the detection and location of objects based on reflection. It operates by radiating energy into space and detecting the echo signal reflected from an object or target. This work analyzes how currents are induced on targets by the electromagnetic waveforms radiated by an antenna when the object is moving at high velocity. It is assumed that the target is a perfect electric conductor moving at high velocity. This work analyzes how the amplitude, the frequency and the duration of these currents are affected by the target velocity. The transmitted electromagnetic waveforms can then be calculated using vector potentials and by using the Lorentz transformation, the electromagnetic waveform is transformed from the stationary reference frame to a moving reference frame. Currents induced on the object can be modeled by using the transformed waveform and the equivalence principle. The object radiates an electromagnetic waveform as a consequence of the induced currents. The radiated waveform is calculated using the vector potentials and once more the reflected waveform is transformed from the moving reference frame to the stationary reference frame using the Lorentz transformation. Finally the equivalence principle was used to calculate currents induced in the antenna by the reflected electromagnetic waveforms. The relationship of the induced current on the antenna as a function of the target velocity is analyzed. [C92]

"Wearable Doppler radar with integrated antenna for patient vital sign monitoring"

A 2.45 GHz wearable Doppler radar unit with radio data link is presented for use in portable patient monitoring and emergency response. Unlike portable Electrocardiograms (ECG) or Photoplethysmography (PPG), the near-field Doppler unit enables monitoring of the person's heart rate without the need for electrical contact or optical access to the patient's skin. The Doppler unit is designed to be embedded in a clothing garment such as a shirt or vest, or used by medical emergency personal in an instrumented blanket or medical stretcher. Since the Doppler unit is placed directly on or behind the patient's torso, the extraneous signals due to relative motion artifacts is greatly reduced. Low-cost design is achieved by employing PWB microstrip elements for the integrated patch antenna, microwave oscillator, and tuning elements. Also, since the distance between the Doppler unit and the patient is fixed, it was possible to tune the detection phase to enable the use of a single mixer diode and eliminate the need for quadrature detection. Measured heart data from this technique shows clear waveform substructure similar to PQRST complex features found in captured ECG data. [C93]

"Autonomous deployment of the UAVSAR radar instrument"

The UAVSAR program was formed to provide repeat pass radar interferometry on an uninhabited aircraft platform. The UAVSAR imaging radar system is housed in an external unpressurized pod that may be attached to an Uninhabited Aerial Vehicle (UAV), although initial flight tests were performed aboard a Gulfstream-III aircraft with flight test personnel on-board. Since the radar science missions are to be eventually flown without an on-board operator, all data collection must be performed autonomously from take-off to landing. The Automatic Radar Controller (ARC) is the main instrument flight computer responsible for a myriad of tasks, including commanding the radar configuration and monitoring the aircraft flight path to search for data collection waypoints provided by an on-board flight plan. The pod environment and various hardware units are monitored during the mission to assure the radar instrument remains within an operable range. The ARC communicates

with a Radar Operator Workstation (ROW) to receive updated real-time operational commands and to download up-to-date hardware status and telemetry. The ROW provides operator displays for monitoring the health of the radar system and also displays sampled radar waveforms in time and frequency domains. The aircraft location is provided by the on-board GPS/INU and downloaded by the ARC for plotting the current location onto Google maps using software developed at JPL. The UAVSAR platform has been flown throughout most of California and has recently completed successful deployments to Greenland and the Aleutian Islands. A nearly identical UAVSAR pod will be attached to a Global Hawk UAV platform in early 2010 for uninhabited operational flight tests. An additional pod containing another L-band antenna and GPS/INU unit will also be attached to the Global Hawk platform providing dual Lband data collection capability. The command and communication implementation for Global Hawk has been modified from the original GUI test U--.S. Government work not protected by U.S. copyright ? IEEEAC paper#1558, Version 1, Updated 2009:10:27 platform. During flight tests on the GUI the Radar Operator Workstation (ROW) was on-board with the test team. For the Global Hawk flight tests, the Radar Operator Workstation will be in the Global Hawk Operations Center located at the Dryden Flight Research facility. Communications to the ARC will utilize a relatively low speed Iridium satellite communications link. This paper will describe the functionality of the UAVSAR Global Hawk radar instrument flight and ground systems. We will also discuss fault detection and recovery options provided by these systems. We will describe the capabilities of monitoring and controlling the radar instrument during flight from the Global Hawk operations facility and describe the operational timeline for a typical science mission. [C94]

"Multitarget track before detect with MIMO radars"

Recent advances in Multiple-Input-Multiple-Output (MIMO) radar systems show that they have the potential to improve detection and localization performance of targets over bistatic and multistatic radars. Unlike beam forming, which presumes a high correlation between signals either transmitted or received by an array, the MIMO system exploits the independence between signals at the array elements due to transmit diversity. Previous works focus on waveform design, signal processing and target localization with MIMO radars while no attention has been given to tracking algorithms. In this work, the problem of tracking multiple targets using MIMO radars is considered. The scenario includes multiple targets in a widely-separated MIMO architecture in which Radar-Cross-Section (RCS) diversity can be utilized. Multi target version of Track-Before-Detect (TBD) algorithm is implemented for the collected M ГґB— N orthogonal signals at the receiver, where M is the number of transmitters and N is the number of receivers. Besides having the advantage of integrating information over time on unthresholded measurements to yield detection and tracking simultaneously, the TBD technique enables tracking and detecting targets in low Signal-to-Noise-Ratio (SNR) environments. Also, a modified multiple sensor TBD, which weights the target observability to the sensor as a result of target RCS diversity in the likelihood calculation to best fit the centralized MIMO tracking is proposed. Finally, Monte Carlo simulations are performed to evaluate the performance of the proposed tracking algorithm. [C95]

"Diversity gain for MIMO radar employing nonorthogonal waveforms"

Initially we formulate a very general hypothesis testing problem where we attempt to distinguish between zero-mean Gaussian clutter-plus-noise only and returns which are a linear transformed version of a zero-mean Gaussian random vector plus this clutter-plus-noise. We show that the diversity gain of the optimum processing for this hypothesis testing problem must be less than or equal to the rank of the linear transform. Next we apply this result to study diversity gain for optimum MIMO radar processors for cases with M transmit antennas, N receive antennas, and a target composed of Q scatterers. If the transmitted waveforms span a lower dimension M' than M, then the largest possible diversity gain is no greater than min(NM', Q). We also show a diversity gain of min(NM', Q) can be achieved under certain conditions. For a general correlated Gaussian clutter-plus-noise model and a general correlated Gaussian reflection coefficient vector, the diversity gain for noncoherent and coherent processing is discussed. Extensions of all results to cases with nonGaussian reflections and clutter-plus-noise are discussed. [C96]

"A novel approach to synthesize the range profile via predesigned stepped-frequency waveforms"

In stepped-frequency radar systems, the phase error due to target motion in each burst make range profiles blur. Conventional technology, such as motion compensation, requires velocity estimation to eliminate the distortion of the synthetic range profile. However, it suffers a major drawback, namely that it is difficult to achieve real-time accurate estimation of the velocity of the target. A novel technology is presented to achieve a focused target range profile via predesigned stepped-frequency waveforms. By applying a new stepped frequency waveform, HRRP of the target can be obtained by the Fourier transform without any other process. The simulation results demonstrate the effectiveness of the proposed technology. [C97]

"The analysis of ground penetrating radar signal of small objects based on generalized S

transform"

In order to do some preliminary analyses on characteristics of ground penetrating radar (GPR) signal of objects in time and time-frequency domain, and discuss how to roughly estimate the size of an object as well as distance between two objects, firstly the characteristics of GPR signal in time domain was studied in this paper as the size and the distance were changing respectively, secondly the characteristics in time-frequency domain was studied through generalized S transform (GST), the extraction rule of twin-peak attribute was analyzed, the determination of transformation parameter and frequency point was solved. It is pointed out that the size of an object can be estimated in combination of time domain waveform and twin-peak attribute, the definition of a small object can be given according to the size and objective, the resolution of two objects can be improved by twin-peak attribute and the distance can be roughly estimated combined with the attribute and time domain waveform. [C98]

"Measurement and mitigation of the ionosphere in L-band Interferometric SAR data"

Satellite-based repeat-pass Interferometric Synthetic Aperture Radar (InSAR) provides a synoptic high spatial resolution perspective of Earth's changing surface, permitting one to view large areas quickly and efficiently. By measuring relative phase change from one observation to the next on a pixel-by-pixel basis, maps of deformation and change can be derived. Variability of the atmosphere and the ionosphere leads to phase/time delays that are present in the data that can mask many of the subtle deformation signatures of interest, so methods for mitigation of these effects are important. Many of these effects have been observed in existing ALOS PALSAR data, and studies are underway to characterize and mitigate the ionosphere using these data. Since the ionosphere is a dispersive medium, it is possible in principle distinguish the ionospheric signatures from the non-dispersive effects of deformation and the atmosphere. In this paper, we describe a method for mapping the ionosphere in InSAR data based on a multi-frequency split-spectrum processing technique. We examine a number of PALSAR data sets, including fully polarimetric and single-polarization 28 MHz bandwidth data, where anomalous effects in phase, amplitude and image registration have been observed. We demonstrate the estimation of the ionosphere by means of the split spectrum technique for estimating differential TEC, whereby a radar waveform is transmitted over the full PALSAR spectral band and widely separated portions of the receive spectrum are processed independently and compared for dispersive effects, and quantify its performance. [C99]

"Cognitive tracking radar"

For the first time ever, this paper presents the design and implementation of a next-generation of tracking radar systems: the cognitive tracking radar (CTR). At the heart of the CTR, we have a cognitive waveform-selection (CWS) algorithm that can optimally pick the transmit waveform from a prescribed library, in response to information fed back from the receiver to the transmitter. In accordance with dynamic programming, the waveform-selection algorithm seeks to minimize the expected tracking error over a horizon of prescribed length. Approximation of the problem is also studied to mitigate the burden of computational load. To evaluate the system, we introduce computer experiments on a classical ballistic target tracking problem, the results of which confirm the superiority of the CTR over a conventional radar with fixed waveform. [C100]

"Monolithically integrated InP wafer-scale 100-channel Ч 10-GHz AWG and Michelson interferometers for 1-THz-bandwidth optical arbitrary waveform generation"

We discuss monolithic integration of a 100-channel AWG with a 10-GHz channel spacing with 100 Michelson-interferometer-based phase- and amplitude-modulators. The AWG showed approximately 10 dB crosstalk, and the twin-integrated devices comprise a 2Г,Bї InP wafer. [C101]

"Feasibility of range estimation using sonar LPI"

Using a detailed waveform-based simulation framework, a study on the feasibility of LPI sonar is performed for covert range estimation. A frequency selective channel filter is applied for realistic ocean simulation. The platform uses matched filtering and the target uses energy detection for processing the received signal. The objective of the platform is to estimate the range to the target while ensuring that the target still fails to detect the platform's pinging LPI waveform. A platform-target encounter scenario was designed for Monte Carlo simulation. Evaluation of system parameters was performed to assess for the feasible conditions for covert range estimation. [C102]

"Fast code design for sensors in noncooperative networks"

In this paper, we consider the problem of waveform design for radar sensors that operate in a noncooperative network. This is a system in which multiple radars share some common features, but they do not cooperate in the detection stage of processing. Our goal is to increase the performance of an element of the sensor network,

and, at the same time, to limit the interference induced by this element of interest on remaining sensors. The resulting problem is Nondeterministic Polynomial hard, namely an optimal solution can not be calculated in polynomial time. However, it is possible to relax the original problem into a Semidefinite Programming Problem, which is convex. This convex problem can be solved in polynomial time. Starting from an optimal solution to the relaxed problem, we construct a near-optimal solution of the original nonconvex problem, and evaluate its quality via the approximation bound. The proposed technique, referred to as "Waveform Design in Noncooperative Environment" (WDNE), enjoys the benefits of polynomial time complexity. Finally, we analyze via simulation the performance of the WDNE procedure. [C103]

"A stochastic-gradient method to design optimal space-time codes for MIMO radar detection"

We consider a MIMO radar system with widely-spaced transmit/receive antennas and study the problem of designing the signal waveforms transmitted by each source node so as to maximize the detection probability for a fixed false alarm rate under correlated Gaussian clutter. The proposed design procedure relies on a stochastic-gradient search and is general enough to be applied to any statistical target model. Examples are provided to compare the performance of the proposed codes with other known coding schemes. [C104]

"The periodic ambiguity function-Its validity and value"

The periodic ambiguity function (PAF) relates to Woodward's ambiguity function (AF) like periodic autocorrelation relates to autocorrelation. AF is defined for a finite signal, processed by its matched filter. PAF can handle periodic signals with infinite (or large) number of periods, and a processor that is matched to fewer periods. PAF suits practical scenarios found in radar employing coherent pulse train or CW waveforms. This paper revisits the PAF and its properties, demonstrating its value and viability. [C105]

"Multistatic measurements in a controlled laboratory environment"

In recent years, a novel mathematical framework for analyzing and designing multistatic radar systems has been proposed. It was argued through numerous simulation examples that multistatic radar system performances can be significantly improved by shaping the multistatic ambiguity function. Based on this framework, rules for waveform selection, sensor positioning and adequate weighting of different receivers have been developed. In this work, we present multistatic measurements obtained in a controlled laboratory environment to support some of these recent findings and conclusions. The experimental setup consists of a Lab-Volt™ radar system operating at X-band, Tektronix arbitrary waveform generator and Tektronix digital oscilloscope. Multistatic point target radar measurements for different system configurations are analyzed. [C106]

"Application of MIMO to IFSAR"

Synthetic Aperture Radar (SAR) provides all day, all weather and long stand off range capability of imaging large areas of the Earth. Single pass Interferometric SAR (IFSAR) using a pair of vertically displaced phase centers can be effectively used to estimate height using SAR images corresponding to each phase center. In recent years, multiple input multiple output (MIMO) radar techniques have received considerable attention. In this paper, we discuss the application of MIMO radar techniques for improving IFSAR height estimation. Additionally, we discuss IFSAR height estimation using multiple SAR images. We present an approach for selecting transmit waveforms to facilitate the computation of multiple SAR images corresponding to the virtual phase centers inherent in MIMO processing. With minimal modifications to existing two phase center IFSAR systems height estimation accuracy can be improved using MIMO techniques. Specifically, if the separation distance of the two phase centers is D, then using MIMO techniques the two phase center IFSAR system is transformed into a virtual three phase center IFSAR system with antenna element separation D and antenna length 2D. Example results are presented to demonstrate the benefits of this approach. [C107]

"Passive bistatic WiMAX radar for marine surveillance"

In this study we investigate the feasibility of using passive bistatic radar to exploit WiMAX communication signals as transmitters of opportunity for marine surveillance. The range and Doppler characteristics of such a system are first assessed through ambiguity function analysis on a typical set of WiMAX data transmission waveforms. Theoretical simulations are then used to investigate the ability of passive WiMAX radar for detecting marine vessels within three busy shipping areas in the UK, and in the presence of noise and interference signals. The initial analysis shows a range resolution of 5.6 m is achievable. Additionally, the simulations demonstrate specific scenarios where WiMAX radar may be used as a low cost surveillance device for detecting both small and large marine vessels in port areas and open waters. [C108]

"High density FPGA based waveform generation for radars"

Various modulation techniques are usually utilized to enhance the radar performance, or to add more capabilities to the radar that otherwise would not have been possible. Digital generation methods of frequency modulated continuous wave signals include direct waveform synthesis and frequency synthesis. The implementation of waveform generation and upconversion method are described in this paper with a simplified digital implementation technique using FPGAs (Field Programmable Gate Array). The design follows a systematic approach following steps of timing generation from external encoder, baseband modulated waveform generation, upconversion of the waveform to intermediate frequency, filtering and finally frequency synthesis using external DDS (Direct Digital Synthesizer). The design is also capable of generating BITE waveform for test checking in the system. Our design is capable of generation of waveform for stationary as well as non-stationary radars. For non-stationary radars, the waveform is so generated that the doppler effect due to the movement of the radar is compensated. The paper explains more on this. This work mainly focuses on the fact that the total design has been implemented on a single FPGA and the implementation solution utilizes the efficient FPGA resources so as to meet the timings in crucial applications. Moreover, the paper enhances the features of the design with simulation and real time results used to validate the design. [C109]

"Performance bounds on MIMO radar with optimized coded constant modulus waveforms"

A multiple-input, multiple-output (MIMO) radar system uses multiple, spatially diverse transmitters and receivers with separable, independent waveforms with the goal of enhancing resolution and, thus, improving performance. Key to the achievement of these performance benefits is the degree to which the transmitted waveforms may be separated on receive, e.g. the correlation properties amongst the waveforms. A previously defined correlation metric useful for designing "good" waveforms is simplified and its global minimum prescribed for M coded constant modulus waveforms each consisting of N chips and shown to be equal to M-1 (independent of the number of chips). The theory is validated using random phase waveforms as well as optimized waveforms using a previously defined iterative procedure ("CAN"), which is shown to effectively achieve the derived minimum bound. An important consequence of this large level of correlation residue for an optimal waveform set when used to perform a ground moving target indicator (GMTI) function in an airborne radar observing distributed clutter is that the rank of the resulting MIMO interference covariance is increased beyond that of an idealized orthogonal waveform set leading to significant degradation in the clutter mitigation performance, as shown through simulation. An approach to mitigating this effect through the use of partially optimized waveforms tailored to the scenario of interest is demonstrated to achieve the performance of an idealized orthogonal waveform set. [C110]

"An adaptive iterative scheme of Doppler centroid estimation for bistatic forward-looking SAR"

For high quality synthetic aperture radar (SAR) processing, Doppler centroid estimation is an essential procedure. According to the range migration characteristic of bistatic forward-looking SAR, an adaptive iterative scheme of Doppler centroid estimation is proposed in this paper. This scheme utilizes the fact that, in the range compressed and azimuth time domain, the range migration slope of point target response is proportional to the Doppler centroid for BFSAR. It estimates Doppler centroid by searching for the range migration slope based on the minimum waveform entropy. Simulation results validate the effectiveness of this method. [C111]

"ACF-based classification of phase modulated waveforms"

Classification of radar waveform phase modulation based on a sequence of observations is a simple problem complicated by a number of nuisance parameters. Without prior knowledge of waveform carrier frequency, time offset, amplitude, initial phase, and bandwidth, application of a matched filter classifier is not achievable. One must instead rely on waveform features that are invariant to these parameters. This paper presents an invariant feature set for waveform classification. Testing of these features on simulated radar waveforms has illustrated the desired invariance properties and robustness to low signal-to-noise ratio. [C112]

"Computationally efficient resampling of nonuniform oversampled SAR data"

A computationally efficient technique is developed to resample SAR data oversampled in the slow-time domain for a platform accelerating along the track. The algorithm segments the data between uniformly spaced points on the synthetic aperture, then performs a weighted average on the demodulated SAR data in each segment to adjust the effective sample position on the aperture. The weighting is derived using a first-order Taylor series approximation and used parameters from the velocity and acceleration of the platform and the radar waveform. [C113]

"Target detection in MIMO radar in the presence of Doppler using complementary sequences"

In this paper, we present a method for detecting a point target using multiple antennas when the relative motion between the receivers and the target induces a non-negligible Doppler shift. As a key illustrative example, we consider a 4Ч4 system employing a unitary matrix waveform set, e.g., formed from Golay complementary sequences. When a non-negligible Doppler shift is induced by the target motion, the wave-form matrix formed from the complementary sequences is no longer unitary, resulting in significantly degraded target range estimates. To solve this problem, we adopt a subspace based approach exploiting the observation that the receive matrix formed from matched filtering of the reflected waveforms has a (non-trivial) null-space. Through processing of the waveforms with the appropriate vector from the null-space, we can significantly improve the detection performance. We provide simulation results to confirm the theoretical analysis. [C114]

"Multipath exploitationwith adaptivewaveform design for tracking in urban terrain"

We integrate multipath exploitation with adaptive waveform design in order to increase the tracking performance of a vehicle moving in urban terrain. Mitigation of both clutter and strong multipath returns can result in increased target detection. However, exploiting multiple bounces from obstacles such as buildings can be shown to increase radar coverage and scene visibility, especially in the absence of direct line-of-sight paths. For this purpose, we formulate the multipath propagation of an arbitrary number of specular bounces in urban terrain for three-dimensional motion. We then further exploit and optimize multipath returns by dynamically selecting the parameters of the transmitted waveform to minimize the predicted mean-squared tracking error. We demonstrate our proposed approach in a realistic urban environment by varying the type of measurement to include regions of obscuration and different number of multipath bounces. [C115]

"Robust MIMO radar detection for correlated subarrays"

Previously, the well-known Optimum Gaussian Detector (OGD) has been extended to the Multiple-Input Multiple-Output (MIMO) case where all transmit-receive subarrays are considered jointly as a system such that only one detection threshold is used. In this extension, all subarrays have been assumed to be widely separated and the transmitted waveforms are assumed to be orthogonal. However, the necessary separation needed for each subarray to be uncorrelated depends on several factors and it might not be possible to ensure that this condition is always respected, especially in the case of moving platforms. Moreover, perfectly orthogonal waveforms do not exist. Hence, we consider in this paper, a new robust MIMO detector that is able to maintain the same Probability of False Alarm (Pfa) irregardless of the correlation between the subarrays. [C116]

"Iterative design of MIMO radar transmit waveforms and receive filter bank"

In this paper, we propose an iterative design approach to jointly optimize probing signal waveforms and a receive filter bank for a multiple-input multiple-output (MIMO) radar under a constant modulus constraint. The design goals are to approximate a desired beampattern and to minimize the auto-/cross- correlation levels of the probing signal waveforms for different time lags and between different spatial angles. Since the overall design problem is nonconvex, we propose to optimize the transmit probing signals and receive filter bank separately and alternately. The optimization of receive filter bank is a standard least squares problem, while the optimization of the constant modulus transmit signal waveforms is a norm-constrained least squares problem which can be approximately solved using a low-rank semidefinite relaxation procedure. We demonstrate the effectiveness of our proposed approach through a simulation example. [C117]

"Constant envelope waveform design for MIMO radar"

A method for generating constant envelope (CE) waveforms to realise a given covariance matrix for a closely spaced MIMO radar system is proposed. In contrast to available algorithms, the technique provides closed form solutions for finding the required waveforms and suggests that waveforms can be chosen from finite alphabets such as binary-phase shift keying (BPSK) and quadrature-phase shift keying (QPSK). Gaussian random-variables (RV's) are mapped onto CE non-Gaussian RV's using memoryless non-linear functions. The relationship between the correlation of Gaussian RV's at the input to the nonlinear functions and non-Gaussian RV's at their output is established. Simulation results are presented to demonstrate the effectiveness of the methodology. [C118]

"Waveform decorrelation for multitarget localization in bistatic MIMO radar systems"

The autocorrelation and crosscorrelation properties of transmit waveform set have great effect on the performance of MIMO radar systems. However, it is difficult to design waveform set which have ideal autocorrelation property as well as crosscorrelation one. In this paper, a decorrelation method has been proposed to cancel the effects of the autocorrelation and crosscorrelation of the transmit waveform by exploiting

the given statistical properties of waveform. The correlation property of noise after decorrelation is also analyzed. Then a close form solution for localization of the multiple targets is presented via ESPRIT. Simulation results demonstrate the effectiveness of the proposed methods. [C119]

"Multi-target tracking using multi-modal sensing withwaveform configuration"

We investigated the joint multi-modal operation of the asymmetric character of the fields of view of radar and electro optical (EO) sensors for multi-target tracking applications. We proposed a joint multi-modal sensing mode based on using dynamic agility selection to optimize the tracking performance of multiple maneuvering targets. The proposed method jointly designs waveforms for radar sensing and resolution switching modes for EO sensing, when both sensor measurements experience high false alarm rates. Rao-Blackwellized particle filtering is used to track an unknown number of targets within an adaptive framework that yields the optimized joint sensor configuration. We demonstrated the performance of the proposed adaptive tracking system using numerical simulations. [C120]

"A ternary pulse compression code: Design and application to radar system"

In this paper, we present new developed ternary code-punctured binary sequence-pair, give its definitions and the autocorrelation properties. We also investigate Doppler shift performance of the proposed code. The significant advantages of this ternary codes over conventional pulse compression codes, such as the widely used Barker codes, are zero autocorrelation sidelobes and the longer length of the code which can be as long as 31 so far. We apply our new ternary codes to radar system for target detection and observe that our codes outperform some other conventional pulse compression codes. [C121]

"Ambiguity Function analysis of WiMAX transmissions for passive radar"

In this paper the feasibility of a WiMAX transmissions based Passive Bistatic Radar (PBR) is analysed. The Ambiguity Function (AF) of the considered waveform of opportunity is characterized with reference to different transmission modes. The signal AF is shown to yield regularly spaced undesired peaks which might strongly limit the target detection capability of a WiMAX-based PBR. These sidelobe structures have a deterministic nature mainly related to the OFDM modulation exploited by WiMAX transmissions. A proper filter, based on the knowledge of the expected value of the signal Autocorrelation Function (ACF), is implemented to cope with this limitations and its performance is evaluated against simulated data generated according to the IEEE 802.16e Standard. The proposed approach is shown to yield an effective removal of the undesired peaks in the AF thus making the considered waveform more attractive for PBR medium range surveillance. [C122]

"Canadian HF Over-the-Horizon Radar experiments using MIMO techniques to control auroral clutter"

High frequency Over-the-Horizon Radar (OTHR) provides an economical means to track noncooperative air targets over large expanses of land and ocean. However, early attempts to run OTHR in Canada in the 1970s were confounded by the presence of intense radar clutter originating in the auroral zone. Recent advances in Multiple-Input Multiple-Output (MIMO) OTHR technology, namely orthogonal waveform transmit arrays and fully sampled receive arrays, provide an opportunity to revisit the possibility of OTHR in Canada. An OTHR testbed has been built in Ottawa, Canada to determine the capabilities of the technology. The testbed consists of a MIMO OTHR with 4 transmit channels and 4 receive channels. Some preliminary data show that MIMO processing is effective in suppressing the clutter. It is then proposed to upgrade the testbed to a larger-scale system. [C123]

"Frequency-hopping code optimization for MIMO radar using the hit-matrix formalism"

There has been a recent interest in the application of multiple-input multiple-output (MIMO) communication concepts to radars. While traditional phased-array radars transmit coherent waveforms from their many antenna elements, MIMO radars transmit incoherent waveforms from their transmitters, which offer additional benefits like spatial diversity and spatial resolution. In recent literature, the optimization of orthogonal frequency-hopping waveforms for MIMO radars has been discussed. This optimization is done using a `cost function' derived from a newly formulated MIMO radar ambiguity function. In our paper, we extend the scope of this ambiguity function to large values of target Doppler. We also propose the use of the `hitmatrix' as a tool to optimize frequency-hopping codes under the large Doppler scenario, since it results in a cost function with a significantly lower computational complexity. The hit-matrix is a generalization of the hit-array, which has been used in the context of frequency-hopping waveforms for phased-array radars. [C124]

"3 GS/s S-Band 10 Bit ADC on SiGeC Technology"

In advanced applications such as digital radar, Ultra Wide Bandwidth communications and software defined radio, the need for instantaneous bandwidth often drives system design decisions. Access to high speed data converters enabling up and down conversion directly in the L Band and S Band removes the limit imposed by bandwidth scarcity and allows the design of flexible and simplified system architectures. Broadband ADC's (Analogue to Digital Converters) are key enabling components which open up new design opportunities for digital Receiver systems. In this regard, this paper describes a new 10bit 3GS/s ADC with 5 GHz Bandwidth, based on a 200 GHz SiGeC bipolar Technology, which enables the direct digitizing of 1GHz arbitrary broadband waveforms directly in the high IF region closer to the Antenna (L-Band or S-Band). [C125]

"Waveform design by Task-Specific Information"

We propose a new waveform design metric called Task-Specific Information (TSI). As its name suggests, TSI is an information-theoretic metric formulated for a specific task or set of tasks. For example, in this paper we consider the problem of correctly classifying a linear system from a set of known alternatives. The TSI metric directly quantifies information about the hypotheses while previous information-based approaches quantify mutual information related to potential system realizations. Thus the TSI framework is a more direct measure of task-related performance. In addition, for the problem statement considered in this paper it is possible to find a globally optimum solution through gradient-based search techniques. We compare the performance of TSI and conventional waveform designs. [C126]

"An interpretation of Woodward's ambiguity function and its generalization"

We suggest a new interpretation of Woodward's ambiguity function as the expected value of an operator. The operator represents the physics of the interaction of the waveform with the object. This approach provides a new approach to understanding the return signal at the receiver and can reveal more detailed understanding of the underlying interactions within the return signal that are not usually brought out by standard signal processing techniques. [C127]

"An indoor S-band radar receive array testbed"

This paper describes a multi-channel S-band radar receive system designed as a laboratory testbed system for studying wideband radar array signal processing. The receive array was designed using a combination of low-cost commercial-of-the-shelf components and a custom-designed surface-mount printed circuit board assembly. It has been tested using LFM-CW waveforms with a center frequency of 2.4 GHz and a bandwidth of 600 MHz. By using components manufactured to operate in the "Wi-Fi" wireless communications band, the cost of the system has been minimized. This paper presents the design of the system, test results, and some sample ARD surfaces from the system. [C128]

"Software-defined radar for MIMO and adaptive waveform applications"

The development of a software-defined radar testbed is described. The testbed is to be used to explore advanced techniques such as multiple-input multiple-output radar and adaptive waveforms. The system features a fully programmable, dual-channel, arbitrary pulsed waveform generator with a quadrature downconverting receiver. The system can generate waveforms of up to 500 MHz instantaneous bandwidth at a center frequency tunable from 2-18 GHz. The RF front end features two independent transmit and receive channels that can be multiplexed between four dual-polarized transmit and four dual-polarized receive antennas. [C129]

"Blind multipath separation for waveform recovery"

The separation of multipath signal components by spatial filtering in a narrowband antenna array is addressed for cases where diffuse scattering and array calibration errors may cause the spatial signatures of the received propagation modes to deviate significantly from the plane-wave array manifold. The distorted wavefronts may have complex spatial signatures that are difficult to accurately characterize and mutually resolve on the basis of array manifold models described by few parameters. Furthermore, the temporal signature of the source waveform may also be quite arbitrary, with no known deterministic or statistical properties that can be utilized for multipath separation. This problem calls for blind waveform estimation methods that rely on relatively mild assumptions. An alternative blind spatial filtering technique referred to as the Generalized Estimation of Multipath Signals algorithm, or GEMS, is introduced for this purpose and tested on experimental data provided by the high frequency (HF) radar program of the Defence Science and Technology Organization (DSTO), Australia. [C130]

"Multistatic radar imaging of moving targets"

We develop a linearized imaging theory that combines the spatial, temporal, and spectral aspects of scattered waves. We consider the case of fixed sensors and a general distribution of objects, each undergoing linear motion; thus the theory deals with imaging distributions in phase space. We derive a model for the data that is appropriate for narrowband waveforms in the case when the targets are moving slowly relative to the speed of light. From this model, we develop a phase-space imaging formula that can be interpreted in terms of filtered backprojection or matched filtering. For this imaging approach, we derive the corresponding phase-space point-spread function. We show plots of the phase-space point-spread function for various geometries, and various combinations of waveforms. [C131]

"Optimal transmitting diversity degree-of-freedom for statistical MIMO radar"

Statistical multiple-input multiple-output (MIMO) radar may improve the fluctuated target detection by utilizing the multiple separate transmitting and receiving elements. Nevertheless, the transmitting power of single element is reciprocal to the transmitting element number, and the ultimate detection performance of MIMO radar may be inversely deteriorated with the increase of the transmitting elements. In this letter, the optimal transmitting diversity DOF, i.e., the optimal separate transmitting elements, is defined based on the proposed likelihood ratio test (LRT) detectors. Furthermore, with the given false alarm probability and detection probability, the closed-form optimal DOF approximations are derived for the two sub-forms of statistical MIMO radar, i.e., distributed MIMO radar and multiple-input single-output (MISO) radar, respectively. It is shown that a small transmitting diversity DOF, as well as the small number of orthogonal transmitting waveforms, may be needed for optimizing the statistical MIMO radar spatial diversity performance. Finally, numerical experiments are also provided to demonstrate the effectiveness of the proposed methods. [C132]

"Space-Range Adaptive Processing for waveform-diverse radar imaging"

Waveform-diverse radar arrays have been proposed as a method to facilitate single pulse imaging as well as to potentially enable simultaneous multi-mode operation. Transmitting different waveforms on the elements of a uniform linear array consequently raises the spatial and temporal sidelobes of the receiver matched filter. In this paper a recursive minimum mean square error based receiver design denoted as Space-Range Adaptive Processing is presented. The new method is capable of mitigating space range sidelobes thereby providing enhanced sensitivity for this transmission scheme. [C133]

"Ambigutiy function of SAR based on OFDM waveform"

Recently many researchers have turned their interests to Orthogonal Frequency Division Multiplexing (OFDM) signal since its promising features in radar. This paper concerns a novel Synthetic Aperture Radar (SAR) system which employs this OFDM signal. Though the OFDM will bring lots of advantages, the performance may be changed since the signal of SAR is different from conventional ones. To evaluate the change, this paper will give a theoretical analysis and the corresponding simulation results from the viewpoint of ambiguity function. This ambiguity function is equivalent to the role of Point Spread Function (PSF) which is often used in SAR for evaluating resolutions. Comparing to the conventional SAR with LFM signal, it is proved that the resolution of SAR based on OFDM is equivalent to the conventional one or even better. This ambiguity function also provides a principle for selecting various OFDM signals as the transmit signal of SAR. [C134]

"Analysis of MIMO radar ambiguity functions and implications on clear region"

Multiple input multiple output (MIMO) radar offers the potential for improved performance over more traditional single input multiple output (SIMO) radar. MIMO radar operates by transmitting separable waveforms from multiple transmitters and the resulting radar echos are received by multiple receivers. While there is a great deal of literature discussing the benefits of MIMO techniques, a handful of publications discussing the limitations of MIMO radar techniques have appeared in the literature. Of particular interest is the work addressing the reduction of the clear area in range-Doppler space. Using a particular form of the MIMO ambiguity function, it was shown for a MIMO radar transmitting N waveforms there is a reduction of the clear area by a factor of 1/N. In this paper, we repeat this analysis for the ambiguity function applicable to a coherent MIMO radar. We show the MIMO ambiguity function proposed in does not fully capture some important features of coherent MIMO radar and differs from versions of the ambiguity function proposed by other authors. In the second half of this paper, we derive the MIMO ambiguity function for coded pulse train waveforms. In addition to the traditional narrowband assumption, we develop the MIMIO ambiguity function using the "start-and-hop" radar signal model. [C135]

"MIMO radar sparse angle-Doppler imaging for ground moving target indication"

We present in this paper a regularized sparse signal recovery algorithm, referred to as sparse learning via

iterative minimization (SLIM), to provide ground moving target indication (GMTI) through multiple-input multiple-output (MIMO) radar angle-Doppler imaging. A slow-time modulation scheme with code division multiplexing is employed to achieve transmit diversity. In this way, we avoid the high correlation properties of orthogonal waveforms and the Doppler ambiguity that is encountered with Doppler division multiplexing schemes. After removing jammer and clutter effects using semi-unitary projections, we show that SLIM, using primary data only, is able to form sparse angle-Doppler images and to provide for accurate target localization. [C136]

"Fast computations of constant envelope waveforms for MIMO radar transmit beampattern"

Designing transmit beampattern with MIMO radars generally requires the waveforms to be able to have arbitrary cross-correlation values. In contrast to the available algorithms, the proposed technique provides a closed-form solution for the synthesis of covariance matrix, R, of the waveforms to obtain desired beampattern match. To synthesis R the constraints and redundant information in R are leveraged, which convert the constrained problem into un-constrained problem. Next a novel method for generating the constant-envelope (CE) waveforms to realise the synthesised covariance matrix, R, is proposed. This method also yields a closed-form solution and choose the symbols from the binary-phase shift-keying (BPSK). Here, Gaussian random-variables (RV's) are mapped onto the CE RV's by a memoryless non-linear transformation, which converts the problem of finding the non-Gaussian RV's to realise a given covariance matrix R into finding the Gaussian RV's to realise covariance matrix Rg. Simulation results are presented to demonstrate the effectiveness of both methodologies. [C137]

"Range-angle dependent waveform"

In this paper the concepts of the Frequency Diverse Array and the Waveform-Diversity MIMO radar systems are combined. When the elements of an Electronically Steered Array transmit a number of pseudo-noise codes at slightly different carrier frequencies simultaneously, the coherent summation of the codes originates a waveform whose shape changes in both angle and range. In fact, the MIMO technique provides the angle-changing characteristic, whilst the FDA technique contributes to a range-changing propagating waveform. Therefore, this technique allows to associate a waveform to each point of the range/angle of the space, with the possibility of recovering this information at the receiver after appropriate processing. [C138]

"Calibration system stability plans for a long-term Ecological Airborne remote sensing project"

The National Ecological Observatory Network (NEON) Airborne Observation Platform (AOP) will fly an imaging spectrometer, small footprint waveform LiDAR and high-resolution digital camera to observe both the human drivers of climate change and the biological consequences of environmental change at a continental scale. The project is planned for a 30-year period. To be meaningful as an ecological climate data record, the AOP data set must have a continuous and consistent calibration effort. This paper briefly describes plans for the development of a robust calibration and validation plan to ensure data continuity from instrument-to-instrument, flight-to-flight, and year-toyear over the lifetime of the NEON project. [C139]

"Analysis of the correlation properties of digital satellite signals and their applicability in bistatic remote sensing"

This paper presents a study of relevant correlation properties of signal transmitted from commercial communication satellites in order to evaluate their potential use as "signal of opportunity" for bistatic remote sensing. The ambiguity function for the XM radio satellites was computed analytically from published information on the modulation schemes and bandwidth, under the assumption that the data modulation is random. The model was then experimentally tested by recording the received signals from these satellites. Next, a cross-correlation waveform for digital signal reflected from random rough surface was simulated. Scattering model that were originally developed for Global Navigation Satellite System (GNSS-R) signals was applied to the modified simulator to incorporate the derived ambiguity function. The simulator was then used to generate synthetic waveform with a realistic signal to noise ratio (SNR). Retrieval algorithms for ocean surface roughness and reflectivity that were derived originally for GNSS-R, were applied to these simulated signals. Non-linear least square methods were applied to invert a scattering model and estimate the slope variances of the probability density function (PDF), which best fits the measurements of the reflected XM signal waveform. The SNR for the experimental data was found to be within 0.5dB of the theoretically calculated SNR. [C140]

"Successive cancelation approach for Doppler frequency estimation in pulse Doppler radar systems"

In this paper, a successive cancellation approach is proposed to estimate Doppler frequencies of targets in pulse

Doppler radar systems. This technique utilizes the Doppler domain waveform structure of the received signal coming from a point target after matched filtering and pulse Doppler processing steps. The proposed technique is an iterative algorithm. In each iteration, a target that minimizes a cost function is found, and the signal coming from that target is subtracted from the total received signal. These steps are repeated until there are no more targets. The global minimum value of the cost function in each iteration is found via particle swarm optimization (PSO). Performance of this technique is compared with the optimal maximum likelihood solution for various signal-to-noise ratio (SNR) values based on Monte Carlo simulations. [C141]

"Time reversal adaptive waveform in MIMO radar"

EM multipath propagation is common in radar and wireless communications. Most radar systems are designed assuming line-of-sight (LOS), not multipath. In this paper, we extend our prior work on Multi-Input Multi-Output (MIMO) radar in the absence of interference [1], to consider MIMO radar detection in high clutter. We develop a subspace MIMO target model and a statistical model for MIMO radar clutter that accounts for the spatial and spectral properties of radar returns. We show that, using orthogonal waveform signaling, the time reversal MIMO radar yields higher detection performance than conventional statistical MIMO radar in high clutter. [C142]

"Use of the merged dual-frequency radar altimeter backscatter data over China land surface"

It is a special way to investigate continental surfaces using radar altimeter, besides scatterometers and Synthetic Aperture Radar among the active microwave remote sensing sensors for the altimeter works at the nadir point of satellite and at dual-frequency, which can measure the backscatters from different layers instantaneously. The aim of this paper is to merge multi-radar altimeter dual-frequency backscatter measurements over land surface to achieve better spatial and temporal resolution. The 0.5°Ч0.5° merged altimetry backscatter maps between 66° N to 66° S over land surface every 6 days are generated in Ku, C, and S band for the period from January 2002 to June 2009. Temporal profiles of backscatters are examined for main land types (desert, forest, savanna) to validate the dataset and to analyze radar response to land surface variability through 8 years. [C143]

"Icesat lidar and global digital elevation models: applications to desdyni"

Geodetic control is extremely important in the production and quality control of topographic data sets, enabling elevation results to be referenced to an absolute vertical datum. Global topographic data with improved geodetic accuracy achieved using global Ground Control Point (GCP) databases enable more accurate characterization of land topography and its change related to solid Earth processes, natural hazards and climate change. The multiple-beam lidar instrument that will be part of the NASA Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) mission will provide a comprehensive, global data set that can be used for geodetic control purposes. Here we illustrate that potential using data acquired by NASA's Ice, Cloud and land Elevation Satellite (ICEsat) that has acquired single-beam, globally distributed laser altimeter profiles (± 86°) since February of 2003. The profiles provide a consistently referenced elevation data set with unprecedented accuracy and quantified measurement errors that can be used to generate GCPs with sub-decimeter vertical accuracy and better than 10 m horizontal accuracy. Like the planned capability for DESDynI, ICESat records a waveform that is the elevation distribution of energy reflected within the laser footprint from vegetation, where present, and the ground where illuminated through gaps in any vegetation cover. The waveform enables assessment of Digital Elevation Models (DEMs) with respect to the highest, centroid, and lowest elevations observed by ICESat and in some cases with respect to the ground identified beneath vegetation cover. Using the ICESat altimetry data we are developing a comprehensive database of consistent, global, geodetic ground control that will enhance the quality of a variety of regional to global DEMs. Here we illustrate the accuracy assessment of the Shuttle Radar Topography Mission (SRTM) DEM produced for Australia, documenting spatially varying elevation biases of several mete--rs in magnitude. [C144]

"Assessment of tree and crown heights of a maritime pine forest at plot level using a fullwaveform UltraViolet Lidar prototype"

This study aims to determine the potential of a new lidar prototype with an ultraviolet laser and a medium footprint for retrieving forest parameters. The lidar is embedded on an ultra-light aircraft. The choice of the Landes forest in southwestern France as study area was made regarding the flat topography of the area and the stand height consistency. We chose three plots from different stands (different height characteristics) and compared the lidar derived metries to field measurements. To derive metries from lidar data, we summed the lidar waveforms within a plot and calculated derived reflectance profiles to correct the lidar signal from the occlusion effect. We then retrieve plot mean total and mean crown base heights measurement from reflectance profiles. We obtain a good consistency of the lidar measurements compared to field measurements, even if we noticed the existence of a 5 to 10% bias probably linked to the lidar sampling strategy. [C145]

"Extracting strctural land cover components using small-footprint waveform lidar data"

Previous work has shown the ability of waveform LiDAR sensors to accurately describe various land cover types [1] and biomass estimates made in the field [2]. What is lacking, however, is a way to describe the different structural components that are embedded in the digitized backscattered energy from the LiDAR pulse. This study aims to extract structural components from waveform LiDAR data in terms of woody, herbaceous, and bare ground components from data collected over a savanna environment in and around Kruger National Park (KNP), South Africa. These components are comprised of metrics extracted from the waveforms and validated using biomass measurements made in field plots. Different size windows around plot centers, 3 Ч 3 pixels and 9 Ч 9 pixels (resulting in 1.5m and 4.5 m footprint, respectively), were used to examine scale effects of larger footprints. It was found that composite waveforms resembling plot sizes (9 Ч 9) most often are able to describe more than 80% of the woody biomass variability across the entire study site, and individually for two of the three land uses within the area. However, the herbaceous component of the waveform did not correlate well with the field measurements, while the bare ground component was verified visually in a side-by-side comparison with optical imagery. [C146]

"Effects of forest disturbances on forest structural parameters retrieval from lidar waveform data"

The effect of forest disturbance on the lidar waveform and the forest biomass estimation was demonstrated by model simulation. The results show that the correlation between stand biomass and the lidar waveform indices changes when the stand spatial structure changes due to disturbances rather than the natural succession. This has to be considered in developing algorithms for regional or global mapping of biomass from lidar waveform data. [C147]

"Preliminary experimental results for RF tomography using distributed sensing"

Traditional high-value monostatic imaging systems employ frequency-diverse pulses to form images from small synthetic apertures. In contrast, RF tomography utilizes a network of spatially diverse sensors to trade geometric diversity for bandwidth, permitting images to be formed with narrowband waveforms. Such a system could use inexpensive sensors with minimal ADC requirements, provide multiple viewpoints into urban canyons and other obscured environments, and offer graceful performance degradation under sensor attrition. However, numerous challenges must be overcome to field and operate such a system, including multistatic autofocus, precision timing requirements, and the development of appropriate image formation algorithms for large, sparsely populated synthetic apertures with anisotropic targets. AFRL has recently constructed an outdoor testing facility to explore these challenges with measured data. Preliminary experimental results are provided for this system, along with a description of remaining challenges and future research directions. [C148]

"Optimal algorithms for spaceborne altimeter"

This paper is dedicated to new methods of space altimeter altitude and sea surface significant wave height (SWH) measuring. These methods are based on the fundamentals of Bayesian optimal measure method of a parameter. Optimal discriminators of the parameters are developed using the least square error of the estimate criteria, apart from others papers which mostly minimize the least square error of altimeter waveform fitting function. Potential measurement accuracy calculation results are also presented. [C149]

"Soil dielectric and senisitivity analysis for subsurface imaging applications based on distributed Sensor Networks"

The concept of a subsurface imaging technique based on Unattended Ground Sensor Networks operating in the VHF range using ultra-wideband waveforms was recently proposed in. In this approach a forward model for realistic subsurface environment based on the Dyadic Green's function for a stratified medium and an inversion technique using an ultra-wideband near-field focusing were presented. Simulation results showed that very good lateral and depth resolution could be achieved. Before carrying out an experiment to test the proposed technique, three vital aspects of the work which are imposed by practical limitations are investigated and presented in this paper. First, the sensitivity analysis to assess the signal penetration depth in realistic subsurface environments for various frequencies is performed. Analysis of the frequency requirements of the inversion as they relate to depth resolution is also analyzed. A semi-analytic soil dielectric model originally devised for microwave frequencies is extended to VHF and validated using measurement results available in literature. [C150]

"Realization of the NASA Dual-Frequency Dual-Polarized Doppler Radar (D3R)"

This paper describes some of the novel technologies adopted in the realization of the NASA Dual-frequency Dual-polarized Doppler Radar (D3R) system for to be used by the GPM ground validation program. A description of the transceivers and major trades that lead to a solid-state architecture is presented. Other aspects enabling the design such as the waveform design and generation and the digital receiver is also described. Data measured from a similar power amplifier was used to estimate the expected range side lobe performance. An estimate of the expected sensitivity based on the transceiver parameters also presented. [C151]

"Automation of object extraction from LiDAR in urban areas"

Light Detection and Ranging (LiDAR) has become a valuable data source for urban data acquisition. This paper gives an overview about current trends in the automation of object extraction from LiDAR data. These trends are caused by the technical development of LiDAR sensors that enable the acquisition of point clouds at higher resolution as well as the recording of the full waveform of the returned signal, and by the adoption of processing techniques from the Computer Vision and Pattern Recognition communities. Triggered by these developments, new applications are being found for LiDAR data. [C152]

"Fusion: A fully ultraportable system for imaging objects in nature"

To improve satellite-derived estimates of terrestrial plant production and exchange of CO2, water, and energy with the atmosphere, scientists need to consider ecosystem composition, structure, function, and health. This can be accomplished through the fusion of Light Detection And Ranging (LiDAR) data, which can provide 3D information about the vertical and horizontal distribution of vegetation and hyperspectral remote sensing, which can inform us about variations in biophysical variables (e.g., photosynthetic pigments) and responses to environmental stressors (e.g., heat, moisture loss). Satellite observations from upcoming Decadal Survey missions will provide NASA with the unique opportunity to fuse LiDAR data from ICESat-II, DESDynI, and LIST with hyperspectral and thermal imagery from HyspIRI and GEO-CAPE. This synergy will augment and enhance the individual science objectives of decadal survey missions, and will allow scientists the opportunity to develop 3D models of plant canopies that better describe global cycling of carbon, water and energy. Multiple NASA's Earth Science Focus Areas are served by this science, including carbon cycle and ecosystems; water and energy cycle; and climate variability and change (i.e., ecosystem responses and feedbacks to climate change). One of the major obstacles to the development of data fusion algorithms is the availability of accurately co-registered data of similar grain size. This is often the case when instruments are flown on different platforms and at different times during a field campaign. We believe that "instrument fusion" is a prerequisite to "data fusion", and we have developed a system the integrates a full-waveform LiDAR, narrow band hyperspectral imager, and broad band thermal imager in a single, compact and portable instrument package that could be readily deployed on a number of observation platforms. FUSION will provide accurate co aligned datasets that are neede--d for: (i) calibration and validation of satellite-derived land products; (ii) development of data fusion algorithms; and (iii) combine observations from multiple sensors to characterize ecosystem composition, structure, function, and health. [C153]

"Relations between SAR tomography and full-waveform LIDAR for structural analysis of forested areas"

Active remote sensing techniques, like SAR tomography and full-waveform LIDAR, are able to capture the 3D reflectance function at or inside objects. They are therefore of special interest for analyzing forest environments. Research goals are the derivation and characterization of the different physical measurement aspects of data taken over forested areas, as well as establishing mutual relations in such a way that LIDAR data can be used to calibrate and correct 3D density data of SAR tomography. The paper outlines the phenomenology of forested areas in SAR tomograms and full-waveform LIDAR data and sketches a simple mathematical methodology for linking SAR and LIDAR reflection density profiles. [C154]

"MIMO SAR processing with azimuth nonuniform sampling"

This paper analyses ambiguity suppression caused by multiple-input multiple-output (MIMO) SAR azimuth nonuniform samplings. Two methods are analyzed: azimuth spectrum reconstruction algorithm and minimum mean square error (MMSE) imaging algorithm. The azimuth spectrum reconstruction algorithm can reconstruct the scene fine resolution, while the nonideal orthogonality of multi-channel encoding waveforms causes azimuth ambiguous in SAR imaging. The MMSE imaging algorithm can perfectly reconstruct, while it requires high SNR. [C155]

"Characterization of layered media using full-waveform inversion of proximal GPR data"

Full-waveform inversion of proximal ground penetrating radar (GPR) data is used to determine the

electromagnetic properties of layered media. The radar system consists of a vector network analyzer combined with an off-ground horn antenna operating at ultra wideband. The GPR wave propagation is modeled for a multilayered medium using a recursive Green's function computed in the frequency domain. The antenna and its interactions with the layered medium are modeled using a linear system of complex transfer functions. GPR signals were acquired in laboratory above a two-layered sand medium and two concrete slabs separated by a thin air layer (simulating a fracture). Subsequent inversions permit to retrieve the electromagnetic properties and the dimensions of these thin-layered media. For humid sand, GPR-derived dielectric permittivities showed a good agreement (RMSE = 1.65) with measured volumetric water contents. Dimensions of the three-layered concrete medium could be retrieved with a millimetric accuracy. The method is promising for the non-destructive characterization of multilayered media, including thin layers, owing to the full-waveform inversion of the radar data in a large frequency bandwidth. [C156]

"Pulse design method for UWB vehicular radar system"

A frequency-domain pulse design method for ultra wideband (UWB) vehicular radar system is proposed. Morlet wavelet pulses with the diverse dilatation factors are randomly selected as basis ones. By adjusting these parameters such as the dilation and the value of the amplitude spectral, the corresponding power spectral density (PSD) of linear combination pulse is obtained which must match the FCC's PSD mask as closely as possible and maximize the bandwidth. Then the combination coefficients are directly obtained by the solution of frequency-domain restraint equation group. Simulation results show that the PSD of combination pulse has larger bandwidth than that of single Morlet pulse and complies with the FCC spectrum mask. [C157]

"Application of the deconvolution method in the processing of Full-waveform Lidar data"

Full-Waveform Lidar (light detection and ranging) records the entire backscatter signals of each emitted pulse, which is benefit to know the surface features. Full-waveform Lidar has strong ability in detecting the vertical structure of vegetation and terrain. The location or height information can be extracted from the received waveform. Most common extraction techniques may be invalid sometimes, such as Gaussian decomposition will be invalid when the received signal cannot be composed of pure Gaussian function combinations. In the application of processing returned signal, the method of deconvolution has the unique advantages in extracting parameters of position, amplitude range and height. It has been widely used in spectroscopy, signal recovery, signal analysis, signal modeling and so on. In this study, deconvolution was used to remove the characteristic of the transmitted waveform form the received waveform to obtain a surface response. The simulated waveforms were used to investigate the potential of deconvolution in Full-waveform Lidar data analysis. The results showed that the Gold's method of deconvolution was suitable for solving the problem. [C158]

"Deterministic propagation modeling for joint radar and communication systems"

In this paper investigations on the performances of joint radar and communication systems in realistic traffic scenarios are presented. This is achieved by combining dedicated MatLab models for transmitter and receiver with a deterministic propagation simulator based on ray-tracing. Two different approaches towards a joint implementation of radar and communications with one common transmit signal are regarded. In the simulations in particular the direction of arrival estimation with the reflected signal has been investigated for different waveforms and beam-forming algorithms. [C159]

"Study on Defocus compensation using variable pulse repetition time stepped-frequency waveform"

In this paper, a new technology for compensating the defocus due to the velocities of multiple moving targets is presented. By using this technology, the blur produced by defocus can be compensated when the velocities are unknown. And a method is proposed to solve the range-Doppler coupling caused by the multiple targets. The effectiveness of the algorithm is illustrated with simulation results. [C160]

"Integrated X-band FMCW front-end in SiGe BiCMOS"

An integrated X-band FMCW front-end is reported. The front-end unites the core functionality of an FMCW transmitter and receiver in a 0.25 μm SiGe BiCMOS process. The chip integrates a PLL for the carrier generation, and single-side band and image-reject mixers for up- and down-conversion of the waveform. The front-end has been designed to co-operate with COTS integrated direct digital synthesisers and ADCs. The measurements show an output power of 0 dBm, P1dBat the receiver input of -11 dBm and a side band suppression of the mixer in the transmit chain of >40 dBc. The MMIC measures 1.8Ч1.5 mm2. This integrated front-end paves the path for future planar 2D integration of FMCW phased-array radars at X-band. [C161]

"A quantitative assessment of the compatibility of Ultra Wideband with radiolocation services"

In this coexistence study, the effect of an Ultra Wideband (UWB) MB-OFDM signal, as defined in the ECMA-368 standard, on an S-band radar device working in the 3.1 GHz to 3.4 GHz range is investigated. An extensive series of 6460 measurements, done with 20 different radar waveforms and for various radar and UWB signal levels is analyzed, using a laboratory test bed specifically designed for this purpose. The interfered radar signal is acquired by a spectrum analyzer and then processed on a stand-alone PC. Different post-processing techniques are applied, depending on the type of the selected radar receiver structure. [C162]

"Design and realization of a radar simulation system base on CPCI bus"

In this paper, design and implementation of a radar signal simulation system is introduced. It is based on standard CPCI bus and follow the design principle of standardized, modular and extendable in design process. This system is made up of standard hardware and the simulated waveform can be obtained from any algorithms. This system is flexible to extend based on complexity of the algorithms. [C163]

"A novel method of resolving velocity ambiguity in the pulse doppler radar"

In this paper, a novel method of resolving velocity ambiguity in the pulse Doppler (PD) radar is proposed. By using multi-carrier-frequency waveform and Chinese Remainder Theorem (CRT), this method is able to overcome the velocity ambiguity. Furthermore, a modified algorithm with better robustness is deduced and its performances are analyzed in detail. Specific conclusions are verified with some simulation results. [C164]

"TropiSAR: Exploring the temporal behavior of P-Band SAR data"

The TropiSAR campaign has been conducted in August 2009 in French Guiana with the ONERA airborne system SETHI. The main objective of this campaign was to collect data to support the Phase A of the Earth Explorer candidate mission, Biomass. Several specific questions need to be addressed to answer the recommendations of the ESAC group and the data collection strategy has been constructed accordingly. The first part of the paper lists these specific questions. We then describe the selected test sites, followed by a summary on the radar instrument and the radar configuration (geometry and waveform). The data acquisition plan is provided and the temporal behaviour of the P-Band data is explored. [C165]

"High-resolution 3-D radar imaging using pseudo-random noise coded waveform"

In this paper, high-resolution 3-D radar imaging using a 3-step image formation procedure based on the Huggens-Fresnel's principle is analyzed and discussed. To achieve high spatial resolution, large antenna array is required. The array can be implemented with a synthesized antenna array, or a sparse antenna array. To achieve high range resolution, pseudo-random noise (PN) coded signal waveform is used. The ability of generating high-resolution 3-D imaging is verified by computer simulation. Numerical simulation shows the reconstructed 3-D radar image of an object. PN coded signal waveforms also has the advantage of noise immunity. Applications of the high resolution 3-D radar imaging can be in ground penetration radars, microwave medical imaging, and down-looking SARs. [C166]

"Coherent MIMO radar for GMTI"

In addition to imaging, coherent MIMO radars have a strong potential for detecting moving objects and estimating their parameters. This paper investigates different MIMO schemes based on spatial, waveform, and frequency diversity for their GMTI capability. The fully configurable MIMO radar MIRACLE X is taken as the baseline design for comparing the different approaches. [C167]

"ISAR imaging of an aircraft target USING ISDB-T digital TV based passive bistatic radar"

Passive bistatic radars (PBRs) exploit existing transmitters such as TV broadcasts as the source of illumination. PBR is consisted of two receivers, with one antenna pointed at the source and the other at the target, and the target range is determined by correlating the signal scattered by the target with the signal directly arrived at the receiver. Since PBR does not transmit any waveform, it consumes lower power, and no frequency allocation is required. We have conducted a field experiment exploiting terrestrial digital TV broadcast to assess the feasibility of ISAR (Inverse Synthetic Aperture Radar) observation based on PBR. The wide and flat spectrum of the OFDM signal and the small gap between the channels enables us to obtain high range resolution of up to several meters by exploiting multiple physical channels. Therefore, moderate resolution ISAR imaging is expected to be possible. In this paper, PBR based ISAR algorithm is briefly explained, and the first example of observed PBR based ISAR image of an aircraft target is shown. [C168]

"Fetch limited sea scattering spectral model for HF-OTH skywave radar"

Sea Normalized RCS, and Doppler spectra have been revised for HF-OTH Clutter Modelling. The Hasselmann model is firstly introduced to predict the sea directional spectrum of fetch-limited sea and results have been compared with the Pierson-Moskovitz model used for large scale ocean remote sensing. Results show that the closed fetch-limited sea has lower NRCS compared with ocean for similar wind intensity and direction. For this reasons RCS and Doppler spectra must be predicted taking into account of the fetch dimension. In future work we will generalize this interesting approach to fetch-limited wind, time-limited pulse, in order to show the waveform effect on Doppler spectrum. [C169]

"Using airborne & space lidars for large-area inventory"

NASA plans to launch two space lidar missions over the next decade, and at least one proposal for a space lidar is being considered by the European Space Agency. All designs call for single-beam or multi-beam profiling systems. These space ranging systems, like the ICESat/GLAS lidar that collected over 1.91 billion waveforms between January 2003 and October 2009, must necessarily be used as sampling tools to characterize vegetation cover and to estimate forest volume, biomass, and carbon globally. Recent investigations conducted by these authors have centered on developing, testing, and refining statistical approaches that can incorporate airborne and space lidar acquisitions to inventory large areas. [C170]

"DVB-T passive radar for vehicles detection in urban environment"

Passive radar systems exploit non-cooperative transmitter to detect targets in areas of interest. Some of the main advantages of such systems with respect to conventional radars include low cost architectures, low energy requirements and potentially null probability of intercept. In this paper a low-cost solution for vehicles detection making use of passive radar concept is presented. A Software Defined Radio (SDR) solution and commercial antennas have been used to realize a DVB-T passive radar demonstrator. An analysis of the DVB-T signal is firstly presented together with a study of its capability as radar waveform. Afterwards an experimental setup is presented and analysed and finally some results of targets detection are shown. [C171]

"Reciprocal spectrum algorithm for radar imaging with frequency sampling waveform"

A radar imaging algorithm named reciprocal spectrum algorithm (RSA) is proposed in this paper to get higher resolution in azimuth direction with frequency sampling waveform. Theoretical analysis and simulation results show that the algorithm can give better performance than the tradition range Doppler algorithm (RDA) at the cost of peak value reduction at the object points in radar image. [C172]

"Application of AWE to scattering analysis of the double-negative medium"

The PMCHWT equation of the double negative media (DNG) is obtained based on its constitutive relationship. And the surface currents and radar cross section (RCS) at a single frequency point is computed by Method of moments (MOM). The asymptotic waveform evaluation (AWE) technique for dispersive dielectric medium is deduced and applied to electromagnetic scattering analysis of double-negative medium within a given frequency hand. [C173]

"Fast RCS computation over a frequency band based on general asymptotic waveform evaluation: Geometric modelling by NURBS surface"

To fast calculate the radar cross section (RCS) of an arbitrarily shaped three-dimensional (3D) perfect electric conductor (PEC) body over a frequency band, the method of moments (MOM) in conjunction with the general asymptotic waveform evaluation (GAWE) is applied in this paper. And the 3D body is modelled by the non-uniform rational B-spline (NURBS) surface through the compute aided geometric design (CAGD). Numerical simulations of a square plate and a sphere are shown. Good agreements between the GAWE and the exact solutions obtained by MOM are illustrated. And the GAWE is more effective in computing the RCS over a frequency band. It is necessary to note that the MOM in conjunction with the GAWE technique can be also applied to predict the mono-static RCS of an arbitrarily shaped 3D PEC body. [C174]

"Noise suppressions in chaotic lidars under different synchronization schemes"

Lidar has been extensively studied for its applications in target detection, range measurement, and imaging. Compare with other light source, chaotic lidar (CLIDAR) has the advantages of very high range resolution and never repeated waveform benefited by the broad-band chaotic waveform used. However, the channel noises between the transmitter and the receiver may decrease the quality of the correlation in the conventional chaotic

lidar scheme. In this paper, we numerically study the resistances of the channel noise utilizing chaos synchronization in different schemes. [C175]

"Frequency based oscilloscope triggering scheme"

This paper presents a novel frequency based oscilloscope triggering technique for measurements involving complex waveforms that are challenging even today. Proposed technique is capable of providing stable triggering even in the case of complex periodic waveforms category where commonly used level triggering scheme fail to perform adequately and may be used in problem of estimating many typical signal processing situations, such as Doppler estimation of radar and sonar returns, vibration measurements, geophysical data processing, and surveillance observations of the electromagnetic spectrum. For stable display of a signal in an oscilloscope, it must be triggered at its base frequency. In this technique, frequency of all harmonics present in test signal is retrieved using FFT and the base repetition rate of the signal is found by selecting the frequency of lowest harmonics present in the test signal. Numerous complex test waveforms are generated and their harmonic contents are analyzed in the virtual environment of LabVIEW™ software. To verify the efficacy of the proposed technique, it is implemented using LabVIEW™ software and PCI DAQ card. It is found that the proposed technique is equally effective in detecting the base repetition rate of complex as well as simple waveforms. Technique proposed in this paper would be of interest to instrumentation design engineers. [C176]

"Performance Analysis of Communications & Radar Coexistence in a Covert UWB OSA System"

Far-field target detection, multi-sensor communications, and security are essential requirements of first-emergency networks. A radar-communications system is a potential opportunistic spectrum access (OSA) solution, harnessing the coexisting advantages of radio detection and ranging (RADAR), and wireless communications. A multi-functional waveform has been designed, by embedding an Orthogonal Frequency Division Multiplexing (OFDM) signal within a spectrally notched ultra-wideband (UWB) random noise waveform. Extending that development, this paper analyzes the waveform's Bit-Error-Rate (BER) and Ambiguity Function (AF) formulations to demonstrate its OSA ability, that offers reliable multi-user communications, and high range and Doppler resolution in target detection. We further conclude that up to 30% of the available UWB bandwidth can be simultaneously utilized for concealed data communications without adversely affecting radar performance or its physical layer covertness. [C177]

"Polarization Filtering Based Interference Suppressions for Cooperative Radar Sensor Network"

The radar members are likely to interfere with each other if their waveforms and polarized states are not orthogonal in radar sensor network (RSN). In this paper, we propose the oblique projection polarization filtering (OPPF) based interference suppressions for RSN where each radar member is equipped with the orthogonally dual-polarized antenna (ODPA). In our discussed cooperative environment, under which radar members share their polarized states, members radiate EM waves using the same waveform but different polarized states, however, their polarized states are not needed to be orthogonal. Doppler-Shift and its uncertainty are not involved due to the independence from the polarized state, which makes the proposed method simple and effective. The results demonstrate that, after passing through the proposed OPPF scheme, each radar member can effectively suppress the echoes from the others while keep its own amplitude and phase unchanged, which improves the target detection performance of the RSN. Theoretical analysis is done, and the simulation results are illustrated, both showing the proposed method suitable for suppressing interferences for RSN. [C178]

"Comparison between ETM+ imageries and ICESat-GLAS waveforms for forest classification"

The paper presents a method for classifying Light Detection And Ranging (LiDAR) full waveform data, using an artificial neural network (ANN) approach. The ANN classifier used was a multilayer perceptron trained through the generalized predefined learning rule functions. Compared with the unsupervised classification based on Landsat 7 ETM+ (Enhanced Thematic Mapper Plus) images, the ANN classifier was suitable to better represent the nonlinearity in the LiDAR waveforms dataset. The multilayer perceptron neural network has proved to be a very effective tool for the classification of waveforms data. The classification results show that forest classification accuracy for broadleaved forest and needleleaved waveforms using ANN classifer is better than the classification accuracy of ETM+ image based-unsupervised classifer. Whereas, the overall classification accuracy of testing datasets using ANN classifier with using waveform data without a prior class probabilities is lower than the unsupervised classifier based-image. [C179]

"Inverse filtering operation for reconstruction of distorted GPR response"

This study proposes inverse filtering operation for reconstruction of ground penetrating radar (GPR) responses in order to remove waveform distortion caused by transmitting and receiving antenna characteristics. As an

example, we apply it to measured pulse response from a metallic sphere and show the effectiveness of the method. [C180]

"A model of non-coherent airborne MIMO space-time adaptive processing radar"

Compared to single-input multiple-output (SIMO) radar, airborne multiple-input multiple-output (MIMO) space-time adaptive processing (STAP) radar transmits mutually orthogonal or non-coherent waveforms. The waveform diversity increases degrees of freedom (DOFs) of MIMO STAP radar and results in the variation of clutter characteristics. To make things worse, there exists many non-ideal factors in practical project that affect performance of MIMO STAP. Considering all such situations, we derive the covariance matrix of echo signals by utilizing waveform covariance matrix (WCM) and error covariance matrix tapering (CMT) to simplify the MIMO STAP in this paper. Signal to interference plus noise ratio (SINR) performance simulation results verify that MIMO STAP radar has a better spatial resolution than SIMO radar generally and improving in orthogonality of transmitting waveforms can obtain a better SINR performance. [C181]

"Design of mismatched filters for oversampled signals"

Most of the prior work in the field of sidelobe suppression filtering for radar pulse compression focused on the design of mismatched filters for binary codes. However, in practice these binary codes are spectrally shaped to obtain analytic signals. The spectrally shaped binary code can be sampled at as low as the Nyquist rate, but in practice it is oversampled to avoid aliasing. The spectral shaping determines the necessary bandwidth and hence the sampling rate for the waveform. One of the spectrally efficient modulation techniques is based on quadriphase coding. As this spectrally shaped waveform is analytic, design of the mismatched filters in complex domain is needed. In this paper, application of minimax constrained complex LMS algorithm is proposed for the design of mismatched filters for oversampled signals. [C182]

"Collision-avoidance radar for bicyclist and runners"

This paper provides a summary of the analysis and design process with respect to the development and prototyping of a Bicycle Radar for a Senior Capstone Project at Wright State University in collaboration with the Air Force Research Laboratory Sensors Directorate. The basic radar technology adopted for this project is a commercial integrated (miniaturized) K-band FMCW Monopulse Module that is recently designed for future Intelligent Automotive Cruise Control Applications. The design documentation, preliminary test outputs, and discussions within the sections of this paper describe a number of novel features of this Bicycle Radar Design including the methodology for overlaying the K-band range-angle data onto streaming video on the iPhone. Additional discussions pertain to radar waveform generation, control, and processing. A section on potential follow-on activities as well as a discussion on technology options and applications of the resulting system concept is also provided. [C183]

"Antenna compensation for UWB GPR systems applied in Non-Destructive testing"

Non-Destructive testing is an enhanced technique based on applying the inverse scattering algorithms upon the received scattered Electromagnetic EM waves for computing some important parameters of the material characteristics as permittivity and reflection coefficients. Unfortunately, the Ultra Wideband (UWB) antennas can dramatically affect the received signal and result in considerable degradation of the overall performance of the UWB GPR system. The isotropic, fully matched, unity gain and frequency independent antenna assumption could never be accepted for the typical UWB antennas, where the radiation characteristics and matching properties vary considerably with the frequency, introducing directionally asymmetric bandwidth reduction and waveform dispersion. Therefore an efficient antenna compensation technique would be introduced in this paper with the corresponding successive EM simulation results. [C184]

"Wavelet-modulated pulse for compressive sensing in SAR"

A new wavelet modulated pulse is proposed for synthetic aperture radar (SAR). Conventionally SAR image is constructed using chirp, i.e., FM in the range direction, and the Doppler effect in the azimuth direction. The proposed scheme is to physically modulate the amplitude of the radar pulse (AM) using wavelets. Such a radar pulse results in the shift of the wavelets in the temporal domain due to the range, while the Doppler effect causes variation of the scaling coefficient. In both directions, pulse compression can be achieved by taking advantage of the autocorrelation function of the compactly supported orthogonal wavelets and processing the echo signal in the two directions accordingly. Furthermore, by using wavelet modulated pulses, the echo signal is equivalent to the wavelet transform (WT) to the target area. Since WT has been proved more effective in image compression than conventional discrete cosine transform (DCT), wavelet-modulated pulse is equivalent to compression to the SAR image thus to achieve compressive sensing. Experiments have been performed using

the latest embedded software defined radio (SDR) technology. Equipped with the most recent FPGA and digital signal processors along with high speed analog-to-digital and digital-to-analog converters, the SDR allows signal processing tasks commonly done by analog circuits to be performed digitally with high flexibility in algorithm design. Based on the developmental need of the user, the small form factor software defined radio (SFF SDR) can serve as a simple data collection device for waveform testing or it can be programmed into a real-time embedded radar system. [C185]

"Constrained multi-object Markov decision scheduling with application to radar resource management"

Hierarchial radar resource management uses multi object Markov decision scheduling with a constraint on the resources. In this paper we give a detailed description of constrained multi-object Markov decision scheduling in its general form and the separation that is achieved in the dynamic programming level using Lagrange multipliers. We then apply this general model to obtain a simultaneous beam and waveform scheduling method for radars based on an objective function that depends on both state and action. This method extends on a previous hierarchial method for beam scheduling with an objective function defined only on state. We further improve the objective function based on entropy reduction. This criterion makes the resource management to be more flexible in favor of measurements that carry more information. [C186]

"Radar tracking performance when sensing and processing compressive measurements"

Radar tracking performance is improved when using waveforms at high delay-Doppler resolution with concentrated ambiguity functions. High resolution measurement acquisition and processing, however, requires high rate sampling and intensive processing. Alternatively, compressive sensing and processing can be used to significantly reduce data rates with no loss in resolution. The drawback is, however, that using compressive measurements increases ambiguity function sidelobes and thus tracking error. In this paper, compressive sensing and processing is applied to single target tracking. The effect of compressive sensing and processing on the ambiguity function sidelobes is examined. Moreover, estimation using compressively sampled and processed Bjojrck CAZAC sequences is shown to be improved over estimation using linear frequency modulated waveforms sampled at the Nyquist rate. This shows that low-rate acquisition and processing maintains reliable tracking performance at high resolution, while simplifying the receiver and reducing computational expense. [C187]

"Ground-UAV platform geometries for radar imaging"

This paper provides a summary of comparative analysis pertaining to a systems trade study with platform geometries that encompass either one, two, or three distributed RF sensing platforms. The discussion is focused on analysis of a basic set of UAV trajectory parameters associated with performing sky-looking radar imaging. The baseline one-platform case corresponds to one ground-based radar transmitter/receiver. The two-platform case involves one ground-based radar transmitter/receiver and one UAV with a passive receiver and the three-platform case involves one ground-based radar transmitter and two UAV's each equipped with a passive receiver. This notional analysis is conducted with a narrow-bandwidth waveform within the L-Band region of the radar spectrum and notional parameters of the moon are adopted for the object-of-interest for radar imaging. Results indicate that the trajectories of the UAV's can be pre-selected to improve comparative radar imaging performance. [C188]

"WiMAX ambiguity function for PCL systems"

Passive coherent location (PCL) radar systems use signals of opportunity as the off-board source of electromagnetic illumination. The analysis of the structure, spectral, and spatial properties of emerging commercial waveforms becomes a critical component of future PCL radar systems design. This paper presents an ambiguity function analysis of the emerging IEEE 802.16 OFDM signal known as "WiMAX" for passive radar applications. The simulated WiMAX wave structure shows desirable range and Doppler resolution properties for passive radar applications. [C189]

"A novel adaptive learning method for low-sidelobe step frequency waveform designing"

For a step frequency waveform, high range resolution can be achieved by inter-pulse synthesis processing and its sidelobe level can be controlled by weighting in frequency domain. However, high range sidelobe arise when the frequency steps is sparsely spaced. For this, low sidelobe can be obtained in two ways. One is by signal processing after receiving. And the other is to design the waveform with low sidelobe. In order to avoid the SNR loss, The latter is more effective. In this paper, a novel adaptive learning method is given. The method can adaptively adjust the frequencys by max sidelobe discrepancy between the matched filtering out of present and the ideal one. The result of simulation shows that it can approach the optimal frequencys for which the max

sidelobe is lowest. [C190]

"Target detection with distributed radar sensor networking systems (DRASENS)"

An innovative radar sensor networking system is introduced for effective target detection. By using orthogonal coding waveforms, the number of radar echoes generated by the radar network from the same target is maximized for the best fusion processing result. Several centralized signal detection schemes are investigated for the networking system and their performances are evaluated. [C191]

"Parameter estimation of moving target for stepped-frequency radar under temporal-correlated clutter"

Proposed is a maximum likelihood (ML) estimation method to estimate the parameter of the moving target for high range resolution stepped-frequency radar in strong clutter background. In this study the temporal correlated clutter is used. By transmitting frequency-hopping waveform and using the spectrum density of the clutter, the method may accurately estimate the moving target parameter in strong clutter. Numerical experiments illustrate the effectiveness of the proposed method. [C192]

"Method to determine CPI for ubiquitous radar"

Ubiquitous radio: is a new radar system that provides continuous and uninterrupted multifunction capability within a coverage volume. Continuous coverage from close-in "pop-up" targets in clutter to long-range targets impacts selection of waveform parameters. The CPI (Coherent Processing Interval) must be long enough to achieve a certain signal-to-noise ratio (SNR) that insures the efficiency of detection. This paper analyzes the condition of detection in the case of low SNR, discusses three different cases that would occur during integration and presents a method to determine the CPI. The simulation results show that it is available to determine the CPI for targets detection with SNR as low as -26dB in the experimental system. [C193]

"Design based on MCU for the echo simulator of the range extended target"

It is important for the high resolution radar to design the simulator for generating the echoes of the range extended target. In this paper, a simulator design which is based on Micro Controller Unit (MCU) is proposed for generating the echoes of the range extended target. Because those echoes change rapidly and the corresponding period is longer, the high speed FIFO is selected as the data cache. In the idle time of system, waveform data is transferred from MCU to FIFO, whereas in the operating time of system it is transferred from FIFO to D/A converter at a high speed in order to output the waveform. The experimental results show the design can meet the purpose of the echo simulator of range extended target. [C194]

"The inversion of crop height based on small-footprint waveform airborne lidar"

Due to limited vertical resolution, the waveform of vegetation whose height is relatively low will superpose on soil waveform. Therefore, lidar full-waveform data were mainly used in forestry, but no research in the crop. In this paper, in order to derive crop height, a gaussian decomposition algorithm based on transmitting waveform is adopted to distinguish the crop waveform from soil waveform, and to extract peak location and pulse width from raw waveform data, proving it is a reliable and highly accurate decomposition algorithm. Moreover, the decomposition algorithm lays the proper foundation for obtaining other crop biophysical parameters. [C195]

"Relationship of target identification performance and waveform parameters"

In this paper, we established rigorous relationship between target recognition performance and the parameters of a fixed waveform via Kullback-Leibler information number of single observation (KLINs). The method we proposed takes advantage of the methodology of sequential hypothesis test. It depicts the target recognition efficiency of certain radar waveform parameter in the metric of average number of necessary signal (ANS) transmission. Compared with the traditional simulation methods in literature, it is a more efficient and valuable one to find the optimum values of a certain waveform parameter. Simulation results about the parameters of LFM signal show the validity of the method. [C196]

"Orthogonal waveform set design for netted radar"

Orthogonal netted radar system requires the transmitted waveforms with a very low autocorrelation and cross-correlation sidelobe peak level. Pseudo-random Phase Coded Modulation (PCM) waveform is suitable for orthogonal design in this sense. In this paper, the correlation properties of Gold sequences as binary phase codes are discussed. Numerical examples are presented to demonstrate the desired orthogonal properties of the

coded pulse signal. The effect of Doppler shift and computation cost are also discussed. [C197]

"Orthogonal waveforms design and performance analysis for MIMO sonar"

In this paper, a Multiple-Input Multiple-Output (MIMO) sonar system which can deal with multiple targets is discussed, where orthogonal waveforms are transmitted simultaneously. According to the requirement of waveform orthogonality, the orthogonal frequency division pseudo-random signal (OFD-PR), orthogonal frequency division determinant signal (OFD-LFM) and the spread-spectrum code-based signal (Gold-BPSK) are designed. The Maximum Likelihood (ML) DOA estimator and CRB for MIMO sonar is described. The performance of MIMO sonar based on different waveforms is analyzed via experiments in an anechoic water tank. Simulation and experimental results show that the waveforms which we design possess the higher resolution for multiple source DOA estimation than its phased-array and they could resolve the two targets with a separation of 1/2 beam width at low SNR. The analysis of DOA estimates and experimental results show that the OFD-PR signal has much better performance than others. [C198]

"Multipath reflectivity estimation in urban environments for Synthetic Aperture Radar images"

Synthetic Aperture Radar (SAR) images a target region reflectivity function in the multi-dimensional spatial domain of range and cross-range. SAR synthesizes a large aperture radar in order to achieve a finer azimuth resolution than the one provided by any on-board real antenna. Conventional SAR techniques assume a single reflection of transmitted waveforms from targets. Nevertheless, today's new scenes force SAR systems to work in urban environments. Consequently, multiple-bounce returns are added to direct-scatter echoes. We refer to these as ghost images, since they obscure true target image and lead to poor resolution. By analyzing the quadratic phase error (QPE), this paper demonstrates that Earth's curvature influences the defocusing degree of multipath returns. In addition to the QPE, other parameters such as integrated sidelobe ratio (ISLR), peak sidelobe ratio (PSLR), contrast (C) and entropy (E) provide us with the tools to identify direct-scatter echoes in images containing undesired returns coming from multipath. [C199]

"On the Signal Processing in the Life-Detection Radar Using an FMCW Waveform"

The progresses and difficulties faced in the life-detection radar signal processing are introduced in the paper. First, the progresses in signal processing are shown, including obtaining the breathing and heartbeat frequency by using self-correlation process and composing the mode vector to discriminate a life by using time-spectrum analysis and singular value decomposition. Then, the difficulties faced now are discussed. Echoes from the obstructions in the direction of radar antenna are main interference. How to control the interferences are discussed and a combinative approach of body movement and life information detection is brought forward in the paper. [C200]

"Waveform Design and Optimization in Radar Sensor Network"

We investigate the use of information theory to design waveforms for the measurement of extended radar targets in radar sensor networks (RSN). The different channel gains for transmitting signals from different radar sensors are introduced to model the radar system channel. Given the transmitting signals, we optimized the estimation waveforms that maximize the mutual information between a target ensemble and the received signal within additive Gaussian noise given the transmitting signals so that characteristics of the target could be well recognized. We also study the maximum mutual information with the constraints of the number of radar sensors, waveform energy and duration, which could be taken into consideration when waveforms are designed for RSN. [C201]

"Robust target estimation in compressive sensing based colocated MIMO radar"

A colocated multiple-input multiple-output (MIMO) radar system is considered, in which the transmitters and receivers are nodes of a small scale wireless network. The sparsity of targets in the illuminated space allows target detection based on compressive sensing (CS) techniques. A receive node compresses the received signal via a linear transformation, Φ, referred to in CS theory a measurement matrix. The compressed samples are subsequently forwarded to a fusion center, where an ℓ1-optimization problem is formulated and solved for target information. CS-based MIMO radar achieves the same localization performance as do traditional methods but with many fewer measurements. Unlike previous work, we consider the case in which the targets might be located across several range bins, and the delay of the first reflected signal is unknown and, due to the small number of compressed samples, cannot be estimated accurately. A new measurement matrix is proposed that is constructed based on the transmit signal waveforms and also accounts for all possible discretized delays of target returns within a given time window. It is shown that reduced bandwidth transmit waveforms can lead to a measurement matrix that improves signal-to-interference ratio (SIR), but on the other hand, using waveforms that

are too narrowband increases the coherence of the sensing matrix, thus invalidating the conditions for the application of the CS approach. Therefore, the transmit waveforms must be chosen carefully to guarantee the desired performance. [C202]

"Wavelet Transform and its Application to ICESat-GLAS Full Waveform Data"

Based on wavelet transform (WT), this paper proposed an approach to extract ICESat/GLAS full waveform characteristics. Through wavelet decomposition of the full waveform data, setting the threshold function and reconstructing signal, the filtered waveforms were achieved. All comparisons were performed on simulated LiDAR full waveform signals with typical back scattering noise. In the simulation and comparison, the root mean square error (RMSE) of the coefficients dropped by 0.7188 in this way, and the Signal-to-Noise Ratio (SNR) increased by 16.17 dB. The results showed that the wavelet transform method was better than the Gaussian method on de-noising and the signal by wavelet transform reserved useful information of the echo waveform. In the filtering process, the wavelet transform can effectively suppress the waveform "overlay" problem. [C203]

"Research on the linear frequency diverse array performance"

The application of the linear frequency diverse array (LFDA) provides the more freedom for the waveform design in time, frequency, amplitude and phase domain. The antenna pattern of the LFDA is analyzed firstly. The main-lobe width of the antenna pattern is narrower and narrower with the increasing of the frequency interval between antenna elements. The ambiguity function of both LFDA and the conventional broadband linear frequency modulation (LFM) signals is compared. The blur between range and Doppler of the LFDA ambiguity function is improved evidently. The simulation and assay indicate that the application foreground of the LFDA is comprehensive. [C204]

"Frequency diversity for active sonar/radar application and optimal receiver design"

MIMO (Multiple Input Multiple Output) concept has been explored for radar/sonar application recently for improving target detection and estimation performance. The existing work in this direction mainly investigates the spatial diversity and waveform designs based on the assumption of the same carrier frequency for multiple transmitters. In this work, we investigate the frequency diversity by using multiple narrowband transmitters of different center frequencies. We prove that the ambiguity function for such signal is not an optimal receiver, and propose an optimal receiver for signals with different frequency components. [C205]

"Integrated Coastal Observation Network (ICON) for real-time monitoring of sea-level, sea-state, and surface-meteorological data"

National Institute of Oceanography (NIO) has established an Integrated Coastal Observation Network (ICON) of in-house designed and developed Internet-accessible real/near-real time reporting cellular based sea-level, sea-state, and surface meteorological (Met) stations at several locations on the Indian coasts & Islands (http://inet.nio.org). Subsurface pressure sensors and downward-looking microwave radars are incorporated in the sea-level station network. Sea-level, Met, and surface wave parameters are acquired using dedicated Linux based data loggers and uploaded to an Internet server at 5-, 10- and 30-min intervals, respectively with the use of GPRS cellular modems. The sensors and data loggers are powered from sealed lead acid batteries, which are charged through solar panels. The ICON provides graphical presentation of sea-level information (observed sea-level, predicted tide, residual sea-level); significant wave height and wave direction; and Met information (vector-averaged wind speed & direction, barometric pressure, atmospheric temperature, solar radiation, relative humidity, and rainfall). Installation of sea-level sensors free from the influence of stilling-wells and long narrow tubes renders the measurements ideal for tsunami and storm-surge studies by preventing waveform distortion and non-linearity of largeamplitude short-period signals. The network maintains accurate time-stamp of the dataset through Internet-time synchronization using network time protocol (NTP). Real-time reporting capability of ICON yields several benefits, such as (i) remote monitoring of proper working condition of individual stations; (ii) implementation of repair/maintenance in the shortest possible time, thereby minimizing break in the time-series data stream; (iii) periodic arrival of data stream from all stations at a single central server, thus yielding backup for the data from all the stations; (iv) access to the latest in-situ information; (v) allows possible-- use of data with automated real-time running numerical models for operational forecast. In contrast to the limited bandwidth provided by INSAT transmitters, coastal observations at high bandwidth at significantly low cost have become realizable using cellular GPRS network. The NIO-network allows, Internet based real/near-real time tracking and monitoring of sea-level, sea-state, and meteorological conditions along the Indian coasts and islands and from almost anywhere-an issue of considerable practical significance during natural disasters such as storm, storm-surge, and tsunami. [C206]

"Wireless tomography, Part I: A novel approach to remote sensing"

Wireless tomography, a novel approach to remote sensing, is proposed in Part I of this series. The methodology, literature review, related work, and system engineering are presented. Concrete algorithms and hardware platforms are implemented to demonstrate this concept. Self-cohering tomography is studied in depth. More research will be reported, following this initiative. [C207]

"Designing for spectral conformity: Issues in power amplifier design"

Spectral constraints placed upon radar systems by regulatory agencies require the design of highly linear amplifiers. Spectral spreading in power amplifiers is a result of transistors operated in the nonlinear regime to optimize efficiency. Several different methods are employed by power amplifier designers to maximize both linearity and efficiency. The methods of predistortion, feedforward, envelope tracking, Doherty, and "Linear Amplification Using Nonlinear Components" (LINC) are discussed in this paper. Tradeoffs and challenges inherent in these design approaches are surveyed. [C208]

"Thinned spectrum radar waveforms"

Small phase perturbations applied to a stepped-frequency or linear-frequency-modulated radar waveform have been proposed as a means to generate frequency nulls in the spectrum of the transmitted waveform. By nulling selected frequencies (or thinning) in the spectrum of transmitted pulses, the interference between the transmitted and received signals is reduced, which facilitates the spectral cohabitation of multiple RF users. Preliminary experimental results of two methods of spectral nulling are presented with consideration to in-band and out-of-band interference. Range processing is examined to determine the effects of the phase perturbation on radar operations. [C209]

"Geometric diversity versus frequency diversity an imaging example"

In classical radar, frequency diversity offers one method of obtaining additional information about targets. With the most basic form of frequency diversity, namely increased bandwidth, high range resolution is afforded to the user. Geometric diversity can also offer the potential for increased resolution, and is the multi-static dual to frequency diversity (increased bandwidth) in classical mono-static radar. In the extreme case, 360 degrees of geometric diversity (tomography) offers sub-wavelength resolution, even under the monochromatic assumption. Operational constraints can limit the system performance. Frequency diversity and geometric diversity can be used in various combinations to obtain the best image under these constraints. For example, frequency allocation can limit the available bandwidth. Geometric diversity with a single or multiple narrowband signals can provide the required system performance. Imaging performance can be evaluated using two factors: resolution and target dynamic range. Resolution is the ability to distinguish two closely separated targets and dynamic range is the ability to determine the presence of a 'weak' target in the presence of a 'strong' target. [C210]

"ISAR imaging in sea clutter via compressive sensing"

We investigate the application of compressive sensing (CS) to inverse synthetic aperture radar (ISAR) imaging of moving targets. We present our results for a simulated target immersed in different levels of sea clutter. Comparison between traditional and CS approaches to ISAR imaging reveal that our based CS algorithm offers some advantages compared to traditional ISAR imaging under certain limited operating conditions that are nevertheless of practical interest. We conclude by pointing out directions for future work in extending the results of this paper. [C211]

"Frequency diverse waveforms for compressive radar sensing"

High range resolution radar systems use wideband frequency modulated waveforms to estimate the spatial distribution of the scatterers in the scene. Estimation of range profiles from backscatter energy is a linear inverse problem. The emerging field of compressive sensing has provided provable performance guarantees and signal recovery algorithms for random sub-sampling of sparse or compressible signals. In this paper a novel compressive sensing strategy for radar is introduced which relies on using waveforms with frequency diversity on transmit and random aliasing on receive, that shifts the burden of the sampling operator from the receiver to the transmitter. The transmitter and receiver structure for compressive sensing is described and the sensing matrix for the proposed compressive sensing strategy is derived for use in compressive sensing recovery algorithms based on sparsity regularized inversion. A preliminary experimental demonstration of the compressive sensing strategy is given through sampling of staggered multifrequency linear FM signals through a single low rate A/D. [C212]

"Waveform design for low frequency tomography"

There are multiple applications that would benefit from the ability to produce three dimensional, high resolution, imagery collected at low operating frequency; among them remote archeological survey of ruins through foliage, and searching for voids in collapsed structures and underground. High vertical resolution circular SAR requires the use of wide-to-ultra wideband waveforms, a problematic aspect in the modern RF spectral environment, particularly at lower frequencies. RF tomography offers the potential to yield high, 3-dimensional resolution using spectrally sparse, narrowband waveforms simultaneously with operation at frequencies that have demonstrated favorable penetration through intervening dielectric media. In this paper we explore this potential by evaluating minimal spatial support tomographic apertures combining diverse narrowband signals with the form (trajectory) of the monostatic collection aperture. Results are presented in terms of image quality metrics: those frequency combinations that jointly minimize peak and rms voxel sidelobe level, cardinal axis resolution length and voxel volume. It is shown that, generally, the frequency selection is a soft constraint in terms of the achievable resolution and image sidelobe levels; that the tomographic aperture with spatial sampling that is linearly continuous and substantially less than hemispherical yields high spatial resolution, and that there is interaction between the form/shape of the tomographic and the waveform set. [C213]

"Pareto-optimal radar waveform design"

This paper deals with the problem of Pareto-optimal waveform design in the presence of colored Gaussian noise, under a similarity and an energy constraint. At the design stage, we determine the optimal radar code according to the following criterion: joint constrained maximization of the detection probability and constrained minimization of the Cramer Rao Lower Bound (CRLB) on the Doppler estimation accuracy. This is tantamount to jointly maximizing two quadratic forms under two quadratic constraints, so that the problem can be formulated in terms of a non-convex multi-objective optimization problem. In order to solve it, we resort to the scalarization technique, which reduces the vectorial problem into a scalar one using a Pareto weight defining the relative importance of the two objective functions. At the analysis stage, we assess the performance of the proposed waveform design scheme in terms of detection performance and region of achievable Doppler estimation accuracy. In particular, we analyze the role of the Pareto weight in the optimization process. [C214]

"Altitude estimation method using assumed altitude reliability based on multipath propagation model"

The problem of multipath propagation in the tracking low-altitude targets with a radar is addressed. It is well known that multipath fading causes bias errors to the target altitude over the sea. Since multipath propagation depends on the frequency of the radar waveform, the actual target altitude and range, estimation of the bias errors is difficult problem. In this paper, we propose an altitude estimation method using multipath propagation model. Our method uses the reliability of each assumed altitude hypothesis based on multipath propagation model to estimate the real altitude of targets. Through computer simulation trials, the validity of our method is confirmed. [C215]

"LFMCW SAR waveform generation with frequency nonlinearity suppression"

Linearly frequency modulated (LFM) signals are desired in many electronic systems. For example, linearly frequency modulated continuous wave (LFMCW) radar has the good performance of lightweight, cost-effective, and high-resolution imaging. However, the presence of frequency nonlinearity in the transmitted signal will result in contrastand range-resolution degradation. In this paper, the impact of frequency nonlinearities on LFMCW synthetic aperture radar (SAR) system is addressed, and one parallel direct digital synthesizer (DDS)-driven phase locked loop (PLL) frequency synthesizer to synthesize wideband LFM signals is designed, and an adaptive system nonlinearity compensation technique is employed. In this way, an example wideband LFM synthesizer with good performance frequency linearity is designed. [C216]

"Waveform design with stopband and correlation constraints for cognitive radar"

One of the main objectives of cognitive radar is to adapt the spectrum of transmit waveforms to certain needs, such as avoiding reserved frequency bands or narrowband interferences. Besides spectral requirements, good correlation properties of the transmit waveforms are also desired in specific applications, such as range compression. Moreover, practical hardware constraints usually require the transmit waveforms be unimodular (i.e. only phase-modulated). In this paper, we propose a new algorithm named SCAN (stopband cyclic algorithm new) to design unimodular sequences with spectral power suppressed in arbitrary bands and with low correlation sidelobes as well. The SCAN algorithm, which starts from random initializations, can generate many sequences possessing similarly good properties. Furthermore, the SCAN algorithm is based on FFT (fast Fourier transform)

operations and thus is computationally efficient, which facilitates long-sequence design and real-time waveform update. [C217]

"Sonar waveform design for optimum target detection: The impact of object burial state"

The design of transmit waveforms in sonar and radar that optimize the probability of detection of a known target is an area of active interest. Previous research has demonstrated the benefits of optimal transmit waveforms for enhanced target detection, versus the transmission of more conventional waveforms such as broadband LFM pulses. For maximum benefit, the scattering function or frequency response of the target to be detected must be known, along with the spectral or statistical properties of the environment. In this paper, we examine the impact of a mismatch between the expected frequency response of the target, for which the optimal transmit waveform was designed, and the actual frequency response of the target. In particular, we design the optimal sonar transmit waveform based on the free-field response of the target, and then examine the effects on detection performance of burial of the target in sediment. Simulations of the sonar backscatter from a steel sphere in the water column and at various stages of burial demonstrate that the impact of mismatch becomes increasingly detrimental as the target becomes increasingly buried. For fully buried targets, the impact is such that transmitting a simple broadband LFM pulse can yield improved detection relative to "optimal" waveform design wherein there is a mismatch between the expected (free-field) and actual (buried) frequency response of the target. [C218]

"Waveform diversity and advanced signaling strategies for the Hybrid MIMO Phased Array Radar"

The Hybrid MIMO Phased Array Radar, or HMPAR, is a notional concept for a multisensor radar architecture that combines elements of traditional phased-array radar with the emerging technology of Multiple-Input Multiple Output (MIMO) radar. A HMPAR comprises a large number, MP, of T/R elements, organized into M subarrays of P elements each. Within each subarray, passive elementlevel phase shifting is used to steer transmit and receive beams in some desired fashion. Each of the M subarrays are in turn driven by independently amplified phase-coded signals. This paper proposes new transmit signal selection strategies based on the observation that some MIMO signal sets, such as those proposed by us previously, cause a very rapid sequential or raster scan across some field of view. Exploiting this property allows one to create and process multiple beams simultaneously. Furthermore, there exists a range-angle coupling in the transmit and receive signals that may lead to high-resolution target localization. [C219]

"Golay waveforms and adaptive estimation"

An iterative range profile estimation process is derived for Golay waveforms. The Re-Iterative Super Resolution (RISR) algorithm is used in conjunction with Golay waveforms and processing for radar range-Doppler estimation. Various additional range-Doppler estimation methods that use RISR and Golay waveforms and processing are simulated for the sake of comparison. Range and Doppler sidelobes are seen in simulation to be mitigated to a significant extent by using RISR in conjunction with Golay waveforms and processing. [C220]

"Simulation and Analysis of the Effects of Tropospheric Scattering Channel on Signal Waveforms"

Tropospheric scattering channel is a random channel. When the signal transmitted through the troposphere, the multi-path fading could cause signal waveform distortion. In this paper, based on a valid tropospheric scattering channel model, respectively, from the time domain and frequency domain the reasons why the signal waveform was distortion were analyzed. Radar pulse as the transmit signal, and simulate the received signal waveform in different antenna beam width angle. The results show that the signal waveform is impacted in different degrees at the different antenna beam width angle. [C221]

"A Novel Range Detection Method for 60GHz LFMCW Radar"

The linear frequency-modulated continuous-wave (LFMCW) millimeter-wave radar has been widely used in automotive industry applications. The motivation of this paper is to propose a segmented range detection (SRD) method on the foundation of plentiful mature research on the target detection of LFMCW radar. According to the SRD method, the detection range (about 150m in the scene of vehicular collision warning) is divided into several segments and triangular modulation waveform which consists of several different frequencies is designed. Compared with typical digital signal processing method, the SRD method can availably decrease the bandwidth of the IF signal, therefore the in-band noise will be significantly reduced and the signal to noise ratio (SNR) improved. Additionally, different range resolutions can be achieved and average range resolution improved. The SRD method is also validated through multiple outdoor experiments with the use of 60 GHz LFMCW millimeter-wave radar system designed by our research group. The efficiency of the SRD method is demonstrated in terms of ranging accuracy and range resolution after the analysis of experiment results. [C222]

"Target localization in multipath environment through the exploitation of multi-frequency array"

In this paper, we propose a multi-frequency array structure that achieves accurate target localization in a multipath environment. The use of multi-frequencies enables decorrelation in the array to operate direction-of-arrival (DOA) estimation for coherent arrival paths, whereas the spatial filtering of the signals makes the paths separable for robust range estimation. Multi-frequency radar techniques are then applied for range estimation of each path. The target position is identified by the shortest range coupled with its DOA. [C223]

"Time-Range Adaptive Processing for pulse agile radar"

Some radar systems utilize pulse agility to mitigate interference or synthesize bandwidth. Transmitting different waveforms on a pulse-to-pulse basis can have deleterious effects when traditional pulse-Doppler processing is employed. In this paper a recursive MMSE-based receiver design, denoted as Time-Range Adaptive Processing, is presented. The new method jointly adapts in range and Doppler, thus yielding enhanced sensitivity when compared to adaptation in each dimension separately. [C224]

"A multi-target detector using mutual information for noise radar systems in low SNR regimes"

Target detection is one of important roles of radar systems. In this paper, we present a detection method using total correlation based on information theory for noise radar systems which enables a system detects multiple targets at low signal to noise ratio regimes. The proposed method utilizes the largest eigenvalue of the sample covariance matrix to extract information from replica of the transmitted signal, and can perform better than the conventional total correlation detector when reflected signals have intermediate or low signal to noise ratio. In addition, in order to avoid ambiguous target detection, we find thresholds to guarantee the detection performance with the same receiving antenna elements for a given false alarm probability. The threshold is computed from the largest and smallest eigenvalue distributions based on random matrix theory. Simulations show the proposed detection method can be used for intermediate and low signal to noise ratio environments, and the thresholds provides exact target detection. [C225]

"Optimal mismatched filter bank design for MIMO radar via convex optimization"

In this paper, a mismatched filter bank is designed for suppressing the autocorrelation peak sidelobe level (PSL) and the peak cross-correlation level (PCCL) of an orthogonal polyphase sequence set applied in a multiple-input multiple-output (MIMO) radar system. The mismatched filter bank is obtained by minimizing a weighted maximum of the PSL and PCCL on the basis of the convex optimization. Compared with the iteratively reweighted least squares (IRLS) method, the proposed convex method can get the optimal mismatched filter bank with the minimum PSL and PCCL, and can also control the system signal-to-noise ratio loss (SNRL). Numerical examples show that the optimal mismatched filter bank at the cost of a slight SNRL can achieve a good improvement of the PSL and a moderate improvement of the PCCL, if the filter length P and the weighting factor w between the PSL and PCCL are appropriately chosen. [C226]

"Analysis of the performance of a multiband passive bistatic radar processing scheme"

The bistatic radar has been revitalized over the last few years through the rapid development of the passive bistatic radar technology. Passive bistatic radar systems have unique properties, especially is time on target high compared to traditional radar systems, as well as the freedom in choosing from the available transmitters of opportunity. This paper will focus on how to take advantage of the latter of these two special properties in order to achieve better range resolution while maintaining the high coherent processing interval. [C227]

"Cognitive radar for target tracking in multipath scenarios"

In this paper, we propose a cognitive radar system for target tracking in the presence of multipath reflections. We exploit the inherent spatial diversity offered by the multipath environment by constructing a new measurement vector, which we refer to as a virtual measurement vector. We employ broadband Orthogonal Frequency Division Multiplexing (OFDM) signalling at the transmitter and implement adaptive waveform design by minimizing the posterior Cramer Rao bound (PCRB) on the target state estimates to find the optimal weights to be transmitted on each subcarrier bin of the OFDM signal. We demonstrate with numerical simulations that the mean square error in the case of a cognitive radar is significantly lower than the mean square error in the case of a standard radar. [C228]

"Bat-inspired multi-harmonic waveforms"

Bats achieve remarkable target detection and selection performance in the most challenging environments. These activities are carried out mainly by echolocation, i.e. by transmitting pulses at ultrasound frequencies and processing the echoes from targets. Because they have relied on high level performance for survival, as a consequence of natural selection, it is believed that they have evolved in order to optimise these capabilities. Echolocation calls are very sophisticated, diverse, and commonly composed of a number of harmonic components. If evolution has resulted in multi-harmonic waveforms there might be advantages deriving by doing so. In this paper we simulate multi-harmonics waveforms and exploit advantages or disadvantages by a range analysis of their ambiguity functions. Results are discussed in relation to the radar and sonar case. [C229]

"Radar transmit waveform design for lossy propagation channels"

This paper proposes that radar transmit codes can be tailored to a specific target scene through the use of Marginal Fisher Information (MFI). Where peak sidelobe level (PSL) and Total Integrated Sidelobe Level (TISL) are metrics frequently used in determining the quality of radar transmit codes, well performing free-space waveforms with low PSL and TISL may not be optimal for lossy propagation channels. When some knowledge is available regarding the propagation characteristics of the scene, MFI can be used to develop transmit codes with significantly increased estimation accuracy over codes designed to be optimal for free-space cases. [C230]

"An adaptive multimodal radar system with progressive resolution enhancement"

This paper describes the architecture for an adaptive multimodal RF sensor that is capable of both a wide and narrow field of view. The architecture consists of a test-bed that will enable the generation of linear frequency modulation waveforms of various bandwidths. This paper discusses the proposed architecture, multimodal algorithm and simulation results. [C231]

"SMSE-based DSA radar waveforms"

Previous communications systems research has demonstrated that the Spectrally Modulated, Spectrally Encoded (SMSE) framework is well suited to SDR platforms and operation in both contiguous and non-contiguous spectrum given its ability to generate a wide variety of multicarrier waveforms such as OFDM, NC-OFDM, MC-CDMA, NC-MC-CDMA, CI/MC-CDMA, NCCI/MC-CDMA, and TDCS. In this paper, SMSE waveforms are extended for use in sparse frequency radar systems. Sparse frequency radar can be capable of dynamically sensing available spectrum, and tailoring the transmitted waveforms to suit the instantaneous RF environment conditions, simultaneously transmitting energy in multiple noncontiguous spectrum bands. Conventional radar performance metrics are reviewed, and a new metric is introduced which specifically addresses performance of noncontiguous spectrum waveforms through comparison to contiguous spectrum waveforms. Through simulation, various examples are shown to illustrate and characterize the impairments that are introduced in processing these classes of non-contiguous spectrum waveform returns, specifically the generation of large range sidelobes. [C232]

"An MIMO-MTI approach for through-the-wall radar imaging applications"

In this paper, we apply Multiple-Input Multiple-Output (MIMO) configurations to Moving Target Identification (MTI) for urban sensing using radars. In particular, we consider MIMO-MTI formulations for detecting slow-moving personnel inside enclosed structures and behind walls. Using signal multiplexing from two transmitters and several receiver positions, it is shown that the virtual array (co-array) implementing MIMO schemes, applied to stepped-frequency radars, permit improvement in image resolution of moving targets. Laboratory experiments are conducted to validate the proposed approach with targets walking behind walls. [C233]

"Channel probability ensemble update for multiplatform radar systems"

Cognitive radar (CR) is a recently proposed concept that depicts the radar channel in a probabilistic manner. In a multiplatform or networked radar system, some parameters or dimensions of interest are visible (i.e., resolvable) to one radar and not to others depending on the geometry of the scenario. For a radar with new measurements, Bayesian methods to update the cell ensemble probabilities in the non-visible parameters are needed. Here, we show how the overall probabilistic understanding of the channel can be updated despite the fact that some cells are non-visible or "ambiguous". Unfortunately, the number of calculations needed to accomplish a full update is exponentially related to the number of cells. As such, we also introduce a technique that reduces the calculations immensely. Finally, we apply both update techniques to a two-platform radar system trying to form a two-dimensional probability ensemble of the channel. [C234]

"Embedding information into radar emissions via waveform implementation"

In this paper an approach for the joint design of multiple receive filters is described that enables the use of different waveforms during a radar CPI while minimizing the attendant Doppler coherency degradation due to range sidelobe clutter modulation. This capability allows for a set of unique radar waveforms to serve the dual purpose of acting as communication symbols while acceptable radar performance is maintained. The receive filter design approach is based upon the well-known Least-Squares (LS) mismatch filter formulation. The novel modification is the iterative adaptation of the desired response such that all the waveform/filter pair responses are driven to be identical. [C235]

"The impact of internal clutter motion on a sample matrix inversion space-time adaptive processing algorithm and the GMTI minimum detectable velocity"

A MATLAB simulation was constructed to better study the effects of internal clutter motion on a notional X band monostatic airborne radar employing a ground moving target indicator (GMTI) algorithm to detect slow velocity targets of low radar cross section. A sample matrix inversion (SMI) fully adapted post-Doppler space-time processor (tapered and untapered) was utilized and the internal clutter motion model of Ward [1] was applied to the overall simulation. As one would expect, the untapered version yielded slightly better results but in all cases final minimum detectable velocities of about 1.0 meter/second were obtained. By judicious choice and implementation of a reduced rank/dimension algorithm, it should be possible to obtain similar MDV results. [C236]

"Using time reversal of multipath for intra-pulse radar-embedded communications"

This paper considers the problem of embedding a covert communication waveform into the backscatter from an illuminating radar by an RF tag/transponder within a multipath environment. We propose to exploit the multipath via time reversal, which is ideally suited for backscatter communications. Multipath time reversal induces a spatio-temporal focusing of the embedded communication waveform at the desired receiver while distorting it at all other locations thus further reducing the probability of intercept. Specifically, the paper addresses the case where the radar waveform is known to the tag/transponder thus allowing for estimation of the multipath via coherent processing (i.e. pulse compression). Within the radar-embedded communications context the use of the estimated multipath is compared with the case when no multipath knowledge is employed. [C237]

"Mitigation of radar interference with WiMAX systems"

In this paper, the effect of radar-induced electromagnetic interference (EMI) on a WiMAX base station receiver is investigated through the use of MATLAB models. The three types of radar pulses investigated include: a short, wideband, chirp pulse; a long, narrowband, chirp pulse; and a long, sinusoidal pulse. The benefits of superimposing these pulses in the guard interval and/or guard band of the WiMAX waveform are explored. [C238]

"Target RCS exploitations in compressive sensing for through wall imaging"

In this paper, target radar cross-section (RCS) is utilized to improve the performance of compressive sensing (CS) when applied to sensing through wall based on RF modality. Using step-frequency SAR imaging, it is shown that the selection of frequencies emitted at each antenna position of the SAR system can benefit from a priori knowledge of the target RCS. Frequencies with high target response allow the CS performance to be more robust to noise and are able to reveal target presence in noisy and cluttered environments. [C239]

"Rapid waveform adaptation for nearly optimal detection in colored interference"

A cognitive radar can dynamically design its transmit waveform in response to changing environmental knowledge, which may be obtained a priori, estimated online, or both. We consider the detection of targets in wide-sense stationary additive colored Gaussian noise. Cognitive radar has been shown to provide potentially significant improvements for this problem. However, existing algorithms may be too computationally demanding for some scenarios. We present an approach that can be implemented in the most demanding scenarios. This approach trades optimality for reduced computational complexity by computing a large library of nearly optimal waveforms before operation, and retrieving them rapidly at runtime. [C240]

"A wide field of view radar for Sense and Avoid on UAV using space coloring waveforms"

Up to now, UAV are employed in crisis or war times. For training purposes, some areas are especially attributed for UAV deployment in a limited space area and in a limited time slot. In the future, both for emerging civilian applications and for training purpose, these limitations will no longer be acceptable and UAV will have to be inserted in the general Air Traffic. Thus, "Sense and Avoid" systems will be mandatory. The radar is the most

pertinent non-cooperative "all-weather" sensor because it provides, by essence, accurate ranging, direction and closing speed. In this paper, we propose a low cost radar solution based on space coloring waveforms. This design allows the implementation of the radar within the UAV airframe without any moving parts. [C241]

"Signal detection in multi-frequency Forward Scatter Radar"

The peculiarity of Forward Scatter Radar (FSR) is the absence of range resolution. As a consequence, possible low signal-to-clutter ratio is the most limiting factor in FSR detection. In this paper we will discuss non-coherent and coherent FSR Doppler signal processing and consider an alternative cross-correlation approach, which could be called `quasi-coherent' processing. Multi-frequency radar enables correlation of Doppler output of one of the channels with another which can be considered as the matching waveform, or the reference signal, to the first signal. This leads to a compression of the FSR return by cross-correlation with enhanced processing gain, and, consequently, enhanced detection. [C242]

"Pseudo-noise waveform synthesis for SAR applications"

The paper presents the research carried out at Warsaw University of Technology on area of waveform design for Noise Synthetic Aperture Radar (SAR). The aim of the article is to present the method of creating complex pseudo-noise waveform with reduced side lobes of autocorrelation function in observation area. [C243]

"Ramp response radar imaging: Analysis of frequency parameters"

Low frequency imaging in radar domain can have applications for stealthy or buried targets. Transient scattering response from a ramp waveform is related to the profile function of the target, namely its transverse cross-sectional area along the line-of-sight, and it thus provides information about the target size, orientation and geometrical shape. Indeed, such profile functions can be used for generating a 3-dimensional image of the target shape. However the required frequency band is very large and may involve difficulties for experiments as well as simulations. That is why, we propose to study the effect of these frequency parameters on targets profile functions and, consequently, on their reconstructed shape. [C244]

"Electronic protection for digital shared aperture array radar"

We have developed a digital shared aperture array radar architecture which supports sub-aperture partitioning of a conformal array to improve time energy management for achieving radar search and track functions over 360 degree azimuth coverage. The digital array system consists of a plurality of digital transmit sub-arrays and digital received sub-arrays. For transmit operation, different frequencies or orthogonal waveforms can be employed for different apertures using the array control commutator. For receive operation, the sub-arrays are selected for different apertures using the receive data commutator. Essentially, the digital shared aperture supports dynamic partitioning of the aperture for multifunction applications. In this paper, we address these capabilities in the electronic protection (EP) against electronic threats, i.e. jamming and deception. Digital array radar provides digital degrees-of-freedom (DOFs) for transmit as well as for receive. These DOFs are selected by the commutators to support transmit and receive electronic protection. The receive DOFs are used for adaptive processing in jammer cancellation. These DOFs can be exploited in a number of ways through sector selection and digital beamforming to support several advanced processing architectures and algorithms. The digital array capabilities can also be exploited in monitoring jamming spectrum and estimation of the corresponding directions-of-arrival (DOAs). Digital array radar has transmit DOFs which can be used to form a transmit beam with nulls towards the deceptive jammers and separate decoy beams formed towards the deceptive jammers. [C245]

"System considerations for passive radar with GSM illuminators"

The increasing number of communication transmitters makes passive radar an attractive and simple alternative to active radar systems. GSM base stations as illuminators for passive radar enjoy the advantage of digital waveform, frequency diversity and global availability. The problems with these transmitters are the low transmit power and the more or less directive transmit patterns. These limit the achievable range. This paper studies how a useful system can be designed by fusion of bistatic systems using multiple transmitters. [C246]

"Reconfigurable digital receiver for polarimetric radar with dual-orthogonal signals"

This paper outlines the work on the design of a reconfigurable receiver for the PARSAX radar. The FPGA based digital receiver samples incoming signals at intermediate frequency (IF) and processes signals digitally instead of using more conventional analog approaches. In this way it offers more robust system stability and avoids unnecessary multi-channel calibrations of analog circuits. The processing algorithms implemented in the FPGA

chips can be reconfigured adaptively regarding to different transmitted waveforms, and without changing of hardware. The successful development of reconfigurable receiver has been verified by experiment and yields maximum flexibility for the whole radar system. [C247]

"Phase-only tapers for regular planar arrays, a heuristic nonlinear-FM approach"

We present a simple approach to constructing phase-only tapers for regular planar arrays that is analogous to the instantaneous-frequency approach classically used to construct FM-chirp waveforms with high time-bandwidth products. Design experiments for a large triangular-grid array show that the crude results yielded by this method when aperture-beamwidth products are modest can sometimes be "tweaked" into reasonableness. We conjecture that such a taper would improve upon the usual uniform-weight starting point for a nonlinear-optimization approach that seeks out a local optimum. Specific design examples presented here nominally aim to approximate a brick-wall beam and a variant of a Gaussian beam. [C248]

"Medium-PRF detection by non-coherent integration"

The document describes a detection and inherent ambiguity resolution scheme for Medium-PRF waveforms. Medium-PRF waveforms are characterized by ambiguous measurements of both range and doppler. Ambiguities are resolved by changing the pulse repetition frequency (PRF) from burst to burst and by combining the ambiguous results of adjacent bursts. The classical binary integration procedure applies a detection threshold on burst level and combines detections from burst to burst including unfolding of the ambiguities. In this paper the more optimum method of non-coherent integration from burst to burst with inherent ambiguity resolution is discussed. The method provides a significantly improved detection performance. Of particular interest for non-coherent integration is the appearance of ghost targets. The paper proposes a method for deghosting. [C249]

"New capabilities for PCL system: 3D measurement for receiver in multidonors configuration"

For more than 15 years, the interest for PCL (Passive Coherent Location) system has been growing. It began with the analog waveforms like TV and FM; now the interest for digital waveform has increased and especially for DVB-T (Digital Video Broadcasting-Terrestrial). Despite all these interesting progress, some new requirements mentioned by several potential users of such PCL systems have appeared like an altitude estimation and especially for low altitude targets. Some works have began in this area especially for tracking consideration. In order to illustrate the PCL capabilities, we'll present some elevation measurements using a 2D array with DVB transmitters in a SFN (Single Frequency Network) configuration. The corresponding 3D tracking results will also be presented. These measurements will be analysed according to the "GPS" reference plots. In a second part, after a short description of the main differences between the three main kinds of illuminators (FM, DAB, DVBT), we'll consider the complementarities of these potential donors in order to outline some elementary rules for choosing the most appropriate waveforms according to our final requirements. [C250]

"Through the wall MIMO radar detection with stepped frequency waveforms"

In this paper, we present through the wall (TTW) radar detection simulations with an emerging radar architecture which is the multiple-input multiple-output (MIMO) radar. The urban environment, especially in TTW detection, is very tough for radar detection. With the aim of improving the detection performances, we use several spaced antennas in transmission which gives a spatial diversity leading to different points of view of the scene. So as to keep diversity we choose linearly independant waveforms and more particularly we utilize the hyperbolic frequency hop codes. We first begin by introduce the problems and applications of TTW detection. Then we will present the geometric configuration of the scene and the wall attenuation and target modeling. After what, we will expose the waveforms used in transmission and the processing to perform detection. We finish with some preliminary results and conclude about this work. [C251]

"Information-theoretic algorithm for waveform optimization within ultra wideband cognitive radar network"

A novel information-theoretic approach for designing the excitation ultra wideband (UWB) waveforms within a cognitive radar network is developed. This method utilizes the mutual information (MI) between subsequent radar returns to extract desired information from the radar scene. With this approach, the radar system constantly learns about its surroundings and adopts its operational mode accordingly based upon the MI minimization criterion. Subsequently, the positioning algorithm makes use of this information about the radar scene to generate more accurate location estimates. Numerical results demonstrate an improvement in the probability of target detection even at low values of receive signal-to-noise ratio (SNR). The proposed algorithm also promises a better delay-Doppler resolution of the target, which can be analyzed through the radar ambiguity function (AF). Simulation data show an improvement in the target discrimination ability in the presence of noise

and clutter. [C252]

"High range resolution DVB-T Passive Radar"

Passive Radar systems, also referred to as Passive Coherent Location systems (PCL), exploit reflections from illuminators of opportunity (IO) in order to detect and track objects. Digital waveforms like DVB-T and UMTS signals offer wide bandwidth channels which allow achieving good spatial resolution. Moreover, they have spectral properties which are nearly independent of the signal content. Such waveforms exhibit an ambiguity function with a thumb-tack shape and bandwidth that is constant in time. This paper focus on the usage of multiple channels of the same IO (e.g.: DVB-T or UMTS channels) in order to improve range resolution and make target recognition and radar imaging feasible. Specifically, two different architectures based on the exploitation of multiple DVB-T channels have been considered. A DVB-T transmission system has been simulated with a Simulink® model compliant to. Simulation results are presented and discussed in order to evaluate the system performance in terms of spatial resolution. [C253]

"Radar and radio data fusion platform for future intelligent transportation system"

We present a software-defined data fusion system which integrates both radar (sensing) function and radio (communication) function within a single transceiver platform. In the proposed architecture, the radar mode and the radio mode operate in different time slots. The required modulated waveform is generated with the help of a direct digital synthesizer (DDS) that is able to control signal parameters such as amplitude, frequency and phase with very high resolution. For the radar mode, a specially arranged trapezoidal frequency modulation continuous-wave (TFMCW) modulation scheme is adopted, which combines three time intervals, namely an up-chirp, a constant-frequency period and a down-chirp. As such, range-velocity ambiguity can be resolved. Moreover, a constant-frequency period follows the radar cycle in the transmitted signal, which can be encoded with information data using different modulation schemes such as ASK, FSK, PSK, and some combinations among them. A low-frequency prototype for the 5.9-GHz dedicated short range communication (DSRC) system was designed and prototyped. Both system simulation results and preliminary measurement results have proved the proposed concept. The presented system has demonstrated such advantages as low cost, low complexity, and versatile functionality, which promises to play an important role in the design of future intelligent transportation system. [C254]

"Radar polarimetry using sounding signals with dual orthogonality-PARSAX approach"

The article describes specific aspects of the radar polarimetry using sounding signals with dual-orthogonality. Such signals provide the unique opportunity to measure all elements of the polarization back-scattering matrix simultaneously, during one sweep/pulse period of radar signal. This approach has been implemented in the IRCTR PARSAX radar system, the fully polarimetric high-resolution Doppler FMCW radar. The digital architecture of the radar starts from intermediate frequency and makes the radar fully reconfigurable in terms of sounding waveforms and processing algorithms. [C255]

"Solid state pulse Doppler radars for maritime traffic surveillance-Review of architecture and trade-off analysis"

Maritime traffic surveillance radars are in use for several decades, they are mostly based upon magnetron pulse emitters and simple non coherent signal processing. While the lack of coherent signal processing capabilities is compensated by strong pulse power, there is still a demand for improving detection and tracking performances especially in front of heavy sea clutter for detecting small and evasive targets. The solutions that address such demands are based upon the use of solid state transceivers which allow to generate and to process specifically designed waveforms incorporating for example frequency or phase codes. [C256]

"MPAR: Waveform design for the weather function"

An integrated target/weather surveillance at medium range, i.e. for the Terminal Manoeuvre Area (TMA) in the frame of Air Traffic Control (ATC) and regional weather monitoring, is made possible by MPAR (Multifunction Phased Array Radar) techniques, allowing a single technology to satisfy different requirements. The guidelines for system design, needed for cost/benefit analysis, were described in a previous EuRAD paper. As in many other radar applications, pulse compression is a key element to achieve the required MPAR performances with low-cost solutions using relatively low-peak-power Transmit/Receive modules. This paper describes a preferred novel solution for the waveforms to be used in the weather function of the MPAR. Performance comparison with more traditional codes is also presented. [C257]

"Bandwidth assignment for target tracking in coherent distributed aperture radar networks"

Multiple target tracking using networks of coherently integrated radar apertures is a current research topic that promises improved tracking accuracy and more efficient system implementations. The design of such tracking systems is complicated by the multiple subsystem functions involved in overall system performance. The separate isolated design of these functions results in suboptimal system performance. In this paper we consider the overall multiple radar system optimization by means of aperture waveform bandwidth allocation. In general, a greater aggregate bandwidth assigned to a target results in a more accurate target track. However, since multiple targets are simultaneously tracked, the data network transmission capacity limits the overall throughput resulting in a resource assignment problem. The assignment problem is specifically to assign available multi-radar bandwidth in a manner that maximizes the number of targets that achieve a terminal tracking error that is less than the maximum error allowed. We introduce a multistage control framework to demonstrate the performance of a proportional assignment procedure for countering a saturation attack. Conclusions for designing suitable distributed radar systems are given. [C258]

"Experimental validation of high-permittivity ceramic double-ridged horn antennas for biomedical ultra-wideband diagnostics"

Low-power ultra-wideband (UWB) radar sensors are attracting more and more attention, e.g., for biomedical diagnostics. In contrast to established techniques like X-ray tomography or invasive approaches, UWB radar offers the potential for remote access and, based on suitable waveforms, ultra-low power signal intensities. THis paper presents a complete characterization of a miniature ceramic double-ridged horn antenna. The input matching, radiation pattern, and impulse response reveal a performance promising for biomedical diagnostics. A further improvement and miniaturization will become accessible by optimized manufacturing processes and feed impedance, respectively. Preliminary volunteer measurements showed the suitability of the antennas for the envisaged applications and justify our approach. [C259]

"Cognitive adaptive waveform technique for HF skywave radar"

In High-Frequency (HF) Over The Horizon (OTH) radar, the space-time variation of the ionospheric channel, external noise as well as transmission channel limitations, is one of the most critical and challenging aspects of the system design and control. Waveforms parameters must be adaptively tuned to the actual external conditions. The purpose of this paper is to define and analyse a technique to set the waveform parameters in a cognitive way as a function of the operating conditions. Measurements of the external ionospheric channel and noise as well as a priori knowledge of the national frequency allocation plan will be the support of the waveform adaptive algorithm. [C260]

"Spectrum crowding and Cognitive Radar"

The ever increasing demand on remote sensing capabilities directly conflicts with the accelerating loss of spectrum allocation. Increased spectral awareness and waveform diversity can be applied to this problem through cognitive processing and control of modern radar. This paper motivates the development of essential technology for this purpose. [C261]

"Radar waveform design for detection of weapons"

We present waveform design based on signature exploitation techniques for improved detection of weapons in urban sensing applications. We consider a single-antenna monostatic radar system. Under the assumption of exact knowledge of the target orientation and, hence, known impulse response, matched illumination approach is used for optimal target detection. For the case of unknown target orientation, we propose waveform design based on subspace decomposition of the target impulse response matrix corresponding to the various aspect angles. Numerical electromagnetic modeling is used to provide the impulse responses of an AK-47 assault rifle for various target aspect angles relative to the radar. Simulation results depict an improvement in the signal-to-noise-ratio (SNR) at the output of the matched filter receiver for both matched illumination and subspace waveforms as compared to a chirp waveform of the same duration and energy. [C262]

"UWB noise acoustic atmospheric radar"

In this paper we discuss a new approach to create the acoustic atmospheric radar (sodar) which is based on noise sounding waveform. Such sounding waveform fits all formal requirements to UWB signals and has remarkable characteristics including extremely high range and speed resolution. It is important to remember that all these good properties exist only in the case when we have independent samples. The noise signal forms the independent samples because of its nature. The prototype of the radar is described and investigated

theoretically, using computer simulation, and in natural conditions. Non-parametrical signal processing algorithm is developed based on statistical approach and digital signal processing. It has wonderful properties of invariance to the group of the noise and signal transforms and stable level of the false alarm probability can be applied for both acoustic and microwave UWB noise radars. The use of the FFT algorithm increases the speed of calculations and gives us the possibility of constructing digital random signal radars. The results of this project confirm that the random signal radar is one of the most interesting types of radar. It combines properties of UWB radar with some additional features, based on random nature of the sounding waveform. These new properties allow us to simplify signal detection algorithms and measure a distance, an azimuth and a target velocity simultaneously with high resolution and accuracy. [C263]

"MIMO radars or is it smart antennas?"

Radars were originally designed as detectors of targets. The goal was to transmit a signal with the maximum available power and then observe whether the received signal contained a portion of the transmitted signal. A matched filter was then designed using the transmitted waveform to detect the received signal and based on some statistical hypothesis testing a decision was made on whether a target is present or absent. However, when multiple targets are to be examined or one wants to search for a low observable near a large target, the conventional detection based radar processing is not adequate. A need for finding small targets in the presence of clutter and jammer evolved into an estimation theory problem rather than detection. It is illustrated that use of a phased array in a SIMO mode can perform quite well as one does not have to worry about the inhomogenity of the clutter associated with multiple transmissions in a MIMO system as the processing becomes quite complicated. Also, the compensation of mutual coupling becomes difficult in a practical deployment on a moving platform. It is important to note that one can still exploit the advantages of super-resolution processing using estimation theory keeping the advantages of a single high power transmitting antenna in a phased array deployment. This paper illustrates such a methodology which has been in the published literature for at least a decade and compares it with the recent MIMO developments. Examples are presented related to a single snapshot based least squares methodology that can cancel interferer in the main beam using a phased array radar but performing a deterministic processing using the same number of degrees of freedom as a multisnapshot case for coherent processing. [C264]

"Passive radar imaging of moving targets with sparsely distributed receivers"

We develop a novel passive image formation method for moving targets using measurements from a sparse array of receivers that rely on illumination sources of opportunity. We use a physics-based approach to model the wave propagation and develop a passive measurement model that expresses the measurement at each receiver in terms of the measurement at a different receiver. This model eliminates the need for knowledge about the transmitter locations and waveforms in the proposed image formation method. We formulate the image formation problem as a Generalized Likelihood Ratio Test (GLRT) for unknown target location and velocity using the proposed passive measurement model. We form the image in spatial and velocity space using the space- and velocity-resolved test-statistics. [C265]

"Fast calculation of wide-band RCS for three-dimensional PEC objects based on preconditioned AWE technique"

The asymptotic waveform evaluation (AWE) technique combined with the method of moments (MOM) is often applied to accelerate the calculation of the wide-band radar cross section (RCS) of the target. However, the technique is still quite time-consuming for solving the inverse of impedance matrix when the objects are electrically large. In this paper, Krylov subspace iterative methods are applied to solve the matrix equation derived from electric field integral equation instead of matrix inverse. The dual threshold incomplete LU factorization preconditioner is adopted to improve the convergence behavior of the Krylov subspace iterative methods. The numerical computation shows that the results in this paper are in good agreement with the results obtained by the method of moments at each frequency, and the computational efficiency is improved greatly. [C266]

"MIMO radar joint estimation of target location and velocity with multiple subcarrier signals"

This paper analyzes the effect of waveform parameters on the joint target location and velocity estimation by non-coherent multiple-input multiple-output (MIMO) radar transmitting multiple subcarriers signals without energy constraint. How the number of subcarriers influence the estimation accuracy is illustrated by considering the joint Cramer-Rao bound (CRB) and the mean square error (MSE) of the maximum likelihood (ML) estimate. The non-coherent MIMO radar ambiguity function (AF) with multiple subcarriers is developed and investigated by changing the number of subcarriers, the pulse width and the frequency spacing between adjacent subcarriers.

The numerical results show that more subcarriers means more accurate estimate and higher localization resolution, larger pulse width results in worse performance of target location estimation, while the frequency spacing affects target location estimation little. [C267]

"Impact of flight trajectory on the detection and selection of flowers by nectar-feeding bats"

Echolocating mammals, such as bats, have evolved an excellent ability to detect, select and identify the targets they depend on for their survival by echolocation even in the most challenging environments. They simultaneously adapt their trajectory and diversify transmission parameters such as waveform, bandwidth and time duration, to obtain high level detection and classification performance that is far better than that obtained by modern radar and sonar systems. This paper exploits the information available to the bat along its in-flight trajectory aiming at assessing the impact of choosing the right trajectory on detection and classification performance. A set of experimental data consisting of HRRPs of one inflorescence of Rhytidophyllum auriculatum is analysed and results are discussed and related to the case of radar and sonar systems. [C268]

"MIMO radar for sense and avoid for UAV"

UAV are easily deployable platforms. Up to now they carry payloads (surveillance, combat) for military purposes in crisis or war time. For training, UAV are flown in special areas attributed in a limited space and a limited time slot. In the future, UAV will also be used for civilian tasks. For these reasons, UAV will have to be inserted in the general Air traffic and "Sense and Avoid" systems will be mandatory. Among the possible sensors, the radar is the most pertinent one: it is "all-weather" and provides accurate range, direction and closing speed. In this paper, a low cost solution based on the coherent "MIMO" principles is described. This solution allows the location of the radar within the UAV airframe without any moving parts, hence provides a high reliability level. The rationale of the proposed architecture is explained, then the enabling technologies and related waveforms are described. [C269]

"Spread Spectrum Digital Beamforming (SSDBF) radar"

Spread Spectrum Digital Beamforming (SSDBF) overcomes the CSWAP and the scalability in bandwidth-and-frequency limitations of Conventional Digital Beam Forming (CDBF) by eliminating the requirement of "one digital transceiver per element" while enabling fully capable digital beamforming with minimum hardware (and consequently minimum volume and heat dissipation) per element. SSDBF enables low-cost/low-profile/low-power digital beam forming phased arrays that scales in frequency (L through Ka and higher), bandwidth (100's MHz) and subarray size (100's elements per subarray) with a single down-converter, single digital receiver and single Nyquist-rate ADC for the entire subarray. It achieves this by replacing the MMIC T/R module at each element with much simpler bi-phase re-modulating hardware, and by re-modulating and aggregating the return signal incident at each element such that it can perfectly recover the complex baseband-equivalent of the RF signal of each element without mutual interference and with negligible noise performance degradation. The bi-phase re-modulator at each element can be extremely small and low power and amenable to implementations as simple as a single RF switch mounted directly at the antenna element with associated ON/OFF switch control logic built on the back. Thus SSDBF truly enables flat, thin, lightweight conformal phased arrays and has the potential of reducing phased array costs by, possibly, multiple orders of magnitude relative to CDBF state-of-the-art. The SSDBF parameters and waveforms are flexible, programmable and can be tailored and adapted, practically, to support any radar or communications applications. In a project for DARPA, Applied Radar is developing an X-band SSDBF-based radar prototype in which the SSDBF features and performance have been demonstrated. In this paper, we describe the SSDBF method for a radar application including simulation, indoor testbed and open-range test results. [C270]

"Copyright page"

The following topics are dealt with: intelligent platform networks; adaptive learning algorithms; cognitive radio; spectrum sensing and management; signal estimation and tracking; Bayesian machine learning; cognitive radar processing; waveform agile intelligent adaptive sensor signal processing; collaborative sensing techniques; learning theory and modelling; and game theoretic tools for cognitive radio. [C271]

"Efficient beam scanning, energy allocation, and time allocation for search and detection"

Recently-developed unique and innovative concepts for efficient radar search and detection are reviewed. These results provide answers to the two fundamental search questions: (1) Where should the radar beam point during the next increment of search effort (energy and time)? (2) How much radar effort should be expended during the next increment of search effort? These results provide the most efficient allocation of radar search effort in both space and time which maximizes target detection performance and minimizes radar search energy and time.

Typical savings of several dB of radar power-aperture product and/or expected (average) detection time are obtained. These new techniques are practical and can be used in the next generation of radars with agile beams and variable-energy search waveforms. Furthermore, the problem formulation and solution are very general, so these search and detection techniques developed for radar can also be applied to other both active (transmitting and receiving) and passive (receive only) electronic sensors: optical, IR, UV, sonar, seismic, passive RF, astronomy, etc. [C272]

"Improved range resolution for FMCW HF surface wave radar"

A modified signal processing for FMCW waveform has been proposed that yields an improved range resolution without increasing the transmitted signal bandwidth. The chirp duration is reduced by an appropriate factor while the interval of the beat signal sequence considered for the range transform is kept constant. This modification implies a range transform over several chirp sweeps and an interleaving technique for the Doppler transform. Range resolution is improved without affecting the maximum unambiguous Doppler. This is achieved on the expense of a reduction of the maximum unambiguous range. Actually, this is not a restriction for HF SWR systems where the maximum range is limited by surface wave attenuation. However, a minimum practical range bin size is given either by the size of the targets considered or by the acceptable size of range side lobe level coming along with increasing range resolution. With this approach first and second order sea clutter is reduced which is of significant interest for ship detection. [C273]

"Waveform diversity and knowledge based signal processing in distributed radar"

The asymmetric threat of the twenty-first century is presenting a challenge for the information and sensors domain. The intelligent aggregation of information and sensor data in real-time is required. The use of waveform and geometric diversity along with knowledge based signal processing in distributed radars and heterogeneous sensors is necessary. Three example cases are presented illustrating how to intelligently aggregate information and sensor data for delivering the desired effects to the asymmetric threat. [C274]

"Through wall ranging and imaging using UWB random noise waveform: System design considerations and preliminary experimental results"

In this work, a portable and real-time through-wall random noise radar is presented. The system is inherently covert and is immune from interference and jamming since a random noise waveform is used. By combining mature cross-correlation and SAR algorithm with FPGA-based receiver technology, the system is able to perform real-time range detection as well as imaging of targets, including human beings, behind a wall. [C275]

"FPGA-based Radar Signal Processing for Automotive Driver Assistance System"

Safety and comfort applications are addressed using driver assistance (DA) systems like adaptive cruise control (ACC) system using long range radar (LRR) or short range radar (SRR) or both. Novel waveforms and functionalities applied to next generation DA multi-sensor systems and their corresponding complex algorithms require advanced digital hardware supporting high computation rate and severe real-time constraints. In this paper, we present a flexible FPGA-based architecture for digital control and signal processing of a DA system. The considered DA system makes use of a new particular waveform to enhance capabilities of old generation ACC radar. Hardware/software partitioning has been explored in order to match the real-time requirement of the system. Development steps, from algorithm specification to on-board demonstration, are detailed. Promising results in terms of resources use and execution time are shown using a prototyping board with a single Virtex-II Pro device. [C276]

"Research on the cascaded inverter with hybrid control of step waveform and instantaneous feedback"

This paper proposes a hybrid control method for cascaded inverter with step waveform and instantaneous current control. With this method, one part of the cascaded unit uses step waveform control, and the other part of the cascaded unit uses instantaneous control. The output voltage comes from the two parts in series. This method can decrease the switching time, reduce the switching loss. The structure of the system is very easy. The theory analysis and simulation is done, and the simulation results show the validity of the proposed method. [C277]

"Analysis and design of soliton oscillators using harmonic balance"

Soliton oscillators enable the generation of short-time pulses, applicable in sampling of fast signals or as probe signals in radar systems. The soliton oscillator is made up of a feedback loop containing an amplifier stage and

a nonlinear transmission line. In this paper, an efficient technique for the harmonic balance design of these oscillators is presented. The bifurcation behavior of this kind of oscillators is analyzed in depth, with a detailed study of their oscillation modes. The sources of non ideality of the soliton-train waveform have also been investigated. The techniques have been applied to a first prototype at 1 GHz with very good agreement with the measured results. [C278]

"Through wall imaging based on electromagnetic modeling using UWB noise waveform"

Different electromagnetic models using the UWB noise waveform as incident waveform are setup. For each model, imaging result is obtained using back projection algorithm after cross-correlation processing of every received echo with the transmit noise signal. [C279]

"Optimal Adaptive Waveform Selection Based on ADP in Cognitive Radar"

Cognitive radar is a new framework radar system proposed in 2003 and waveform selection is an important problem in this type of radar. In this paper, we design a knowledged-based (KB) waveform selector and use stochastic dynamic programming model to describe waveform selection problem. To solve the problem of curses of dimensionality, we use approximate dynamic programming (ADP) in our solution. This method is operative and efficient. [C280]

"Ku-band retrodirective radar for ballistic projectile detection and tracking"

A Ku-band radar has been developed for detection and tracking of sniper rifle bullets and other ballistic projectiles. The radar utilizes a novel retrodirective architecture based on separate 8-element receive and transmit antenna arrays. A pseudorandom noise waveform provides for precise ranging and high processing gain. Digital filtering allows for discrimination of high-velocity bullets and small supersonic projectiles up to at least 1700 ft/s, as demonstrated experimentally in field tests. [C281]

"Development of a FPGA-based high speed FFT processor for wideband Direction of Arrival applications"

A parallel and pipelined Fast Fourier Transform (FFT) processor for use in the Direction of Arrival (DOA) estimation of a wideband waveform is presented. The selected DOA algorithm follows the Coherent Signal Subspace Method (CSSM). The target device for implementation is a Xilinx Virtex-5 Field Programmable Gate Array (FPGA). The FFT processor was developed in MATLAB Simulink using the Xilinx System Generator block-set to auto-generate VHDL code. Although the parallel and pipelined architecture uses a large portion of the available FPGA resources, the architecture does yield a high throughput. [C282]

"A brief history of waveform diversity"

The U.S. Air Force has set an ambitious goal to be able to anticipate, find, fix, track, target, engage, and assess-anything, anytime, anywhere. We will not achieve order of magnitude improvement in detection and tracking performance solely through larger antennas and more power. Instead, advanced signal processing techniques and system concepts will be required. Achieving the sought after demanding goals will instead require a distributed network of heterogeneous sensors. [C283]

"A simple control arithmetic of step wave cascaded multilevel inverter with different voltage step"

Besides effectively reducing the voltage stress of switches, the cascaded multilevel inverter could also improve the quality of output waveforms by addition of waveforms. The step waveform addition is a usual method. The addition could reduce the loss of switches, but the introduced angle of flow calculating methods of cascade inverters based on step waveform addition are only suitable for cascaded inverters with the same voltage step. To this situation, an angle of flow calculating method of inverters with the different voltage step is proposed in this paper. The method is very suitable for the application of solar battery cascaded inverters and fuel battery cascaded inverters. The method follows the equal area principle, and the online calculation is realized by some constraint conditions. Finally, the correctness of the method is validated by simulations. [C284]

"Some autocorrelation properties of phase-coded waveforms"

In this paper we study some autocorrelation properties of a train of identical signals overlaid with a phase coding. Prior publications have investigated this problem under the assumption that, for the purpose of the phase coding, the original (uncoded) signal forming the train is divided into a number of bits that are either all identical or all distinct. This paper extends the discussion to the case of repeated bits. We derive and analyze sufficient

conditions for cancelation of the waveform's autocorrelation sidelobes located around the main lobe area. [C285]

"STAP performance analysis for MIMO radar with waveform diversity"

This paper studies the waveform effect on the space time adaptive processing (STAP) of multiple-input multiple-output (MIMO) radar systems. A general signal model based on waveform diversity is constructed for MIMO STAP. System sensitivity and optimal adapted pattern are investigated according to waveform diversity. These studies show how the MIMO STAP performance is affected by waveform diversity, based on which we can do better trade-off to balance the system performance under different conditions. [C286]

"Cancellation of range ambiguities with block coding techniques"

This paper presents radar signaling schemes for cancellation of late time arriving echos. Signal reflections arriving delayed at the radar when the radar has already emitted a next pulse result in range ambiguities and materialize as potential false targets. In this work we propose pulse block coding techniques to distinguish echo reflections originating through the recently emitted pulse and those impending from subsequent pulses. The methods introduced require only simple matched filtering operations at the receiver and permit usage of arbitrary waveforms with potential for waveform diversity gains. [C287]

"MIMO radar angle-range-Doppler imaging"

Through waveform diversity, multiple-input multiple-output (MIMO) radar can achieve higher resolution and better sensitivity to slowly moving targets than phased-array radar systems. Furthermore, with a MIMO antenna array, the linear independence of reflected signals from scattering points allows for the direct application of adaptive array processing techniques. High levels of noise and strong clutter presence, however, significantly worsen detection performance. The iterative adaptive approach (IAA), a non-parametric and user parameter-free weighted least-squares algorithm, was recently shown to offer improved resolution and interference rejection for array processing applications. In this paper, we extend IAA to perform angle-range-Doppler imaging using a MIMO radar system. We furthermore demonstrate the superior performance of a MIMO radar system compared to a single-input multiple-output (SIMO) radar system. [C288]

"Reduced-complexity delay-Doppler correlator for time-frequency hopping signals"

The delay-Doppler correlator is most commonly used for target detection in a radar system. It is essentially a two-dimensional filter matched to the hypothesized delay and Doppler shifts of echoes reflected from the illuminating signal. More recently, it has been applied in communication to the detection of signature sequences generated from artificially introduced time-frequency shifts of a base sequence. In this paper, we derive a computationally efficient delay-Doppler correlator for a class of time-frequency hopping waveforms that can be represented by segments of equal-length sinusoids. These sequences can be found in applications such as continuous waveform radar and device identification in wireless communication. By applying sliding discrete Fourier transform and exploiting the structure of the waveform, the number of multiplications required for evaluating the entire delay-Doppler range can be reduced by a factor equaling the length of the sequence. [C289]

"Block Least Mean Squares processing of noise radar waveforms"

Noise radars usually employ correlation processing of waveforms. However, vulnerability to clutter is a serious disadvantage of this approach. This paper considers using Least Squares (LS) based methods. In particular, highly efficient Block Least Mean Squares (Block LMS) algorithm is studied in details. The formula for integration gain of Block LMS is derived. Compared to analogue quantity for correlation processing, it shows significant advantage of the proposed solution in terms of robustness to clutter. The Doppler response of the algorithm is analyzed, which-under proper choice of algorithm parameters-is identical to that of correlation approach. Simulation experiments confirm that when heavy clutter is present, the proposed method outperforms correlation processing significantly. [C290]

"Spatial, temporal, and spectral aspects of radar data"

We develop a linearized imaging theory that combines the spatial, temporal, and spectral aspects of scattered waves. We consider the case of fixed, distributed transmitters and receivers, and a general distribution of objects, each undergoing linear motion; thus the theory deals with imaging distributions in phase space. We derive a model for the data that is appropriate for any set of waveforms, and show how it specializes to familiar results when the targets are far from the antennas and when narrowband waveforms are used. [C291]

"Derivation of the frequency mismatch probability in linear FMCW radar based on target distribution"

In LFMCW (linear frequency modulated continuous wave) radar, there is a nonzero probability for mismatches to occur under certain conditions. This probability strongly depends on the modulation employed as well as on the distribution of targets in the radar's field of view, i.e. the application of the radar sensor. Hence to reduce mismatches in a given application, an effective approach is to carefully design the modulation used. Instead of utilizing extensive simulations, we derive the distribution of mismatches analytically, solely based on the modulation parameters and a given distribution of targets. Based on that mismatch distribution, an application-specific optimization of the modulation is feasible. [C292]

"System architectures and algorithms for radar imaging by MIMO-SAR"

The multi-input / multi-output (MIMO) principle is well known for communication applications, whereas at least the name dasiaMIMOpsila is relatively new for radar applications. Nevertheless, the principle has been analyzed and used in a few examples since the early 80s or even before. A MIMO-radar is characterised by a number N of transmitting and a number M of receiving antennas forming N times M Tx/Rx pairs where each propagation path from the nth transmit antenna to the object to the mth receive antenna is made available to the signal processing. This can be achieved by temporal multiplexing, spatial coding and/or orthogonal waveforms. A further step is to transfer this technique to the SAR case. Additionally, the whole array is moving, SAR processing can be applied. Possible geometries of MIMO-SAR are along track arrays (reduction of azimuth-ambiguities, moving target indication, super resolution) or across track arrays (reduction of elevation-ambiguities, interferometry, 3D down-looking SAR). In this paper, some aspects of moving MIMO-arrays for SAR will be addressed. [C293]

"CPM-based radar waveforms for efficiently bandlimiting a transmitted spectrum"

In this paper we shall demonstrate how a polyphase-coded radar waveform can be implemented using a continuous phase modulation (CPM) framework so as to achieve spectral containment while maintaining a constant envelope to maximize energy-on-target. Current modulation techniques such as derivative phase shift keying (DPSK) and minimum shift keying (MSK), which are applicable to binary-coded waveforms, are well-known implementation schemes for spectral containment. The CPM implementation is applicable to polyphase codes and can also achieve better spectral containment, though a by-product is increased range sidelobes that result due to the deviation from the idealized code (implicitly defined for squared-shaped chips). To ameliorate the increased range sidelobes, a version of least-squares mismatched filtering is employed that accommodates the continuous nature of the CPM structure. Also, continuous rise/fall-time transitions of the pulse are addressed as part of the holistic implementation of the CPM-based waveform. It is observed that for the CPM implementation the rise/fall-time becomes the limiting factor on spectral containment and a rather simple scheme based on Chireaux out-phasing is suggested as a means to ldquoslow downrdquo the pulse rise/fall. [C294]

"Circuit level analysis of analog signal processing based MIMO radar system"

Conventional digital signal processing (DSP) based systems, when expanded into a multi input multi output (MIMO) system, suffer from increase of power consumption and computational burden. In this paper, an analog based MIMO radar system is introduced. The proposed system uses a combination of wavelets as its pulse at transmitters. Using the property of wavelets being orthogonal in time, our proposed system achieves waveform diversity. Implementation of a MIMO radar system based on analog circuitry results in significant decrease in power consumption of the system. This was verified by comparing systems with similar performance and estimating their power consumption. While our proposed system consumed 422.2 mW, a DSP-ASIC MIMO radar system consumed 2621.6 mW, a conventional DSP-ASIC single input single output (SISO) radar system consumed 1767 mW, and a conventional DSP-FPGA SISO radar system consumed 4158 mW. [C295]

"Extending the frequency matching in linear FMCW radar exploiting extreme frequencies"

Frequency matching is an essential block of the signal processing chain in LFMCW (linear frequency modulated continuous wave) radar. Its task is to associate frequency detections obtained in multiple measurements. Under certain conditions, this association may fail and frequency detections from multiple real targets may be combined to a mismatch. The classification of a frequency association as match (real target) or mismatch (ghost target) is commonly regarded impossible if we only have frequency detections. Yet in this paper we show that even in this case, a reliable classification is possible when special attention is paid to the two outermost frequencies in each spectrum. Furthermore, the radar's modulation can be designed such that the reliable classification can be achieved in the regions of interest of the distance-velocity-plane, i.e. application-specific. [C296]

"Distributed aperture OFDM radar"

This paper presents a new method of obtaining frequency diversity using orthogonal frequency division multiplexing (OFDM). Exploiting spatial diversity, the key advantage of a distributed aperture radar, requires orthogonality in, for example, the frequency, time, waveform, dimensions across sensors. This paper focuses on the simplest of these cases; frequency orthogonality. Here we address the key drawback associated with frequency diversity: whereas the use of multiple frequency bands requires additional RF hardware, an OFDM-based system needs only a single oscillator and demodulator while yet maintaining frequency orthogonality. OFDM employs many sub-carriers within a single frequency band instead of occupying different frequency bands. Separation of the signals can be performed oversampling of the incoming signal followed by a Fast Fourier transform (FFT). [C297]

"Multi-carrier radar waveform schemes for range and Doppler processing"

A processing technique that utilizes the OFDM communication waveform as the radar waveform is considered. The double use of the waveform for communications and radar enables establishing radar networks communicating through the radar beam. The processing technique exploits the Doppler sensitivity of the OFDM to reduce the Doppler ambiguity. An enhancement to the waveform and the processing is proposed to completely eliminate the Doppler ambiguity. [C298]

"Direct wave estimation of non-cooperative bistatic pulse radar using LMS adaptive filter"

In this paper, an adaptive inverse filter is applied to estimate the non-cooperative bistatic pulse radar transmitted waveform from a clutter-corrupted direct-path signal, given some a-priori knowledge of the transmitted waveform. Some experiments have been done to simulate the process of direct wave reconstruction using LMS adaptive filter. The simulation results show that the adaptive filter does a fairly good job of mitigating the corruption of the direct-path signal. [C299]

"Study of Side Lobes Suppression for Using Pulse Compression in Weather Radar"

In this paper, low rang time side lobes for pulse compression in weather radar can be achieved by an integrated scheme using non-linear FM, tapering transmission waveform, mismatched windowed filter. The simulation process to search optimum realization scheme is presented to make sure least enlargement of main lobe pulse-width while mitigating energy of side lobes. The result of simulation indicates that side lobes can be less than 60 dB while main lobe width will not surpass 0.66 mus. In the end, the implement of the scheme is designed for realization. [C300]

"Investigations of RL-Loaded Bowtie Antenna for Low-Resolution GPR"

A resistively-inductively loaded (RL-loaded) bowtie antenna for impulse ground penetrating radar (GPR) is theoretically and experimentally investigated. The antenna has been designed for transmission of Gaussian-like pulses with duration of 6 ns (100 MHz central frequency). As ultra-wideband (UWB) antenna, it is suitable for low-resolution GPR that can be used in tunnel geology forecast. The simulating results and the Smith chart created by the network analyzer are analysed. We implement lumped resistor-inductance loading (RL-loading) to the antenna. Experimental results show that VSWR of the loaded antenna is less than 2.5 in the band 0-300 MHz while the transmission efficiency keeps unchanged basically after loading. The RL-loading raised in this paper makes the narrow pulse generator and the antenna-feed system get matched. Time-domain waveforms and radiation pattern of the antenna are shown in this paper. [C301]

"Radar Signal Environment Simulation Based on Quadrature Multiple Waveform Synthesis Method"

The principle of multiple quadrature waveform synthesis (MQWS) is introduced, which is based on the theory of quadrature modulation. Its adaptability to pulse signals is analyzed. Combined with pre-saved waveform data, this method can be used in radar signal environment simulation and it can simplify the requirement for the hardware implementation with general-purpose and flexibility characters. The realization experiments show that it can fulfill the signal's simulation of various radar types. [C302]

"Sub-nanosecond pulse generator for through-the-wall radar application"

This paper presents a sub-nanosecond pulse generator intended for a transmitter of through-the-wall surveillance radar. The basis of the generator is a step recovery diode, which is used to sharpen the slow rise time edge of an input driving waveform. A unique pulse shaping technique is then applied to form an ultra-wideband Gaussian pulse. A simple transistor switching circuit was used to drive this Gaussian pulser, which

transforms a TTL trigger signal to a driving pulse with the timing and amplitude parameters required by the step recovery diode. The maximum pulse repetition frequency of the generator is 20 MHz. High amplitude pulses are advantageous for obtaining a good radar range, especially when penetrating thick lossy walls. In order to increase the output power of the transmitter, the outputs of two identical generators were connected in parallel. The measurement results are presented, which show waveforms of the generated Gaussian pulses approximately 180 ps in width and over 32 V in amplitude. [C303]

"Waveform diversity in distributed radar"

The desire to anticipate actions before they occur is a goal within the military. Cognitive sensor and communications systems along with distributed radar systems are key enablers to meet this need. Close in sensing examples are provided showing the value of waveform diversity in distributed radar. The use of waveform diversity presents a challenge to the electromagnetic compatibility (EMC) community. [C304]

"Estimating temporal multipath via spatial selectivity: Building environmental knowledge into waveform design for radar-embedded communications"

We consider the problem of embedding a communications signal into the backscatter induced at an RF tag/transponder by pulsed radar illumination given the competing constraints of high data rate and low probability of intercept (LPI). In this work spatial selectivity is addressed as a means to provide lower intercept probability without sacrificing data rate or receiver error performance. Here spatial selectivity is achieved by incorporating the forward scatter (i.e. multipath) effects between the radar and tag into the information-bearing embedded communication waveform intended for reception at the radar. The multipath is incorporated via a time reversal framework thereby enabling spatial focusing which inhibits interception by an eavesdropper. The focus of this paper is upon the accurate estimation of the multipath given that prior knowledge of the transmitted radar waveform may not be available. [C305]

"Adaptive Pulse Regulations to Achieve High Range Resolution within the Unambiguous Window"

In this article, we consider a kind of high resolution radar system with adaptive pulse adjustment for target detection and locating. There exist a trade-off between the ambiguity range distance and the resolution, we adaptively regulate the carrier spacing to make the ambiguity range window large enough to contain all target extent with a specified DFT size. Doppler shift and the target moving velocity is considered for target range resolution. We also present the critical value for each sub-pulse sequence to quickly obtain all scatters. The waveform at the receiver side after low pass filter and IFFT procedure is shown to illustrate the effectiveness of the proposed approach. [C306]

"Properties of ambiguity functions for weighted pulse trains with Oppermann sequences"

In this paper, we consider properties of the auto-ambiguity and cross-ambiguity functions of weighted pulse trains with Oppermann sequences. Several properties are examined and proved which in turn allows for reducing the design space for optimization of a particular design. The insights gained from these properties are consolidated in a formal framework leading to procedures that can be used for a more structured waveform design. Numerical examples are provided to illustrate the relationship between sequence parameters and performance characteristics. [C307]

"A novel digital beam-forming concept for spaceborne reflector SAR Systems"

The trend in the conception of future spaceborne radar remote sensing is towards the use of digital beam-forming techniques. These systems will comprise multiple digital channels, where the analog-to-digital converter is moved closer to the antenna. This dispenses the need for analog beam steering and by this the use of transmit/receive modules for phase and amplitude control. Digital beam-forming will enable synthetic aperture radar (SAR) which overcomes the coverage and resolution limitations applicable to state-of-the-art systems. Moreover, new antenna architectures, such as reflectors, already implemented in communication satellites, are being reconsidered for SAR applications. This paper introduces a new digital beam-forming radar concept based on the combination of a reflector with a digital feed array. For a system example the SAR performance is estimated. Finally a novel digital signal processing approach, exploiting the signal properties of the transmitted waveform, is presented. [C308]

"Adaptive waveform generator for radar systems"

Purpose of this paper is to present basic concepts and an automatic tool for the design of radar waveforms suitable for implementation in modern multifunctional or surveillance systems. [C309]

"A New Method for Estimating the Number of Targets from Radar Returns"

This paper introduced linear frequency modulation (LFM) waveforms and proposed a new method based on the Wigner transformation and Hough transformation, the new method was used to estimate the number of targets contained in the LFM radar returns. At last we got the simulation result through experiments. The simulation results show that as long as the waveforms meet the certain conditions, the number of targets contained in the LFM radar returns can be estimated exactly by the new method, whose algorithm is simple and easy to implement in works, so it has good technical expansibility, so it could not only be applied to the field of military, but also the field of civil. [C310]

"Wideband Sonar Signal Design for Moving Target Parameter Estimation"

The signal waveform design of wideband high frequency sonar is proposed. Using the ridge slope invariability property of wideband HFM signal, moving target parameter estimation is discussed. Real time results are presented and show the prospect of wideband HFM signals in underwater signal processing applications. [C311]

"Design of Frequency-Hopping Waveforms Based on Ambiguity Function"

Integrated sidelobe level(ISL) criterion and the maximal sidelobe level(MSL) criterion are used to design frequency-hopping waveforms based on ambiguity functions respectively in this paper. Some simulation results are given and analyzed. The performance of the proposed algorithm is validated by numerical simulations. [C312]

"Effect of range ambiguity on space based AMTI clutter suppression and mitigation method"

Air moving target indication (AMTI) using space based radar (SBR) is attractive. In order to detect airborne target in clutter and measure the target's range at the same time, SBR usually use medium PRF waveform. Theoretical analysis and experimental results show that range ambiguity cause target's range ambiguity and clutter's range foldover. Range ambiguity significantly degrades the clutter suppression performance. A method based on orthogonal waveform for mitigating the range ambiguity effects is presented in this paper. The orthogonal waveform is launched in sequence. Then multi-channels matched filter is used to receive the replay pulse. Experimental results illustrate that the method is effective. [C313]

"Temporal difference learning waveform selection"

The largest difference between cognitive radar and other adaptive radar is the adaptivity of transmitter in cognitive radar. How to optimally decide or select the radar waveform for next transmission based on the observation of past radar returns is one of the important issues. In this paper, with the stochastic dynamic programming model of waveform selection, we use the method of temporal difference learning to solve this problem and realize the adaptivity of waveform selection. The simulation results show that the uncertainty of state estimation using temporal difference learning is less than that using fixed waveform. [C314]

"Design and realization of arbitrary radar waveform generator based on DDS and SOPC technology"

A radar waveform generator is designed, employing directly digital modulation method based on DDS and SOPC technology. It is able to output arbitrary signals with amplitude, frequency or phase modulation under the control of signal characteristics description words out putted from an external computer. Up to four waveforms with different modulation can be generated simultaneously by single circuit module with good quality. Parameters of each waveform are programmable and easy to be updated. [C315]

"Use of prior information in active sonar tracking"

A Bayesian tracking model is proposed that uses measurement likelihood functions based on predicted signal-to-noise ratios (SNR) in active sonar data. The predicted SNR modeling can incorporate prior information, such as the presence of known discrete and persistent clutter objects. The likelihood model assumes an exponential distribution of returns with a mean based on the predictive model that incorporates assumed SNR of the targets, known clutter, and background clutter, and the beam response and waveform ambiguity functions. Two variations of an example based on simulated frequency modulated (FM) and continuous wave (CW) signals is used to assess target detection and localization performance. Significant enhancements are observed when prior knowledge of clutter is incorporated into the measurement model in these idealized examples. [C316]

"Recurrent lobes reduction of stepped-frequency LFM pulse train using ambiguity function"

Stepped-frequency linear frequency modulation (LFM) pulse train is one of the well-known waveforms employed in modern wideband radar to efficiently achieve good range and Doppler resolution without increasing requirements on overall system cost and complexity. Unfortunately, this waveform associates with a drawback of undesirable spikes, known as dasiarecurrent lobes or grating lobespsila due to the fixed frequency step. We investigate a generic stepped-frequency LFM pulse train and analyze its significant characteristics by using ambiguity function in more details, especially for zero-Doppler cut and zero-delay cut. Then we propose a method that allows us to reduce grating lobes below a desired threshold level. Two special cases for reduction are discussed for the specific relationships among waveform parameters. Both the analytical and numerical methods for parameter design are given along with distinct examples, which show that selecting a certain larger overlap ratio makes no need to suppress these spikes. [C317]

"Performance analysis and correlation selection with Doppler measurements"

In target tracking system, Doppler radar or active sonar can provide both range and range rate measurements. With some kinds of waveforms, the range and range rate measurement errors are correlated. It is pointed in [1] that the negative correlation can improve the steady state tracking performance greatly and the tracking performance under positive correlation will be worse than that under no correlation. With further simulation in this paper, it can be seen that the tracking performance under positive correlation is not always worse than that under no correlation. Under the assumption that the range and range rate accuracy are not affected by the correlation, the relationship between the tracking performance and the correlation is revealed through one-step analytical analysis. For better tracking performance, the absolute value of the measurement correlation coefficient should be as big as possible and its sign should use the opposite sign of the one step prediction covariance correlation. [C318]

"A simulation technique for high frequency Doppler spectra and comparison with high-bandwidth WERA data"

HF ground wave radar data, collected as part of the European Radar Ocean Sensing Experiment (EuroROSE) in Lyngoy, Norway during April, 2000 using a Wellen Radar (WERA) system with an FMCW waveform, are compared with data simulated from models designed at Memorial University. The similarities between them give a solid confirmation not only of the backscattering cross sections developed for the FMCW waveform, but also of the simulation algorithm for the radar received signal. However, two significant differences need to be highlighted. Firstly, the amplitude of the high-frequency spectral tails is about 10 dB higher for the field data as compared to the simulated spectra. Secondly, the Bragg peak for the real Doppler spectrum is much wider than that for the simulated spectrum. Such differences between the simulated and field Bragg regions may result from, among other possibilities, current fluctuations on the scattering patch. [C319]

"Performance analysis of DOA estimation for MIMO sonar based on experiments"

In this paper, a Multiple Input Multiple Output (MIMO) monostatic sonar scheme that can deal with multiple targets is presented, where orthogonal waveforms are transmitted simultaneously. Meanwhile the Capon estimator for this sonar system is derived in detail. And the performance of the MIMO sonar is analyzed via experiments in an anechoic water tank, as compared with its phased-array counterpart. The used sonar array is a uniform linear array with 10 closely spaced elements. Experimental results show that, by orthogonal transmit, this sonar system could achieve 12~15 dB additional array gains over its phased-array counterpart, which means the maximum detection range could be doubled; also, the angle resolution capability could be significantly improved at lower SNR. [C320]

"An Improved Algorithm for Waveform Scheduling"

Cognitive radar can adaptively modify their performance to suit a variety of environments and select the best sequence of waveforms to track the targets with higher possible accuracy. In this paper, based on the stochastic dynamic programming model of waveform scheduling, an improved algorithm for waveform scheduling is proposed. The simulation results show that the proposed algorithm can minimize the uncertainty of state estimation compared to fixed waveforms and approaches the optimal waveform scheduling scheme. [C321]

"A 2 pJ/bit pulsed ILO UWB transmitter at 60 GHz in 65-nm CMOS-SOI"

The paper describes a 2 pJ/bit transmitter with 1.5 Gbps data rate with Pulsed Injected Local Oscillator (p-ILO) and 0 dBm peak output power that 0.16 mm2active area in 65-nm CMOS-SOI. Input digital pulses modulate the oscillator at 60 GHz from On to Off state. The occupation bandwidth is 7 GHz for a 300 ps modulating pulses.

This millimeter wave output frequency oscillation is locked to one of the numerous harmonic components of the pulse generator synthesized around 60 GHz, which permits to obtain a stable pulse to pulse phase condition. Thanks to this very non linear injection using pulses switching, a super high order N harmonic injection is obtained. With a 500 MHz input pulse data rate (N = 60 GHz = 500 MHz = 120) the phase noise is -92 dBc/Hz at 100 KHz which is very close to the theorical 20 log(N) dB increasing phase noise. The peak conversion efficiency is more than 18 % and the maximum peak output power is 7 dBm. Output pulse waveform and phases are coherent with input modulated pulses, which make this transmitter suitable for Automotive Radar, Giga bit WLAN, Wireless Sensor Networks and localization. [C322]

"High-resolution direction finding of coherent sources in the presence of model errors using alternating projections"

Direction finding with coherent source waveforms is of practical importance in radar array processing, e.g. for specular multipath propagation. Furthermore, high-resolution methods require an accurately calibrated array. In this paper, we combine local and global manifold correction with maximum likelihood direction finding using the method of alternating projections. We use simulations to study the effect of array errors and noise. We further apply the combined algorithm to real data recorded using a radar array for an automotive application. [C323]

"Optimal waveform precoder design for narrowband MIMO radar systems"

This paper addresses the problem of coded waveform design for Multiple Input-Multiple Output (MIMO) radar systems. The paper proposes a signal model based on the assumption of a small array aperture relative to the signal wavelength and a single target in far field. It is argued that near maximum likelihood performance can be obtained by choosing the transmitted waveforms on different antennas to be orthogonal. The Cramer-Rao Bound (CRB) for estimating the target distance, radial velocity and wavenumber is derived. The paper presents a convex optimisation procedure to yield an optimal energy distribution across the transmitted signals. Simulations demonstrate a reduction in CRB in the order of 25% compared to the use of a random unitary code. The paper concludes by indicating a natural generalisation of the method to optimal design for MIMO tracking radars. [C324]

"Beampattern optimization by minimization of quartic polynomial"

Beampattern synthesis is a common problem in array signal processing. Recently, methods for beampattern optimization using multiple simultaneously transmitted waveforms have been published in the context of MIMO radar. In this paper, we formulate the beampattern optimization problem as minimization of a multivariate quartic polynomial. The advantage of this approach is that iterative line searches are not needed and that the low-rank case can be solved directly without finding the minima of the full-rank system. The method does not guarantee convergence to the global minimum, but numerical examples provided demonstrate that results comparable to the other approaches are achieved. [C325]

"Cramйr-Rao lower bounds for the joint estimation of target attributes using MIMO radar"

We derive the Cramer-Rao lower bound (CRLB) on the covariance of the joint estimates of the parameters of moving targets using measurements from multiple-input, multiple-output (MIMO) radars. We first derive the CRLB for MIMO radars with colocated antennas for estimating the target's direction of arrival, range and range-rate. We then demonstrate that the CRLB for phased array radars is a special case of the CRLB for MIMO radars with colocated antennas. We also derive the CRLB for MIMO radars with widely-separated antennas for estimating the target's location and velocity, and we compare it to the CRLB for the multistatic radar. For both types of MIMO radar systems, we show that the CRLB is related to the parameters of the transmitted waveforms, as demonstrated with numerical simulations. [C326]

"Clutter rank Of MIMO radar with a speical class of waveforms"

In this paper, the rank of clutter covariance matrix (CCM) is studied for space-time adaptive processing (STAP) implemented on the multiple-input multiple-output (MIMO) radar with waveform diversity. It is found that the clutter rank is dependent on the rank and structure of the covariance matrix of the transmitting waveforms, and that clutter rank of orthogonal waveforms acts as the upper bound for all kinds of waveforms. More specifically, three simple rules are proposed to estimate the clutter rank for one special class of waveforms. This class of waveforms, though we call it special, indeed can include coherent waveforms, orthogonal waveforms, as well as part of partially correlated waveforms. In this way, the method of estimating the clutter rank for both coherent and orthogonal waveforms are herein unified. The application of these rules only requires the computation of the waveform covariance matrix (WCM) and a polynomial based on the WCM, thus it is convenient and computationally efficient. The proposed rules are well verified by simulation results and also general enough to

be suitable for both conventional space time radar systems and the MIMO radars with orthogonal waveforms. [C327]

"MIMO radar: Snake oil or good idea?"

MIMO communication is theoretically superior to conventional comm. under certain conditions, and MIMO comm. also appears to be practical and cost effective in the real world for some applications. It is natural to suppose that the same is true for MIMO radar, but the situation is not so clear. Researchers claim many advantages of MIMO radar relative to phased array radars (e.g., better detection performance, better angular resolution, better angular measurement accuracy, improved robustness against RFI & ECM & multipath, etc.). We will evaluate such assertions from a system engineering viewpoint. In particular, there are serious tradeoffs of MIMO vs. phased array radars relative to cost, system complexity and risk, considering numerous real world effects that are not included in most theoretical analyses. Moreover, in many cases one can achieve essentially the same radar system improvement with phased array radars using simpler less expensive and less risky algorithms. We evaluate roughly a dozen asserted advantages of MIMO radar relative to phased arrays. [C328]

"Polyphase sequences with good correlation properties"

Design of sequences with good auto and crosscorrelation properties is one of the main tasks in several applications, including multi-user radar, sonar, and communications. In this paper we describe a new construction of polyphase sequences with optimal correlation properties. The construction includes, as special cases, a family of finite chirps and two previously proposed families of communications sequences. The main tool used in the construction is the finite Zak transform. The construction suggests several further generalizations that can be obtained by operating exclusively on subgroups of the permutation group. [C329]

"Frequency agile stepped OFDM waveform for HRR"

High range resolution (HRR) is an important feature for radar, aiming at target classification. The range resolution is inversely proportional to the bandwidth of the transmitted signal. Pulse burst waveforms can achieve HRR at low expenses when the carrier frequency increases from one pulse to the next, stepping and synthesizing the wide bandwidth. In such a stepped frequency approach the resolution is determined by the bandwidth of the total pulse burst. With the orthogonal frequency division multiplexing (OFDM) waveform, the time/frequency pattern of the transmitted radar signal is fully flexible while the waveform can be generated easily by IFFT. The novelty of this paper is to demonstrate how the combination of frequency agility and HRR processing into one system can benefit from the OFDM flexibility. An elementary scenario with a single stationary or low speed point target is assumed. [C330]

"Transmit coding with a range ambiguity"

Often a requirement of radar is a high pulse repetition frequency, as such range ambiguities are a consequence of this requirement. One approach to resolve said ambiguities is to use a non-uniform PRF. The interest in this paper is to utilize a uniform PRF and pulse diversity to resolve a single or multiple range ambiguities through temporal coding. An algorithm will be introduced that is completely scalable to any type of scenario that will quickly create a custom set of M unique transmit codes that can be used at every pulse of the transmitter in order to resolve range ambiguities. [C331]

"GMTI MIMO radar"

Multiple-input multiple-output (MIMO) extensions to radar systems enable a number of advantages compared to traditional approaches. These advantages include improved angle estimation and target detection. In this paper, MIMO ground moving target indication (GMTI) radar is addressed. The concept of coherent MIMO radar is introduced. Comparisons are presented comparing MIMO GMTI and traditional radar performance. Simulations and theoretical bounds for MIMO GMTI angle estimation and minimum detectable velocity are presented. The simulations are evaluated in the time domain, enabling waveform design studies. For some applications, these results indicate significant potential improvements in clutter-mitigation SINR loss and reduction in angle-estimation error for slow-moving targets. [C332]

"Panel discussion: MIMO radar-fact or fantasy?"

The Special "MIMO Radar-Fact or Fantasy?" Session at the 4thInternational Waveform Diversity and Design Conference will be comprised of 20 minute technical presentations by each of the five invited speakers who were selected based on the quality of the papers that they had presented at other venues, their preeminence in the technical community as judged by their professional positions, their published journal papers or books, as

well as their potentially controversial opinions on the potential benefits and pitfalls, that could result from the introduction of MIMO architectures into modern radar systems. The final 20 minutes of this 2 hour special session will be a open panel discussion involving the five prior speakers and Marshall Greenspan as the panel discussion moderator. [C333]

"Distributed waveforms for networked meteorological radars"

Distributed waveforms for resolving ambiguities for Doppler weather radar systems are presented in this paper. The novel approach is a network-based technique where spatially distributed monostatic radars are used to mitigate ambiguities in the measurements. The networked waveform system offers many advantages. First, it decouples the range ambiguity and velocity ambiguity from each other, whereas range and velocity ambiguities are coupled together in a waveform for single radar. Second, the networked waveform can be designed to measure very high velocities without the need for complex waveforms and advanced processing at each radar node. This minimizes the computational load on each node. Third, it can be used with low cost transmitter that has limited ability to support complex waveforms as opposed to a significantly expensive single radar system with complex waveforms. Fourth, the networked waveform system can be designed to meet a specific requirement over the coverage region without being restricted by limitation of an individual radar node in the network. Fifth, the distributed waveform enables direct estimation of dealiased wind field, which is critical for kinematic analysis of storm structure. Based on the results obtained from simulation it is observed that distributed waveform can provide high unambiguous velocities. A distributed waveform was implemented with a four node radar network and preliminary results show that the networked approach is a viable solution. [C334]

"Analysis of range-angle coupled beamforming with frequency-diverse chirps"

Recently range-dependent (or time-varying) beamforming has been presented as a method to spread transmit energy over a desired spatial extent via a linear frequency shift across the waveforms transmitted at each element of an array. This element-level waveform diversity yields additional degrees of freedom relative to traditional beamforming techniques for which some sensing benefits have been suggested. In this paper, chirp waveforms with slightly different starting frequencies are analyzed to characterize the associated range-dependent beampattern. Specifically, it is determined that by utilizing this particular waveform structure, the energy transmitted over a pulse duration can be spread in a practically linear manner within the spatial extent specified by two angles despite the nonlinear relationship between spatial and electrical angles if the set of frequency-diverse chirps are appropriately parameterized. Additionally, a space-range ambiguity diagram is formulated. The ambiguity is discussed for the traditional and frequency-diverse array scenarios. [C335]

"MIMO phased-array for SMTI radar"

Summary form only given. Waveform diversity techniques for radar have gained considerable interest over the past several years. Novel radar waveforms have been proposed to improve detection performance and metric accuracy (i.e., angle estimation performance). This paper explores the potential for using a waveform diversity technique known as Multiple Input, Multiple Output (MIMO) radar to improve the detection performance of slow moving surface targets from a moving radar platform. The MIMO radar system achieves superior performance by transmitting unique uncorrelated waveforms from each antenna subaperture as opposed to the traditional approach of transmitting a single coherent waveform across the entire aperture. The results show that the radar system minimum detectable velocity (MDV) can be reduced by exploiting the ability of a MIMO system to effectively increase the radar antenna aperture. [C336]

"A comparative study of target localization in MIMO radar systems"

In the paper, a study of target localization performances is presented for coherent multiple-input multiple-output (MIMO) and single-input multiple-output (SIMO) radars systems with widely separated elements. The evaluation is based on the best linear unbiased estimator (BLUE), providing the localization mean squared error (MSE) in a closed-form solution. This estimator elucidates the relation between the radar locations, target location, and localization accuracy through the use of the geometric dilution of precision (GDOP) metric. Contour maps of the GDOP relate a given deployment of sensors and the achievable accuracy to the at various target locations. This metric is shown to represent the spatial advantage of the system. The best achievable accuracy for both configurations is derived. MIMO radar systems with coherent processing are shown to benefit from higher spatial advantage, compared with SIMO systems. The advantage of the MIMO radar scheme over SIMO is evident when considering the achievable accuracy for a radar system with M transmitters and N receivers, rather than 1 transmitter and MN receivers. It is shown that MIMO radar, with a total of M + N sensors, has twice the performance (in terms of localization MSE) of a system with (MN + 1) sensors. [C337]

"MIMO radar angle-doppler imaging via iterative space-time adaptive processing"

We consider using multi-input multi-output (MIMO) radar to improve the ground moving target indication (GMTI) performance, especially for slowly moving targets, for airborne surveillance systems. The increased virtual aperture afforded by MIMO radar systems enables many advantages, including enhanced spatial resolution, improved parameter identifiability and better performance for GMTI. To obviate the need of secondary data for space-time adaptive processing (STAP), we apply herein a user parameter-free and secondary data-free fully automatic weighted least squares based iterative adaptive approach (IAA) to angle-Doppler imaging via a standard MIMO scheme, two simplified MIMO schemes (which employ switching strategies for transmission), and also a conventional single-input multi-output (SIMO) scheme. The high-resolution angle-Doppler images formed by IAA, using the primary data only, are provided to compare the performance of the three MIMO schemes as well as the SIMO scheme. [C338]

"Classification of flowers by bats: comparison with the radar case"

In recent years, with the development of high range resolution radars, the desire to be able to identify targets under all weather and clutter conditions has become of great importance. This is an activity carried out with great success by echolocating mammals such as nectar feeding bats that are able to detect and select flowers of bat-pollinated plants even in a dense clutter environment. In this paper data consisting of acoustically generated high range resolution profiles of four bat pollinated flower heads are analysed. Multi perspective classification performance is assessed and compared with the radar case. There are close parallels that suggest lessons can be learnt from nature. [C339]

"Signal direction finding for low complexity radar"

We propose a novel beamforming algorithm for a three element system that suppresses an interference signal while still being able to measure a target's interferometer phases. Unlike most direction-of-arrival (DOA) estimation algorithms, our algorithm does not use a grid search. Instead the estimates result from a closed form solution, a great advantage in time sensitive applications. The derivation of the algorithm is presented, and its statistical performance is examined with simulations. Additionally, our numerical results demonstrate that our algorithm not only requires lower computation but also is capable of achieving more reliable DOA estimates than those found with the well known multiple signal classification (MUSIC) algorithm. [C340]

"Virtual radar antenna beamforming using orthogonal coding waveforms"

In this paper, an innovative approach to form virtual radar antenna beams is proposed. These virtual beams are shown to be equivalent to those obtained with a traditional phased array of the same size in term of antenna gain and resolution. These beams are formed through digital filtering and using orthogonal coding waveforms. It is shown that using multiple beam forming filters, multiple virtual beams can simultaneously be formed, each having maximum gain and finest resolution. [C341]

"Adaptive Noise Waveform Design for Radar"

This paper introduces an adaptive radar waveform technique where a standard LFM waveform is used as an initial seed. The seed waveform is changed using a phase-only adaptive technique to minimize the resulting waveform's power in specific areas associated with in-band and adjacent-band spectral regions. Adjacent-band power minimization reduces interference to other spectral users, while in-band power minimization improves the waveform performance in matching interference environments. The resulting waveform retains a constant modulus which is valuable for practical transmitters, yet exhibits a variable degree of phase noise. Results are shown for three levels of computational convergence in the power minimization process. Ambiguity functions are plotted for each waveform to illustrate waveform performance characteristics such as radar resolution, target ambiguities, sidelobe response, and Doppler tolerance. [C342]

"A Hybrid Mimo Phased-Array Concept for Arbitrary Spatial Beampattern Synthesis"

Multiple-input multiple-output (MIMO) radar is a multiple aperture technology characterized by the ability to transmit diverse signals at each aperture. This is in contrast to traditional phased-array radar whereby a single signal is transmitted with a phase shift applied at each element to enable steering of the transmit beam. The hybrid MIMO phased-array radar (HMPAR) concept is an outgrowth of the monostatic MIMO construct, in which all sensors have the same view of the far-field target. In the HMPAR, the full transmit array is partitioned into sub-arrays which can be electronically steered in different directions and driven by separate transmit waveforms; furthermore the configuration of the array into sub-arrays can be changed. Here we explore the variety of transmit beam patterns that could be achieved using such a system. [C343]

"WDD'09 Agenda-at-a-glance"

{no data available} [C344]

"Radar based automatic target system"

This paper describes the novel application of both dual tone CW and ISAR techniques to measure the position of a small high velocity projectile as it passes through a defined sensory virtual plane, so forming the basis of an automatic targeting system for live fire training. Simulation and initial experimental results are presented, as well as a general description of the system. [C345]

"Multistatic ambiguity function-A tool for waveform selection in distributed radar systems"

The multistatic ambiguity function has been proposed as a tool for analyzing and designing multistatic radar systems. It was demonstrated through previous examples that multistatic radar system performances (e.g. probability of detection, range and velocity resolution) can be improved by shaping the multistatic ambiguity function through waveform selection, sensor positioning and adequate weighting of different receivers. In this work we study P3, P4 and Frank polyphase codes when applied in multistatic radar systems and illustrate the significance of adequate waveform selection. [C346]

"The use of geometric diversity for spectral dominance in underground imaging"

Underground imaging of dielectric and conductive anomalies performed using ground penetrating radars (GPRs) requires expensive wideband systems to increase the resolution. The advent of tomographic principles in multi-monostatic GPRs dramatically improved the imaging capabilities and suggested the possibility of reducing the bandwidth of the probing waveform. In this work we propose to extend the tomographic principles to the case of below-ground distributed sensing, thus taking advantage of the geometric diversity. We show that, by using geometric diversity, the frequency content required to image below-ground targets is drastically reduced to virtually a single monochromatic signal, thus achieving full spectral dominance in the waveform design. [C347]

"Best bases selection for wavelet domain communication systems towards dynamic spectrum access"

The ever growing demand for wireless services has placed enormous burden on valuable resources such as spectral bandwidth. This has resulted in a major rethinking in resource allocation policies culminating in an explosion of research activity towards dynamic spectrum access (DSA) for optimum spectrum usage. wavelet domain communication system (WDCS) has been propounded as a suitable candidate for DSA. WDCS uses transform domain processing where wavelet analysis is used to gauge the environment, identify interference zones and reshape the transmission waveform profile. In this article we present a survey on the performances of various wavelet families for a packet based WDCS. The attempt is to understand the impact of waveshapes on the performance of the WDCS. Various wavelet families including Daubechies, Coiflet, Symlet, Maximally Frequency selective wavelets, Meyer and Bi-orthogonal wavelets are considered. The results of this study will be useful in deducing the best bases for WDCS system design in the context of DSA applications. [C348]

"Improved waveform design for target recognition with multiple transmissions"

This paper presents a matched waveform technique for target class identification, i.e., a multiple hypotheses testing (MHT) framework. This technique is shown to improve classification performance of SNR-based matched waveforms derived from a probability-weighted spectral variance (PWSV) approach. The technique, which allows for real-time adaptive waveform transmission, is also shown to be computationally efficient. [C349]

"Multistatic waveform design for seeing through the wall"

We present the matched illumination based waveform design for improved detection of targets behind walls and in enclosed structures using a multistatic radar system. The generalization of the matched illumination waveform design concept for through-the-wall multistatic operation bridges the problem to multiple-input multiple-output (MIMO) operation and puts in context the offering of MIMO to urban sensing and imaging of targets in enclosed structures. [C350]

"Simulation of the front-end of a MEMS based ultra narrow band tomographic imaging system"

This paper describes a simulation architecture used to simulate an ultra narrow band radar tomographic imaging (UNBRaTI) system. The work is being performed at Rochester Institute of Technology. The paper lays the

groundwork for an effort to develop a systems level approach for the simulation and analysis of an UNBRaTI system using traditional radio frequency (RF) components as well as micro-electro-mechanical systems (MEMS) based components. The utility of the approach is its ability to apply sound systems engineering principles and techniques to compare and contrast traditional RF components with MEMS based components and their effects on system level performance. The simulation has been architected for ease of scalability in order to analyze basic to complex system configurations. [C351]

"Constant envelope OFDM for power-efficient radar and data communications"

This paper offers a tutorial treatment of constant envelope OFDM, covering power efficiency and spectral efficiency tradeoffs and discusses recent advancements in applying CE-OFDM to radar. A dual-use architecture is proposed offering both radar and communications capabilities on a common platform. [C352]

"A minuscule distances' measurement using K-band Doppler technology"

This paper discusses a new approach to measure very short distances between objects using two frequency Continuous waveforms and based on a K-band Doppler technology. The system's operation is performed using two-frequency radar to obtain expeditiously and highly accurate measurements for stationary and moving objects. Experiments have been conducted and a mathematical presentation of the system's model has been formulated along with computer-based simulations to study the performance and to validate the effectiveness of the proposed system's model. The obtained results demonstrate the capability of the system to adapt a short distance range. [C353]

"Novel Waveform Generation Principle for short-range FMCW-Radars"

The FMCW-radar-principle is widely used for short range radar systems. The basic idea for FMCW-radars is to generate a linear frequency ramp as transmit signal. There are too widely used principles for range-Doppler-processing: generation of ramps with different slopes and generation of a sequence of short ramps processed by a two-dimensional FFT. The developed ramp generation sequence also applies two-dimensional Fourier transforms, but allows to reduce the baseband bandwidth. The principle can be also regarded as an extension of a frequency stepped-CW-radar with intertwined ramps. In the following the method is derived for systems with and without I/Q-demodulator and first measurement results on a 24 GHz-system are presented. The waveform generator has been implemented on a FPGA. [C354]

"Adaptive OFDM radar for detecting a moving target in urban scenarios"

We address the problem of detecting a moving target in an urban canyon using an orthogonal frequency division multiplexing (OFDM) radar and exploiting the multipath reflections. The multipath propagation increases the spatial diversity of the radar system and provides different Doppler shifts over different path. In addition, the use of broadband OFDM signal provides frequency diversity to the system. We develop a parametric measurement model that accounts for the multipath components at multiple frequencies as well as Doppler shifts. Then, we develop a statistical detection test and evaluate its performance characteristics. Based on this, we propose an algorithm to optimally design the spectral weights for the next transmitting waveform. We present a few numerical examples to illustrate our analytical results. We demonstrate the achieved performance improvement due to the exploitation of multipath propagation, OFDM signalling, and adaptive waveform design. [C355]

"Extensible simulator for waveform diversity testing"

Exotic waveforms can be formulated, and assessed, using purpose-written waveform generators and matched receivers. However, more comprehensive testing in an environment similar to operational conditions requires a large investment in coding. Furthermore, even bespoke simulators are usually written for the monostatic case, and have limited facilities to handle multiple transceivers distributed in space and time. These considerations led to the development of FERS, the flexible extensible radar simulator, which has been launched as an Open Source initiative. The simulator can handle an arbitrary number of transmit / receive nodes, targets, all distributed in time and space. Waveforms and signal processing can be added in a simple way through a well defined interface. This paper discusses the needs for such a simulator, its design, the high performance computing aspects and concludes with some examples. [C356]

"A signal level simulator for netted radar waveforms evaluation"

When evaluating the performances of radar waveforms, it is crucial to understand how the signal is affected by multiple interactions with the environment and the system hardware. Analysis of complex radar systems, such as multistatic and netted designs (see Fig. 1) is often intractable without the application of a dedicated radar

simulation system. Recent research into radar simulation has focused primarily on synthetic aperture radar (SAR) systems and is not entirely applicable to traditional radar systems concerned with the location and tracking of remote targets. A complete simulator has been designed for the accurate simulation of raw returns in complex, multistatic and netted radars and is applicable to pulsed and continuous wave (CW) systems, and both active and passive radar systems. The flexible simulator for multistatic radars (FERS) can be used to simulate radar systems with arbitrary waveforms and arbitrary numbers of receivers, transmitters and scatterers. In this paper, algorithms for the simulation of raw radar return signals are presented, based on interpolation and modification of the transmitted signal and modelling of the radar hardware and environment. The algorithms are expected to be especially valuable for the simulation of emerging radar technologies, such as Passive Coherent Location (PCL), netted radar and phased array radar. Preliminary results, presented in this paper, suggest that these algorithms can simulate physical systems with excellent accuracy. [C357]

"Range estimation algorithms comparison in simulated 3-D flash LADAR data"

Range estimation algorithms have been applied to simulated 3-D flash laser radar data to test for accuracy and bias. Simulated data is modeled after hit mode performance of the Advanced Scientific Concepts 3-D flash laser radar camera. Hit mode is a mode of operation that stores buffered samples into memory only after a set number of photoelectrons have been observed by the detector. In hit mode, waveforms may not be centered within the range gate and may not contain the true peak of original waveform. Under these conditions traditional range estimation techniques could prove ineffective. A peak estimator, matched filter, and maximum likelihood estimator were tested for performance as waveforms shift position within the range gate. This paper suggests the best scenario for implementing each algorithm and shows the overall effectiveness of the matched filter when incorporated in the time domain. 1000 trials with noise were conducted for each waveform position and performance was judged based on mean square error and standard deviation of the range estimations. [C358]

"Optimal and robust waveform design for MIMO radars"

Waveform design for Target identification and classification in MIMO radar systems has been studied in several recent works. While the previous works considered signal independent noise, here we extend the results to the case where signal-dependent noise, clutter, is also present and then we find the optimum waveform for several estimators differing in the assumptions on the given statistics. Computing the optimal waveforms for MMSE estimator leads to the Semi-definite programming (SDP) problem. Finding the optimal transmit signals for CSLS estimator results in a minimax eigenvalue problem. Finally it is shown that equal power waveforms are the best transmit signals for the SLS estimator. [C359]

"Transmit/receive beamforming for MIMO radar with colocated antennas"

We propose a new technique for multiple-input multiple-output (MIMO) radar with colocated antennas. The essence of the proposed technique is to partition the transmitting array into a number of subarrays that are allowed to overlap. Each subarray is used to coherently transmit a waveform which is orthogonal to the waveforms transmitted by other subarrays. Coherent processing gain can be achieved by designing a weight vector for each subarray to form a beam towards a certain direction in space. Moreover, the subarrays are combined jointly to form a MIMO radar resulting in higher resolution capabilities. Simulation results show the substantial improvements offered by the proposed technique as compared to previous techniques that validate its effectiveness. [C360]

"Unimodular sequence design for good autocorrelation properties"

Unimodular (i.e., constant modulus) sequences with good autocorrelation properties are useful in several areas, including communications, radar and sonar. The integrated sidelobe level (ISL) is often used to express the goodness of the autocorrelation properties of a given sequence. In this paper, we present several cyclic algorithms for the local minimization of ISL-related metrics. To illustrate the performance of the proposed algorithms, we present a number of examples including the design of sequences that have virtually zero autocorrelation sidelobes in a specified lag interval, and of long sequences that could hardly be handled by means of other algorithms previously suggested in the literature. [C361]

"Cognitive MIMO sonar based robust target detection for harbor and maritime surveillance applications"

Robust detection of various hostile threats is vital to protect Navy ships and other facilities within harbor and maritime environments. Traditional single-input single-output (SISO) sonar transmits single acoustic waveform by single projector, which has a few disadvantages including low target detection probability, low resolution, vulnerability of interception by the enemy, sensitivity to jamming, etc. Multi-input multi-output (MIMO), typically

applied to communications and radar solutions, is an emerging technology that can be applied to sonar to overcome many of the SISO sonar disadvantages. In this paper, cognitive monostatic/bistatic/multistatic MIMO sonar approaches are proposed. MIMO sonar transmits different orthogonal acoustic waveforms from multiple projectors with different spatial distributions. Through space-time-waveform diversity, MIMO sonar is able to apply coherent processing techniques over the received signals, and acquires more diversity gains. The cognition concept proposed in the literature for radar and wireless communication is applied to MIMO sonar to improve its robustness and adaptability. The advantages of proposed cognitive MIMO sonar will be demonstrated by Monte Carlo computer simulations and compared to the SISO techniques. [C362]

"Study on Sine Waveform Inverter Based on S-Domain Repetitive Control"

The key of the sine waveform inverter design is to assure the quality and stability of its output waveform, as well as the adjusting ability to different kinds of loads. The repetitive control technology is used in this paper to realize the periodic signal tracking control of the sine waveform inverter, and a new method of stability analysis and design of repetitive controlled sine waveform inverter is also proposed. Analog repetitive controller is realized by using analog delay chip MN3304, and repetitive control for the single phase sine waveform controller is researched. The experiment results show that this method is valid. [C363]

"Joint MIMO radar waveform and receiving filter optimization"

The concept of MIMO (multiple-input multiple-output) radar allows each transmitting antenna element to transmit an arbitrary waveform. This provides extra degrees of freedom compared to the traditional transmit beamforming approach. It has been shown in the recent literature that MIMO radar systems have many advantages. In this paper, we consider the joint optimization of waveforms and receiving filters in the MIMO radar when the prior information of target and clutter are available. A novel iterative algorithm is proposed to optimize the waveforms and receiving filters such that the detection performance can be maximized. The proposed algorithm guarantees that the SINR performance improves in each iteration step. The numerical results show that the proposed methods have better SINR performances than existing design methods. [C364]

"Stepped-Frequency Waveform radar demonstrator and its jamming"

In this paper we present some applications of the stepped-frequency signal waveform designed for the obtention of HRRP (High Resolution Range Profiles) and ISAR (Inverse Synthetic Aperture Radar) images for their ulterior use in NCTI (non-cooperative target identification). For this purpose, we have developed a stepped-frequency radar demonstrator, capable of generating very stable in phase coherent pulses. A careful study thereof is presented, providing examples of actual targets as measured by the radar and discussing the main advantages and disadvantages of this waveform. On the other hand, jamming could severely affect the reliability of measurements at wartime. Consequently, we have also evaluated the impact of deception jamming on this waveform by creating a prototype jammer which can simulate both static and dynamic targets. [C365]

"Constant-modulus partially correlated signal design for uniform linear and rectangular MIMO radar arrays"

A method for generating partially correlated signals that result in arbitrary rectangular transmit beampatterns in a MIMO radar system is described. These signals are computed using frequency-offset complex exponentials (1-D) or Kronecker products of frequency-offset complex exponentials (2-D), followed by pointwise multiplication of the transmit signal vectors by a scalar pseudo-noise spreading sequence. Except for the spreading sequence, which can be pre-computed, the signals are given in closed form and thus require no numerical optimization. The transmit beampattern shape is controlled by one scalar parameter in 1-D and two scalar parameters in 2-D. The transmit beampattern is the convolution of a rectangle with a sincsquared function in 1-D, and the separable product of such functions in 2-D. The signals are constant-modulus, have desirable temporal autocorrelation properties, and are simple to compute. [C366]

"MIMO Radar with Frequency Diversity"

We propose a new multiple-input, multiple-output (MIMO) radar system with colocated antennas that can greatly reduce target fluctuations. This is achieved by employing frequency diversity. The proposed MIMO radar system results in a radar array with frequency-division multiplexing that can also incorporate beamforming to design the transmission beam pattern. After presenting an overview of existing MIMO radar systems and their related signal models, we provide a detailed description of the proposed frequency diversity technique and the corresponding transmitter and receiver structures. Furthermore, we present a maximum likelihood estimation algorithm that incorporates frequency diversity with MIMO radar, derive the corresponding Cramer-Rao lower bound, and

demonstrate its improved performance using numerical results. [C367]

"Waveform-agile sensing for range and DoA estimation in MIMO radars"

We propose an agile sensing algorithm to optimally select the transmission waveform of a multiple-input, multiple-output (MIMO) radar system in order to improve target localization. Specifically, we first derive the Cramer-Rao lower bound (CRLB) for the joint estimation of the antenna reflection coefficients and the range and direction-of-arrival of a stationary target using MIMO radar with colocated antennas. The resulting CRLB, that is a function of the transmitted waveform, is then compared to the estimation performance of a maximum-likelihood estimator. We configure waveform parameters to minimize the trace of the predicted error covariance by assuming that the covariance of the observation noise is approximated by the CRLB for high signal-to-noise ratios. In particular, we optimally select the duration and phase function parameters of generalized frequency-modulated chirps to minimize the estimation mean-squared error under constraints of fixed transmission energy and constant time-bandwidth product. [C368]

"Autocorrelation and modulus constraints in radar waveform optimization"

Two methods of constraining the waveform auto-correlation sequence (ACS) in a radar waveform optimization problem are compared. The first method directly constrains the envelope of the waveform ACS, whereas the second method indirectly constrains the waveform ACS through the imposition of a similarity constraint. Both methods are imposed in conjunction with constraints on the waveform modulus. The resulting nonlinear programming problems were formulated for a specific example, and solved using standard numerical algorithms. The results indicate that the similarity constraint may not be a useful means of constraining the waveform ACS when the waveform modulus is simultaneously constrained. The results also demonstrate that phase-only optimization can provide a significant decrease in computation time while providing near optimal results. [C369]

"The Frequency Diverse Bistatic System"

In this paper we analyze the frequency diverse array (FDA), modifying some of its characteristics. Through a reconsideration of the organization of the array, which we termed ldquowavelength arrayrdquo (WA), a new pattern, dasiaorthogonalpsila to the standard phased array, can be achieved. The bistatic combination of a WA and a receiver originates the dasiafrequency diverse bistatic systempsila (FDBS), which can be a significant application of this concept. [C370]

"Optimization and waveforms for compressive sensing applications in the presence of interference"

Compressive sensing concepts have potential applications to multiple RADAR problems, which include moving target indication, and RADAR imaging in two and three spatial dimensions. Currently known sufficient conditions for reliable sparse signal reconstruction do not seem to be directly applicable or practical for some traditional RADAR problems. But experiments and mathematical invariance properties of some reconstruction methods indicate that useful products can often be obtained using these methods for circumstances outside the usual conditions. [C371]

"Practical considerations for intra-pulse radar-embedded communications"

This paper examines some of the practical aspects of waveform design for intra-pulse radar-embedded communications. Specifically, the generation of communication waveforms at the tag is considered for the case when forward scatter (i.e. multipath) is present thus altering the received version of the radar waveform at the tag and potentially producing a mismatch between the tag and desired receiver. Also, because it may be difficult to precisely determine the exact temporal length of the incident radar waveform (especially when multipath is present), the communication waveform design process may employ a larger than necessary temporal extent to ensure the incident waveform is completely captured. The impact of this temporal expansion of the communication waveforms is considered where it has been found to actually improve performance (in the absence of multipath). As such a rule-of-thumb for the total expanded time-bandwidth product is determined as a function of observed symbol error rate performance. [C372]

"Range sidelobe suppression in a desired Doppler interval"

We present a novel method of constructing a Doppler resilient pulse train of Golay complementary waveforms, for which the range sidelobes of the pulse train ambiguity function vanish inside a desired Doppler interval. This is accomplished by coordinating the transmission of a Golay pair of phase coded waveforms in time according to the 1's and -1's in a biphase sequence. The magnitude of the range sidelobes of the pulse train ambiguity function is shown to be proportional to the magnitude spectrum of the biphase sequence. Range sidelobes inside

a desired Doppler interval are suppressed by selecting a sequence whose spectrum has a high-order null at a Doppler frequency inside the desired interval. We show that the spectrum of the biphase sequence obtained by oversampling the length-2MProuhet-Thue-Morse (PTM) sequence by a factor m has an Mthorder null at all rational Doppler shifts thetas0=2pil/m, where lne0 and mne1 are co-prime integers. This spectrum also has an (M-1)th-order null at zero Doppler and (M-h-1)thorder nulls at all Doppler shifts thetas0=2pil/(2hm), where lne0 and mne1 are again co-prime and 1leshlesM-1. [C373]

"Adaptive waveform design in rapidly-varying radar scenes"

We consider a waveform-agile sensing algorithm for designing transmitted waveforms in rapidly-varying radar scenes to improve target detection performance. Specifically, we first track the scattering function of rapidly-varying sea clutter in low signal-to-clutter ratios (SCRs) at each burst by estimating the clutter's space-time covariance matrix. Simultaneously, we schedule the waveform to be transmitted in the next burst by minimizing the sea clutter influence based on the estimated clutter statistics. The effectiveness of our waveform-agile sensing approach is demonstrated by detecting a moving target in heavy sea clutter using configured waveforms, and then comparing the resulting performance to that of detecting the target using fixed-parameter linear frequency-modulated w.aveforms. [C374]

"Mitigation of radar range ambiguities via waveform diversity"

The USAF is considering a number of radar systems as a method to achieve persistent intelligence, surveillance and reconnaissance (ISR) over the Earth's surface. A comprehensive approach must be taken that identifies feasible radar system parameters, geometry, area coverage and processing approaches that will provide needed moving target indication MTI (both ground and air) performance. From the signal processing perspective, there are a number of unique technical challenges facing this concept. Issues which will need to be addressed include the restriction of antenna aperture and the need to locate and detect targets at shallow grazing angles These and other phenomenology will impact the ability of algorithms implemented by the system to perform image formation, target detection and parameter estimation. This paper presents a new approach to the problem of radar range ambiguities in synthetic aperture radar (SAR) imagery and surface moving target indication (SMTI). By using a combination a priori knowledge of the collection geometry, orthogonal waveforms and an alternative approach to traditional matched filter processing, it can be shown that the effects of the ambiguities can be mitigated and provide image quality and SMTI performance with little degradation as compared to the non-ambiguous case. [C375]

"Passive Coherent Location as Cognitive Radar"

Cognitive radar describes a generic radar system that is capable of adapting its transmission waveforms and cooperation with other sensors in order to achieve superior detection, recognition and tracking of targets. For example, the sensors of a cognitive radar system might use the illumination signals to carry broadcast data, allowing the sharing of target information. In this paper we postulate that it would be possible to implement a cognitive version of passive coherent location (PCL) which has much in common with the broad cognitive radar concept, but adapts only to the waveforms it senses in the environment, and exploits those that are most useful to it for target detection. In addition, it would model the terrain to improve coverage and provide countermeasures against direct signal saturation. By its name, PCL does not transmit, but relies on emissions from other radiating systems, such as broadcast services, other radars, cellular radio, WiFi, and so on. It is clear that such a system, consisting of multiple, cooperating receivers, can achieve excellent performance in the presence of deliberate jamming, difficult terrain and attempts at target stealth. In the civilian radar domain, the technology offers opportunities for bandwidth conservation. [C376]

"Orthogonal multicarrier phased coded signal for netted radar systems"

Orthogonal multicarrier radar waveforms have been designed for netted radar systems, where several radar stations are active simultaneously. The waveforms are phase-coded using orthogonal Golay complementary sets, derived from Reed Muller codes. These codes constrain the PMEPR of the signal to a maximum a 3 dB. Besides, ambiguity functions and cross-ambiguity functions with low sidelobes have been obtained. The possibility to encode data relative to the transmitter configuration (position, direction of the beam,...) in the radar waveform is also demonstrated. [C377]

"FullAnalyze: A Research tool for handling, processing and analyzing full-waveform lidar data"

Full-waveform (FW) lidar systems provide range profiles of the Earth topography. They are acquired from airborne platforms or from satellites. Many applications derive from the use of such data, from the extraction of 3D point clouds to the inversion of vegetation profiles. Nevertheless, handling range profiles is much more

difficult than handling 3D point cloud. The aim of this paper is to present a research tool based on opensource libraries that can process and visualize such data. We focused our work on the implementation on the 2D/3D interface that gives the possibility to visualize the interaction between the lidar electromagnetic waves and the Earth topography. Moreover, this tool integrates several processing steps of FW Lidar data. [C378]

"SAR altimeter retracker performance bound over water surfaces"

This paper provides the theoretical limit for the performance of a Maximum Likelihood Estimation (MLE) DDA re-tracker for different Significant Wave Height (SWH) conditions based on Cramer-Rao Lower Bound (CRLB) analysis. [C379]

"Forest biomass retrieval from lidar and radar"

The use of lidar and radar instruments to measure forest structure attributes such as height and biomass are being considered for future Earth Observation satellite missions. Combined use of lidar sampling data and complete global coverage of L-band SAR data for vegetation 3D structure mapping requires some new data processing and fusion technologies. In this study, the potential information on biomass from a lidar waveform and the required lidar samples for reliable biomass estimation were investigated using both model and real data. First, the Laser Vegetation Imaging Sensor (LVIS) data was used to generate an above-ground biomass map of the study site. The map was considered to represent the true biomass of the area. Then random samples were taken from the biomass image and the correlation between biomass and co-located SAR signature was studied. The proper model was used to extend the biomass from lidar samples into all forested areas in the study area. The new biomass map was compared with the original biomass map derived from LVIS data. The results showed the potential of the combined use of lidar samples and radar imagery for forest biomass mapping. [C380]

"Compressed sensing for Synthetic Aperture Radar imaging"

In this paper, we introduce a new Synthetic Aperture Radar (SAR) imaging modality that provides a high resolution map of the spatial distribution of targets and terrain based on a significant reduction in the number of transmitted and/or received electromagnetic waveforms. This new imaging scheme, which requires no new hardware components, allows the aperture to be compressed and presents many important applications and advantages among which include resolving ambiguities, strong resistance to countermeasures and interception, and reduced on-board storage constraints. [C381]

"Co-located MIMO radar with orthogonal waveform coding: Cramйr-Rao Lower Bound"

In this paper, we derive and analyze closed form (nonmatrix) expression of the Cramer-Rao lower bound (CRB) for the location and the velocity of moving targets contaminated by a structured noise (clutter echoes) and a background noise. The context of our analysis is the co-located MIMO (multiple-input multiple-output) radar system, ie., we dispose of multiple antennas in transmission and reception which are close in space. In addition as it is standard in modern MIMO radar, several noncoherent orthogonal waveforms are transmitted. The analysis of the proposed expressions of the CRB allows to better understand the characterisation of the target. In particular, we prove (1) the estimation of the direction parameter and the velocity of the target are cross-linked ; (2) it is more difficult to estimate the target velocity if the radar station is moving ; (3) if the radar station is not moving, the estimation of the target velocity is isotropic ; (4) it is more difficult to accurately localize fixed or slow moving targets and finally, the CRB for a MIMO radar is a lower bound of the one for the SIMO (single-input multiple-output) radar. [C382]

"Lidar waveform modeling using a marked point process"

Lidar waveforms are 1D signal consisting of a train of echoes where each of them correspond to a scattering target of the Earth surface. Modeling these echoes with the appropriate parametric function is necessary to retrieve physical information about these objects and characterize their properties. This paper presents a marked point process based model to reconstruct a lidar signal in terms of a set of parametric functions. The model takes into account both a data term which measures the coherence between the models and the waveforms, and a regularizing term which introduces physical knowledge on the reconstructed signal. We search for the best configuration of functions by performing a Reversible Jump Markov Chain Monte Carlo sampler coupled with a simulated annealing. Results are finally presented on different kinds of signals in urban areas. [C383]

"Contribution of airborne full-waveform lidar and image data for urban scene classification"

Airborne lidar systems have become an alternative source for the acquisition of altimeter data. In addition to

multi-echo laser scanner systems, full-waveform systems are able to record the whole backscattered signal for each emitted laser pulse. These data provide more information about the structure and the physical properties of the surface. This paper is focused on the classification of full-waveform lidar and airborne image data on urban scenes. Random forests are used since they provide an accurate classification and run efficiently on large datasets. Moreover, they provide measures of variable importance for each class. This is crucial to analyze the relevance of each feature for the classification of urban scenes. Random Forests provide more accurate results than Support Vector Machines with an overall accuracy of 95.75%. The most relevant features show the contribution of lidar waveforms for classifying dense urban scenes and improve the classification accuracy for all classes. [C384]

"Forest parameter mapping based on lidar and SAR data"

Vegetation spatial structure including plant height, biomass, vertical and horizontal heterogeneity, is an important factor influencing the exchanges of matter and energy between the landscape and atmosphere, and the biodiversity of ecosystems. Estimation of boreal forest canopy height is an extremely urgent research because it is essential for understanding ecosystems changing by human activities and climate change. Data from lidar and radar contain information relevant to different aspects of the biophysical properties of the vegetation canopy. GLAS (Geoscience Laser Altimeter System) and ALOS PALSAR data were used to test the combined use of lidar samplings and radar images for canopy height and stand biomass mapping in our test area. The result showed that maximum tree height and biomass in gLAS footprints can be predicted by GLAS waveform data. By using these sampling data parameters retrieval models using SAR data only can be developed. These models were applied to the entire SAR image, and the results were assessed using large-scale forest inventory data. [C385]

"An MSK Waveform for Radar Applications"

We introduce a minimum shift keying (MSK) waveform developed for use in radar applications. This waveform is characterized in terms of its spectrum, autocorrelation, and ambiguity function, and is compared with the conventionally used bi-phase coded (BPC) radar signal. It is shown that the MSK waveform has several advantages when compared with the BPC waveform, and is a better candidate for deep-space radar imaging systems such as NASA's Goldstone Solar System Radar. [C386]

"Hybrid diversity strategy using MIMO radar for target tracking"

For the development of radar systems with enhanced performance in target detecting and tracking abilities, various research groups have been investigating multiple input multiple output (MIMO) based radar systems. They have shown that MIMO radars perform better compared to conventional systems like bistatic or even SIMO radars. Especially MIMO capitalizes several diversity parameters inherent to its design to give higher resolution in both range and range rate. Several papers address these diversities. The current work aims at parameterizing these diversities especially spatial, waveform and frequency diversities and hence designing a system which employees a the resultant diversity constraints on the transmitter architecture and on the type and properties of transmit signals. As done in conventional system analysis, here also the formulation of ambiguity function is addressed and in the process a new tool called ambiguity function pair is developed. It has been shown with example evaluations that this ambiguity function pair is more mature in analyzing and tracking targets with systems employing diversity constraints. In the process of evaluation a new strategy with adaptive framework for tracking targets and getting higher range resolution and is addressed. [C387]

"Nonuniform pulse intervals and nonuniform frequency steps for managing radar ambiguity properties"

The theory of nonuniform or irregular sampling has many new application areas. With pulsed radar, a classic example of nonuniform sampling is staggered PRF which provides aid for MTI or Doppler processing. For example with a conventional surveillance radar, PRF is often too low for decent Doppler analysis due to operational requirement of unambiguous range. This paper discusses a nonuniform sampling scheme that guarantees a desired unambiguous measurement. The approach is applied to two experiments. First, staggering a sequence of PRIs provides desired unambiguous Doppler. Second, range ambiguity is solved correspondingly with a stepped frequency waveform. Of course, one can achieve these by utilizing conventional uniform sampling but with considerably higher number of samples. Results with real pulsed radar recordings prove the applicability of the sampling scheme. [C388]

"Connecting the dots between laser waveforms and herbaceous biomass for assessment of land degradation using small-footprint waveform LiDAR data"

Measurement and management of vegetation biomass accumulation in ecosystems typically involves extensive field data collection, which can be expensive and time consuming, while leaving the user with relatively crude inputs to intricate biomass models. Light detection and ranging (LiDAR) remote sensing, which provides extensive height measurements of terrain and vegetation, has become an effective alternative to characterize vegetation structure. In this paper, we report on ongoing efforts at developing signal processing approaches to model herbaceous biomass using a new generation of airborne laser scanners, namely full-waveform LiDAR systems. Structural and statistic-based feature metrics are directly derived from LiDAR waveforms at the pixel level and related to plot-level field data. Initial results reveal a definite correlation between the LiDAR waveform and herbaceous biomass. Ongoing research focuses on the links between fractional cover estimated from imaging spectroscopy and woody biomass. [C389]

"Waveform considerations for dual-polarization Doppler weather radar with solid-state transmitters"

Adequate sensitivity of weather radars using low-powered solid-state transmitter is achieved by using pulse compression waveforms. However, pulse compression waveforms have drawbacks of blind zone and range side lobes. In this paper, we present a methodology to address the major challenges in designing the waveforms for an X-band dual polarization Doppler radar operating with a solid-state transmitter. Here, frequency diversity wideband waveforms are proposed to mitigate low sensitivity of solid-state transmitters and the range eclipsing problem associated with pulse compression. An analysis of the performance of pulse compression using mismatched compression filters is reported. The performance of the proposed system is also quantified using signal and system simulations. [C390]

"Advanced paris altimeter based on delay compensation of Doppler Waveforms"

Measuring ocean mesoscale variability is one of the main objectives of next generation satellite altimeters. Among the alternative solutions proposed to overcome the limitations of conventional altimeters, the PARIS concept has been proposed, which exploits GNSS signals reflected from the ocean surface and allows performing altimetry along several points simultaneously over a wide swath with sub-decimeter accuracy in spatial scales of 50-100 Km. The present paper proposes to adopt for a PARIS altimeter a multilook unfocused Doppler processing in order to improve height precision and accuracy. The proposed processing concept is a simplified extension to PARIS of the delay/Doppler processing adopted in conventional radar altimetry. The analyses reported in the paper show that, for open access GPS L5 navigation signal, an improvement of height precision up to 30% could be achieved without modifications to the RF front-end. [C391]

"Comparing wind speed retrievals from GPS reflectometry with SFMR surface wind speeds in Huricane Ike (2008)"

Recently, a compact system, able to record raw GPS intermediate frequency (IF) samples has been designed and tested by the research group at the CU/Aerospace Engineering Sciences Department. Such an approach provides the most fundamental measurement, enabling the most advanced and complete post-processing, with data volumes on the order of 1GB/minute. In 2008 this system was flying on board the NOAA WP-3D aircraft which collected research-mission data on Hurricane Ike. During two flights there was collected about 800 GB of raw data for flight lags that transverse the hurricane eye and away from it. After the flights the correlation waveforms for both direct and reflected signals were retrieved from the raw data for all available satellites and sea surface roughness estimates were produced. Those retrievals were compared with the Step Frequency Microwave Radiometer (SFMR) measurements of the surface wind speed. As expected, the data show a high sensitivity of the GPS bistatic radar signals to ocean surface roughness. However, the system of swells generated by various parts of the hurricane complicates the picture and makes the problem of wind retrieval non-trivial. [C392]

"An analysis of phase synchronization mismatch sensitivity for coherent MIMO radar systems"

In this study, the hybrid Cramer-Rao bound (CRB) is developed for target localization, to establish the sensitivity of the estimation mean-square error (MSE) to the level of phase synchronization mismatch in coherent multiple-input multiple-output (MIMO) radar systems with widely distributed antennas. The lower bound on the MSE is derived for the joint estimation of the vector of unknown parameters, consisting of the target location and the mismatch of the allegedly known system parameters, i.e., phase offsets at the radars. Synchronization errors are modeled as being random and Gaussian. A closed-form expression for the hybrid CRB is derived for the case of orthogonal waveforms. The bound on the target localization MSE is expressed as the sum of two terms, the first represents the CRB with no phase mismatch, and the second captures the mismatch effect. The latter is shown to depend on the phase error variance, the number of mismatched transmitting and receiving sensors and the system geometry. For a given phase synchronization error variance, this expression offers the means to analyze

the achievable localization accuracy. Alternatively, for a predetermined localization MSE target value, the derived expression may be used to determine the necessary phase synchronization level in the distributed system. [C393]

"Collision avoidance radar system using UWB waveforms signature for road applications"

The concept of the intelligent car consists in equipping the vehicle with an optimum number of sensors such as radar, in order to perceive the environment which surrounds it, to ensure an automatic guidance control of the vehicle and to communicate with the external medium. In this paper, we propose to exploit the UWB technology for road radar applications, in order to profit from its inherent advantages (good range resolution, low power consumption, low price etc.). All exiting studies on UWB radar concerns essentially medical and military applications. The originality of this radar is its capacity to detect easily various obstacles and to give their signatures. This paper describes the used radar and presents an interesting study of the adapted UWB waveforms which allow location and signatures of different kind of obstacles detected in short ranges with a good resolution. [C394]

"Target tracking in the time-frequency domain for a driving aid application"

Driving aid is an important emerging radar application. Among associated technological issues, detecting and tracking potential obstacles (cars, pedestrians, static objects ...) is of key interest. In this context, we propose an original tracking method, based on particle filtering, where the observation of the state vector is the cross-ambiguity function of the backscattered signal. Simulations for various waveforms demonstrate the improvement brought compared to the conventional approach, in which a detection step precedes the tracking. [C395]

"Strategies for FMCW radars"

In this paper, we present a comparison of two strategies for FMCW radars. The potential presence of multiple targets implies using specific waveforms for beat frequencies association. Here, we compare performance of two such waveforms in terms of targets distance and velocity estimation. Our comparison, based on theoretical bounds derivation is validated by Monte Carlo simulations. In particular we show that Barankin variance bounds yields conclusions that are in good agreement with results of simulation experiments. [C396]

"A fast Maximum Likelihood method for improving AMCW lidar precision using waveform shape"

Amplitude Modulated Continuous Wave imaging lidar systems use the time-of-flight principle to determine the range to objects in a scene. Typical systems use modulated illumination of a scene and a modulated sensor or image intensifier. By changing the relative phase of the two modulation signals it is possible to measure the phase shift induced in the illumination signal, thus the range to the scene. In practical systems, the resultant correlation waveform contains harmonics that typically result in a non-linear range response. Nevertheless, these harmonics can be used to improve range precision. We model a waveform continuously variable in phase and intensity as a linear interpolation. By approximating the problem as a Maximum Likelihood problem, an analytic solution for the problem is derived that enables an entire range image to be processed in a few seconds. A substantial improvement in overall RMS error and precision over the standard Fourier phase analysis approach results. [C397]

"Mono-static MIMO radar array design for interferences suppressing"

The multiple-input multiple-output (MIMO) radar has drawn considerable interest recently. Many notable research results have been obtained, such as virtual receive array (VRA) concept for orthogonal waveform transmitting MIMO radar. The mono-static MIMO radar proposed in this paper shares the same transmit and receive antenna array, so it is very similar to conventional transmit/receive (T/R) digital beamforming (DBF) radar. The VRA concept can be easily extended to T/R DBF radar system by re-designing the antenna array structure. In this paper, an optimal antenna array design for mono-static MIMO radar is proposed in order to improve the interferences rejection capabilities. The minimum redundancy array (MRA) concept is also used to maximize the antenna virtual aperture for an array of given numbers of elements. Simulation results show that compared with the T/R DBF radar, the proposed monostatic MIMO radar can effectively improve the interferences rejection capabilities, especially the mainlobe interferences rejection capabilities. Moreover, mono-static MIMO radar with MR VRA has better interferences rejection performance than mono-static MIMO radar with uniform VRA. [C398]

"X-band PN radar experimental platform with high accuracy"

A high accuracy experimental platform for X-band PN radar performance evaluation has been created in our research lab. This PN radar platform could be used for the applications such as unmanned-aerial-vehicle anti-

collision, and short-range distance measurement etc. It includes compact size X-band radar transceiver, baseband signal processing in FPGA, high speed analog to digital converter (ADC), arbitrary waveform generator (AWG), and Matlab Simulink tools. Our measurement result shows this PN radar has high accuracy within detection range. The detected range error is 0.082 m. The radar carrier frequency is 9.5 GHz. [C399]

"Target detection in MIMO radar using Golay complementary sequences in the presence of Doppler"

In this paper, we present a method for detecting a point target using multiple antennas when the relative motion between the receivers and the target induces a non-negligible Doppler shift. As a key illustrative example, we consider a 4 ГґВ— 4 system employing a unitary matrix waveform set, e.g., formed from Golay complementary sequences. When a non-negligible Doppler shift is induced by the target motion, the waveform matrix formed from the complementary sequences is no longer unitary, resulting in significantly degraded target range estimates. To solve this problem, we adopt a subspace based approach exploiting the observation that the receive matrix formed from matched filtering of the reflected waveforms has a (non-trivial) null-space. Through processing of the waveforms with the appropriate vector from the null-space, we can significantly improve the detection performance. We provide simulation results to confirm the theoretical analysis. [C400]

"Integrated full-waveform analysis of ground penetrating radar and electromagnetic induction data for non-invasive reconstruction of multilayered media"

We present a new integrated method for full-waveform modeling of zero-offset, off-ground ground penetrating radar (GPR) and electromagnetic induction (EMI) in multilayered media. For both GPR and EMI systems, a vector network analyser (VNA) is used as transmitter and receiver. The antennas and their interactions with the investigated medium are modeled in the frequency domain by means of a linear system of complex transfer functions. The air-subsurface is represented by a 3-D multilayered medium, for which Maxwell's equations are exactly solved. These approaches have been validated in laboratory conditions, demonstrating the high accuracy of the GPR and EMI models. The results show great promise for non-invasive reconstruction of multilayered media using GPR and EMI. [C401]

"Alternating projection for MIMO radar waveform design"

Recently there has been a surge of interest in waveform design for multiple-input multiple-output (MIMO) radar, and a great deal of efforts have been devoted to this topic. In this paper, we revisit an earlier examined MIMO radar waveform design problem which optimizes both minimum mean-square error estimation (MMSE) and mutual information (MI). We formulate a new waveform design problem and provide some further results, which complement the previous study. More specifically, we present an iterative optimization algorithm based on the alternating projection method, to determine waveform solutions that can simultaneously satisfy a structure constraint and optimize the design criteria. Numerical examples are provided, which illustrate the effectiveness of the proposed approach. In particular, we find that the waveform solutions obtained through our proposed algorithm can achieve very close and virtually indistinguishable performance from that predicted in the previous study. [C402]

"OFDM MIMO radar design for low-angle tracking using mutual information"

We develop an information theoretic waveform design algorithm for target tracking in the presence of multipath. We employ a co-located multiple-input-multiple-output (MIMO) radar configuration using wideband orthogonal frequency division multiplexing (OFDM) signalling scheme. Apart from the frequency diversity provided by OFDM, we also exploit polarization to resolve the multipath signals by using polarization-sensitive transceivers. Thus, we can track the scattering coefficients of the target at different frequencies along with its position and velocity. We apply a sequential Monte Carlo method (particle filter) to track the target, while integrating an optimal waveform design technique based on mutual information criterion. Our numerical examples demonstrate the achieved performance improvement due to the adaptive waveform design. [C403]

"MIMO radar waveform design: a divergence-based approach for sequential and fixed-sample size tests"

A multi-frame, multiple-input, multiple-output radar detection problem is considered here. Different waveform design strategies are inspected for both fixed-sample size and sequential test. The unified treatment of the two cases is a direct consequence of the divergence-based merit function used in the optimization process. It is proved that no strategy is uniformly optimal, and that the diversity order is limited by the available energy budget. [C404]

"Golay complementary waveforms for sparse delay-Doppler radar imaging"

We present a new approach to radar imaging that exploits sparsity in the matched filter domain to enable high resolution imaging of targets in delay and Doppler. We show that the vector of radar cross-ambiguity values at any fixed test delay cell has a sparse representation in a Vandermonde frame that is obtained by discretizing the Doppler axis. The expansion coefficients are given by the auto-correlation functions of the transmitted waveforms. We show that the orthogonal matching pursuit (OMP) algorithm can then be easily used to identify the locations of the radar targets in delay and Doppler. Unambiguous imaging in delay is enabled by alternating between a Golay pair of phase coded waveforms at the transmission to eliminate delay sidelobe effects. We then extend our work to multi-channel radar, by developing a sparse recovery approach for dually-polarimetric radar. We exploit sparsity in a bank of matched filters, each of which is matched to an entry of an Alamouti matrix of Golay waveforms to recover a co-polar or cross-polar polarization scattering component. [C405]

"Design and implementation of HPRF stepped frequency radar echo simulator"

A HPRF stepped frequency radar echo simulator for performance evaluation and test of radar system is introduced in this paper. The echo model of HPRF stepped frequency radar is analyzed, and its expression, considering range ambiguity and relation between intermediate frequency bandwidth and range window, is given. This paper proposed an implement scheme of HPRF stepped frequency radar echo simulator based on DAC chip AD9736. The simulator can generate kinds of radar baseband and intermediate frequency waveforms realtime, including clutters and noise if needed. It also supports data replay and provides common digital interface such as Ethernet, RS422 etc. So the simulator has the feature of universal usage. Finally, testing result demonstrates the effectiveness of the simulator. [C406]

"Multi-static synthetic aperture radar image formation"

In this paper, we consider a multi-static synthetic aperture radar (SAR) imaging scenario where a swarm of airborne antennas, some of which are transmitting, receiving or both, are traversing arbitrary flight trajectories and transmitting arbitrary waveforms without any form of multiplexing. The received signal at each receiving antenna may be interfered by the scattered signals from multiple transmitters and the additive thermal noise at the receiver. Standard bi-static SAR image reconstruction algorithms result in artifacts in reconstructed images due to these interferences. In this paper, we employ microlocal analysis in a statistical setting to develop a novel filtered-backprojection (FBP) type analytic image formation method that suppresses artifacts due to interference from multiple transmitters while preserving the location and orientation of edges of the scene in the reconstructed image. [C407]

"Direction finding for MIMO radar with colocated antennas using transmit beamspace preprocessing"

The problem of direction finding for multiple targets in mono-static multiple-input multiple-output (MIMO) radar systems is considered. Assuming that the targets are located within a certain spatial sector, we focus the energy of multiple (two or more) transmitted orthogonal waveforms within that spatial sector using appropriately designed transmit beamforming. The transmit beamformers are designed so that match-filtering the received data to the waveforms yields multiple (two or more) data sets with rotational invariance property that allows applying search-free direction finding techniques such as ESPRIT. Unlike previously reported MIMO radar ESPRIT-based direction finding techniques, our method is applicable to arbitrary arrays and achieves better estimation performance at lower computational cost. [C408]

"Modular system design for a new S-band marine radar"

This paper describes a new approach to marine radar design. New IMO regulations allow marine radars to be designed with solid state transmitter power amplifiers using pulse compression waveforms and coherent Doppler processing. This gives a new flexibility and better possibilities to control the transmitter spectrum. The modular system design applies to waveform generation, signal processing and RF hardware. [C409]

"Waveform design for MIMO radar using an alternating projection approach"

Revisiting an earlier examined multiple-input multiple-output (MIMO) radar waveform design problem which optimizes both minimum mean-square error estimation (MMSE) and mutual information (MI), we formulate a new waveform design problem and provide some further results in this paper, which complements the previous study. More specifically, we present an iterative optimization algorithm based on the alternating projection method, to determine waveform solutions that can simultaneously satisfy a structure constraint and optimize the design

criteria. Numerical examples are provided, which illustrate the effectiveness of the proposed approach. In particular, we find that the waveform solutions obtained through our proposed algorithm can achieve very close and virtually indistinguishable performance from that predicted in the previous study. [C410]

"Exploiting correlation in target detection using MIMO radar with angular diversity"

Multiple-input multiple-output (MIMO) radars utilize multiple waveforms simultaneously to improve performance. A MIMO radar in which angular diversity is achieved by using widely distributed antennas has been proposed before. This type of system is also known as the statistical MIMO radar. Typically, it has been assumed that the signals received by different antennas are either fully correlated or independent depending on the configuration. We make a more realistic assumption of partially correlated scattering from the target. In this paper, we show that taking the correlation of the scattered signals into account can improve the probability of detecting the target. It is shown that the scattering statistics do not need to be known, but can be estimated reliably from the received signal if a certain type of scattering model is assumed. In this paper, the GLRT using the maximum likelihood estimates of the unknown parameters is proposed for target detection. [C411]

"Finite-sample optimal joint target detection and parameter estimation by MIMO radars"

We consider MIMO radar systems with widely-spaced antennas. We treat the problem of detecting extended targets when one or more target parameters of interest are unknown. We provide a composite hypothesis testing framework for jointly detecting the target along with such parameter estimation while only a finite number of signal samples are available. The test offered is optimal in a Neyman-Pearson-like sense such that it offers a Bayesian-optimal detection test, minimizes the average maximum likelihood parameter estimation error subject to an upper bound constraint on the false-alarm probability, and requires a finite number of samples. While the test can be applied for concurrently detecting the target along with estimating any unknown parameter of interest, we consider the problem of detecting a target which lies in an unknown space range and find the range through estimating the time delays that the emitted waveforms undergo from being illuminated to the target until being observed by the receive antennas. We also analyze the diversity gain which we define as the rate that the probability of mis-detecting a target decays with the increasing SNR for a controlled false-alarm and show that for a MIMO radar with Ntand Nrtransmit and receive antennas, respectively, the diversity gain is NtГґB— Nr. [C412]

"Compressed sensing for MIMO radar-algorithms and performance"

Compressed sensing techniques make it possible to exploit the sparseness of radar scenes to potentially improve system performance. In this paper compressed sensing tools are applied to MIMO radar to reconstruct the scene in the azimuth-range-Doppler domain. Conditions are derived for the radar waveforms and the transmit and receive arrays so that the radar sensing matrix has small coherence and sparse recovery becomes possible. Theoretical performance bounds are presented and validated by numerical simulations. [C413]

"Wide band frequency synthesis"

Radar systems, operating for SAR (Synthetic Aperture Radar) for ground observation or for surveillance, need very high resolution. The achievement of very high resolution in the range of 15 cm or less, that enables stationary targets analysis, requires wide instantaneous bandwidth, accurate and programmable waveforms. On the other hand, low velocity moving targets to be discriminated from stationary ones are demanding in low spurious and low phase noise. This paper presents a low noise and flexible digital frequency synthesizer for wide band application suitable for very high-resolution Radar. [C414]

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"Classification of SHOALS 3000 bathymetric LiDAR signals using decision tree and ensemble techniques"

Coastal Management is a complex issue that is facing policy makers and scientists around the world. Monitoring the coast can be difficult given the vast stretch of water which needs to be covered. Ship-based surveys can

take weeks to perform mapping of the coastal zone. LiDAR bathymetry is a tool which shortens the survey time at reduced survey cost. The objective of this paper is to describe the parameterization of the LiDAR waveform from the SHOALS 3000 LiDAR system and show how it can be successfully used for classification of bottom habitat. Decision tree techniques and ensemble methods are used for classification purposes. The Rotation Forest ensemble method provided the greatest overall classification accuracy of 91% averaged over all fractions of the training data. [C416]

"On MIMO radar transmission schemes for ground moving target indication"

We compare several multiple-input multiple-output (MIMO) radar transmission schemes, including code division, time division and Doppler frequency division multiplexing approaches, for ground moving target indication (GMTI). To utilize probing waveforms with low sidelobe levels for range compression, we transmit sequences specifically designed to have low correlation levels. At the receiver side, we apply the iterative adaptive approach (IAA), which uses only the primary data, to form high resolution angle-Doppler images. To mimic real world scenarios, we apply our algorithms to a simulated dataset which contains high-fidelity, site-specific, simulated ground clutter returns. By combining the usage of intelligent transmission schemes, probing waveforms with good correlation properties, and the adaptive angle-Doppler imaging approach, we show that slow moving targets can be more clearly separated from the clutter ridge in the angle-Doppler images and potentially more easily detected by MIMO radar than by its conventional single-input multiple-output (SIMO) counterpart. [C417]

"Construction of unimodular sequence sets for periodic correlations"

Sequence sets with good periodic correlation properties can be used in many areas, including communications, medical imaging, radar (such as over-the-horizon radar) and sonar. Practical hardware constraints, such as power amplifiers, usually require the transmitted waveforms be unimodular. We present herein new computationally efficient algorithms that can be used for the design of unimodular sequence sets with essentially zero auto-correlation sidelobes and cross-correlations in a specified time lag zone, as well as of sequence sets with good correlations over all time lags. The proposed algorithms start from random phase initializations and can generate many different sequence sets (including very long sequence sets) possessing similarly good correlation properties. [C418]

"Design and implementation of multi mode Radar Target simulator using Direct Digital Synthesizer"

Idea of Hardware Radar simulator is to electronically generate the Radar illuminated environment without switching on actual Radar transmitter in the field. This paper describes the implementation of Radar Target simulator using advanced technology of arbitrary waveform generator (Direct Digital Synthesizer chip) & FPGA. The Radar Target Simulator has the advantage of measuring of system response, evaluating and optimizing the performance of radars without expensive field trips to harsh regions and can be used to test the radar without interfering with commercial wireless devices. It replicates the feed-through signal between transmit and receive antenna for CW Radar, Conventional Pulsed Radar (with pulse width >70ns) and LFM Pulse Compression Radar. In each mode it accurately generates phase-coherent transmit pulses & simulates target echoes (replication of transmit pulse) with following programmable parameters; (a) Target range by time delay (b) Doppler shift to simulate moving target through phase control of pulses (c) Signal strength to simulate SNR target echoes With the above mentioned salient features this Target Simulator can be used to develop and test Radar Algorithms e.g. Digital Receiver/Pre-processing, Pulse Compression Algorithm, Target detection, Range calculation/range resolution test up to 10m, Doppler Processing and tracking of single or multiple targets. Hence, operating in the 10 to 170MHz range, the target simulator is well-suited to the task of generating multiple phase-coherent signals in the IF range. The output is also compatible with frequency converters, which extends useful operation into the RF realm. The prototype can operate in a stand-alone configuration and can be used for algorithm development, testing and evaluation of the radar in the laboratory. [C419]

"High resolution Doppler estimation using highly Doppler tolerant signals"

We propose a new technique for Doppler estimation and also provide details of experimental verification of the same. The proposed method utilizes pulses of a highly Doppler tolerant signal to estimate the Doppler with very high resolution. This method is both analytically tractable and computationally efficient. We have compared various waveforms as candidate signals for this technique and have derived performance bounds for the estimation and the estimate resolution using simple physical insights into the problem. The details of the experimental verification of the theoretical principles is also mentioned. [C420]

"Sensor scheduling with waveform design for dynamic target tracking using MIMO radar"

Multiple-input, multiple-output (MIMO) radar systems have gained significant attention as they can enhance

target detection, identification and parameter estimation performance. In this paper, we consider the problem of optimizing the target tracking performance of a widely-separated MIMO radar system by scheduling the transmitter sensors and adaptively designing their waveforms. Specifically, for a tracking scenario consisting of a large number of MIMO radars, we propose: (a) a transmitter scheduling algorithm to achieve tracking performance gains based on resource constraints; and (b) an adaptive waveform optimization algorithm that further improves tracking performance. Under an ideal receiver assumption, we evaluate the predicted tracking mean-squared error using the derived CrameГ‚Вїr-Rao lower bound (CRLB) on the estimation of the target states. The scheduling algorithm is then formulated as a mixed boolean-convex optimization problem to minimize the CRLB. The optimum waveform parameters are adaptively obtained using sequential quadratic programming. The effectiveness of combining the MIMO radar technology with adaptive waveform design and sensor scheduling was demonstrated with simulations. [C421]

"MIMO radar, SIMO radar, and IFIR radar: a comparison"

This paper focuses on a simple beamforming problem and compares the MIMO and SIMO radar systems for the case where the transmitter and receiver are collocated. The simplicity of the application allows one to see clearly where the advantages of MIMO radar come from, and what the tradeoffs are. The comparison also includes a third system called the IFIR radar (interpolated FIR radar). The MIMO radar offers advantages in terms of clutter reduction, especially when the extra coherent integration time can be exploited, but it does not offer an SNR advantage-in fact the SNR is worse than that of the SIMO radar when extra integration cannot be performed. The IFIR radar, which is essentially a simple variation of phased array radars, has an advantage over the SIMO radar in terms of clutter reduction, and does not compromise SNR in order to achieve this. The multiple orthogonal waveforms used in MIMO radar typically require extra bandwidth for fixed range resolution but the IFIR radar does not require extra bandwidth. [C422]

"Generalized frequency modulated waveform libraries for radar tracking applications"

The aim of this paper is to produce a methodology for discussing the design of small efficient waveform libraries. We will need two building blocks for the methodology. The first is a generic collection of waveforms from which the small library will be chosen. In this instance, we represent the generic waveforms as generalized frequency-modulated pulses, though in fact this collection is quite general and able to encompass most practical waveforms used in radar. [C423]

"Target detection in MIMO radar using Golay complementary sequences in the presence of Doppler"

In this paper, we present a method for detecting a point target using multiple antennas when the relative motion between the receivers and the target induces a non-trivial Doppler shift. We consider a 4 ГѓВ— 4 system employing sets of unitary waveforms. In case of a non-trivial Doppler shift induced by the target motion, the waveforms are no longer unitary, and unambiguous target ranging is not possible. To solve this problem, we adopt a subspace based approach where we show that the unitary waveforms used have a non-empty null-space under certain conditions, and by processing the waveforms with vectors from the null-space, we can significantly improve the detection performance. [C424]

"On MIMO waveform design for non-Gaussian target detection"

We consider a multiple-input multiple-output (MIMO) detection problem with M widely-spaced transmit antennas and L widely-spaced receive antennas (not necessarily co-located), and we study the problem of designing the signal waveforms transmitted by each source node under non-Gaussian target scattering and temporally-correlated Gaussian clutter. Two figures of merit are investigated for space-time code optimization under a semi-definite rank constraint and a received signal-to-clutter ratio constraint: 1) the lower Chernoff bound (LCB) to the detection probability for fixed probability of false alarm, and 2) the mutual information (MI) between the observations available at the receive nodes and the MГѓВ—L Г‚Вїchannel matrixГ‚Вї generated by a target, assumed present tout court. If the scattering distribution possesses some suitably defined properties of exchangeability and unitary invariance, we show that MI-optimal and LCB-optimal space-time coding admit a simple closed-form solution. Finally, a case study of relevant practical interest is examined in depth so as to compare the proposed design criteria and to assess the impact of signal non-Gaussianity on the detection performances. [C425]

"Alternate projections technique for radar waveform design"

An alternate projections technique is applied to efficiently generate sparse frequency waveforms with constraints on the frequency band suppression levels as well as on range sidelobes. With a complexity of only O(N log N),

the algorithm could rapidly generate constant power noise-like sparse frequency waveforms that are very suitable for low probability of intercept radars. It has also proven its ability to generate waveforms having ideal periodic autocorrelation function comparable to well known ideal codes. [C426]

"Fitting derivative autofocus for stepped frequency radar"

High range resolution (HRR) profiles can be obtained using stepped frequency waveforms. A burst of linearly frequency modulated pulses on different carrier frequencies are transmitted and a suitable signal processing combines the returned echoes from each pulse to obtain a wide synthetic bandwidth. Target motion during stepped frequency processing causes several degradation effects, which inevitably reduce the desirable range resolution. This paper describes an autofocus technique that can be employed to compensate motion degradation effects on HRR profiles. The algorithm is based on a function of the derivative of the range profile as a measure of range profile focus. As an application the estimation accuracy of target to radar radial speed is tested in case of both one and two reflectors at different SNR (signal to noise ratio) using Monte Carlo simulation. The performances, in terms of standard deviation of radial velocity estimation of the proposed algorithm have been compared with that obtained with the contrast technique. [C427]

"Developments in foliage penetration radar"

Radars have been developed to detect buildings and vehicles under dense foliage using Synthetic Aperture Radar modes. More recently, systems and waveforms have been developed to detect moving vehicles and people in the presence of foliage clutter and signal loss. This paper summarizes the system design aspects of FOPEN SAR, and points to future developments for multimode operation. [C428]

"Airborne Radar and shipborne sonar: Recent advances and compared solutions"

The detection of slowly moving target in a strong backscattering background (clutter for radar, reverberation for sonar) is a challenge to both Airborne Radars and Surface Ship or Submarine Sonars communities. In this paper, after outlining the similarities and differences between the above and under-water domains, recent advances in the areas of waveforms design and beam-forming will be described. In a first part, more efficient wide-band Doppler waveforms for sonar will be introduced together with their advantages in terms of detection, and wideband coherent waveforms for radar moving targets detection will be presented. The second part will focus on the implementation of adaptive beam-forming for sonar and coloured transmission space time beam-forming for radar. Results on reverberation reduction obtained on a towed array sonar in CW mode will be discussed, and perspectives for coloured transmission radar systems will be outlined. [C429]

"Low cost moving target tracking and fire control"

Classical solutions for moving target tracking and fire control are complex and costly as they involve high performance radar, specific weapons and highly accurate seekers. The innovative solution described in this article uses a multiplatform configuration to simultaneously track target and weapon, thanks to a GMTI mode with a wide velocity waveform. The accuracy of the initial designation and the subsequent target+weapon update allow the use of a simpler weapons, drastically reducing the global mission cost. [C430]

"3 GS/s S-Band 10 Bit ADC and 12 Bit DAC on SiGeC Technology"

In advanced applications such as digital radar, Ultra Wide Bandwidth communications and software defined radio, the need for instantaneous bandwidth often drives system design decisions. Access to high speed data converters enabling up and down conversion directly in the L Band and S Band removes the limit imposed by bandwidth scarcity and allows the design of flexible and simplified system architectures. Broadband ADC's (Analogue to Digital Converters) and DAC's (Digital to Analogue Converters) are key enabling components which open up new design opportunities for digital transceiver systems, including digital down and up-conversion closer to the antenna. In this regard, this paper describes new 10bit 3GS/s ADC and 12 Bit 3GS/s DAC, based on a 200 GHz SiGeC bipolar Technology, which enables direct digitizing or synthesing of 1GHz arbitrary broadband waveforms directly in the high IF region closer to the Antenna. [C431]

"WiMAX signal waveform analysis for passive radar application"

WiMAX is the latest globally accepted wireless broadband access standard, which is also a valuable illuminator for passive radar. This paper analyzes the ambiguity function of WiMAX signal to evaluate its suitability as radar waveform. Simulation and experimental results demonstrate that WiMAX signal has a `bed of nails' type ambiguity function, whose properties depend on its frame structure, length of cyclic prefix and effective bandwidth. The modulation method has no effect on the ambiguity function. [C432]

"Bandwidth formula for Linear FMCW radar waveforms"

The International Telecommunications Union provides recommendations regarding spectral emission bounds for primary radar systems. These bounds are currently in review and are defined in terms of spectral occupancy, necessary bandwidth, 40dB bandwidth and out-of-band roll-off rates. Here we derive out-of-band domain spectral envelopes, bandwidth formula and roll-off rates, for various Linear FMCW radar waveforms including sawtooth (LFMCW), Quadratic Phase Coded LFMCW, LFM Pulse Train, and Hann amplitude tapered LFMCW. [C433]

"Low frequency radar targets 3-dimensional imaging using ramp response signatures"

Low frequency imaging in radar domain can have applications for stealthy or buried targets. We consider a technique using transient scattering response from a ramp waveform, which is proportional to the profile function of the target, i.e. its transverse cross-sectional area along the line-of-sight, and consequently, gives information about target size, orientation and geometrical shape. Usual 3-dimensional image generation from ramp responses uses approximate limiting surfaces and is limited to single convex objects. We propose here a new algorithm to reconstruct the global shape of any perfectly conducting target from its ramp response signatures. [C434]

"Relation between the peak to average power ratio and Doppler sidelobes of the multi-carrier radar signal"

The performance of the multi-carrier radar signal is investigated using the ambiguity function. The multi-carrier waveform under consideration is modulated by random phase coding, with the intention to combine radar and communications and at the same time solve the Doppler ambiguity. The connection between the instantaneous power of the waveform and the Doppler sidelobes of the ambiguity function are explored. The variance of the Doppler sidelobes, which arises from the random phase coding of the carriers, is connected to the peak to average power ratio of the waveform. [C435]

"Waveform design and processing for multichannel MIMO radar"

In MIMO radar several transmitters broadcast independent waveforms which must be separated at the receivers. Typically waveforms having low auto- and cross-correlation values are used. This study proposes the transmission of several waveforms across multiple independent channels by each transmitter. Waveform sets formed from mutually-orthogonal complementary codes are shown to provide perfect resolution of returns with no cross-transmitter interference when separated in time. Square-complementary waveforms separated in frequency and subject to nonlinear processing can also resolve targets but introduce cross terms instead of correlation sidelobes. Cross terms are mitigated with frequency agility and pulse-Doppler processing. [C436]

"Noncircular waveforms exploitation for Radar Signal processing: Survey and study for agile radar waveform"

With new generation of Active Digital Radar Antenna, there is a renewal of waveform generation and processing approaches, and new strategies can be explored to optimize waveform design and waveform analysis and to benefit of all potential waveform diversity. Among these strategies, building and exploitation of the Noncircularity of waveforms is a promising issue. Up to the middle of the nineties, most of the signals encountered in practice are assumed to be second order (SO) circular (or proper), with a zero second correlation function. However, in numerous operational contexts such as in radio communications, the observed signals are either SO noncircular (or improper) or jointly SO noncircular with a particular signal to estimate, to detect or to demodulate, with some information contained in the second correlation function of the signals. Exploitation of this information in the processing of SO noncircular signals may generate dramatic gain in performance with respect to conventional processing and opens new perspective in signal processing. The purpose of this paper is to present a short overview of the interest of taking into account the potential SO noncircularity of the signals in signal processing and to describe the potential interest of SO noncircular waveforms for radar applications. [C437]

"Measurement and analysis of clutter signal from GSM/DCS and UMTS-based passive radar"

Passive radars have been known to the scientific community since their first application as a system to detect bombers by means of shortwaves radiated by radio broadcasting towers in 1935, though they lately raised a renewed interest among researchers for some specific features that make them more appealing than classic active radar systems. In fact, having the transmitter and receiver located at two different positions, and the adoption of signals carrying other kinds of information such as GSM(either classical or the 1800/1900 MHz DCS

version) or UMTS waveforms, makes passive radar virtually undetectable and economically advantageous. In the paper, a measurement system used to characterize the clutter from a GSM/DCS and UMTS-based passive radar is presented. The main objective is to study the statistical properties of the clutter signals, find theoretical models fitting the measured clutter data, and analyze the differences between the modulated carriers of the two different standards. [C438]

"Waveform optimal design for MISO space-based radar system"

Based on space-borne multiple-input single-output radar systems, a novel orthogonal bi-phase coding waveform optimization design method is presented. However, it is impossible to design a set of codes with ideal impulsive autocorrelation and idea zero cross-correlation performances. Hence, only the shape of its main-lobe and side-lobe near the detected range cell is considered as the optimization criteria. The aperiodic correlation properties are discussed. Simulation results show that the proposed algorithm is effective and feasible. [C439]

"Intelligent M3R Radar Time Resources management: Advanced cognition, agility & autonomy capabilities"

The capabilities of modern multifunction/mission Radar can be only fully realized by using new sensor control strategies and the most obvious sensor management imperative is the development of optimal realtime waveform scheduling algorithms. For this purpose, Thales is studying Intelligent Radar Time Resources management for Multi-mission extended air Defence radar used for both Air and Ballistic Missile Defence, based on innovative Active Electronically Steered Antenna technology. This paper describes the functional architecture of radar resources management used for adaptive time budget optimization and key enablers for advanced cognition, agility and autonomy capabilities. We conclude with simulation in the ASTRAD framework. [C440]

"A efficient DOA estimation algorithm of coherent sources for MIMO radar"

To estimate the DOA of coherent sources of MIMO radar, a new spatial smoothing (SS) technique based on MIMO radar is presented using the diversity of the transmitted waveform and the independence of the transmitting-receiving channel. In the technique, the array is not necessary to be divided into sub-arrays, the received signal of the virtual sub-arrays are extracted from the output of the matched filter banks of MIMO radar, and then the auto-correlation matrix of the sub-array is derived. The technique in this paper can avoid the reduction of the array effective aperture, and adapt to arbitrary array structures, and increase the maximum number of coherent signals that can be estimated. Some numerical examples are simulated to verify the effectiveness of the technique. [C441]

"Poly-phase encoded waveform optimal design for space-borne MISO radar systems"

The application of multiple input techniques to sparse space-borne radar offers a number of advantages, including mitigating the effect of the target scintillation and being more freedom of signal processing. A novel orthogonal poly-phase encoded waveform optimization design method is presented. It is combined the Genetic Algorithm (GA) with the frequency functions designed by window functions to reduce the computation complexity. For the radar system, multiple transmissions of orthogonal coding signal and single reception, the high ISL of the optimized waveforms may cause degradation of the detection performance of the ground moving target. So, there is a trade-off optimization between the orthogonality and side-lobes of the signals. Simulation results show the effect of the transmission waveforms characteristic on the system's detection performance. [C442]

"Convex optimization applied to transmit beampattern synthesis and signal waveform design for MIMO radar"

This paper deals with designing the signal waveforms transmitted via multiple-input multiple-output (MIMO) radar antennas to approximate a given transmit beampattern, and also to minimize the cross-correlation of different echoes. In this paper, we consider a non-uniform but fixed elemental power constraint instead of the uniform elemental power one while still maintaining the same total transmit power. With the relaxed constraint and for a given power gain, we first construct a set of transmit beams or signal waveform vectors with globally optimal peak sidelobe levels. Next, we combine these beams or the corresponding vectors according to some ratios to synthesize a desired transmit beampattern or its corresponding probing signal matrix. Convex optimization is applied to get these vectors and their ratios. Numerical comparison shows that our synthesized transmit beampattern has lower peak sidelobe levels and also has lower crosscorrelation peak sidelobe levels due to relaxing the uniform elemental power constraint. Additionally, the probing signal transmitted by each antenna element has a constant modulus because of the fixed elemental power constraint. [C443]

"Estimation of direction of arrival for wideband coherent signals with known waveforms"

A Direction of Arrival (DOA) estimator for wideband coherent signals with known waveforms and unknown amplitude is presented in this paper, which is extended from the estimation algorithm for time delay, referred to as WRELAX. The method can be called coherent space-time RELAX (CST-RELAX), which is a relaxation-based minimizer of a complicated nonlinear least squares cost function and is implemented in both space and time domain. Numerical examples in the presence of white and colored noise respectively are provided to demonstrate its performance and compare with other well-known algorithms including CSM (Coherent Subspace Method) and wideband RELAX. The proposed method improves the estimation accuracy and has an excellent resolution. [C444]

"Performance analysis on MIMO radar waveform based on mutual information and minimum mean-square error estimation"

Multiple-Input Multiple-Output (MIMO) technology can improve the performance of radar by spatial diversity. Two methods for designing MIMO radar waveform are introduced in this paper. The first one is to design waveforms that maximize the conditional mutual information (MI) between the reflected waveform and the channel impulse response. The second one is to minimize the minimum mean-square error (MMSE) in channels estimation. A particular analysis of detection performance is made here to illuminate the improvement. Finally the simulation results are presented and the performances of the two approaches are compared. [C445]

"Coherent spectrum synthesis of frequency-stepped chirp signal"

Stepped frequency radar signal has been widely used for its high range resolution and low instantaneous bandwidth. Frequency-stepped chirp signal is a useful waveform which can decrease the frequency step number while the synthesized bandwidth remains unchanged. The spectrum synthesis method based on coherent addition is introduced to avoid the range ambiguity or "ghost" images caused by the conventional IFFT processing. In order to avoid the amplitude ripples caused by the superposition of the sub-spectrum boundaries, a spectrum synthesis method based on stitching without superposition is introduced and analyzed in detail. Besides, this method is more computational effective compared with the coherent addition method. Analysis and simulation results show that the stitching without superposition method can get a more desirable high resolution range profile than the coherent addition method and can be easily applied for its computational efficiency. [C446]

"A method of waveform design based on multi- eigenvecor selection"

Cognitive radar is a newly proposed radar system, which may adaptively and intelligently interrogate a propagation channel using all available knowledge including previous measurements. Thanks to a great important role of the adaptive waveform design technique in cognitive radar, it receives much more attention in the near future. However, due to the existence of aspect uncertainty and sensitivity characteristic of the target's impulse response, it is difficult to adaptively design waveform for target recognition task, which also often leads to the available approaches ineffective. In order to solve the problem, a new method termed Multi- Eigenvector Selection is proposed in the presence of additive Gaussian coloured noise (AGCN) in this paper, which optimizes via selecting multi-eigenvector and tries to improve the separability effectively. Experimental results prove the efficiency of the proposed method compared to the existing methods. [C447]

"Design and realization of the step frequency echo simulator based on DDS"

In the development of the step frequency radar, time and costs would be greatly curtailed by applying the echo simulator of step frequency waveform to verify the signal processing system. This paper analyzes the characteristics of step frequency echoes in detail and describes the implementation of the point-target echo simulator based on DDS. The experimental results of the scheme show that the equipment closely simulates the echo of step frequency signal and the feasibility of this method is also soundly proved. [C448]

"Diversified MIMO SAR waveform analysis and generation"

Inspired by recent advances in multiple-input and multiple-output (MIMO) radar, which has the potential to dramatically improve the performance of radar systems over single antenna systems. This paper proposes a waveform diversity-based MIMO synthetic aperture radar (SAR) concept. The fundamental difference between MIMO SAR and conventional SAR is that the latter seeks to maximize coherent processing gain, while MIMO SAR capitalizes on the diversity of target scattering to improve imaging performance. The system concept and signal models are developed. An example diversified waveform using for MIMO SAR is designed, along with several computer simulations that investigate the correlation performance of the designed waveform. Furthermore, a direct digital synthesizer (DDS)-based approach of diversified waveform generation, in which

parallel DDSs are applied, is proposed for MIMO SAR systems. [C449]

"A New Waveform Design Method for Cognitive Radar"

In cognitive radar system, how the transmitted waveform adapts in response to information regarding the radar environment is an important problem. In this paper, the waveform design for cognitive radar is viewed as an optimization problem. Then a new waveform design method for cognitive radar is proposed, which uses IPM (interior-point method) to carry out the optimization task. The simulation results demonstrate the validity of our algorithm. [C450]

"Design of modified spectrum filter based on Mismatched Window for NLFM signal"

In the radar field, Non-Linear Frequency Modulation (NLFM) signals are widely used. The conventional design method of side-lobe suppression filter for NLFM signal is based on the principle of stationary phase with the window functions and the modified spectrum algorithm. A new filtering technique of Modified Spectrum Filter based on Mismatched Window (MSFMW) algorithm is proposed in this paper. This method respectively designs the NLFM signal and the pulse compression filter based on different window functions. So the spectrum magnitude of the filtered waveform is proportional to the window function which is different from the one used for waveform design. The performance of the pulse compression can be modified by the different window functions. The simulation results demonstrate that the Ratio of Main-lobe peak to Side-lobe peak (RMS) can be increased by 0.8 ~ 7.7dB, without changing the main-lobe width. [C451]

"Analysis of phase noise effect on noncooperative wideband bistatic receiver"

Noncooperative narrow-band coherent processing techniques have been developed, however, this capability for wideband signals processing require to investigate further. Of all the obstacles preventing coherent reception techniques from making transition into the optical domain, phase noise caused by system imperfections is one of them. This kind of phase error will defocus discrete scattering centres in the range-Doppler image, which will preclude target identification and analysis. The amount of phase noise in signal is directly related to its so-called bandwidth, the 3 dB line width of its power spectrum. Numerous investigators have studied the effects of laser phase noise. We will examine the effects it has on the performance of this receiver. Both theory and application of this original work is extended in this paper. The research defined a system configuration and assessed its potential performance via modelling. It was developed to support pulse compression of wideband waveforms for applications. The associated implementation issues introduced by electro-optical component characteristics were discussed. Coherent detection was used to implement difference mixing for subsequent digital processing. [C452]

"A waveform diversity technique for countering RGPO"

In modern battlefield the jammer performing deception jamming of range gate pull off (RGPO) generates a false target and causes the radar to break its track on the target. The use of waveform diversity to remove the false target from the real one is considered. Received signal model under deception jamming is built on the base of the principle of RGPO. A new kind of design method for waveforms orthogonal in frequency domain is proposed and the correspondence signal processing method for removing the false target under RGPO is deduced. Its validity is proved by the simulated experimental results. [C453]

"A target velocity measurement method in submillimeter step frequency radar"

A target velocity measurement method based on positive and negative step frequency waveforms is presented in this article. Using the characteristic of positive and negative step frequency waveforms, three signal process methods are introduced. With these methods we can get different velocity resolution and unambiguous velocity range. Combining these methods we can get the precise target velocity without ambiguity. A signal process flow and matlab simulation are given in the end. [C454]

"Image formation algorithm for missile borne MMW SAR with phase coded waveform"

The feasibility of the application with phase coded waveform to missile borne Millimetre Wave (MMW) Synthetic Aperture Radar (SAR) system was investigated. Based on theory analysis, the geometry model was simplified, the expression of the equivalent range and the Range-Doppler image formation algorithm were deduced simultaneously. The phase coded waveform is pulse compression signal, and it can depress the peak value power and provide large bandwidth, so the phase coded waveform is usually employed in SAR systems in order to acquire the low probability of intercept. The image results concentrated on the point array target and the area scene. Simulated results demonstrate that the SAR system with phase coded waveform has the ability to get the

image of the target, and hence, the results validate the effectiveness of the image processing method. [C455]

"Experimental results for shadow inverse synthetic aperture radar"

Bistatic Shadow Inverse Synthetic Aperture (SISAR) offer a number of promising features such as: simple hardware; enhanced target radar cross-section (RCS); a long coherent interval of the diffracted signal; robustness to stealth technology; In spite of a number of theoretical research efforts in the application of SISAR for target imaging, there are few experimental results available that are able to confirm the theory and specify problems of SISAR's practical design. This paper is dedicated to the experimental study of the feasibility of SISAR micro-sensors for the imaging of ground vehicles. A motion compensation method based on waveform entropy is presented in the paper. Finally experimental results, conclusions and recommendations are presented. [C456]

"A Novel Waveform Scheduling Method"

One of the important issues for cognitive radar is how to optimally decide or select the radar waveform for the next transmission based on the observation of past radar returns. In this paper, with the stochastic dynamic programming model of waveform scheduling, the optimal algorithm of waveform scheduling is proposed. In order to solve the problem that we can not compute the exact value function under some circumstances, we step forward in time using an approximation of the value function from the previous iteration. The simulation results testify validity of our algorithm. [C457]

"Lateral velocity estimation using an FMCW radar"

This paper addresses the estimation of the lateral velocity using a Frequency-Modulated Continuous-Wave (FMCW) radar. Usually lateral velocity estimation is performed by evaluating the range information during multiple sweeps by means of a tracking algorithm. Another approach is to use the Doppler frequency shift during one chirp of an FMCW waveform in conjunction with the instantaneous aspect angle of the target. But all these algorithms ignore the phase information between nearby chirps. In this contribution an estimator based on the phasing between adjacent sweeps is presented using contrast optimization in combination with the discrete polynomial-phase transform in order to reduce the computational demands of the proposed estimator. This approach makes it suitable for real-time implementation with state of the art technology. [C458]

"On the trade-off between mainlobe width and peak sidelobe level of mismatched pulse compression filters for linear chirp waveforms"

In the work of the authors (2007), they introduced a technique for generating mismatched pulse compression filters for linear frequency chirp signals. The technique minimizes the sum of the pulse compression sidelobes in an Lp-norm sense. It was shown that constant, extremely low sidelobe levels (better than 60 dB) can be achieved for minimal mismatch loss but with some broadening of the compression peak. This paper investigates the tradeoff between the sidelobe level and the mainlobe width for mismatched filters designed using Lp-norm techniques. [C459]

"A comprehensive analysis on detection performances of LPI signals filtering strategies"

This paper focuses on the detection performances achievable in the presence of Low Probability of Intercept (LPI) radar signals. It well known that the radar community is widely investigating LPI waveforms to reduce the Range Advance Factor (RAF) obtainable with Electronic Support Measure (ESM) systems. Several filtering strategies for LPI signals processing are already available in open literature, but a formal analysis on different detection strategies and a comparison on the detection probability has not yet carried out. In this paper we propose several detectors, using different signal filtering algorithms and different detection strategies. Moreover a comprehensive analysis for all the proposed receivers is carried out for different LPI waveform, also in comparison with the classical Fast Fourier Transform (FFT) filtering, widely adopted by current ESM systems. [C460]

"Merging frequency agile OFDM waveforms and Compressive Sensing into a novel radar concept"

Compressive sensing (CS) is a new tool that intends to estimate the original information by means of convex optimization, using just a few measurements. In radar this original information consists of the range-Doppler map of the observed scene. The method allows undersampling since the band-limitedness of the waveform is no longer the limiting criterion, which turns to be the sparsity of the scene. Essentially, this article opens new prospects for radar waveforms by focusing on the orthogonal frequency division multiplexing (OFDM) signal in comparison with chirps, and shows how the concept of agility fits in a natural way with CS as a processing tool.

Examples with conventional matched filtering support fair comparisons. The scenario of a 1D range profile sparsely filled with bright spots or point targets is investigated. [C461]

"PicoSAR- an advanced lightweight SAR system"

PicoSAR is an ultra-lightweight SAR based on active array antenna technology. The complete system, including waveform generation, 2-channel receiver, inertial measurement unit, real-time signal processing and motion compensation is housed in a compact unit weighing less than 10 kg which can be easily installed in a wide range of aircraft. The system delivers excellent performance, with ranges in excess of 20 km and resolutions down to below 0.3 m. The paper describes the key technologies of the system and shows examples of system performance. [C462]

"Monopulse and coherent integration: perfomance and waveforms"

Purpose of the paper is the description of a technique dedicated to the recovery of monopulse performance loss in phased array radars (PAR) using both Low PRF Waveforms and High PRF Waveforms (here in after LPRF and HPRF respectively). [C463]

"Welcome to EuRAD 2009"

It is my pleasure, as conference chairman, to welcome you to the 6th European Radar Conference (EuRAD 2009) being held in Roma as part of the European Microwave Week (EuMW). EuRAD started six years ago thanks to a wonderful idea of our Dutch colleagues and friends from IRCTR and Delft University and in particular to the determination of prof. Leonard Ligthart. Since then, EuRAD has grown into one of the largest European and worldwide recognised radar events, both in terms of quality (guaranteed by a rigorous, peer review of a substantial abstract) and of quantity: in fact, the number of proposed contributions has steadily increased during six years. This year, in spite of the present international financial crisis, we have received 189 submissions to this conference, with more than 18% increase with respect to the very successful EuRAD 2008 edition. EuRAD submissions are now about 15% of the whole EuMW, making this conference the second largest of the EuMW and with an increase of its duration of more than two full days. The accepted papers are organised into twelve oral sessions plus four Focused Sessions and one common session EuMC/EuRAD (summing up to eighty-three podium presentations), complemented by a poster session. Moreover, five invited papers of wide interest are presented in the Opening and Closing sessions. This year, I feel that the strong reduction in the number of parallel sessions will enhance the benefit for the attendees. The programme covers a wide range of radar topics including Radar Subsystems and Technology, Signal Processing, Design and Evaluation, Systems and Applications; two focused sessions are dedicated to Space Radars and their Environmental Remote Sensing applications, one to Space-Time Adaptive Processing and one to Passive Radar, while the common session with EuMC is dedicated to through-the wall radar imaging. In addition to that, the programme includes other "hot" topics such as ultra wide band radar, multilateration-, interception/analysis of radar signals, new radar waveforms and OFDM radar, sea and OTH radar, phased arrays and more, with a wide and updated overview on the most recent advances in radar technology and applications. [C464]

"Recent advances in waveforms for radar, including those with communication capability"

New scalable and flexible waveforms offer a great number of new opportunities for object- or environment-tailored signal processing. The paper will discuss two classes of such flexible waveforms, i.e. single carrier waveforms with orthogonal modulations and multiple carrier coded waveforms. These waveforms may for instance be used for the benefit of scalable resolution, fast unambiguous Doppler assessment, two-channel code-orthogonality supporting to measure the full back scatter matrix in radar polarimetry, and message transfer in a network by radar. [C465]

"Mainlobe Width Reduction Using Linear and Nonlinear Frequency Modulation"

High range resolution can be achieved by various methods in a radar system. Simple pulse systems are narrow band, easiest and least expensive to maintain, but one can achieve only limited resolution. To achieve good range resolution pulse compression technique giving low range sidelobes is employed in radar and sonar. Pulse compression is accomplished by employing phase modulation and frequency modulation. Bi-phase coded waveform employs phase modulation techniques. The Barker codes are the only known bi-phase codes with minimum sidelobes. In this paper, linear frequency modulation (LFM) and nonlinear frequency modulation (NLFM) are introduced in the bi-phase coded waveforms and their effect on the sidelobe levels, mainlobe width, Doppler tolerance are studied. [C466]

"Future event"

This paper dealt with the following topics: ITER CODAC; XFEL; machine protection system; synchronous Ethernet-based system; DAQ; microTCA; ATCA; control system; data acquisition system; fusion experiment; large-scale experiment; intelligent platform management controller; J-PARC; T2K experiment; fine grained detector; front-end electronics; time projection chambers; photodetectors; read-out electronics; waveform sampling; microchannel plate devices; picosecond timing; DTL; beam phase measurement system; energy measurement system; proton accelerator; ATLAS- RPCs ROD; embedded microprocessor; GLink chip-set; FPGA; embedded serial transceivers; ATLAS; triggering system; parallel computer; receiver assistant congestion control; jitter; EAST plasma discharges; online information; LHCb experiment; EPICS channel access; Internet communication engine; NEXT prototype; BESIII; TOF experiment; monitoring system; Wendelstein 7-X experiment; DC-DC converters; clock data recovery; Webscope; fusion data analysis and visualization; high-speed data injection; MAPS; serial link transmitter; microBooNe experiment; time-of-flight PET-MR; detector module; Ethernet LAN; gamma decays; CMS barrel electromagnetic calorimeter; online system; superKamiokande experiment; experiment at CERN; DWDM link; ALICE system; PET scanner; statistics-based online baseline restorer; digital filters; noise reduction; precision calibration; intellectual signal classifier system; wave union TDC; on-chip processing; real-time sampling system; JET tokamak; electronic noise; odor discrimination; time-mark technology; logic system; EUDET pixel telescope system; gas detectors; dynamic partial configuration; PITZ; MTF; interlock system; nuclear fusion devices; CompactPCI HA platform; railway radar system; clock synchronization; radiotherapy treatment planning; Monte Carlo methods; processing system; storage system; Ethernet prototyping; 2D X-ray detectors; hardware-software codesign; space charge simulation; unifie- d interconnect network; GlueX experiment; signal procesing; CMS ECAL detector; and other related topics. [C467]

"Statistical MIMO radar under non-Gaussian target scattering"

We consider a multiple-input multiple-output (MIMO) detection problem with M widely-spaced transmit antennas and L widely-spaced receive antennas, and we optimize the signal waveforms transmitted by each source node. Two figures of merit are investigated for space-time code optimization under a semi-definite rank constraint and a received signal-to-clutter ratio constraint: (1) the lower Chernoff bound (LCB) to the detection probability for fixed probability of false alarm, and (2) the mutual information (MI) between the observations and the target scattering matrix. If the scattering distribution possesses some properties of exchangeability and unitary invariance, we show that MI-optimal and LCB-optimal space-time coding admit a simple closed-form solution. As an application, the detection of a compound-Gaussian target is examined. The robustness of code design under Gaussian scattering is also investigated. [C468]

"Overview of present/future needs of MWP for defence system applications"

For many years, optical-microwave technologies have appeared as promising for numerous applications. Indeed, fibre-based communications are well established nowadays in digital transmission systems. The maturity and the performances of optoelectronic components, in terms of spectral purity and linearity, are such that today they enable optical transmission and processing of analogue broad-bandwidth microwave signals. Moreover, the inherent parallel nature of light, the low sensitivity to electromagnetic perturbations and the capability to perform processing functions in the optical domain allow the introduction of new concepts such as local oscillator distribution, optical beam-forming, adaptive filtering or radar signal and waveform generation. These new concepts are good candidate for application and further validation into ship or ground-based radars, as well as into space or airborne systems. [C469]

"A new approach for DVB-T Cross-Ambiguity Function evaluation"

In this paper the use of Digital Video Broadcasting-Terrestrial (DVB-T) signals as waveform of opportunity for Passive Bistatic Radar (PBR) is addressed. A new approach for DVB-T Cross-Ambiguity Function (CAF) evaluation is proposed, which exploits a linear filter based on the knowledge of the expected value of the ambiguity function. The proposed approach is able to remove the unwanted deterministic peaks in the CAF due to specific features of the DVB-T signal, as guard intervals and pilots. The performance of the conceived filter is evaluated against simulated data and compared to other existing approaches. It is shown to yield more robust performance in terms of CAF improvement with reduced computational load and system complexity. [C470]

"Monitoring of St. Sophia Cathedral interior using Ka-band Ground Based Noise Waveform SAR"

This work is devoted to measurement of shifts inside an old Cathedral using a Ka-band ground based noise waveform SAR (GB NW-SAR). Design of this SAR is based upon synthetic aperture antennas and noise radar technology. The system is intended for small shifts measurement at large objects using differential interferometry

technique and it can be used for detection of pre-catastrophic changes. In current experiments, GB NW-SAR was used in monostatic regime with CW signals. Resolution of the GB NW-SAR was ~ 30 cm both in range and azimuth. The SAR has been placed inside the St. Sophia Cathedral in Kiev and used for shifts detection in sealing of the building covered with ancient frescos and mosaics. Precision of shifts measurements up to 0.1 mm has been shown. Influences of reflections inside the building have been analyzed. High stability of the object of interest has been shown. [C471]

"Quasi-simultaneous measurements of scattering matrix elements in polarimetric radar with continuous waveforms providing high-level isolation in radar channels"

This paper presents a new type of sounding signals for polarimetric FM-CW radar and corresponding de-ramping technique for processing, which provide the possibility for simultaneous measurement of all backscattering matrix elements and have high-level isolation between branches of the polarimetric receiver. The radar transmitter forms sounding signal, which has orthogonally-polarized components with orthogonal waveforms. The radar receiver is splitting orthogonally-polarized components of the scattered signals in two parallel receiver channels. Every such channel includes two parallel independent branches, which use wave-form orthogonality of the orthogonally-polarized components of sounding signal to split further signal components for simultaneous estimation of all four complex elements of the polarization backscattering matrix of radar object. The isolation between pairs of such branches in one receiver channel strongly depends on the time interval when scattered signals with orthogonal waveforms occupy the same frequency band. In this paper we propose to use a pair of LFM-signals as orthogonally-polarized components of the sounding radar signal. Both have the same form but are shifted in time relatively to each other. Our analysis shows that such time shift between the components of sounding signal prevent the frequency overlap between polarimetric components of scattered signal. As result, standard de-ramping processing technique can be used in the receiver, providing high level isolation between receiver's branches that simultaneously estimate all elements of the radar target backscattering matrix. [C472]

"Range sidelobes reduction filters for WiFi-based passive bistatic radar"

In this paper the feasibility of a WiFi transmissions based passive bistatic radar is analysed. The auto-correlation function of this waveform of opportunity is characterized with reference to typical signals broadcasted by a 802.11 access point and it is shown to yield a high sidelobe level which strongly limits the useful dynamic range. Proper weighting networks are proposed to cope with this limitations based on the knowledge of the expected value of the signal autocorrelation function. The performance of the proposed technique is evaluated against simulated data generated according to the 802.11 Standards. Moreover the preliminary results are presented against a real data set collected by an experimental setup. The proposed approach is shown to yield a significant improvement of the peak to sidelobe ratio thus making the considered waveform more attractive for passive local area surveillance. [C473]

"Array configurations and space-time adaptive processing for spaceborne distributed GMTI radar"

Ground moving target indication (GMTI) is an important, challenging application of space-based distributed aperture radars. Due to the large baseline of the sparse array, the main beam clutter Doppler spread can be reduced and minimum detectable velocity (MDV) can be improved. The cost is the blind zone problem introduced by spatial ambiguities and the grating lobes due to undersampling in spatial frequency domain. This paper investigates some solutions to the blind zone problem of space time adaptive processing (STAP) technique due to grating lobes and spatial ambiguities. In particular, the concepts of Minimum Redundancy Arrays (MARs) and Optimally Irreducible Arrays (OIAs) are introduced to STAP technique for space-based distributed aperture radars in order to solve the blind zone problem. We propose a method by using Optimally Irreducible Arrays combined with waveform diversity to improve the detection performance and present simulation results to show the effectiveness of the method. [C474]

"A set of triphase coded waveforms: Design, analysis and application to radar system"

Based on the zero correlation zone (ZCZ) concept, we present the definition and properties of a set of new triphase coded waveforms -ZCZ sequence-pair set (ZCZPS) in this paper and propose a method to use the optimized punctured sequence-pair along with Hadamard matrix construct the optimized punctured ZCZ sequence-pair set (optimized punctured ZCZPS). According to property analysis under the Doppler shift condition, the optimized punctured ZCZPS has good autocorrelation and cross correlation properties when Doppler shift is not large. We apply it to radar target detection. The simulation results show that optimized punctured ZCZ sequence-pairs (optimized punctured ZCZPs) outperform other conventional pulse compression codes, such as the well known polyphase code-P4 code. [C475]

"Optimal point target detection with unknown parameters by MIMO radars"

We consider multiple-input multiple-output (MIMO) radar systems with widely spaced transmit and receive antennas. We treat the problem of detecting point targets when one or more target parameters of interest are unknown. We provide a composite hypothesis testing framework for jointly estimating such parameters along with detecting the target while only a finite number of signal samples are available. The test offered is optimal in a Neyman-Pearson-like sense such that it provides a Bayesian-optimal detection test, minimizes the average mean-square parameter estimation error subject to an upper bound constraint on the false-alarm probability, and requires a finite number of samples. While the test can be applied for concurrently detecting the target along with estimating any unknown parameter of interest, we consider the problem of detecting a target which lies in an unknown space range and find the range through estimating the vector of time delays that the emitted waveforms undergo from being illuminated to the target until being observed by the receive antennas. We also analyze the diversity gain which we define as the rate that the probability of mis-detecting a target decays with the increasing SNR and show that for a MIMO radar system with Ntand Nrtransmit and receive antennas, respectively, the diversity gain is 1 for point targets. [C476]

"The optimization of orthogonal coded signal group based on multiple population evolving strategies"

An improved genetic algorithm based on multiple population evolving is presented and applied to the optimization of orthogonal coded signal group for MIMO radar systems. According to the fitness of individuals, the population is divided into three groups and different evolving strategies are applied to every sub-population. The inoculation to all sub-population is actualized. This algorithm can strengthen and preserve the diversity of population. Meanwhile it can enhance the constringency speed and overcome the precocity of GA. Simulation results show that the improved genetic algorithm is effective and the optimized signal can used in MIMO radar. [C477]

"Design and optimization of combined modulation waveform using genetic and simulated annealing algorithm"

Frequency and phase combined modulation waveform has been considered as an important technology that provides significantly improved LPI performance and compression ratio in Radar system. In this paper, genetic simulated annealing algorithm(GASA) has been applied to the design and optimization of the combined modulation waveform. On the basis of genetic algorithm(GA), GASA introduces annealing process in energetic, thus enhancing the searching capability and efficiency in the whole searching scope. The feasibility and high efficiency of the algorithm is validated by the simulation result and implementation in engineering. [C478]

"Downward-looking 3D-SAR with dual-transmit and multiple-receive linear array antennas based on time and waveform diversity"

The dual-transmit and multiple-receive (DTMR) configuration of linear array antennas (LAA) is firstly introduced in downward-looking 3D-SAR imaging in this paper. The geometrical model and the signal model based on the principle of time diversity and waveform diversity are analyzed. The three-dimensional imaging processing algorithm for downward-looking 3D-SAR with DTMR-LAA is given via a stepwise mathematical derivation and the analytic expression of 3D PSF after 3D imaging processing is presented. The simulation results confirm the feasibility of the downward-looking 3D-SAR with DTMR-LAA imaging concept. [C479]

"Sea State Monitoring HF Radar Controller Using Reconfigurable LabView FPGA"

High Frequency (HF) Radars are used extensively for ocean observation and to provide synoptic current maps covering thousands of kilometres. HF Radar for Ocean observation is under development at SAMEER, IIT Bombay Campus. The project is funded by the Government of India, Ministry of Earth Sciences. The controller for this Radar is designed using NI LabVIEW 8.5 Professional System Development platform, National Instruments high precision R series NI PXI 7833 intelligent DAQ with reconfigurable FPGA and onboard memory, NI LabVIEW FPGA compiler and NI PXI 1033 chassis for PC interface. This design is implemented as two modules. 1. FPGA Module:-generates Carrier modulating chirp, switching pulses, synchronising and control signals for operating the radar, and receives Receiver signal samples in FPGA buffers. This design is compiled and synthesised on Xilinx Virtex-II reconfigurable FPGA with 3M gates. 2. Host Module:-This module runs on the Host PC. It is used for reconstruction of time domain Signal (TDS), Power Spectrum (PS) and FFT computation of intra and inter sweep radar echo's, signal processing and wave spectral analysis and display, waveform storage as .jpeg and .bmp files for offline analysis, velocity and significant wave height limit detection and storm/disaster prediction. The FPGA and LabVIEW based design has resulted in a very deterministic system performance, reduced development time and cost and is reconfigurable to adapt new features. [C480]

"Wideband direct RF digitisation using high order Nyquist sampling"

A radar architecture is described in which radio frequency (RF) pulse waveforms are generated digitally in the transmitter and target returns are digitised without analogue down-conversion in the receiver, thereby eliminating most of the analogue components found in typical radar systems. This architecture, which has a number of important advantages over conventional radar systems, can be implemented using broadband digitisation technologies developed recently for the communications industry. [C481]

"Advances in affordable Digital Array Radar"

This paper firstly reviews the issues and benefits of various levels on digitisation in a DAR (digital array radar) as discussed above. It then focuses on the key technology of high levels of digitisation; that of low cost, high performance, small and modular digital receivers. This paper presents current UK R&D employing low cost COTS components to enable this to be realised. Present S Band and X Band digital receiver designs are used as examples of state of the art modular hardware. [C482]

"The relative merits of pre/post-Doppler STAP"

When considering possible implementations of space-time adaptive processing (STAP) techniques, it is apparent that there are two principal approaches; STAP before Doppler filtering (pre-Doppler STAP) and STAP after Doppler filtering (post-Doppler STAP). The two approaches are founded on very different and partly contradicting arguments. This paper tries to collect all these viewpoints. The aim is to give the application engineer, who is not familiar with the details of STAP, a guideline of the basic problem and criteria of choice between pre and post Doppler STAP architectures. [C483]

"The Potential of Combined Lidar and SAR Data in Retrieving Forest Parameters using Model Analysis"

3D Lidar waveform and 3D radar backscatter models based on Radiative Transfer theory were used to simulate waveform and backscattering of various plots with different stand ages and structures, which were generated using forest growth model. The inversion models for estimating forest Above Ground Biomass (AGB) and Average Stand Height (ASH) were derived from the combined simulated database of large footprint Lidar waveforms and L-band polarimetric SAR backscattering using stepwise analysis method. The inversion procedures were then applied to NASA LVIS and ALOS PALSAR data to retrieve forest parameters for the study area. The study area is a 10km by 10km area located at International Paper's Northern Experiments Forest, Maine, USA, where field measurements that include stem coordinate, DBH, species and canopy position were recorded within a 200m by 150 m stand. Heights and AGB of total 7956 trees were estimated by applying species-specific allometric equations to stand measurements. AGB and height were then scaled up to the area according to the LVIS footprint size and location at 149 20m*20m plots, which were used to verify the inversion model developed using simulated database. The study concludes that Lidar waveform indices and SAR backscattering are complementary for forest parameters retrieving, which improved the limitation of signature saturation for regional biomass mapping using SAR data only. The comparison between inversed forest parameters and field measurements shows good consistency. [C484]

"From AESA radar to digital radar for surface applications"

This paper describes how Thales surface radar product policy is evolving from active electronically steered antenna (AESA) radar to digital radar in order to improve its capabilities when operating in challenging electromagnetic environments. It shows how digital receiver technology (with an analogue-to-digital converter behind every antenna element) tailored for the digital beam forming array application is a key enabling technology for enhancing the detection of radiofrequency signals of interest mixed with strong interference. After a description of the architecture and packaging design choices, some recent developments of digital tile receivers in S and X bands are presented. Examples using digital technology are given including M3R, GM400 and SM400. The conclusion focuses on future perspectives in digital radar technology. [C485]

"Fully integrated, highly precise, low-cost phase shifters for commercial maritime phased arrays"

A quadrature phase shifter has been implemented in a quarter micron SiGe BiCMOS technology. The phase shifter core consists of a novel high resolution (2 times 5 bit) direct digitally controlled dual-path programmable gain amplifier driving a successive two pole passive polyphase filter. Since this core is a fully differential device, on-chip baluns have been employed to decrease the number of off-chip components to the minimum. Multi-tanh gmstages are employed to increase linearity. The circuit features 50 Omega compatible single-ended in- and

outputs and a full 360deg phase shifting range. To the author's knowing, the presented phase shifter is the first to be designed for commercial S-band (2.9 GHz ... 3.1 GHz) shipborne radar systems as specified in IEC standard 62388. It generates 1024 equally distributed phase/amplitude states with a maximum relative deviation of below 2%. Therefore, the circuit is a suitable solution for cost-sensitive phased array applications with high precision requirements. [C486]

"On the benefits of space-time adaptive processing in FM ranging airborne radar"

Frequency modulated interrupted continuous wave (FMICW) waveforms can be used to resolve range ambiguities in pulse-Doppler airborne radar operation. The approach is usually associated with high pulse repetition frequency (PRF) modes where ambiguity resolution by means of PRF scheduling can be difficult. However, FMICW modes can broaden the Doppler bandwidth of clutter and therefore lead to reduced target detectability in clutter limited applications. This paper considers the implications of employing space-time adaptive processing (STAP) for clutter suppression in FMICW modes. It is shown that STAP can potentially provide benefits, but a planar array antenna, offering adaptive degrees of freedom in elevation and azimuth, is ideally required. [C487]

"Noncircularity exploitation in signal processing overview and application to radar"

With new generation of Active Digital Radar Antenna, there is a renewal of waveform generation and processing approaches, and new strategies can be explored to optimize waveform design and waveform analysis and to benefit of all potential waveform diversity. Among these strategies, building and exploitation of the Noncircularity of waveforms is a promising issue. Up to the middle of the nineties, most of the signals encountered in practice are assumed to be second order (SO) circular (or proper), with a zero second correlation function. However, in numerous operational contexts such as in radio communications, the observed signals are either SO noncircular (or improper) or jointly SO noncircular with a particular signal to estimate, to detect or to demodulate, with some information contained in the second correlation function of the signals. Exploitation of this information in the processing of SO noncircular signals may generate dramatic gain in performance with respect to conventional processing and opens new perspective in signal processing. The purpose of this paper is to present a short overview of the interest of taking into account the potential SO noncircularity of the signals in signal processing and to describe the potential interest of SO noncircular waveforms for radar applications. [C488]

"Correlation of target transfer functions and Range Profiles as a function of aspect angle and resolution"

▪ TTFs and range profiles de-correlate within 1° change in aspect ▪ Significance of the value of the correlation coefficient ▪ Advantages of working in the frequency domain (TTF) over the time domain (Range Profile) ▪ Number of data points ▪ Isolation of the target within the unambiguous range [C489]

"Correlation of Target Transfer Functions and range profiles as a function of aspect angle and resolution"

An experimental rig was constructed in order to investigate the variation of the radar signature of a 1:32 scale model tank with changes in aspect. By illuminating the target with a wideband stepped frequency waveform, a high range resolution profile was obtained with an associated frequency spectrum that approximated the target transfer function (TTF). It was found that both TTFs and range profiles de- correlated within a 1deg change in target azimuth, more rapidly than previously thought. It was also found that coarser range profiles correlated better than finer ones, but at the loss of a significant amount of distinctive target information. These results have implications for the size of the reference library employed in correlation-matching within the field of non-cooperative target recognition, and also for the number of different waveforms required to enable matched illumination of a target from all aspects. [C490]

"The detection range improvement of two channels FMCW radar"

Beat frequency of FMCW radar contains the range information. The factors which influence the detection range of FMCW radar are discussed including the attenuation of the electromagnetic wave and the energy of FFT processing. For getting the range information more effectively, this paper presents a new idea of two channels FMCW radar system for getting remote object range information. This system has been simulated based on the MATLAB. The simulation shows that this new system can improve the detection range twice over conventional system. [C491]

"MMSE based waveform design for MIMO radars"

Waveform design problem for MIcircldquoMO radars has been studied in several recent works. Although signal dependent noise (clutter) is considered in some works aiming to design waveform to improve target detection in MIMO radars, there are less works on waveform design problem for target classification and estimation in the presence of clutter. Thus, here, we investigate this problem In contrast with previous works, our design leads to the convex optimization problem which can be efficiently solved through numerical methods and it can be guaranteed to converge to optimal solution. Optimal waveforms are found for two scenarios. In the first scenario it is assumed that different transmission antennas see uncorrelated aspects of the target and we consider the correlated target aspects (owing to the closed space anttenas) in the second scenario. Due to the interdependence of signal and clutter, target estimation error of the first scenario will not zero even if the transmit power tends to infinity, i.e., clutter power also increases by increasing the transmission power. This is the major problem in target detection and estimation in the presence of clutter in radars. We show that in the second scenario the MIcircldquoMO radar receiver can nullify the clutter subspace. Thus by increasing the transmission power, estimation error becomes zero in the second scenario. Waveform design for MMSE estimator under both scenarios, leads to the Semi-definite programming (SDP) problems. [C492]

"High duty waveform design for active array airborne surveillance radars"

Future airborne surveillance radars are likely to be composed of solid state active element transmitters with sub arrayed receivers for adaptive processing. To give sensitive detection performance these radars will be required to operate at high duty to deliver high mean powers. This poses new problems for surveillance waveform designers. Two approaches in designing high duty scheduled waveforms are presented. The first approach is by best practice. Equations for high duty waveform design are given. A second approach was taken that used an evolutionary algorithm to optimise to a solution by evaluating a set of waveform performance metrics. A sensitivity metric, modelling adaptive radar detection performance using simplified empirical and algebraic models is presented. Following this a Ghosting/decodability metric is described which uses a novel assessment method for determining a waveform's susceptibility to ghosts and decode problems. Results of both approaches are given throughout. [C493]

"Combining Lidar and InSAR Observations over the Harvard and Duke Forests for Making Wide Area Maps of Vegetation Height"

In this paper, two data sets consisting of co-located full-waveform lidar and InSAR observations are discussed, one over the Duke Forest, near Durham, North Carolina, and the other, the Harvard Forest, located in Western Massachusetts. Data for the Duke forest consists of AIRSAR and GeoSAR (both airborne sensors) interferometric SAR observations spanning in frequency from X-band down to P-band, and data from the GSFC's SLICER instrument. For the Harvard Forest, spaceborne data from JAXA's ALOS/PALSAR mission is used in conjunction with GSFC's LVIS instrument. Early work with SLICER and GeoSAR data has used a lookup table approach for generating a table that correlates the InSAR observables of differential height between X-and P-band observations, and X-band correlation magnitude to lidar derived height. This table was then used for estimating heights over the remaining swath, where lidar data was not available. A similar technique can be used for spaceborne data, in this case, over the Harvard Forest. In this paper, the comparison between lidar observations and the InSAR Duke observations are shown, and then followed by a preliminary treatment highlighting relationships in the ALOS/PALSAR Harvard data that can be exploited for similar purposes. [C494]

"The use of the SHOALS waveforms to mapping habitat within the seamless benthoscape"

The Scanning Hydrographic Operational Airborne LiDAR Survey (SHOALS) consists of an ubiquitous topographic and bathymetric LiDAR system which provides high resolution measurements of emerged and immersed elevation. Besides, the return signals, i.e., waveforms, contain signatures of the benthic return for subtidal area and of the salt marsh cover for intertidal zone. This paper highlights the seamless classification of the coast from the upper marsh to the near-shore. The subtidal seafloor is characterized in applying a supervised classifier to 12 SHOALS-derived benthic variables, supporting by underwater image classification (78.6 %). The intertidal marsh is classified in respect to the combination of a synthetic Vegetation indice (based on Red and InfraRed) and the elevation (95.2 %). The merge of both classifications points out 16 classes with an overall accuracy of 86.9 %. [C495]

"Investigation of a New Multifunctional High Performance SAR System Concept Exploiting MIMO Technology"

In this paper, we introduce an innovative system concept for synthetic aperture radar (SAR) and investigate the performance. Based on multiple-input multiple-output (MIMO) configuration, a versatile SAR operation can be feasible, for instance interferometric and full polarimetric SAR operation over a wide area simultaneously. For

this purpose the space-time coding (STC) and digital beamforming (DBF) are key elements of the proposed MIMO SAR concept. A waveform diversity gain is obtained from the STC scheme, applied on transmit and DBF on receive provides array gain and improved noise performance for each multiple SAR images. In this paper, using a simple transmit diversity technique, well known as Alamouti scheme, the complete processing topology is introduced. The performance is investigated from a system point of view. [C496]

"Theoretical Model of SAR Altimeter over Water Surfaces"

This paper provides a brief overview of the objectives and methodology of the ESA funded project SAMOSA: "Development of SAR Altimetry Studies and Applications over Ocean, Coastal zones and Inland waters", and mainly concentrates on the development of a theoretical model for the mean return echo from a synthetic aperture radar (SAR) altimeter (also know as a delay doppler altimeter or DDA) observations over water surfaces, in the same spirit set by conventional altimeters. [C497]

"Classification of Altimetric Signals using Linear Discriminant Analysis"

This paper addresses the problem of classifying altimetric waveforms backscattered from different kinds of surfaces including oceans, ices, deserts and forests. Appropriate features associated with altimetric radar waveforms are first introduced for this classification. These features are completed by radiometer temperatures and pre-processed using a linear discriminant analysis for dimensionality reduction. The classification of altimetric waveforms is finally achieved using the resulting pre-processed vector with reduced dimension. Different classification strategies are finally considered. These strategies are based on the nearest mean rule, the nearest neighbor method or on the multilayer perceptron. Various simulation results illustrate the performance of the proposed classifier. [C498]

"Low Frequency Sea and Ice Sheet Impulse Responses Acquired by the Global Ice Sheet Mapping Orbiter (GISMO) Demonstrator"

A study of sea and ice sheet surface impulse responses measured at 150 MHz is reported. The presence of both coherent and noncoherent returns is observed due to the low frequency of observation, and attempts to interpret the observed wave-forms are presented. Further analysis using a Monte Carlo simulation of one dimensional surface impulse responses suggests that the physical optics theory should be applicable for modeling the observed waveforms so that they can be used in sensing ice sheet surface properties. [C499]

"Mixed pixel return separation for a full-field ranger"

Full-field amplitude modulated continuous wave range imagers commonly suffer from the mixed pixel problem. This problem is caused by the integration of light from multiple sources by a single pixel, particularly around the edges of objects, resulting in erroneous range measurements. In this paper we present a method for identifying the intensity and range of multiple return values within each pixel, using the harmonic content of the heterodyne beat waveform. Systems capable of measurements at less than 90 degree phase shifts can apply these methods. Our paper builds on previous simulation based work and uses real range data. The method involves the application of the Levy-Fullagar algorithm and the use of the cyclic nature of the beat waveform to extract the mean noise power. We show that this method enables the separation of multiple range sources and also decreases overall ranging error by 30% in the single return case. Error in the two return case was found to increase substantially as relative intensity of the return decreased. [C500]

"Measured and FDTD Calculated Ultra Wide Band (UWB) RCS for treated test fixtures"

This paper presents comparisons of measured, and finite difference time domain (FDTD) calculations of ultra wide band scattering for dimensionally scaled, shaped and treated fixtures and measurements on a ground plane fed by vertically polarized TEM horn antenna operating from 50 MHz to 18.05 GHz. Method of moment (MoM) calculations are used to cross-check measurement and FDTD. UWB exotic material effects should be more easily observed at low scattering levels. Our findings indicate that for multiple target characteristics and over UWB bandwidths, FDTD code furnish a sufficient level of predictive accuracy (i.e. -30 to -40 dBsm) such that it might be applied in RCS predictions of treated targets where exotic RF-material interactions resulting from high power UWB waveforms might be used. RCS predictions could then be applied to improve signal processing algorithms. The paper discussed measurement technique, choice of fixtures, FDTD model, the measurement-model level of agreement and outlines a path to verification. [C501]

"Performance Assessment of GNSS-R Space Based Scatterometry by Means of Delay-Doppler Map"

This paper presents a preliminary analysis of the performance of space based GNSS-R scatterometry. In particular, this paper focuses on the characterisation of the processed delay-Doppler Map (DDM) with respect to the sea surface state as well as to the antenna pattern. The analyses are conducted on simulated waveforms; therefore characterization of models for sea state and scattering description and related assumptions adopted for the simulations are carefully addressed and described. All the analyses have been performed considering the currently broadcasted L1-band GPS C/A code signal. [C502]

"Observation of Lightning Current and Ground Potential Rise in Artificially Trigged Lightning Experiment"

Lightning current and ground potential rise (GPR) results of artificially trigged lightning experiment in Binzhou of Shandong Province during the summer of 2006 are described in this paper. The variation of grounding resistance of grounding electrode is analyzed according to the data of experiment. From the waveform of lightning current, it can be found that the process of lightning flash has two return-strokes. The amplitude of the first return-stroke is 41.59 kA with 6.02/20.24 mus waveform, and that of the second return-stroke is 29.59 kA with 4.8/11 mus waveform. The previous study done by other authors on impulse ground resistance is always limited in the laboratory, which can provide the standard impulse current instead of the factual circumstance. Transient grounding resistance (TGR) including two small return-strokes response is obtained. ATP Simulation is used to calculate the impulse grounding resistance which compares to the factual circumstance. There is time difference between peak current and peak voltage, but the simulation can not tell the difference, which means their front time Tfand time to half value Ttare identical. That is because the simulation model did not take the spark discharge and its electrical parameter change into consideration. The results can help study the process of artificially trigged lightning, meanwhile it proposes the necessity to consider grounding electrode's impulse characteristics under lightning current. [C503]

"Signal Processing Techniques for Feature Extraction and Classification using Small-Footprint Full-Waveform Airborne LIDAR"

Full-waveform digitizer hardware integration within discrete return LIDAR systems provides an enhanced capability to resolve vertical structure within the laser line of sight and potentially classify specific surfaces or objects. However, the subject of waveform signal processing as it applies to surface classification is fairly underdeveloped. This research includes the examination of LIDAR waveform pulse characteristics for known targets and vegetation types. Using these data, a number of signal processing techniques were investigated as precursors to classification engines without prior knowledge of surface slope, or obscuration density. Relevant waveform features were extracted using both Gaussian decomposition method and raw waveform features revealing surface classification distinctions. Preliminary results from this data set indicate that the total integrated waveform energy provides an efficient and rapid methodology for discrimination of vegetation from built surfaces. These results indicate that metrics derived from the full waveforms can be utilized to characterize and classify (to a limited degree) an environment without prior knowledge. [C504]

"Implementation of Pulse Compression on an Airborne Scatterometer"

The pulse compression scheme implemented on the Imaging Wind and Rain Airborne Profiler (IWRAP) is described. Developed at the UMASS Microwave Remote Sensing Laboratory (MIRSL), IWRAP is a dual-band (C and Ku) conically scanning Doppler scatterometer designed to map the atmospheric boundary layer wind fields, ocean surface wind fields, and precipitation within tropical cyclones. IWRAP has previously been deployed using a pulsed transmit waveform with a peak transmit power of 80 watts. This limits the average transmit power and sensitivity for the system which affects the more distant range gates (especially at Ku-band). As a result, IWRAP could operate only at lower altitudes (approx. 5000 ft) causing safety concerns and limiting the missions for which it can be deployed. Increasing sensitivity was achieved by converting IWRAP to a pulse compression radar system. Pulse compression is a technique that combines the increased energy of a longer pulse with the high resolution of a short pulse by implementing a frequency modulated (FM) "chirped" transmit wave-form. This method requires advanced signal processing, in which the received signal is passed through a matched filter to compress the pulse on the receiving end. A system with various chirp/filtering schemes which UMASS has recently developed will be discussed in this paper. [C505]

"Networked Waveform System for Range Velocity Ambiguity Mitigation"

A networked waveform system is developed to overcome the fundamental limitation of a single pulsed Doppler radar in resolving ambiguities. The networked radar system uses the principle that the underlying intrinsic properties of the precipitation medium remain consistent in a network. The ambiguity in range and velocity is resolved by jointly processing the measurements from all the radars in the network. In this paper results for

networked waveform system are shown for simulated data as well as data collected with first generation CASA (The Center for Collaborative Adaptive Sensing of the Atmosphere, an engineering research center established by the National Science Foundation) radars deployed in Oklahoma. [C506]

"Considerations in Pulse Compression Design for Weather Radars"

Pulse compression is a useful technique for weather radar, as an enabling technology to facilitate use of low-power solid state transmitters. It also has the benefit of improving the dynamic range and range resolution of the radar, permitting rapid scanning of a volume. The nonlinear FMpulse waveform described produces the low sidelobe levels required for weather radar applications, while remaining Doppler-tolerant within the range of radial velocities expected for weather radar (plusmn100 m/s). Traditional pulse compression waveforms must be modified to reduce their range sidelobes to levels suitable for use in weather radar. The use of pulse compression involves some changes to the methods used during radar calibration, and places some restrictions on the design and implementation of the RF and IF components of the radar. [C507]

"Digital Beamforming for a 3D MIMO SAR-Improvements through Frequency and Waveform Diversity"

The 3D imaging and nadir looking ARTINO (Airborne Radar for Three-dimensional Imaging and Nadir Observation) principle uses a sparse MIMO antenna array distributed over the whole wings of an airplane. The adaption of the ARTINO principle to high and fast flying airplanes with large wings requires new concepts to deal with PRF limitations. In this paper, an extension of the ARTINO principle is presented based on two different strategies namely the frequency diversity and the waveform diversity. Both concepts allow the implementation of the ARTINO principle to arbitrary airborne platforms. [C508]

"A VHF Radar for Deployment on a UAV for Basal Imaging of Polar Ice"

A VHF-band radar is being developed to characterize polar ice sheets and their basal conditions from a UAV developed specifically for low-altitude polar operation. The radar's 195-MHz center frequency, 30-MHz bandwidth, and 200-W transmit power will map internal layers and ice thickness with a depth resolution of less than 3 m in ice, and image the ice-bed interface. To satisfy the mass and volume constraints of the UAV, a distributed architecture was developed employing transmit/receive modules mounted on each of the eight wing-mounted wide-bandwidth Vivaldi antennas. An eight-channel digital waveform generator will be used to create transmit waveforms to simultaneously measure ice thickness and map internal layers along the nadir track, and image ice-bed interface on the left and right sides of the platform in strip-map mode. [C509]

"Extracting Tree Heights over Topography with Multi-Spectral Spaceborne Waveform Lidar"

It is generally agreed that the optimal footprint size for a spaceborne lidar is 30 m. Over topography such a large footprint can blur the canopy and ground signal together preventing information extraction. Multi-spectral lidar waveforms have been simulated with Monte-Carlo ray tracing over explicit geometric forest models. A method for using multi-spectral waveform lidar to distinguish ground from canopy returns has been tested over a range of ground slopes. The results are promising, with an initial error of +/-5 m for a signal level of only 5,000 photons with noise; an easily achievable figure. The inversion algorithms completely dominate inversion errors for all cases above 10,000 signal photons. [C510]

"A Two-Stage Approach for Decomposition of ICESat Waveforms"

Decomposing a waveform into distinct components by fitting a mixture of Gaussians impacts the ultimate interpretation of the return waveform, because the resulting parameter estimates of the Gaussian mixture directly affect the understanding of vertical structure within laser footprints. Decomposing the waveform into a mixture of Gaussians involves two related problems; (1) determining the number of Gaussian components in the waveform, and (2) estimating the parameters of each Gaussian component of the mixture. In this study, a two-stage approach is proposed and applied over three areas with different land cover characteristics. Experimental results indicate that the proposed two-stage approach typically fits Gaussian mixtures over received waveforms using fewer components, while the SSE value is smaller than that of the corresponding NASA GLA14 product. [C511]

"Comparison of Airborne Radar Altimeter and Ground-based Ku-band Radar Measurements on the Ice Cap Austfonna, Svalbard"

We compare data from the European Space Agency's (ESA) Airborne SAR/Interferometric Radar Altimeter System (ASIRAS) with ground-based Very High Bandwidth (VHB) stepped frequency radar measurements in the Ku-band. Using the VHB radar we have been able to pinpoint the major backscatter sources within the

accumulation area. The ground-based and airborne waveforms show good agreement and we therefore find the ground-based measurements valuable for validation and interpretation of the airborne altimeter waveforms. The comparison shows that the surface and the Last year Summer Surface (LSS) can be tracked in the airborne data, but fails at lower elevations with snow depths less than ~1 m. For ground truth, i.e. snow depth, we use ground based radar profiles (800 MHz), snow pits, snow probing, and density retrieved from 7-12 m deep boreholes using a neutron probe. [C512]

"Basic Radar Altimetry Toolbox"

A NEW SET OF TOOLS FOR ALL ALTIMETRY USERS The field of satellite radar altimetry has matured to a point where it is now time to encourage a multimission approach and conceive an "all-altimeter" toolbox including a tutorial. Such an integrated approach and view is vital not only for assessing the current status of what offers altimeter products but also to show the system and consistency with the past. The Basic Radar Altimetry Toolbox (BRAT) is a collection of tools, tutorials and documents designed to facilitate the use of radar altimetry data for altimetry users, experienced as well as beginners, and particularly the users of the upcoming CryoSat mission. It is able to read most distributed radar altimetry data, from ERS-1 & 2, TOPEX/Poseidon, Geosat Follow-on, JASON-1, Envisat, and the future Cryosat missions, to perform some processing, data editing and statistic and to visualise the results. A version 2 is being developed with additional visualisation features such as waveform viewing. Also, a release for the MacOS is planned. As part of the Toolbox, a Radar Altimetry Tutorial gives general information about altimetry, the technique involved and its applications, as well as an overview of past, present and future missions, including information on how to access data and additional software and documentation. It also presents a series of data use cases, covering all uses of altimetry over ocean, cryosphere and land, showing the basic methods for some of the most frequent manners of using altimetry data. [C513]

"Signal-domain registration for change detection in Time-Reversal SAR"

Change detection is a well-studied area of radar, involving the coherent comparison of two or more images. This is an important tool used to aid in surveillance, battle damage assessment, and other monitoring applications. For many of these applications, registration of the processed SAR imagery is sufficient, as opposed to registration of the raw signal-domain data. Time reversal SAR, however, is an adaptive waveform transmission technique for SAR that requires coherent processing of the data before image formation algorithms are applied. Change detection for TR-SAR, then, must be performed as a pre-processing step. Ideally, the two change detection data collections would occur over the same trajectory and antenna positions, but this is not practical, and signal registration methods, rather than post-processing image registration, need to be developed and used to compensate for variations in the antenna's positions. In this work, we perform registration in the pre-processing stage, i.e., in the signal domain rather than in the image domain. We consider change detection in a mono-static TR-SAR scenario with the SAR antenna mounted on a linear railing, derive a model for the variations in trajectory positions between the two data collections, present our pre-processing methods, and verify them with experimental data. [C514]

"Compressed sensing for OFDM/MIMO radar"

In passive radar, two main challenges are: mitigating the direct blast, since the illuminators broadcast continuously, and achieving a large enough integration gain to detect targets. While the first has to be solved in part in the analog part of the processing chain, due to the huge difference of signal strength between the direct blast and weak target reflections, the second is about combining enough signal efficiently, while not sacrificing too much performance. When combining this setup with digital multicarrier waveforms like orthogonal frequency division multiplex (OFDM) in digital audio/video broadcast (DAB/DVB), this problem can be seen to be a version of multiple-input multiple-output (MIMO) radar. We start with an existing approach, based on efficient fast Fourier transform (FFT) operation to detect target signatures, and show how this approach is related to a standard matched filter approach based on a piece-wise constant approximation of the phase rotation caused by Doppler shift. We then suggest two more applicable algorithms, one based on subspace processing and one based on sparse estimation. We compare these various approaches based on a detailed simulation scenario with two closing targets and experimental data recorded from a DAB network in Germany. [C515]

"Retrodirective airborne radar for urban surveillance"

Urban surveillance with airborne radar systems is very challenging due to blockage of line-of-sight caused by buildings. To overcome this limitation, it is very likely that the radar will be mounted on a small, inexpensive unmanned aerial vehicle (UAV) that can fly directly over an urban area of interest. Unfortunately, such systems provide very little power to their payloads, frequently less than 100 W. Despite recent advances in high-performance computing, it is extremely doubtful that such a limited power budget will be sufficient to both provide

persistent illumination of the region of interest, and implement the very sophisticated radar processing that will be required for urban operation. In this paper, we propose a means of overcoming this power deficit by off loading nearly all of the required processing to a ground station. This is accomplished by a strategy we call ldquoretrodirective airborne radarrdquo. In essence, the waveform used for transmit at a particular pulse time corresponds to a coded version of the signal received during the previous receive interval. A ground station is used to demodulate the signals (originally received at the UAV) and process them. [C516]

"The use of complementary sets in MIMO radar"

In multstatic radar it is desirable to transmit waveforms which are completely mutually orthogonal in order to minimise cross-transmitter interference. Perfect orthogonality is impossible to achieve, and in reality adaptive processing is necessary to remove interference, with some mismatch loss in main lobe size. This study proposes a method of composing waveforms from mutually-orthogonal complementary sets. Each transmitter is assigned a set of complementary waveforms to be separated in frequency. Nonlinear processing of matched filter outputs can completely remove cross-transmitter interference and suppress autocorrelation sidelobes without cost. Cross terms introduced by the nonlinear operation are handled via frequency agility and Doppler processing. The principle is demonstrated by simulation. [C517]

"A fully-integrated arbitrary waveform generator for analog matched filter"

In this paper, a fully-integrated synchronizable AWG for radar pulse compression is presented. For low power operation, we suggested the two-layered x-decoder scheme which includes address increment circuits so that HOaddr buffers need not to be operated in generating the repetitive waveforms. This can save the power consumption of HOaddr buffer by about 9-18% depending on HOaddr toggling ratio. The measurement results using MRSS IC show the chirp signal and Daubechies waveforms successfully. [C518]

"Time-frequency-based millimeter ISAR image formation"

In high range-resolution radar system, in order to achieve high range resolution, signals having wide bandwidth are required. The higher the working frequency is used, the more bandwidth is got. Stepped frequency waveforms in millimeter wave band is available to get one-dimension multiple scattering centers distribution or the profile, furthermore, two dimension multiple scattering centers distribution can also be got while the target is rotated according to the theory of ISAR processing. In order to get experimental data, A millimeter wave ISAR system is designed. The Range-Doppler algorithm and the time-frequency representations have been investigated. One of the time-frequency representations is Wigner-Ville distribution, which has a better energy concentration than the RD algorithm, but when multiple scatters are distributed in one range cell, the Range-Doppler algorithm can also recognize them but the WVD may be blurred. So there is a tradeoff in energy concentration and resolution. [C519]

"Distributed MIMO radar using compressive sampling"

A distributed MIMO radar is considered, in which the transmit and receive antennas belong to nodes of a small scale wireless network. The transmit waveforms could be uncorrelated, or correlated in order to achieve a desirable beampattern. The concept of compressive sampling is employed at the receive nodes in order to perform direction of arrival (DOA) estimation. According to the theory of compressive sampling, a signal that is sparse in some domain can be recovered based on far fewer samples than required by the Nyquist sampling theorem. The DOAs of targets form a sparse vector in the angle space, and therefore, compressive sampling can be applied for DOA estimation. The proposed approach achieves the superior resolution of MIMO radar with far fewer samples than other approaches. This is particularly useful in a distributed scenario, in which the results at each receive node need to be transmitted to a fusion center. [C520]

"Communication-inspired sensing"

Information theory, and particularly the mutual information (MI) has provided fundamental guidance for communications research. In, the MI was first applied to radar waveform design. However, the practical meaning of MI in the sensing context remains unclear. Recently, shows that under the white noise assumption, the water-filling scheme simultaneously maximizes the MI and minimizes the minimum MSE (MMSE). Such an equivalence disappears when the target parameter statistics are not perfectly known. To further the understanding of the practical meaning of MI and to establish a connection between MI and commonly adopted MSE measures for sensing, this paper takes a fresh look at the target estimation problem, by considering the general colored noise, incorporating the normalized MSE (NMSE), and establishing joint robust designs for both the transmitter (waveforms) and the receiver (estimator) under various target and noise uncertainty levels. Our results show that: i) the optimum waveform designs resulted from the MI, MMSE and NMSE criteria are all different; and ii)

compared to MMSE, the NMSE-based designs share more similarities with the MI-based ones, especially when the target and noise statistics are not perfectly known. [C521]

"Removing ping timing ambiguity via data association"

This paper considers the use of a multiple ping active sonar approach in order to track multiple targets. In most underwater target tracking applications that rely on active sonar observations, the sonar sends out a single ping at each scan interval and receives returns that might either be from target(s) or due to clutter. We propose to use a multi-ping paradigm, with the idea that the better detectability of more pings can, assuming a high clutter density, lead to better localization of targets. However, this introduces a timing ambiguity in the ping returns adding a new level of complexity in the data association. In this paper we propose a multi-ping data association (MPDA) algorithm as a solution. MPDA formulates the assignment problem as a linear program, which could then be solved using a primal-dual interior point approach. A comparison is made between three different scenarios: (a) the sonar sends out a single ping in each scan interval; there is no timing ambiguity (which return is due to which ping), (b) the sonar sends out multiple pings within a scan interval and the timing ambiguity is avoided by using orthogonal waveforms for each ping, (c) when the sonar sends out multiple pings, each ping being an identical waveform, within each scan, leading to a timing ambiguity. A well known multiple target tracking technique such as the JPDA is used in cases (a) and (b), while the MPDA algorithm is used to solve the assignment problem in case (c), and is shown to perform better than case (a) in high clutter densities. Case (b), the unrealizable bogey, performs best. [C522]

"A Modified LFM Signal in Coded Ultrasound"

The linear nature of linear frequency modulation (LFM) waveform makes it rather insensitive to frequency shifts, a property which is of great importance in ultrasound imaging. However, relatively high sidelobes remain in the autocorrelation function (ACF). A modified FLM waveform is proposed by combining LFM with binary frequency code. This waveform maintains the linear nature of LFM and at same time low sidelobos are exhibited. Simulated results show the relation between the sidelobes reduction with the amplitude of the binary frequency code. [C523]

"High frequency (HF) radar cross sections of the ocean surface incorporating a continuous wave frequency modulated source"

Frequency modulated continuous wave (FMCW) is often employed in practical HF radar ocean surface remote sensing systems. The first- and second-order monostatic cross sections of the ocean surface in the context of high frequency ground wave radar operation are derived for a dipole source with an FMCW waveform. The Fourier coefficients of the rough ocean surface are described as zero-mean Gaussian random variables. The electric field equations for the reception of vertically polarized radiation scattered from ocean surfaces are obtained. Illustrative comparisons of the cross sections between the pulsed and FMCW waveforms are presented and their properties are addressed. [C524]

"Intrapulse analysis of radar signal by the use of Hough transform"

ELINT/ESM type of electronic intelligence in the primary layer uses parameters measurements of intercepted radar signals. Nowadays modern radar uses more and more complex waveforms. Some waveforms are developed intentionally to make their intercept almost impossible. The main distinctive features of modern radar signal are hidden in its time-frequency structure. In the near past the problem of radar signal feature extraction was considered in time or frequency domain separately, because radar waveforms were relatively simple. Today, however, the signals should be observed simultaneously in both domains. Time-frequency distribution concept offers a new approach in radar signals classification/identification. The paper presents some results of Hough transform application to intra-pulse modulation analysis of radar signals. Linear frequency modulation within the pulse was considered. [C525]

"Sparse signal representation for MIMO radar imaging"

MIMO radar can achieve superior performance over the conventional phased-array radar through waveform diversity. Considerations in transmit waveform and receive filter design are central to attaining improved performance through a MIMO system. Moreover, adaptive array techniques are needed to improve accuracy, resolution and to further provide interference suppression. Recently, the weighted least-squares based iterative adaptive approach (IAA), a non-parametric and user parameter-free method was shown to provide good performance for array processing. In this paper, we demonstrate how IAA can be extended for MIMO radar applications. Our simulations show that IAA outperforms other well-established methods in the field. [C526]

"MIMO radar direction finding performance using Swerling model"

A MIMO radar uses multiple waveforms and other forms of diversity to improve the performance. A statistical MIMO radar that takes advantage of spatial diversity has been proposed earlier. This radar concept aims at mitigating the performance loss caused by fluctuations of the radio cross-section of the target. In this paper, we examine the direction finding performance of the statistical MIMO radar using the Swerling scattering model, which covers both fast and slow fluctuation of the target RCS. The direction finding performance has been studied before, but so far, the different cases of the Swerling model have not been considered. We derive the Cramer-Rao bound or a similar performance measure for each case. Numerical results are also provided. [C527]

"Multiple target tracking using particle filtering and adaptive waveform design"

In multiple target tracking with radar, weak target measurements are often hard to observe due to masking by sidelobes of measurements from stronger targets. The result is lost tracks and deteriorated joint tracking performance. In this work, we design configurable waveforms and adjust the positioning of their ambiguity function (AF) sidelobes to unmask weak targets and improve tracking performance. To track multiple targets, we develop a tracker that is based on the likelihood particle filter and the independent partitions proposal method. The proposed independent partitions likelihood particle filter (IPLPF) accurately processes the high resolution measurements resulting from the use of Bjorck CAZAC sequences that we use to construct our configurable waveforms and tracks a fixed and known number of targets. We provide simulation results that demonstrate the improvement in tracking performance of multiple targets when using adaptively configured MCPC Bjorck CAZAC waveforms versus using non-adaptive configurations or single Bjorck CAZACs. [C528]

"Theoretical assessment of MIMO radar performance in the presence of discrete and distributed clutter"

We consider mitigation of clutter that is distributed in range and Doppler frequency for scenarios that have a difference in the direction-of-departure (DoD) between a target and a clutter patch at the same radar range. We demonstrate that efficient clutter mitigation can be achieved by a MIMO radar with a specific waveform set by (adaptive) non-causal beamforming of the transmit antenna under certain limitations on the total area in range and Doppler frequency occupied by all possible targets and clutter. [C529]

"Radar altimeter echo simulation based on PO method"

Radar altimeter as one of the most important microwave sensors has been playing an important role since later 1970s in ocean environment monitoring, ocean science research and global climate change study, etc. Recently, SAR altimeters have been designed to improve the spatial resolution along the satellite track. Synthetic aperture processing inherently can give a high spatial resolution in the along track direction by combining of several pulses. This paper overviews the development of radar remote sensing. Also, the physical optics method is discussed and the process of electromagnetic simulation of radar altimeter working in burst mode with chirp waveforms over land surfaces is described. [C530]

"Channel estimation error compensation in OFDM based multi-carrier systems"

Orthogonal frequency division multiplexing (OFDM) is shown to be an efficient modulation methodology to combat the frequency selective effects of wireless channels. Frequency domain equalization (FDE) is frequently used in OFDM systems to eliminate the effects caused by the channel. In order to apply FDE, channel taps need to be estimated. In this paper, we investigate the effect of unequal amplitude constellation symbol combined with the channel estimation error on the received signal, for constellations such as M-ary quadrature amplitude modulation (M-QAM) where M >4. We give the problem formulation and propose a constellation distortion methodology in order to improve system error performance. Proposed method is supported by simulation results. [C531]

"Waveform diversity and design: Part II-Issues for waveforms and applications"

Waveform diversity and design (WDD) aspects are considered in this paper drawing relations to some of the functions between the communication system layers from the given user application through to the actual waveforms. The traditional approach to WDD was typically separated within the final waveform, which has previously been composed in a monolithic manner, in an epoch when the low capacity needs, say, associated with the traditional voice-only application coupled with a relative abundance in radio-frequency (RF) spectrum enabled this approach to be deemed satisfactory. However, in more recent times, particularly over the last decade, a wide range of issues have required a need for a reassessment of the conventional WDD approach. The factors which have motivated this need include the proliferation of user applications above the basic

communications need of voice only, to a wide range of Internet services and real-time applications. This broadening of user services and applications challenges the communications design environment particularly due to the limited availability of RF spectrum. The situation is exacerbated further by the current communication user's expectations of a wide range of variable-quality services and applications within mobile environment. WDD techniques can be used to support a breadth of communication needs by supporting the use of efficient waveform, dependent upon the given application and matching the existing communications environment. This paper, forming the second part of the two-part series, aims to demonstrate WDD within a single-antenna context, and the first part identified issues for multi-antenna systems. Features of the importance of the control and management planes are discussed, including, for example, the control loops for the purpose of enhancing performance at the service and application level through WDD techniques. A part solution within this context will employ cognitive radio (CR) especially in the efforts of maximi- sing the availability of current waveforms, and standards within commercial standards are briefly reviewed. [C532]

"Optimal waveform design for cognitive radar"

A key component of a cognitive radar system is the method by which the transmitted waveform is adapted in response to information regarding the radar environment. The goal of such adaptation methods is to provide a flexible framework that can synthesize waveforms that provide different tradeoffs between a variety of performance objectives, and can do so efficiently. In this paper, we propose a waveform design method that efficiently synthesizes waveforms that provide a trade-off between estimation performance for a Gaussian ensemble of targets and detection performance for a specific target. In particular, the method synthesizes (finite length) waveforms that achieve an inherent trade-off between the (Gaussian) mutual information and the signal-to-noise ratio (SNR) for a particular target. In addition, the method can accommodate a variety of constraints on the transmitted spectrum. We show that the waveform design problem can be formulated as a convex optimization problem in the autocorrelation of the waveform, and we develop a customized interior point method for efficiently obtaining a globally optimal waveform. [C533]

"Frontmatter"

The following topics are dealt with: waveform design methods; advances in bioimaging and analysis; relaying and cooperation; stochastic control and decision theory for cognitive radio networks; multiuser MIMO networks; programmable and reconfigurable architectures; MIMO radar and sensor fusion; adaptive filtering; array processing and source localization; beamforming; topics in communications; radar signal processing; multi-rate and digital signal processing; retinal image analysis; information theory; feedback in MIMO systems; computer arithmetic; blind system identification; multi-channel system inversion; speech dereverberation; distributed detection and estimation; wireless network management; OFDM/UWB; MIMO OFDM and cooperative relaying; compressive sensing;functional imaging and analysis; secrecy capacity; interference channels;MIMO broadcast; wireless sensor networks; adaptive methods in Monte Carlo signal; quantization; image/video processing, quantization and coding; speech analysis and recognition; quantization, coding and encryption; limited feedback and precoding; distributed statistical inference; statistical signal processing; forensics and security. [C534]

"Adapting electronic warfare to radar waveforms"

Modern methods of electronic warfare must consider that many sources of information are available to sensor systems. Situation awareness is created in a network of sensors and human operators by a process analysed in this paper. Each step in this process suggests a method of electronic warfare. The analysis is based on a division of radars into two basic groups, surveillance and tracking radars, depending on the amount of information received. Human knowledge is used in surveillance systems and this makes information flooding an effective method of attack. Distraction with noise and chaff and deception with decoys may be preferred in other cases. The conclusions have been tested in trials performed with the Swedish air surveillance system during staff training. [C535]

"The detection range improvement of two channels FMCW radar"

Beat frequency of FMCW radar contains the range information. The factors which influence the detection range of FMCW radar are discussed including the attenuation of the electromagnetic wave and the energy of FFT processing. For getting the range information more effectively, this paper presents a new idea of two channels FMCW radar system for getting remote object range information. This system has been simulated based on the MATLAB. The simulation shows that this new system can improve the detection range twice over conventional system. [C536]

"Waveform diversity and design: Part I-Issues for multi-antenna systems"

This paper, forming the first part of a two-part series, focuses on the design of error control codes (ECC) that are suitable for use in multiple-input multiple-output (MIMO) based systems. It has been shown in the past that the use of multiple antennas at both the transmitter and receiver can improve communication link performance. The use of higher spectral efficiency (increased bits per second per hertz of bandwidth) and link reliability via the implementation of diversity leads to significant increases in data throughput that can be sustained without additional bandwidth or transmit power. In order to further exploit the diversity introduced by MIMO, it is important to optimise use of the physical channel via the design of error control codes specific to the MIMO channel. Codes that have been optimised for use over such channels are termed space-time codes. An investigation of various space-time codes formed from a number of different underlying codes is presented herein. Space-time codes based on both turbo codes and low density parity check (LDPC) codes are investigated. Turbo codes and LDPC codes are discussed as these are two of the most powerful ECC derived for the single input single output (SISO) additive white Gaussian noise (AWGN) channel. The use of MIMO introduces diversity in the spatial domain. Fading across multiple antennas is optimally required to be independent in order to fully utilise the redundancy introduced via multiple antenna use. Diversity in the temporal domain is introduced via error control coding. Space-time codes operate across multiple antennas in order to maximise diversity in the spatial domain (diversity advantage) but also maximise diversity in the temporal domain (coding advantage). The paper explains design rules for maximising both diversity and coding advantage in order to design powerful space-time codes. Two specific examples are presented within the paper, one based on turbo codes and another based on LDPC codes. Turbo c- odes and LDPC codes provide maximum coding advantage for SISO based systems achieving performance extremely close to the AWGN channel capacity and therefore it makes sense to investigate the re-use of such coding schemes within the MIMO environment. There are many uses for MIMO including beamforming techniques typically used in sensor arrays for directional signal transmission or reception but the sole focus of this paper is on the code design for the space-time channel. Furthermore, MIMO and space-time codes have been developed principally for use in terrestrial applications where fading environments are exploited. This paper concludes with ideas for the application of MIMO to problems in satellite communications. [C537]

"Adapting electronic warfare to radar waveforms"

1. Noise is simple but ineffective. 2. Deception requires detailed knowledge and simple situations. 3. Flooding affects operators. 4. Best protection is training and theory. 5. Tests confirm theoretical conclusions. [C538]

"Compressed sensing in MIMO radar"

Compressed sensing is a technique for efficiently sampling signals which are sparse in some transform domain. Recently, the idea of compressed sensing has been used in the radar system. When the number of targets on the range-Doppler plane is small, the target scene can be reconstructed by employing the compressed sensing techniques. In this paper, we extend this idea to the MIMO radar. In the MIMO radar, the compressed sensing technique can be used to reconstruct the target scene when the signals are sparse in the range-Doppler-angle space. To effectively reconstruct the target scene, it is required that the correlation between the target responses be small. In this paper, a waveform design method is introduced to reduce the correlations between target responses. Because of the increased dimensionality in MIMO radars as compared to phased array radars, the impact of compressed sensing will be very significant there. [C539]

"Bat-inspired adaptive design of waveform and trajectory for radar"

We propose to design jointly the waveform and trajectory of a radar mounted on a moving platform, in order to improve the system performance for tracking maneuvering targets. Inspired by bats, we develop an adaptive algorithm that chooses the optimal pulse repetition interval (PRI) and path of the radar. Our method automatically schedules a low PRI when it recognizes that the target executes a maneuvering action. Simultaneously, it selects the radar trajectory which provides the best estimation of the target parameters. We derive our approach under a framework of sequential Bayesian filtering and implement it with a particle filter. We consider a library of target state models associated with different PRI values and use multiple model to schedule the optimal PRI. We apply the posterior Cramer-Rao bound to measure the system performance and decide on the optimal radar path.We demonstrate the advantages of the adaptive radar scheme using numerical examples. [C540]

"MIMO radar with broadband waveforms: Smearing filter banks and 2D virtual arrays"

In this paper MIMO radars with broadband waveforms are considered. A time domain viewpoint is taken, which allows frequency invariant beamforming with a filter bank called the smearing filter bank. Motivated by recent work on two dimensional arrays to obtain frequency invariant one dimensional beams, the generation of two dimensional virtual arrays from one dimensional ULAs is also considered. It is also argued that when the

smearing filter bank is appropriately used, frequency invariant 2D beams can be generated. [C541]

"Efficient time-frequency and bi-frequency signal processing on a reconfigurable computer"

Reconfigurable computers allow applications developers to tailor both the software and the hardware of the computer for efficient execution of computationally intensive algorithms. This increases the speed at which the algorithms are executed, making computationally intensive algorithms more useful for real-time and near real-time applications in electronic intelligence (ELINT) applications. This paper presents a study on the use, accuracy, and efficiency of the SRC-6 reconfigurable computer to perform both time-frequency and bi-frequency signal processing. To test the performance, continuous waveform (CW) radar signal modulations are examined using the Choi-Williams distribution (CWD) to calculate the time-frequency characteristics of a signal. Also, the FFT accumulation method (FAM) is used to calculate the cyclostationary bi-frequency characteristics of a signal. [C542]

"Novel waveform and processing techniques for monostatic and bistatic radar"

In this paper, we study the resolution properties of linear FM pulses (chirps). Based on the ambiguity surface properties of chirp pulses, we propose a transmission strategy and a processing algorithm that has better delay-Doppler resolution than traditional matched filtering. It is shown that the improvement in resolution is accompanied by a small degradation in detection performance. We also discuss the general requirements on the signal set that will result in improved resolution properties when using the proposed form of processing. Our results also show that we can change resolution performance for detection performance under certain conditions. The contribution of our proposed scheme is a significant increase in delay-Doppler resolution without a significant increase in system or computational complexity or a significant degradation in detection performance. We also extend the results to a simple bistatic radar configuration and evaluate the performance for orthogonal and near-orthogonal transmitted signals under varying conditions. [C543]

"Frames and a vector-valued ambiguity function"

The setting is that of vector-valued codes of length N. The background for this setting is our construction of new complex valued constant amplitude zero autocorrelation codes (off dc)-CAZACs, which serve as coefficients for phase coded waveforms with prescribed ambiguity function behavior. Vector-valued CAZACs are relevant in light of vector sensor and MIMO technologies. The goal is to define the discrete vector-valued ambiguity function. Our notion of frame multiplication allows us to make this definition. The theory and relevance of such ambiguity functions is developed, including computation of code from received discrete vector-valued ambiguity function data. [C544]

"Dynamic waveform design for target tracking using MIMO radar"

In this paper, we investigate waveform design for dynamic target tracking using a multiple-input, multiple-output (MIMO) radar system. The agile tracking application is based on our recently derived Cramer-Rao lower bound (CRLB) for estimating target position and velocity, that is represented in terms of the transmitted waveform parameters. Using the CRLB at high signal-to-noise ratio (SNR), we adaptively select the waveform parameters that minimize the predicted mean-squared error (MSE) at each time step. We demonstrate the improvement in agile tracking using numerical simulations. [C545]

"Unitary design of radar waveform diversity sets"

In this work, multiple radar waveforms are simultaneously transmitted, emitted from different ldquovirtualrdquo antennas. The goal is to process the returns in such a way that the overall ambiguity function is a sum of ambiguity functions better approximating the desired thumbtack shape. A 4times4 example involves two spatially separated antennas with each able to transmit and receive simultaneously on two different polarizations. The 4times4 unitary design dictates the scheduling of the waveforms over the four virtual antennas over four PRIs (pulse repetition intervals), and how the matched filtering of the returns over four PRIs is combined in to achieve both perfect separation (of the superimposed returns) and perfect reconstruction. Perfect reconstruction means the sum of the time-autocorrelations associated with each of the four waveforms is a delta function. Conditions for both perfect separation and perfect reconstruction are developed, and a variety of waveform sets satisfying both are presented. [C546]

"Wideband arbitrary waveform generator for enhanced spaceborne SAR"

The paper presents a digital waveform generator for spaceborne applications capable of synthesizing a wide band signal with a high spectral purity and a flexible configuration capability from pulse to pulse. A parallelized

processing architecture is employed to overcome space qualified ASICs clock limits. The baseband generator synthesizes linear and non-linear chirps from DC to 500 MHz. Signal phase and amplitude digital compensation is allowed in both time and frequency domain. Finally the generator is provided with frequency hopping and PSK modulation capabilities. [C547]

"Resolution and unmasking of CLEAN and LMMSE algorithms using coded waveforms"

OFDM waveforms offer strong advantages for integrated communication and radar systems. Nevertheless they require signal processing at the receiver that can serve for sidelobe suppression in order to avoid target masking. In this paper two reiterated filtering techniques, LMMSE and CLEAN, are considered and compared for this type of signal to evaluate their unmasking and resolving capabilities. Masking of a weak target in the sidelobes of a strong target is considered, but also resolution of strong targets spaced equal or less than a resolution cell. Moreover the performance of reiterated LMMSE and CLEAN is compared for OFDM and P3 coded waveforms. When Doppler is present both LMMSE and CLEAN performances degrade. [C548]

"Adaptive waveforms selection for IMM-UKF tracking architecture: application to multifunctional radar systems in heavy cluttered scenario"

Modern phased array radars are able to adaptively manage the way in which they explore the surroundings, both in the space domain (thanks to their beam steering capability) and in the time domain (via a smart selection of convenient waveforms), in order to suit a variety of environments. Multifunction radars, more than tracking radars, are in big need of an efficient way to allocate their limited resources (namely, the radar time) to a number of tasks, so that being adaptive is not only a boost for the tracking performances, but also a way to spare resources during undemanding tasks (i.e. big targets in clear areas) and reroute them towards more difficult ones. [C549]

"Wideband OFDM pulse burst and its capabilities for the Doppler processing in radar"

The use of multicarrier (MC) signals could support a new generation of radar that would provide simultaneously RF agility and Doppler processing. Easy to generate in digital signal processing (DSP), the well-known orthogonal frequency division multiplexing (OFDM), originally a communication waveform, is a first choice candidate. Its flexible structure makes both radar concepts of continuous and pulse burst waveforms, compatible. In this paper, the focus is on the pulse burst. The novelty of the paper is to investigate capabilities for Doppler processing of the OFDM pulse burst in both narrowband and wideband cases. Since the waveformpsilas bandwidth-time (BT) product is high, the analysis starts with the narrowband approximation (very low speeds) and rapidly moves on to the true wideband version (higher speeds) of the Doppler effect, in an elementary scenario with a single point target. [C550]

"An update on the DSTO advanced phased array-proof of concept system"

This paper describes the DSTO ldquoproof of conceptrdquo radar system which has been designed to provide a basis for the testing of many of the recent advances in signal processing, and a new radar techniques have been identified in the literature. Capabilities of the radar include: true time delay beam formation, independent element transmit waveform selection, independent element receive control with up to four channels per receive element. In addition the radar will have digital adaptive beam forming and an advanced control system that operates as part of a network of sensors. [C551]

"Study on non-linear stepped chirp radar system"

The linear stepped chirp radar suffers from (a) signal-to-noise ratio (SNR) losses due to amplitude weighting used to suppress nominal range sidelobes both in sub-pulse and inter-pulse compression and (b) range ambiguities due to periodicities in the inverse discrete Fourier transform (IDFT). The paper analyses the root cause of range sidelobes and proposes a new easily realizable non-linear stepped chirp waveform which achieves low sidelobes without incurring the SNR loss associated with conventional sidelobes suppression techniques. An alternatively DFT processing is introduced which can achieve both unambiguous velocity and high resolution ranging under HPRF mode. Simulation results have been given to prove this scheme. [C552]

"The parameter setting problem of signal OFDM-LFM for MIMO radar"

Multiple Input Multiple Output (MIMO) radar is a new radar technique, which transmits orthogonal signal at the transmitter and forms wide beam. In this paper, we select the orthogonal frequency division multi LFM signal as the orthogonal waveform. In this model, the bandwidth of single LFM and the frequency interval are important. Only the situation of equi-interval frequency is studied here. Assume the bandwidth is fixed, the selection of

frequency interval affects not only the range resolution and processing speed, but also other performance of radar. In this paper, we investigate the relationship of the two parameters, also the concepts of range sidelobe are introduced. Then we demonstrated the random initial phase can suppress the second-class sidelobe. In the end, we draw the conclusion that by appropriate parameter setting, the OFDM-LFM waveform can has good performance in MIMO radar. [C553]

"Ionospheric monitoring by ELF signals received at Moshiri station in Japan"

The observation at Moshiri (Hokkaido), Japan of ELF transmitter signals (~82 Hz) from a Russian transmitter has been described. The detection and identification, wave characteristics. etc. have been analyzed by using the ELF waveform data at Moshiri(two horizontal magnetic fields and one vertical electric field), which are subjected to the conventional FFT (fast Fourier transform) analysis, Nuttal filter etc. The wave characteristics at Moshiri at a distance (~6 Mm) from the transmitter, are compared with those near the anti-podal points, in order to compare with the ELF full-wave propagation theory. [C554]

"Target detection by passive coherent FM based bistatic radar"

Bistatic passive radars have many advantages over the monostatic ones because they are undetectable and silent. In passive coherent location, the original source of energy is derived from a waveform of opportunity in the environment and the re-radiated energy from the target is processed to decide about the existence of the target. More over bistatic radars receive forward scatters from target in place of the backscatters in monostatics systems. As a result of the larger forward scattered RCS, the stealth targets can be detected easier. Passive radar does not need any frequency allocation so are very attractive for surveillance. Multipath effects and direct path interference are two problems that should be solved. For accurate position measurement we used new ambiguity function processing and TDOA methods. This system by using terrestrial FM radio signals could detect a civil plane about 210 Km away. [C555]

"Dynamic frequency selection requirements"

A collection of slides from the authors' conference presentation is given. [C556]

"Application of artificial neural computation in topex waveform data: A case study in water ratio regression"

Using the TOPEX radar altimeter for land cover studies has been of great interest due to the TOPEX near global coverage and its consistent availability of waveform data for about one and a half decades from 1992 to 2005. However, the complexity of the TOPEX Sensor Data Records (SDRs) makes the recognition of the radar echoes particularly difficult. In this paper, artificial neural computation as one of the most powerful algorithms in pattern recognition is investigated for water ratio assessment over Lake of the Woods area using TOPEX reflected radar signals. Results demonstrate that neural networks have the capability in identifying water proportion from the TOPEX radar information, controlling the predicted errors in a reasonable range. [C557]

"Feature extraction using surrounding-line integral bispectrum for radar emitter signal"

In everchanging threat emitter environment, specific emitter identification (SEI) technology extracts subtle but persistent features from received pulse signal to create a fingerprint unique to a specific radar. Unlike conventional five parameters deinterleaving algorithm, which can be grossly ambiguous for radar emitter sorting, the SEI technology provides hardware specific identification. In this paper, we propose an approach for extracting unintentional phase modulation features caused by oscillator based on surrounding-line integral bispectrum. The quantitative features, i.e. bispectra entropy, waveform entropy and mean of surrounding-line integrated bispectra, is extracted using entropy-like function to reveal the subtle difference between emitters. Computer simulations show that how the phase-noise-induced signal changes analysis based on bispectrum approach can be used to determine which of emitters transmitted a pulse signal. [C558]

"Delay-doppler ambiguity function of ultrawideband-throb signals"

The performance of ultrawideband (UWB) radar in target detection, resolution, and recognition depends on the structure of the radar waveform. In this paper, the principles of waveform diversity and design (WDD) for generating periodic and orthogonal UWB-impulse signals are described. A mathematical model for a UWB-throb signal that yields the practical advantages of the widely used linear frequency-modulation (FM) ldquochirprdquo signal is presented. The structure of the UWB-throb signal is designed based on a pulse-time modulation scheme. The delay-Doppler ambiguity function of the UWB-throb signal is derived for performance analysis. Computer plots of the UWB-throb signal, its autocorrelation function, and ambiguity function are generated to

illustrate its characteristics and advantages for high-resolution impulse radar. [C559]

"Use of adaptive non-causal transmit beamforming in OTHR: Experimental results"

We report results from an experiment that applied multiple-input multiple-output (MIMO) waveform techniques to over-the-horizon radar (OTHR). The experiment objective was to demonstrate that adaptive transmitter beamforming could be used to reject spatially discrete radar clutter. In MIMO radar architectures, conventional or adaptive transmitter beamforming occurs following waveform transmission, propagation, scatter from targets and clutter sources, return propagation and finally signal reception. We have successfully rejected spatially discrete clutter to the noise floor of the radar return with rejection in excess of 35 dB achieved using common adaptive algorithms and straightforward training data selection. As part of this we estimated the transmitted waveform direction-of-departure from the transmitter array to the target and used the estimate as the preserved steer direction in the adaptive beamformer. The direction-of-departure estimates agreed well with the true values. [C560]

"CLEAN deconvolution for sidelobe suppression in random noise radar"

The term random noise radar (RNR) refers to a class of radar using random noise as its transmitted signal. Noise waveforms have proven useful in a number of radar applications; however, dynamic range performance suffers due to high range sidelobes. This paper investigates the use of the CLEAN deconvolution algorithm to suppress range sidelobes in noise radar. Simulation results are presented demonstrating the algorithms effectiveness, using both point and contiguous radar targets. [C561]

"Accurate arbitrary resampling with exact delay for radar applications"

In this paper we consider the design of batch and streaming resamplers with arbitrary sample rate change, prescribed accuracy and known exact delay. We are primarily concerned with applying these resamplers in digital radar systems and the major contribution of this paper is to provide expressions for the exact delay through the resampler implementation. The batch resampler can be used to reduce post range- processed radar data to one sample per range cell irrespective of the original receiver sample rate. It permits unstructured joint receiver sample rate fsand radar waveform bandwidth fbselection; with the only requirement that the receiver sample rate achieve Nyquist's sampling theorem criteria for the radar waveform. The streaming resampler can be used to enforce that there are an integer number of samples of the receiver sample rate for each waveform pulse repetition interval Tp. While streaming resampling is usually not required for radar systems with cooperative waveform generation, it can be essential for emitter-of-opportunity radar where the transmitted waveform sample rate may be unknown. [C562]

"Range and cross range joint processing of MIMO radar using DS-CDMA signal"

It has been shown that Multiple-Input Multiple-Output radar can dramatically improve the performance of a radar. In this paper, the Direct Sequence Code Division Multiple Access(DS-CDMA) sequence are used as transmitting waveforms for the different antennas. Due to the high sidelobe of the code correlation, conventional code correlation range compression methods cannot provide a proper range profile of the targets. In this paper, we find that range and cross range joint Capon beamforming provide a higher angle resolution but also suppress the range sidelobe. [C563]

"A novel fractional autocorrelation based feature extraction approach for radar emitter signals"

An effective approach to extract the features of ambiguity function main ridge (AFMR) slice of radar emitter signals is proposed, in which fractional autocorrelation is used to search the AFMR, and moment method is adopted to describe the distribution characteristics of AFMR slice. The results of theoretical analysis and simulation experiments show that, the extracted characteristics vector of AFMR slice clearly expresses the differences of waveform in different signals, and it has strong compactness within clusters and good ability to resist noise. So it can be served as the optional parameter of deinterleaving for complicated radar emitter signals. [C564]

"Long-Term integration algorithm using the HPRF stepped frequency waveform"

A long-term integration algorithm using the HPRF stepped frequency waveform is presented to improve the range and Doppler resolution of moving targets. A stepped frequency radar signal is applied to realize high range resolution; a long-term integration is applied to realize high Doppler resolution. Besides, with the long-term integration, the gain from coherent integration can also be improved a lot, which is of great benefit to the detection of small targets. During this processing, a segment accumulation method is proposed to reduce the

storage and computational requirements; a velocity compensation method based on the keystone transform is presented to overcome the image aliasing due to the coupling effects of moving targets; then a synthetic high resolution image generation method is introduced to synthesize an unambiguous range-Doppler image of moving targets. Finally the performance of this algorithm is demonstrated using simulated data as well as experimental results. [C565]

"Two dimensional imaging of extended targets by MIMO radar using hopped frequency signal"

Multiple input multiple output (MIMO) radar transmits orthogonal or non-coherent waveforms which greatly improve the array aperture. Works published generally only consider narrow band signal and/or point targets located in one range cell. In this paper, the study of range and azimuth angle imaging of extended targets employing wideband hopped frequency signals is discussed. Hopped frequency signal are sensitive to a targetpsilas speed. A kurtosis based criterion is presented for doing motion compensation. In order to mitigate the high side lobe of the hopped frequency signal, a ldquoCLEANrdquo based signal processing procedure is also presented. [C566]

"The study of multi-false targets deception against stepped-frequency waveform inverse synthetic aperture radar"

A method of synthesizing multi-false-targets signal for countering stepped-frequency ISAR is proposed by single-false-target information, and the scheme of the image synthesizer to produce three-false-targets signal against stepped-frequency inverse synthetic aperture radar is given in this paper. The multi-false-targets signal synthesis theory and system architecture of the image synthesizer is firstly described. Then, the simulations to synthesize multiple false targets have been done. Lastly, the multiple false targets deception jamming against stepped-frequency inverse synthetic aperture radar has also been accomplished. The simulation results demonstrate the proposed method is effective and feasible. [C567]

"A new technology of multi-false targets deception against chirp waveform inverse synthetic aperture radar"

Based on single false-target information, the method to produce multi(two)-false targets is proposed from algorithm angle to realize multi-false-targets deception jamming against chirp waveform inverse synthetic aperture radar. In this paper, a modified phase modulation coefficient is firstly proposed, accordingly the method to synthesize multi-false-targets signal is put forward. Furthermore, the scheme that can synthesize the signal of multi-false-targets is given. Lastly, the theory analysis and simulation experiments are done. The simulation results demonstrate that the proposed phase modulation coefficient and the method are feasible and effective. Comparing with the original phase modulation coefficient which can only produce a single false target, the proposed phase modulation coefficient can produce the signal that contains multi-false-targets information, and the two false targets are successfully synthesized. [C568]

"Improved High Range Resolution Profiling using synthetic spectrum processing and stepped-frequency LFM waveforms"

In this paper, an improved synthetic spectrum signal processing schemes using stepped-frequency waveforms is presented which enables High Range Resolution Profiles (HRRP) of targets. This synthetic spectrum schemes contrasted with conventional or hybrid stepped-frequency methods achieves both unambiguous range coverage as well as good range grating lobes without requiring a large number of frequency steps. We present the reason why the grating lobes are located and why the ambiguous ranges are occurred by analyzed the ambiguity function, autocorrelation function and parameter setting of such signal. Because this method need more data memory and computation resource, we studied the factors which effected the performance of high range resolution profiling, such as waveform, processing parameter and system delay, and give a realized application for real time system. [C569]

"High-resolution imaging using a narrowband MIMO radar system"

This paper presents a system model and method for the two-dimensional (2-D) imaging application via a narrowband multiple-input multiple-output (MIMO) radar system with two perpendicular linear arrays. The proposed method utilities the spatial parallel procedure sampling the scattered echoes during a single snapshot illumination, instead of the spatial sequential one sampling the scattered echoes during multiple snapshot illuminations in inverse synthetic aperture radar (ISAR) imaging. Consequently, the complex motion compensation in ISAR imaging can be avoided. Furthermore, in our array configuration, multiple narrowband shared-spectrum waveforms coded with orthogonal polyphase sequences are employed to illuminate a target.

The mainlobe of the compressed echoes from the different filter band for all scatterers could be located in the same range bin, and thus, complex range alignment in classical ISAR imaging is not necessary. Numerical simulations based on synthetic data are provided for testing our proposed method. [C570]

"Snail Identification Based on Fourier Transformation"

Based on the monitoring of satellite remote sensing images, a lot of big progresses have been made in environment analysis and researches about the Schistosome snail breeding ground and the distribution of snails in marshland. This paper focuses on the identification of the Schistosome snail individual goals. Based on the image segmentation by maximum inter-variance, the objects, including snails, are segmented from the background. The radius functions of the typical snails are calculated by scanning the boundary of the object with 8-neighborhood following method. By matching the waveform of Fourier transformation, the snail targets are identified. In the laboratory environment, the recognizing rate can reach over 90% and it has robust in rotation, scaling and translation. [C571]

"Inverse Synthetic Aperture Radar imaging at 580 GHz"

We have demonstrated sub-centimeter resolution inverse synthetic aperture radar (ISAR) imaging using a 580 GHz, frequency modulated continuous wave (FMCW) radar. This ISAR technique uses pulse compression possible with the FMCW waveform to achieve resolution in range, and exploits rotation of the target to achieve resolution in cross-range. The technique relies on the illumination of the entire target rather than scanning with a narrow beam, which permits larger ranges or smaller apertures than real-aperture approaches. The data collection time required for an ISAR image is less than the collection time with a mechanically scanned beam, which is an advantage in highly dynamic scenarios. The ISAR algorithms presented here accommodate radial motion of the target and non-uniform rotation rates. Thus, the algorithms are suitable for applications where the target motion is not under the control of the observer. These algorithms enhance submillimeter-wave radar technology for surveillance and concealed-object detection. [C572]

"A novel method of identifying moving status of bird based on waveform entropy variance"

Surveillance for bird is quite significant for security and development of humanpsilas aviation. ISAR imaging for bird with frequency-stepped chirp high-resolution radar is a novel and vital approach. However, the quality of image could be deteriorated by micro-Doppler effects resulting from birdpsilas flapping wings, and even target can not be identified successfully by radar. It is extraordinarily vital to identify whether bird is gliding or flapping accurately to achieve its clearer image. In this paper, an operated and valid method of identifying moving status of bird with waveform entropy variance is proposed via processing each HRRP(high-resolution range profile) from spectrogram, after the principle of micro-Doppler based on ISAR imaging with frequency-stepped chirp signal is analyzed. The effectiveness of the proposed method is proved by simulation results. [C573]

"OFDM Based UWB Synthetic Aperture Through-wall Imaging Radar"

Ultra wide band technology (UWB) is a new radio technology based on no sinusoidal waves, with very great bandwidths. UWB technology has double advantage: good capacity of penetration in building materials (concrete, brick, wood...), and high resolution (few centimetres) for radar applications. One of the most promising applications is the through the walls and the obstacles imaging, which has multiple outlets so much on the military level (at the time of attacks, taking of hostages...) that in the sector of civil safety (search for people under debris, in a fire...). This paper presents a feasibility study and a performance evaluation of portable UWB synthetic aperture radar (SAR) for through the walls imaging. Our system is based on multi-bands OFDM approach to ensure a double functionality of radar and communication, in possible remote operations. To obtain 2D radar images, back projection algorithm for time inversion was applied to SAR data. Modeling and simulation are carried out under Matlab/Simulink It was found that high resolution radar imaging (about 10 cm) are possible with a signal to noise ratio of -10 dB, for a radar system working below 3 GHz. Parameters such as UWB waveforms and number of OFDM carriers for an optimal radar system operation will also be discussed in this paper. [C574]

"High resolution MIMO-HFSWR using sparse frequency waveform"

In this paper, we propose a concept of multiple-input multiple-output high frequency surface wave radar (MIMO-HFSWR) system with widely separated antennas transmitting and receiving the sparse frequency waveforms. The proposed concept obtains several advantages over the conventional HFSWR system such as finer resolutions and better flexibility. The ambiguity function (AF) was derived in detail to assess the proposed system. The impacts of Doppler effect and the geometry configuration factor are also studied. [C575]

"Radar emitter signal classification based on mutual information and fuzzy support vector machines"

In this paper, a novel method based on mutual information and fuzzy support vector machines for recognizing radar emitter signals is introduced. The radar signal waveforms are the linear frequency modulation (LFM), frequency-coded signals, BPSK and QPSK. The wavelet ridges and higher-order statistics are used to extract signal features. Mutual information measures is used to reduce the redundant components from the feature vectors set. Then these discriminative and low dimensional features achieved are fed to a fuzzy support vector machine classifier for multi-class patter recognition. In simulation, the classifier attains over 78% overall average correct classification rate. Experimental results show that the proposed methodology is efficient for different complex radar signals detection and classification. [C576]

"Modified subspace algorithms for DOA estimation using MIMO array"

This paper proposes two subspace algorithms, named S-MUSIC and S-SSMUSIC, based on the MUSIC and SSMUSIC algorithms for direction finding in MIMO array systems, which achieve improved performance by exploiting the waveform information about the transmitted signals. Numerical results show that the proposed algorithms outperform their traditional counterparts at low SNR. [C577]

"Models and Signal Processing for Millimeter-Wave LFMCW SAR Imaging"

In remote sensing applications, there is a special interest in lightweight, cost effective, and high resolution imaging sensors. The combination of linearly frequency modulated continuous wave (LFMCW) technology and synthetic aperture radar (SAR) technique can lead to such a sensor. As such, this paper concentrates on the models and signal processing of millimeter-wave (mmW) LFMCW SAR for high-resolution imaging, which includes two main parts. In the first part, the system models and useful relations for mmW LFMCW SAR imaging are provided, and an image formation algorithm that takes into account the special characteristics of CW (continuous wave) SAR is investigated. The second part focuses on the impact of LFMCW waveform errors on SAR imagery. The allowable magnitudes of phase error for each category are quantified, and an effective compensation technique for compensating possible frequency nonlinearity errors in LFMCW signals is presented. Thus the novel combination of mmW LFMCW and SAR can pave the way for the development of a small, lightweight, and high resolution imaging sensor. [C578]

"Through wall radar imaging using UWB noise waveforms"

This paper examines the results of our research on the use of ultra-wideband noise waveforms for imaging objects behind walls. The advantages of using thermally generated noise as a probing signal are introduced. The technique of heterodyne correlation, used to inject coherence in the random noise probing signal and to collapse the wideband reflected signal into a single frequency, is presented. We address issues related to locating, detection, and tracking humans behind walls using the Hilbert-Huang transform approach for human activity characterization. The results indicate that noise radar technology combined with modern signal processing approaches is indeed a viable technique for covert high-resolution imaging of obscured stationary and moving targets. [C579]

"Compressive sensing and waveform design for the identification of Linear time-varying systems"

In this paper, we investigate the application of compressive sensing and waveform design for estimating linear time-varying system characteristics. Based on the fact that the spreading function system representation is sparse in realistic system scenarios, we propose a new method for the identification of narrowband, wideband and dispersive systems using a small set of measurements. Through numerical simulations, we successfully demonstrate the feasibility of using compressive sensing to estimate the system spreading function. [C580]

"MIMO Phased-Array for SMTI Radar"

Waveform diversity techniques for radar have gained considerable interest over the past several years. Novel radar waveforms have been proposed to improve detection performance and metric accuracy (i.e., angle estimation performance). This paper explores the potential for using a waveform diversity technique known as multiple input, multiple output (MIMO) radar to improve the detection performance of slow moving surface targets from a moving radar platform. The MIMO radar system achieves superior performance by transmitting unique uncorrelated waveforms from each antenna subaperture as opposed to the traditional approach of transmitting a single coherent waveform across the entire aperture. The results show that the radar system minimum detectable velocity (MDV) can be reduced by exploiting the ability of a MIMO system to effectively increase the radar antenna aperture. [C581]

"A Differential Based Approach for Sense-Through-Foliage Target Detection Using UWB Radar Sensor Networks"

In this paper, the foliage penetration measurement data is provided by Air Force Office of Scientific Research (AFOSR). When radar echoes are in good quality, the detection of target can be achieved by applying our differential based technology on received single UWB radar waveform. We compared our approach in case of no target as well as with target against the scheme in which 2-D image was created via adding voltages with the appropriate time offset. Results show that our approach can work much better. When radar echoes are in poor condition and single radar is unable to carry out the detection, we employ both radar sensor networks (RSN) and RAKE structure to combine the echoes from different radar members and successfully detect the target. [C582]

"UWB Radar system for road anti-collision application"

The inter-vehicles communication is becoming increasingly mandatory to improve the road safety and to allow a better transport management. The concept behind an intelligent vehicle consists in equipping this vehicle with an optimum number of sensors, in order to perceive the environment surrounding it and to ensure an automatic guidance control and the communication with the infrastructure and other vehicles. Among the most often used tools for this objective, we can cite the embedded radar. [C583]

"Detecting and Tracking Separating Objects Using Direct Monopulse Measurements"

A significant complication to the ballistic missile tracking problem is the tendency for target "spawn": one ballistic object becomes two, several or several hundred, of which only one or a few are of concern (warheads), while uninteresting objects such as chaff and boost-rockets comprise the rest. To discern which is which takes time; and during that time it remains vital to maintain surveillance on all objects. Unfortunately these objects are closely-spaced (CSOs), and detection/tracking for CSOs is notoriously difficult. One approach is to use radar waveforms of such high resolution that all objects are "resolved" by a sharp ambiguity function peak. However, not all radar systems have the required bandwidth or operational modes, and inclusion of those modes in new radars would impact the cost. It appears that with unresolved targets there is little that can be done to improve tracking until the targets become resolved. Nonetheless, recent work with advanced statistical modeling of monopulse radar returns has questioned the need for such high resolution: signal processing techniques can "see" inside a previously-closed resolution cell in a similar way that a mis-formed Hubble mirror can be corrected to see clearly.In this presentation we proffer two approaches. In the first, we discuss the maximum-likelihood approach: it turns out that it can be shown that up to 5 targets can be resolved from between two matched filter samples, rather than the one-per- sample case that might otherwise be thought. We also will present an even more advanced statistical approach known as particle filtering. The standard tracking approach is to work with detection "hits"; that is, to separate the signal processing and tracking. The particle filter is a more natural integrated approach, and we have found tracking errors reduced by 50% or more by its use along with significant increase in speed of detection of multiple target spawn. [C584]

"A compressive beamforming method"

Compressive sensing (CS) is an emerging area which uses a relatively small number of non-traditional samples in the form of randomized projections to reconstruct sparse or compressible signals. This paper considers the direction-of-arrival (DOA) estimation problem with an array of sensors using CS. We show that by using random projections of the sensor data, along with a full waveform recording on one reference sensor, a sparse angle space scenario can be reconstructed, giving the number of sources and their DOA's. The number of projections can be very small, proportional to the number sources. We provide simulations to demonstrate the performance and the advantages of our compressive beamformer algorithm. [C585]

"Frequency dependence of range resolution in wideband radar range data"

This paper uses wideband data collected at a radar range data collection facility to show that range resolution, in the sense of being able to resolve closely-spaced scatterers, varies not only as function of bandwidth, but also as a function of frequency. This phenomenon was predicted in a recent paper [1] using simulation results. The present paper verifies those results using real data. The ability to resolve two closely-spaced scatterers is measured using a defined quantity called peak separation quality. The present paper derives an expression for peak separation quality for the synthetic wideband waveforms used at the collection facility. This quantity is shown to vary in a predictable way as a function of both frequency and bandwidth. Data examples verify this result. This phenomenon is significant for wideband distributed aperture applications that use frequency variation to achieve waveform diversity. [C586]

"An Algorithm for Selection of Stepped-Frequency Pulse Trains with Low Sidelobes"

For purposes of a high range resolution radar, it is desirable to transmit signals with wide overall bandwidth. Frequency stepping is one of the known and well-studied techniques that can be used to achieve this goal. The autocorrelation function of a uniform stepped-frequency pulse train suffers from relatively high range sidelobes and grating lobes. The purpose of this paper is to present a new algorithm for designing stepped-frequency waveforms whose sidelobes are suppressed below a desired threshold level. [C587]

"Modelling of the Impact of Antenna Rotation on Clutter Improvement Factor in Naval Radars Operating in Littoral Environments"

Naval operations are increasingly conducted in the littoral environment, requiring extremely high clutter improvement factors (CIF) to be achieved to enable small target detection. This paper describes a littoral clutter model to support synthetic baseband radar data generation and examines the impact of antenna rotation on the clutter filtering required to achieve these high clutter improvement factors. The impact of this analysis on waveform and signal processing design for future naval radars is discussed. [C588]

"Polarization optimization for scattering estimation in heavy clutter"

Controlling the polarization information in transmitted waveforms enables improving the performance of radar systems. We consider the design of optimal polarization for the estimation of target scattering embedded in heavy clutter. The goal is to minimize the mean squared error of the scattering estimation subject to an average radar pulse power constraint. We show that such a problem is equivalent to the optimal design of a radar sensing matrix that contains the polarization information. We formulate the optimal design as a nonlinear optimization problem which can be recast it in a convex form and is thus efficiently solvable by semi-definite programming (SDP). We compare the sensing performance of the optimally selected polarization over the conventional approaches. Our numerical results indicate that a significant amount of power gain is achieved in the target scattering estimation through such an optimal design. [C589]

"Properties of the MIMO radar ambiguity function"

MIMO (multiple-input multiple-output) radar is an emerging technology which has drawn considerable attention. Unlike the traditional SIMO (single-input multiple-output) radar, which transmits scaled versions of a single waveform in the antenna elements, the MIMO radar transmits independent waveforms in each of the antenna elements. It has been shown that MIMO radar systems have many advantages such as high spatial resolution, improved parameter identifiability, and enhanced flexibility for transmit beampattern design. In the traditional SIMO radar, the range and Doppler resolutions can be characterized by the radar ambiguity function. It is a major tool for studying and analyzing radar signals. Recently, the ambiguity function has been extended to the MIMO radar case. In this paper, some mathematical properties of the MIMO radar ambiguity function are derived. These properties provide insights into the MIMO radar waveform design. [C590]

"Extraction of polyphase radar modulation parameters using a wigner-ville distribution-radon transform"

Often used in low probability of intercept continuous waveform (CW) emitters, polyphase modulations can have extremely long code lengths (large processing gain), good sidelobe performance and robust Doppler tolerance. This paper presents an efficient algorithm to autonomously extract the polyphase radar modulation parameters from an intercepted waveform using a Wigner-Ville Radon transform. Results show that our method results in a small relative error in the extracted parameters for signal-to-noise ratios as low as-6dB. [C591]

"Application of Doppler resilient complementary waveforms to target tracking"

The use of complementary codes as a means of reducing radar range sidelobes is well-known, but lack of resilience to Doppler is often cited as a reason not to deploy them. This work describes techniques for providing Doppler resilience with an emphasis on tailoring Doppler performance to the specific aim of target tracking. The Doppler performance can be varied by suitably changing the order of transmission of multiple sets of complementary waveforms. We have developed a method that improves Doppler performance significantly by arranging the transmission of multiple copies of complementary waveforms according to the first order Reed-Muller codes. Here we demonstrate significant tracking gains in the context of accelerating targets by the use of adaptively chosen waveform sequences of this kind, compared to both a fixed sequence of similar waveforms, and an LFM waveform. [C592]

"Diversity-integration trade-offs in MIMO detection"

In this work, a MIMO detection problem is considered. At first, we derive the Generalized Likelihood Ratio Test (GLRT) for arbitrary transmitted signals and arbitrary time-correlation of the disturbance. Then, we investigate design criteria for the transmitted waveforms in both power-unlimited and power-limited systems and we study the interplay among the rank of the optimized code matrix, the number of transmit diversity paths and the amount of energy integrated along each path. The results show that increasing the rank of the code matrix allows generating a larger number of diversity paths at the price of reducing the average signal-to-clutter level along each path. [C593]

"W-band noise radar in short range applications"

Noise Radar Technology (NRT) uses noise waveforms (continuous or pulsed) as a radar signal and correlation processing of the returns for their optimal reception. This paper is devoted to some possible applications of NRT in civil field, in particular to millimetre-wave radars, with comparison of the use of Noise W-band radar versus the more classical FM-CW or pulse compression solutions. [C594]

"Smart beamforming and wideband signals for ground surveillance"

In this paper, dealing with long range ground surveillance radars, it is shown that the simultaneous requirement for wideband waveforms and multiple channels opens the way to new space-time signals and processing techniques, thus improving the detection and classification of multiple ground (and low-flying) targets. [C595]

"A practical approach to wireless Power Quality, Energy and Facilities Monitoring System"

In this paper, the authors discuss the way to adopt the cost effective Short Message Service (SMS) applications to Power Quality, Energy and Facilities Monitoring System. Also, the limited up to 160 characters will be considered during the design, which cannot be used on high data volume such as waveform pattern is not preferred. But for simple message such as voltage dip % is good enough. [C596]

"Kaiser-bessel window weighting function for polyphase pulse compression code"

This paper discusses and shows how the range-time sidelobes of P4 pulse compression waveform can be substantially reduced by applying Kaiser-Bessel amplitude weighting function. Also, a comparison is made with classical amplitude weighting function (i.e. Hamming window) applied to the receiver waveform of 100 element P4 code. Effects of weighting on the Doppler performance of the P4 code are presented. [C597]

"Estimating moving targets behind reinforced walls using radar"

We addressed the important problem in urban warfare of estimating moving targets such as personnel behind a reinforced wall using radar measurements. First, we considered the case in which the reinforced wall is completely unknown. We coherently added measured electric fields to estimate the wall thickness and concrete permittivity, independently. We applied beamforming to estimate the number and locations of the targets. The algorithm proved robust and performed satisfactorily in the case in which the bar parameters are unknown. We also analyzed the problem in which the characteristics of the metallic grid are known. We improved the estimation significantly by modeling the waveform distortion due to the bars. The resulting images are focused and represent the contours of the targets. In addition, the minimal necessary SNR is lower compared with the case in which the influence of the bars on the signal shape is ignored. [C598]

"MIMO radar performance in clutter: Limitations imposed by bounds on the volume and height distributions for the MIMO radar ambiguity function"

In multiple-input multiple-output (MIMO) radar, the efficiency of target detection in clutter that is distributed over a certain range bin-Doppler frequency region depends on the sidelobe level of the waveformspsila auto- and cross-ambiguity functions within this region. We introduce the MIMO ambiguity function as the sum of all auto- and cross-ambiguity functions of the K MIMO radar waveforms, with the integral of this function over some range-Doppler region serving as a measure of the orthogonality (separability) of the waveforms within this region of interest. We derive an upper bound on the attainable ldquoclear areardquo for the MIMO ambiguity function, and show that, with respect to the conventional single-waveform ambiguity function, the maximum clear area is K times smaller for the MIMO system. [C599]

"Binary Phase-Coded Sequence Recognition Based on EMD"

Identifying the phase-coded sequence of the binary phase-coded radar signal is a difficultly issue in the radar countermeasures. In this paper, a new approach of abstracting waveform features of the radar signal and identifying the phase-coded sequences is proposed, based on experimental model decomposition. The proposed approach can successfully identify complex phase-coded signal. Moreover, the presented approach can be applied as an integral part of radar signal recognition algorithm to prevent the electronic support measure (ESM) system from taking actions against false radar signal recognition and consequently avoid the waste of the available resources. Computer simulation results have shown that the proposed approach can successfully identify phase-coded sequences, and the recognition accuracy is greater than or equal to 89% when the signal-to-noise ratio is as low as 8 dB. [C600]

"Minimum redundancy MIMO radars"

The multiple-input multiple-output (MIMO) radar concept has drawn considerable attention recently. In the traditional single-input multiple-output (SIMO) radar system, the transmitter emits scaled versions of a single waveform. However, in the MIMO radar system, the transmitter transmits independent waveforms. It has been shown that the MIMO radar can be used to improve system performance. Most of the MIMO radar research so far has focused on the uniform array. However, it is in general a loss of optimality to assume the array to be uniform. In this paper, the nonuniform array design problem in the MIMO radar is studied. In the SIMO radar, it has been shown that there is a class of linear arrays which minimizes the number of redundant spacings in the array. These are called minimum redundancy linear arrays. It has been shown that this class of arrays has excellent performance in rejection of mainlobe interferences. In this paper, the idea of minimum redundancy linear array is extended to the MIMO radar case. The numerical examples show that the proposed minimum redundancy MIMO radar results in improved rejection of mainlobe interferences, with negligible degradation in sidelobe interference rejection capabilities. [C601]

"Orthogonal two-channel processing of hybrid coding waveform"

A novel waveform which consists of a pair of orthogonal coding waveforms transmitted in high pulse repetition frequencies (PRF) and low pulse repetition frequencies (LPRF) has been proposed. At the receiver, two signal processing channels perform the extraction of target range and Doppler information. Although two processing channels matches coding waveform, there still exists interference of the cross-correlation residues and auto-correlation sidelobes which effects the performance of the whole radar. Traditional method such as matched filter and CLEAN algorithm cannot remove the interference in an optimal way. In this paper, Orthogonal two-channel processing method is proposed to adaptively suppress the interference in the mean square error (MSE) sense and so the two signal processing channel can be thought to be completely orthogonal at every delay time. The signal processing scheme based on it is developed. Target range and Doppler information of high resolution can be extracted simultaneously. [C602]

"Short-range MMW PRC-CW radar utilizing Doppler compensation"

A millimeter wave (MMW) pseudo random code continuous wave (PRC-CW) radar utilizing Doppler compensation is introduced. The novel hybrid transmitted waveform used in this radar combining single frequency pulse with pseudo random binary phase-coded signal is presented which makes consequent target detection through pulse compression independent of Doppler frequency. Doppler frequencies of targets are firstly estimated based on interpolated FFT in the time span of single frequency pulse and the Doppler compensated signal can be constructed. The effect of Doppler mismatch on the correlation detection can be eliminated by processing the compensated signal using conventional pulse compression-FFT, which makes the radar capable of short-range high-speed target detection. The theoretical analysis and simulation result demonstrate the validity of this technique. [C603]

"A new ranging application of UWB modulated by orthogonal waves in wireless sensor network"

In order to decrease the signal length and transmitting time, improve accuracy of the delay time estimate, complete the mission of ranging and communication at the same time, a new ultra wideband (UWB) ranging method is developed in this paper. This method modulates the training sequence and information signals respectively on two carrier waves which are orthogonal mutually, and then combines them to transmit. When the sensor receives the signal, it decomposes the signal with the characteristic of orthogonal waves to get the training sequence and information signals. On this condition, we design the system using this ranging method, analyze the factors which can improve the ranging performance, and simulate the system. The result of the simulation indicates that the system which uses this ranging method can transmit the training sequence and information signals at one time and improve the ranging performance observably. [C604]

"Carrier recovery loop for millimeter-wave heterodyne receiver"

A carrier recovery loop process, for a millimeter-wave heterodyne receiver, is proposed in this paper. The millimeter-wave frequency conversion is performed using a six-port module, avoiding the conventional millimeter-wave active costly mixers. The second frequency conversion is performed using conventional circuits. The carrier recovery is done at the intermediary frequency (IF) part and not at the millimeter-wave one. In this paper, the carrier recovery is demonstrated by showing the spectrum and corresponding waveform of the recovered signal, extracted through the loop from the IF received signal and used for the second frequency conversion. The bits received are transmitted by an arbitrarily incoming QPSK modulation. [C605]

"Three-dimensional Microwave Tomography: Waveform diversity and distributed sensors for detecting and imaging buried objects with suppressed electromagnetic interference"

Microwave tomographic techniques are described in this paper for developing high-resolution images of buried targets using 3D RF CAT Scans with frequency, angular, and polarization diversity and distributed sensors. Surface-contact sensors are used to collect the tomographic data for relay to a circling UAV and transmission to a remote control site (using layered sensing). 3D imaging algorithms have been developed to detect, image, and characterize buried targets. Distributed transmitters and receivers significantly increase unwanted mutual coupling and EM emissions (EMI) that interfere with signal reception, but also increase image resolution. For Ground Penetration (GPEN), reduced mutual coupling and EMI, and improved signal-to-noise ratios (SNR), can be achieved by embedding the transmitter/receiver sensors underground. Simple surface SAR experiments have been performed to detect deep mine shafts at the Zinc Corporation of America. 2D sensor data have been used to validate the 3D processing algorithms. Scale-model lab tests in the DETECT Chamber at AFRL have also been performed to optimize the tomographic images. In addition, WIPL-D models have been used to simulate the embedded and diverse/distributed sensors and to verify the significant enhancement in the received SNR for GPEN obtained by burying the radiating ring under the surface. [C606]

"Cramer-Rao bound for target velocity estimation in MIMO radar with widely separated antennas"

This paper studies the velocity estimation performance for multiple-input multiple-output (MIMO) radar. MIMO radar employing widely dispersed antennas has an advantage in dealing with moving targets. By transmitting orthogonal waveforms MIMO radar can separate these waveforms at each receive antenna and has the ability to observe targets from different directions simultaneously. Unlike conventional radars with co-located antennas, the difficulty of processing targets with small radial velocities is avoided. In this paper, the Cramer-Rao bound is developed for velocity estimation in MIMO radar. It is shown that the antenna placement affects the estimation accuracy significantly. [C607]

"Target localization techniques and tools for MIMO radar"

MIMO (multiple-input multiple-output) radar refers to an architecture that employs multiple, spatially distributed or colocated transmitters and receivers. The widely spaced antenna structure suggests unique features that set MIMO radar apart from other radar systems, making it strongly related to MIMO communications. The widely separated transmit/receive antennas capture different aspects of the target cross section that can be exploited to obtain diversity gain for detection and estimation of the targetpsilas various parameters, such as angle of arrival, and Doppler. The use of coherent processing can provide localization accuracy gains well beyond that supported by the radarpsilas waveform. This paper provides a review of some recent work on computing the Cramer-Rao lower bound (CRLB) on the achievable localization accuracy. The geometric dilution of precision (GDOP) is used as a tool for assessing and illustrating the localization accuracy of the best linear unbiased estimator (BLUE). [C608]

"Moving target emulators for ultra wide band signals: Electrically modulated fragmented surfaces"

MTI radar systems and signal processing algorithms may be made more efficient if a wide range of perfect and background distorted Doppler signatures could be made available to test system hardware and algorithms. This paper addresses emulators of moving vehicle Doppler signatures. Measured Doppler spectra of tracked and wheeled vehicles are used to guide the development of moving target emulators made from ldquoswitchablerdquo reflectivity panels. The geometry of the panels are electrically percolating surfaces The percolating patterns provide 10:1 bandwidths and thus satisfy UWB criteria for frequency response and they use minimal modulating elements. A potential problem is the number of modulating elements on a panel that are required to synthesize the complex Doppler waveform measured on a ground vehicle. [C609]

"Simulator for Velocity Gate Pull-Off electronic countermeasure techniques"

This paper explores the use of implementing deception waveforms in the space-time adaptive processing (STAP) model for efficient waveform optimization in hardware-in-the-loop simulation. By understanding range gate pull-off (RGPO) techniques developed in a generic form, velocity gate pull-off (VGPO) technique models can be explored in a similar manner. The VGPO mathematical models are developed using a STAP framework to simplify the optimization cost function. The STAP model, implemented in MATLAB, is solely used to represent a series of electronic countermeasure signals. Using the proposed implementation, the ECM waveform can be injected in the HILS architecture via simulation or hardware. Initial results reveal that the pulse-indexed STAP representation is M times better than a time-indexed signal representation while naturally including coordinated RGPO/VGPO. [C610]

"Nonadaptive MIMO radar techniques for reducing clutter"

Multiple-Input, Multiple-Output (MIMO) radars enhance performance by transmitting and receiving coded waveforms from multiple locations. This paper describes how MIMO techniques can be used to improve radar performance, especially in airborne GMTI applications. A previous analysis of the clutter-to-noise-ratio (CNR) for stationary, surface-based MIMO radar is extended to the airborne radar scenario. Our analysis shows that MIMO airborne radars will have lower CNRs, resulting in smaller losses when observing stationary and low-velocity targets. We also address the implementation of MIMO radar modes using Electronically Scanned Arrays (ESAs). Herein, we show that implementing MIMO techniques within a subarrayed antenna can result in high sidelobes and/or reduced search rates. To address this problem, we describe how space-time waveform coding can be used to improve performance. Two space-time waveform encoding approaches are proposed: (1) an overlapped virtual transmit subarray approach, and (2) a beamspace MIMO processing approach. A third approach, involving conventional MIMO waveforms and irregular subarrays, is also briefly considered. [C611]

"Using genetic algorithms for radar waveform selection"

Genetic algorithms have proven to be useful tools in optimizing complex problems with large solution spaces. Radar waveform selection is a challenging problem that may benefit from the use of genetic algorithms. Furthermore, advances in the areas of waveform diversity, multistatic radars and knowledge-aided radars are making waveform selection even more challenging. As a design tool we used genetic algorithms to perform waveform selection utilizing the autocorrelation and ambiguity functions in the fitness evaluation. Monostatic, bistatic and multistatic notional examples are presented and early results indicate that genetic algorithms can provide a useful and effective tool in waveform selection for a variety of radar configurations. [C612]

"Matched NLFM pulse compression method with ultra-low sidelobes"

Pulse compression is a promising technique with advantages of high resolution and low peak power. Sidelobe levels are expected to be as low as possible to suppress strong clutters around the target. In this paper, a matched NLFM pulse compression method is put forward that uses Gaussian and sinc functions as the spectral density of the NLFM waveforms. Ultralow sidelobes below -60 dB are obtained with no loss in SNR. Simulation analysis of sidelobe suppression and the Doppler tolerance is presented. Simulation results and hardware implementation show the feasibility and applicability of the generated waveforms. [C613]

"High Range Resolution with digital stretch processing"

This paper describes an approach to high range resolution (HRR) by means of stretch processing by digital deramping. This approach offers advantages that are common for stretch processing, as a moderate data rate for signal processing in the presence of a high bandwidth waveform. In contrast to conventional analogue processing, deramping is realized digitally. The approach of digital deramping offers the possibility to combine the deramp processing with digital down modulation. Moreover, the digital deramping allows to measure and calibrate distortions in the analogue radar front-end. A calibration scheme is presented that incorporates calibration corrections into the digital deramp signal. The calibration scheme is of particular interest for applications in active phased array radars with multiple receive channels. The presented approach offers a number of advantages compared to analogue stretch processing and other approaches to high range resolution. [C614]

"Advanced synthetic aperture radar based on digital beamforming and waveform diversity"

This paper introduces innovative SAR system concepts for the acquisition of high resolution radar images with wide swath coverage from spaceborne platforms. The new concepts rely on the combination of advanced multi-channel SAR front-end architectures with novel operational modes. The architectures differ regarding their implementation complexity and it is shown that even a low number of channels is already well suited to significantly improve the imaging performance and to overcome fundamental limitations inherent to classical SAR

systems. The more advanced concepts employ a multidimensional encoding of the transmitted waveforms to further improve the performance and to enable a new class of hybrid SAR imaging modes that are well suited to satisfy hitherto incompatible user requirements for frequent monitoring and detailed mapping. Implementation specific issues will be discussed and examples demonstrate the potential of the new techniques for different remote sensing applications. [C615]

"Orthogonal pulse compression code design for waveform iversity in multistatic radar systems"

This paper deals with an orthogonal pulse compression code set design problem in multistatic radar systems. Multistatic radar systems can improve radar performance by using a set of orthogonal waveforms with the same operating frequency. We provide the signal model for multistatic radar system using a set of orthogonal pulse compression codes. Moreover, a novel algorithm is proposed to obtain the set of orthogonal pulse compression codes. This algorithm minimizes the sidelobe peak of sum of autocorrelation and crosscorrelation function while maintaining the orthogonality of each code. Some of the designed results are presented by evaluating the characteristics of autocorrelation and crosscorrelation functions. In addition, the waveform diversity system and non-waveform diversity system are compared in terms of the probability of detection performance. [C616]

"OFDM waveforms for frequency agility and opportunities for Doppler processing in radar"

Frequency agility is an important feature when radar operates in jammed environments. With the development of the orthogonal frequency division multiplexing (OFDM) waveform in the communications, the opportunity for a new generation of digital agile radar rises. Old and expensive multi-channel analog agile front ends could be replaced by simpler and cost effective single channel transceivers where the coherent switches in frequency are done digitally. The novelty of the paper is to investigate an agile OFDM waveform so that Doppler can be solved despite the apparent frequency agility. The OFDM performance is assessed from the radar point of view, using the ambiguity function as a tool. Our approach considers a pulse burst, each pulse being implemented with OFDM chips. Three patterns for frequency agility from pulse-to-pulse are studied. Preliminary suggestions to accomplish coherent processing in an agile context are derived. [C617]

"Joint adaptive waveform design and direction-of-arrival tracking"

The ability to adapt waveforms to the changing properties of targets is a very important feature for radars. Adaptive waveform design can improve the estimation and tracking of targets dramatically. In this paper we propose a joint scheme for adaptive multiple waveforms design and multi-target parameter estimation and tracking for extended targets. We combine our previous work on information theoretic waveform design for multiple extended targets with an iterative joint direction-of-arrival and target frequency response estimation. The results can improve wide band high range resolution (HRR) applications. The method is computationally attractive, since the waveform design stage involves convex optimization. The performance gains of the adaptive design process are demonstrated in simulations. The proposed algorithm shows benefits of 2-3 dB compared to flat spectrum waveform in terms of received SNR, and yields better resolution capability due to the adaptive waveform design. [C618]

"Performance analysis of a multi-frequency FM based Passive Bistatic Radar"

In this paper we evaluate the target detection performance improvement of a multi-frequency approach for FM radio based passive bistatic radar. Specifically, we consider the high diversity of the FM radio signals received over different carrier frequencies spanning the 88-108 MHz band since it represents the basis for the request of a multi-frequency operation. The joint exploitation of the waveforms of opportunity received on multiple FM radio channels is shown to yield better performance in terms of detection capability. To demonstrate the effectiveness of the proposed approach two experimental prototypes of FM radio based passive radar receivers have been developed and fielded at the INFOCOM Dept. of the University of Rome ldquoLa Sapienzardquo. The two prototypes are based on two different design approaches: direct RF sampling and signal down-conversion & baseband sampling. The acquisition campaigns that have been carried out with the two prototypes are described together with the collected data analysis and processing. Finally, the results obtained over the collected data set for the single FM channels and after the proposed multi-frequency integration procedure are reported and compared with live air traffic control registrations. [C619]

"On the design of a 2D array HF skywave radar"

New generation of HF skywave radars moves toward 2D array solution to get high signal to noise ratio (SNR), low probability of intercept (LPI), precise electronic scanning, faster scanning time. Critical elements for the design of such a system are radar configuration, antenna design, transmission waveforms and architecture, signal processing, radar management and control system. The goal of this paper is to provide new criteria and

concepts about the design of such radars. [C620]

"Multipath spread-Doppler clutter mitigation for over-the-horizon radar"

This paper discusses two adaptive spatial processing approaches that have been recently proposed for mitigating spread-Doppler clutter in skywave over-the-horizon (OTH) radar. The first is slow-time MIMO (SLO-MO) STAP which uses conventional waveforms that are phase-coded so as to be orthogonal after Doppler processing at the receiver, i.e. in ldquoslow-time.rdquo SLO-MO STAP is proposed as a means of mitigating transmit array sidelobes without costly redesign of legacy transmit or receive OTH radar hardware. The second approach is wavefront adaptive sensing (WAS) which uses a horizontally stratified ionospheric model to motivate a new application of blind source separation (BSS) methods for discriminating targets of interest from spatially distributed Doppler spread clutter. Comparison of these two approaches suggests they each may offer significant performance gains under different ionospheric propagation conditions. [C621]

"A wideband technique for micro-ranging in OTHR"

A method for utilizing wideband transmissions (>100 kHz) in OTHR is proposed. The technique involves the aggregation of multiple narrow band signals into a wideband composite through digital synthesis. The multi-channel signal is received digitally and after normal correlation and Doppler processing is recombined using Whitehead-Malekpsilas phase-frequency technique to provide an orthogonal micro-ranging dimension. The technique is described, and then modeled in an attempt to gauge its effectiveness. The demanding application of OTHR height finding is chosen in the modeling as it requires separation of ionospheric micro multi-path signals to be effective. The modeling shows that ionospheric dispersion limits a direct application of the micro-ranging technique when propagating through an IRI mid-latitude ionosphere with typical frequency selection rules. A simple method of estimating and removing the ionospheric dispersion is proposed and demonstrated to be effective in progressing the technique to provide range resolution approaching that expected with the wideband signal. [C622]

"Convex optimization and MIMO RADAR waveform design in the presence of clutter"

Waveform design for target identification and classification in MIMO radar systems has been studied in several recent works. While the previous works considered signal independent noise and found optimal signals for an estimation algorithm, here we extend the results to the case where clutter is also present and then we will find the optimum waveform for several estimators differing in the assumptions on the given statistics. Several different approaches to the optimal waveform design are proposed, including minimizing the error of MMSE estimator, minimizing the maximum error of the covariance shaping least square (CSLS) estimator and minimizing the MSE error of scaled least square (SLS) estimator. Choosing optimal waveform for MMSE estimator leads to the semi-definite programming (SDP) problem. Finding the optimal transmit signals for CSLS estimator results in a minimax eigenvalue problem. Finally it is shown that equal power waveforms are the best transmit signals for the SLS estimator. [C623]

"Waveform design for MIMO radar using Kronecker structured matrix estimation"

The multiple-input multiple-output (MIMO) radar system is a new kind of radar technology. It can choose flexibly the probing signals transmitted via its antennas or increase the inter-element distance to reduce the cross-correlation of the signals, so that the spatial diversity gain can be obtained. Waveform design is one of the important topics of the MIMO radar. We discuss here the waveform design method for extended radar targets using Kronecker structured matrix estimation. Simulation results are provided to validate the proposed solutions. [C624]

"Frequency-Domain Extracted IFFT Method for Synthetic Aperture Radar Imaging with Frequency Coded Waveform"

Study of frequency coded synthetic aperture radar was concerned in this paper. A new frequency-domain extracted IFFT approach (FDE-IFFT) to obtain high range resolution profile was proposed, and the mathematical principle of this new method was detailed analyzed. Simulation results and series of radar images using time domain back-projection method were given in the end. All results proved that the FDE-IFFT method has better capability of anti-jamming. It is more effective than conventional IFFT method and can be widely used in frequency coded synthetic aperture radar. [C625]

"Optimal signals for MIMO RADAR in the presence of clutter"

Waveform design for target identification and classification in MIMO radar systems has been studied in several

recent works. While the previous works considered signal independent noise and found optimal signals, here we extend the results to the case where clutter is also present and then we will find the optimum waveform for MMSE estimator. Choosing optimal waveform for MMSE estimator leads to the Semi-definite programming (SDP)problem, a convex optimization problem which can be efficiently solved through numerical methods. Explicit solution is developed for this SDP problem in two cases. In the first case, target and clutter covariance matrices are jointly diagonalizable and in the second one, signal to noise ratio (SNR)is sufficiently high. [C626]

"Solving Doppler ambiguity by Doppler sensitive pulse compression using multi-carrier waveform"

A processing technique, which exploits the structure of the multi-carrier signal to obtain range and radial velocity information from the echo signal, is proposed. The novel processing technique executes the Doppler matched filter bank digitally, and solves the ambiguity in the radial velocity measurements in one train of multi-carrier pulses as a result of Doppler sidelobes of the ambiguity function being lower. The processing technique, being independent of the phase coding on the multiple carriers, enables integration of communication and radar waveforms. [C627]

"Conceptual design of a dual-use radar/communication system based on OFDM"

The paper describes a novel system which can be used interchangeably as a radar sensor and communication device. The system is being developed at Miami University using COTS components and its digital part is based on OFDM architecture. Arbitrary waveform generator with high-speed DSP capabilities is being used to create either random or deterministic OFDM waveforms and a high-speed ADC board is used in the receiverpsilas baseband portion to recover the incoming signals. OFDM technique is already widely used in broadband communications; however it is shown that system architecture based on this method of data coding and modulation can also be used in radar with minimum modifications. Indeed, modeling study shows that OFDM radar signals perform well in presence of jamming and interference and possess noise-like qualities making them good candidates for low probability of detect/intercept (LPI/LPD) system implementation. The system concept and design are discussed and LPI/LPD features of OFDM signals are illustrated via spectrogram. Experimental data from a baseband radar/communication digital system transceiver link operating at 300 MHz bandwidth are presented. [C628]

"Measured and FDTD Calculated Ultra Wide Band (UWB) RCS for Treated Test Fixtures"

This paper presents comparisons of measured, and finite difference time domain (FDTD) calculations of ultra wide Band scattering for dimensionally scaled, shaped and treated fixtures and measurements on a ground plane fed by vertically polarized TEM horn antenna operating from 50 MHz to 18.05 GHz. method of moment (MoM) calculations are used to cross-check measurement and FDTD. UWB exotic material effects should be more easily observed at low scattering levels. Our findings indicate that for multiple target characteristics and over UWB bandwidths, FDTD code furnish a sufficient level of predictive accuracy (i.e. -30 to -40 dBsm) such that it might be applied in RCS predictions of treated targets where exotic RF-material interactions resulting from high power UWB waveforms might be used. RCS predictions could then be applied to improve signal processing algorithms. The paper discussed measurement technique, choice of fixtures, FDTD model, the measurement-model level of agreement and outlines a path to verification. [C629]

"ADP-Based Optimal Adaptive Waveform Selection in Cognitive Radar"

The problem of adaptive waveform selection can be viewed as a problem of stochastic dynamic programming. However, the computational cost of solution of optimality equations is very high as a result of large state variable space. So far few suitable scheduling algorithms have been proposed. To account for the aboved shortcoming, we can use approximate dynamic programming (ADP) to solve adaptive waveform selection problem. The scheduling algorithm we proposed can minimize the time taken to detect new targets, detect these targets in accordance with importance, and minimize the use of radar resources. Meanwhile we have a lower computational cost compared with the traditional algorithms. Finally, the whole paper is summarized. [C630]

"Coherent synthesis sparse aperture radar with grating lobes suppressed using frequency MIMO technique"

Coherent synthesis sparse aperture array radar can provide a long baseline with narrower beamwidth at the cost of grating lobes. In this paper, we propose a method to suppress grating lobes based on frequency MIMO technique. By transmitting M orthogonal waveforms with diverse frequencies from subaperture-to-subaperture, M beams can be formed with the same mainlobe direction. However, grating lobes would move to different locations relative to the frequency offset Deltaf. Coherent combining the M beams would suppress grating lobes to a certain level. It is shown that the combined beam using frequency MIMO array is periodically scanning in

range and angle. We further analyze the relationship of scanning period with frequency offset Deltaf and sparse distance L . [C631]

"Multistatic target classification with adaptive waveforms"

Traditional radar systems rely on a predefined suite of waveforms and post-measurement signal processing to achieve such goals as target detection, classification, and tracking. Cognitive radar (CR) is a newly proposed framework in which the radar actively interrogates the propagation channel and adapts its operating parameters in order to maximize performance. We apply CR to a target classification problem by calculating custom waveforms that maximize the information received from the target echoes. A new MIMO waveform is proposed which maximizes the mutual information between a Gaussian random target and the received data under AWGN. The results indicate that the new frequency-domain formulation offers superior performance compared to both a non-adaptive approach and an ad hoc application of spectral waterfilling to the MIMO setting. [C632]

"Adaptive MIMO radar waveforms"

Multiple-Input, Multiple-Output (MIMO) radars enhance performance by transmitting and receiving coded waveforms from multiple locations. To date, the theoretical literature on MIMO radar has focused largely on the use of ldquoorthogonal waveforms.rdquo Practical approaches to approximate orthogonality (e.g., via waveforms characterized by low cross-correlation and low autocorrelation sidelobe levels) have also started to emerge. We show, however, that such waveforms can still perform poorly in adaptive systems. For adaptive MIMO radar systems, another factor is equally important; we call it ldquoMIMO Cancellation Ratio (CR).rdquo In this paper, we introduce MIMO CR and assess the performance of standard waveform classes (e.g., CDMA, TDMA and FDMA) with regard to this new metric. Then, we describe how to create new waveforms that facilitate higher performance adaptive cancellation. Finally, we apply our waveform design methodology to the problem of airborne MTI radar, in which STAP techniques are used to mitigate clutter. [C633]

"MIMO noise radar-matched filters and coarrays"

The noise radar concept can be extended to an array of K transmit antenna and M receive antenna. When independent noise sources are transmitted from each antenna the approach may be viewed as a special case of MIMO radar and matched filters may be derived. In this contribution statistical properties of matched filters for MIMO noise radar are derived. For any array the concepts of the sum and difference coarrays are useful and important tools for understanding an arraypsilas beamforming properties particularly for sparse arrays. Element space matched filters are shown to be related to the concept of the sum coarray and some examples of the advantages of this for sparse transmit/receive array geometry are provided. A variation of this result for beam space matched filters is also presented. [C634]

"Knowledge based signal processing, waveform diversity and systems engineering"

Future multi-mission / multi-mode sensors and radio frequency systems will have to operate in electromagnetically dense signal environments. Furthermore, a diverse cadre of concepts may result in a variety of fielded systems, all operating in close proximity to each other. While this ever growing collection of concepts bodes well for the rapid transition of new technology, these systems must share spectrum, measured data, and mission responsibility in order to perform in an economical and effective manor. Key to the successful fielding of these new sensors is knowledge based control of signal processing algorithms and radiated waveforms, as well as platform dynamics. In this tutorial, foundational technologies and their functional relationships will be presented in order to illustrate performance improvements relative to classical approaches. Knowledge Based STAP, Expert Systems CFAR, RF Tomography and Sensors as Robots technologies are presented as offering a way forward from a radar perspective. [C635]

"Waveform analysis and design"

Summary form only given.Fundamental tools for radar signal analysis-the matched filter response and the ambiguity function-are briefly discussed and demonstrated on basic signals: LFM pulse, coherent pulse train and a coherent train of LFM pulses. Advanced pulse compression signals and sidelobe reduction techniques are then studied, including: frequency modulation (Costas, NLFM, multi-carrier), phase coding (Barker, Frank, P3, P4, P(n,k), polyphase Barker, MPSL), inter-pulse diversity (complementary, step-frequency, orthogonal overlay), weighting and mismatch filters. Also discussed are spectrum sidelobe reduction techniques (derivative phase, Qudriphase transformation, Gaussian windowed sinc), periodic CW waveforms, and waveforms for non-coherent pulse compression. MATLAB software tools for radar signal analysis will be demonstrated. [C636]

"STAP I-Architectures and algorithms"

Space-Time-Adaptive Processing (STAP) is becoming an integral part of modern airborne and space-based radars for performing Airborne Moving Target Indicator (AMTI) and Ground Moving Target Indicator (GMTI) functions. STAP is an application of optimum and adaptive array processing algorithms to the radar problem of target detection in ground clutter and interference with pulse-Doppler waveforms and multi-channel antennas and receivers. Coupled space-time processing is required to optimally mitigate the Doppler spreading of ground clutter induced by radar platform motion. This tutorial will begin with the fundamentals of adaptive beamforming and radar pulse-Doppler processing, move through principles and application of STAP, and conclude with a brief overview of some advanced current research topics. Optimum STAP and a taxonomy of practical STAP architectures and algorithms will be described in depth. Key aspects of a practical STAP algorithm include the methods for estimating the background interference, proper subspace selection, and the technique for computing STAP filter weights. Algorithms for providing rapid convergence, robustness to clutter inhomogeneities, robustness to steering vector calibration errors, and reduced computational complexity will be described. The effect of STAP on subsequent detection and target parameter estimation algorithms will be discussed, with some emphasis placed on adaptive monopulse approaches for STAP radars. Simulation and experimental data will be used to illustrate STAP concepts and algorithmic issues. [C637]

"Radar detection and angle estimation of over-resolved ground vehicles"

Traditionally, moving target indication (MTI) modes tailored to wide-area surveillance (WAS) have employed waveforms with bandwidths matched to the range extent of targets of interest. Matching range resolution to expected vehicle lengths serves to minimize interfering clutter returns while preserving available target power, thereby maximizing target probability-of-detection. Recent advances in waveform generator technology and high-speed digital signal processors for matched filtering have encouraged radar designers to consider wideband waveforms for WAS MTI needs. While providing information for identification and imaging, wideband waveforms complicate the detection process, as an extended target will be over-resolved; that is, returns from a vehicle will be distributed over multiple, fine-resolution range bins. Algorithms for combining these signal contributions are required for detection and angle estimation. Given such algorithms, one wonders whether over-resolving targets leads to detection and angle estimation performance losses as compared to narrowband operation. In this paper we evaluate methods for collecting energy from an over-resolved target for detection and angle estimation processing. We bound the performance of these techniques on typical ground targets and show that the probability-of-detection and angle accuracy is improved through the use of wideband waveforms at high signal-to-noise levels. [C638]

"Waveform optimization for electronic countermeasure technique generation"

Recent work on electronic countermeasure (ECM) technique generation employed genetic algorithm optimization methods to define simple range-gate pull-off waveforms against a generic range-tracking radar simulation. This automated approach has potential to greatly reduce technique development time which is traditionally prolonged by manual experimentation. However, it also inspires a more generalized approach to optimization with hardware-in-the-loop configurations. This work investigates and develops the underlying mathematical and empirical framework for using optimization algorithms for hardware-in-the-loop simulation and testing. Unlike other reported radar/ECM optimization simulations, this approach uses a cost function library and scoring definition to separate simulation from the optimization algorithm, and is easily adapted to hardware-in-the-loop testing. In addition, effects from electromagnetic scattering and radar receiver processing may be measured, removing the need for completely defined objective functions. Finally, this approach nicely generalizes to multiple simultaneous cost function optimization. The method is demonstrated using the wellknown range-gate pull-off technique, but is adaptable to other ECM techniques. Future efforts will investigate specific optimization algorithms for the multi-objective problem. [C639]

"Performance of reiterated LMMSE filtering and coded radar waveforms"

OFDM waveforms offer strong advantages for integrated communication and radar systems. Nevertheless they require filtering at the receiver that can serve for sidelobe suppression in order to avoid target masking. However unmasking is not the only concern, it is crucial to evaluate the filtering scheme both in terms of sidelobe suppression capability but also in terms of output signal to noise ratio. This last criterion is essential when aiming at detecting also weaker reflections. In this paper the theoretical performance of the reiterated filtering technique based on LMMSE is derived and compared to the matched filter. The unmasking capabilities are relevant, but also output power figures. Moreover the performance of reiterated LMMSE is evaluated for OFDM communication-encoded radar waveforms. [C640]

"Analog pulse compressor for radar system"

Pulse compression is commonly used in radar applications to improve range resolution while keeping transmitted peak power low. Conventional approach is either using SAW devices or fast convolution processing, but either solution has significant drawbacks. In this work, analog pulse compressor based on analog matched filter has been proposed using a digital waveform generator and an analog correlator. This scheme not only has advantages over conventional methods, but also adds additional flexibility to the system, and opens up possibilities for future extensions. [C641]

"An adaptive threshold algorithm for detection of pulse radar signals"

An adaptive threshold algorithm has been developed in order to achieve a real time waveform reconstruction of IFF radar pulses. In IFF systems, in order to guarantee the receiver selectivity and immunity regarding external interferences, the use of a narrow bandwidth, high order filter is mandatory. This kind of filter introduces an amplitude and phase distortion on received pulses. In order to achieve a correct reconstruction of the received pulses a real time adaptive threshold locked to the pulse amplitude has been developed. Object of the paper is the description of the algorithm and the presentation of the results obtained for detection and reconstruction of IFF (Identification Friends or Foe) pulses. [C642]

"Development of a high resolution MMW radar employing an antenna with combined frequency and mechanical scanning"

Electronically steerable antennas are expensive, whilst mechanically scanned antennas are of complex construction and hence are prone to failure. Based on the leaky-wave frequency-scanning principle, the spinning grating antenna (SGA) provides beam steering without the need of hinges. Whilst pulsed or stepped frequency waveforms may be implemented with this antenna, a frequency modulated continuous wave (FMCW) waveform allows close range operation at high speed, the possibility of excellent range-resolution, and low-cost signal processing. However, to implement FMCW with the SGA, the inherent scan-angle variation with frequency must first be overcome. Following on from an effort to develop a highly accurate radar system employing closed-loop linearisation to achieve 4 GHz of bandwidth centred at 94 GHz, this paper focuses on simultaneously achieving high angular resolution over a 20 degree scan range with good results. [C643]

"Code optimization with similarity and accuracy constraints"

This paper deals with the design of coded waveforms which optimize radar performances in the presence of colored Gaussian disturbance. We focus on the class of linearly coded pulse trains and determine the radar code which maximizes the detection performance under a control on the region of achievable Doppler estimation accuracies, and imposing a similarity constraint with a pre-fixed radar code. The resulting optimization problem is non-convex and quadratic. In order to solve it, we propose a technique based on the relaxation of the original problem into a semidefinite program. Indeed the best code is determined through a rank-one decomposition of an optimal solution of the relaxed problem. At the analysis stage we assess the performance of the new encoding technique in terms of detection performance, region of achievable Doppler estimation accuracies, and ambiguity function. [C644]

"Sensor placement for improved target resolution in distributed radar systems"

In this work we investigate rules for sensor placement as a way of improving multistatic radar system performances. We follow the approach of shaping the multistatic ambiguity function, but instead of different weighting rules and different waveforms, as studied in recent works, we consider different system geometries. We concentrate our attention on target resolution as a performance measure and present simulation results that illustrate the significance of adequate sensor placement in multistatic radar systems. [C645]

"Along track interferometry for foliage penetration Moving Target Indication"

Moving target indication radars for detection and tracking ground vehicles has received significant interest in the radar literature. However, when the vehicles are moving slowly and in foliage, microwave frequency radars such as X-band are not effective. Foliage penetration (FOPEN) radars using ultra high frequency (UHF) synthetic aperture waveforms have demonstrated consistent detection of stationary ground vehicles. In most applications, the vehicles are stationary to support wide angle, high resolution SAR processing. Along track interferometry (ATI) has been proposed for space based radars to detect moving targets due to the high velocity of the radar. This study will examine the target and processing requirements to detect slowly moving ground vehicles using ATI approaches. A detailed simulation of the target and clutter phenomenology is carried out to illustrate the effects of internal clutter motion and signal decorrelation effects on minimum discernable velocity. [C646]

"Waveform design for distributed aperture using Gram-Schmidt orthogonalization"

In this work, we consider a distributed aperture radar system and present a method for clutter rejecting waveforms and reflectivity function reconstruction. This work generalizes the monostatic radar waveform design method for range-doppler imaging, developed in [1], [2] to distributed aperture radar systems. The designed waveforms also lead to a filtered backprojection type reconstruction of the reflectivity function which can be efficiently implemented in a parallel fashion. [C647]

"Discrete Suppression with ΣΔ-STAP"

This paper presents the hybrid algorithm of SigmaDelta-STAP and direct data domain(D3) which is robust to the discrete interferer. SigmaDelta-STAP provides high performance result with the relatively low complexity of calculation. It also requires small number of training sample to estimate covariance matrix. However this algorithm is vulnerable to the discrete interferer which is target-like interferer with high SNR. This paper shows that SigmaDelta-STAP can suppress discrete interferer signal in conjunction with direct data domain (D3) method which is an effective method to eliminate non-correlated interference such as discrete interferer in the non-homogeneous environment. [C648]

"Air target detection and tracking using a multi-channel GSM based passive radar"

This paper presents a summary of the hardware system design and associate signal processing schemes of a multi-channel GSM based passive radar and most importantly presents new experimental results to demonstrate the multichannel GSM based passive radar ability to detect and track the Doppler frequency of aircraft target as well as measure the aircraft target bearing. [C649]

"Real-time PRF selection for medium PRF airborne pulsed-doppler radars in tracking phase"

This paper proposes a new method to select optimal pulse repetition frequency (PRF) sets for use in tracking mode of medium PRF airborne pulsed-Doppler radar. Neural networks algorithm is used to map from engagement variables to the optimal PRF set. On-line computation during flight can be made real-time after off-line training of the neural network. The training sets for the neural network need to be generated by selecting optimal PRF set for the possible engagement scenarios from which range-Doppler clutter map is calculated to check the decodability and detectability for all PRF candidates. The PRF sets generated by the method must guarantee the maximum detectability inside the target tracking window as well as maintaining good decodability. Simulation result shows that the proposed method has much better range-Doppler detection performance compared to the previous algorithms by applying different optimal PRF set to different engagement scenarios and target positions. [C650]

"How will waveform diversity affect electromagnetic compatibility?"

This paper will provide a general overview of the new research area called waveform diversity (WD), and its potential impact to the EMC community. The scope of research that is considered WD is broad in both technical content and application. The two main application areas are radar and communications across the RF spectrum. WD is beginning to transition from theory to operational systems, and the effect on RF design and EMC analysis may be significant. This paper will describe WD, what has motivated people to research it, and potential effects to the EMC community. [C651]

"Feasibility study of a low-cost system-on-a-chip UWB pulse radar on silicon for the heart monitoring"

In February 2002 the FCC authorized the marketing of a new class of radiofrequency devices: the ultra-wide-band (UWB) systems. One of the most interesting applications for which the UWB systems are addressed is related to the medical imaging. This paper addresses the feasibility study of a novel fully integrated 3.1-10.6 GHz UWB radar on a standard silicon technology for the heart wall monitoring. A theoretical frequency-dependent model of the losses of the electromagnetic radiation in the channel (the human chest) in which the radar operates has been derived. The preliminary specifications of each building blocks have been derived by basic theory in the conditions of the addressed scenario. System simulations have been carried out by means of the Ptolemy simulator within Agilent ADS2005ATMin order to claim the preliminary theoretical study. The CAD analyses have shown that the correlator-based radar topology allows us to approach the realization of such a system-on-a-chip pulse radar in a modern silicon technology (as such as the standard CMOS 90 nm). [C652]

"Image contrast and entropy based autofocusing for polarimetric ISAR"

In recent studies the possibility of extending autofocusing techniques to fully polarimetric ISAR systems has been proposed. The image contrast and entropy based autofocusing techniques have been proposed in the last decade as some of the most common techniques for obtaining well focused single polarisation ISAR images. In this paper, the two techniques are extended and applied to fully polarimetric ISAR data. A performance analysis is then provided and compared to single polarisation ISAR using real data. [C653]

"Polarimetric ISAR autofocussing techniques: Comparison of results"

This paper briefly describes a number of scalar, partially polarimetric, and fully polarimetric ISAR image autofocusing approaches that are based upon the PPP and ICBA autofocusing techniques. All approaches are then compared and contrasted using real world data provided by the Defence Science and Technology Organisation of Australia. From this analysis the ICBA approach results in an improved image focus as defined by the image contrast, image entropy and image peak measures, whereas the performance of the PPP based approaches are mixed at best. [C654]

"Knowledge base technologies for waveform diversity and electromagnetic compatibility"

Waveform diversity in multistatic radar systems can enhance distributed radar system performance. Dynamically changing the electromagnetic emanations of radar and communications systems however poses an electromagnetic compatibility (EMC) challenge. Data are provided illustrating how waveform diversity improves multistatic radar system performance. An approach for maintaining EMC in a dynamically changing environment is provided along with an example knowledge base (KB) solution. [C655]

"Waveforms in virtual tomographic arrays"

Distributed sensing systems incorporating RF tomography allow a trade-off between spatial and spectral diversity, however a large number of widely spaced sensors is conventionally thought to be required. A practical method of reducing the number of sensor nodes is introduced via the concept of the virtual tomographic array. Furthermore, the geometry of this virtual array is electronically reconfigurable. Optimal resource allocation is accomplished instantaneously, with dynamic control based upon matching sensing modalities to site specific target and clutter observables. [C656]

"Varying FM rates in adaptive processing for distributed radar apertures"

Previous work in waveform diversity for distributed apertures for target detection has focused largely on orthogonal transmissions. This paper investigates an alternative approach; implementing waveform diversity based on differing slopes of the linear FM pulse to the application of target detection for a distributed radar aperture system in the presence of noise and clutter. This paper add develop the required signal model corresponding to the proposed system, accounting for the cross-coupling between the linearly FM pulses. This paper determines whether applying this type of waveform diversity will result in improved performance in the discrimination of the target from noise and interfering sources and compare the performance whether this method is a feasible solution. A crucial step is the optimization of the FM rates using sequential quadratic programming. [C657]

"Optimal sparse waveform design for HFSWR system"

High frequency surface wave radar (HFSWR) systems operate in heavily congested high frequency (HF) band. It is very difficult to find continuous clear channels for the wide-band HFSWR systems. Both the conventional frequency modulated continuous wave (FMCW) and the frequency modulated interrupted continuous wave (FMICW) are not able to solve the problem. The sparse waveform design can mitigate the interferences influence by discontinuous spectra waveforms; however, it gives rise to high range side lobes, which can't be suppressed by traditional spectral weighting. In this paper, we investigate a genetic algorithms (GAs) based sparse waveform optimization approach for HFSWR systems. Simulation results show an optimal transmitting sparse waveform solution. [C658]

"Code selection for radar performance optimization"

In this paper we consider the synthesis of radar waveforms in the presence of colored disturbance. We focus on the class of coded pulse trains and determine the best radar codes according to some established optimality criteria. We propose three coding methods. Two of them are based on the maximization of the detection performance under a control on the estimation accuracy of the target Doppler frequency. The third relies on the maximization of the detection performance under a binary constraint on the code alphabet. Two proposed techniques require the solution of non-convex optimization problems which are solved resorting to the theory of

relaxation and semidefinite programming. At the analysis stage the performances of the new coding strategies are assessed also in comparison with a standard radar code both in terms of detection probability and target Doppler estimation accuracy. The results show that the proposed techniques may lead to codes whose performances are close to the benchmark curves. [C659]

"Waveform design for radar-embedded communications"

This paper considers the embedding of a covert communication signal amongst radar backscatter by means of a tag/transponder that lies within the illuminated area of the radar. Past approaches have operated on an inter-pulse basis whereby a communication symbol/identifier is relayed to an intended receiver by imparting a Doppler-like phase-shift to each of a successive series of incident radar pulses. In contrast, the approach proposed in this paper operates on an intra-pulse basis whereby the incident radar waveform at the tag/transponder is "re-modulated" into one of a set of different waveforms each representing a different communication symbol. The particular design issues for these re-modulated waveforms are discussed and three general design methods are proposed. The effectiveness of the different methods is assessed in terms of the probability of communication error as a function of the respective powers of the embedded communication signal, the masking radar backscatter, and noise. The relative "covertness" of the resulting waveforms is also discussed. [C660]

"One-step optimal measurement selection for linear gaussian estimation problems"

This paper considers the problem of choosing the optimal linear measurement for the estimation of a state vector X in a Bayesian context where the prior distribution for X is multivariate Gaussian. The motivation for this comes from waveform-agile active sensing systems that have the capability of choosing transmit or illumination waveforms in real time. The measurement is characterized by a measurement matrix B with an energy constraint along each row. Qualitatively, the optimal solution applies the available transmit energy to each of the eigenmodes of the prior covariance of X, such that more energy is applied to modes with higher prior variance, in an attempt to bring the posterior variances down to a small common value. The allocation of the energy along the various eigenmodes requires the solution of a straightforward waterfilling problem. [C661]

"Distributed and Layered Sensing"

One can easily envision future military operations and emerging civilian requirements (e.g. intelligent unmanned vehicles for urban warfare, intelligent manufacturing plants) that will be both complex and stressing and will demand innovative sensors and sensor configurations. The goal of our research into distributed and layered sensing is to develop a cost effective and extendable approach for providing surveillance for a variety of applications in dynamically changing military and civilian environments. Within distributed and layered sensing, we foresee a new sensor archetype. In this paradigm, sensors and algorithms will be autonomously altered depending on the environment. Radars will use the same returns to perform detection and discrimination, to adjust the platform flight path and change mission priorities. The sensors will dynamically and automatically change waveform parameters to accomplish these goals. Disparate sensors will communicate and share data and instructions in real-time. Intelligent sensor systems will operate within and between sensor platforms such that the integration of multiple sensor data provides information needed to achieve dynamic goals and avoid electromagnetic fratricide. Intelligent sensor platforms working in partnership will increase information flow, minimize ambiguities, and dynamically change multiple sensors' operations based upon a changing environment. Concomitant with the current emphasis on more flexible defense structures, distributed and layered sensing will allow the appropriate incremental application of remote sensing assets by matching resources to the situation at hand. In this paper, we discuss the electromagnetic compatibility (EMC) issues that must be addressed and understood as part of the development of a futuristic intelligence, surveillance and reconnaissance concept utilizing distributed and layered sensing waveform diverse systems. These systems involve the innovative integration of cutting edge technolog- ies such as: knowledge-based signal processing, robotics, wireless networking waveform diversity, the semantic web, advanced computer architectures and supporting software languages. This concept is projected as an autonomous constellation of air, space, and ground vehicles that would offer a robust paradigm to build toward future deployments. The goal is to develop waveform-time-space adaptive processing for distributed apertures that could reduce EMC issues. [C662]

"A frequency diverse Doppler radar for range-to-motion estimation in urban sensing applications"

In this paper, statistical bounds on carrier diverse range estimation are provided. Single frequency (Doppler) radars cannot be used in range estimation due to their range ambiguities. An additional frequency can be used to increase the maximum unambiguous range to accepted values for indoor range estimation of moving targets. The target is assumed to have a linear translation motion profile. The dual frequency radar can also be used to

estimate the actual target velocity, by conducting two different Doppler data measurements, separated by a time period, over which the target continues to exhibit the identical linear translation motion. The parametric model is developed, and the identifiability of the parameters is validated by the non-singularity of the Fisher information matrix. We provide Cramer-Rao bounds for the parameters and show their dependency on the observation period assuming partial knowledge of motion and noise parameters. [C663]

"Cross-eye jamming of monopulse radar"

Radar seeking missiles present a serious threat towards ships and aircraft. In cross-eye jamming a missile seeker is deflected by signals from two onboard antennas transmitting out of phase with signals of nearly equal strength. The limits on cross-eye performance imposed by scattering have been studied when scattering takes place far from the propagation path. It will be shown that a digital cross-eye system with several antenna units can be seriously affected by scattering from sea waves and terrain. [C664]

"The peak sidelobe distribution for binary codes"

Low aperiodic-autocorrelation peak sidelobe levels (PSLs) relate to enhanced range resolution for binary-phase-coded radar and communication waveforms. Typical methods to identify the minimum-attainable PSL for a given code length N require exhaustive calculations whose computational burden grows exponentially with N. In this project, exact PSL histograms were determined for computationally practical lengths. These histograms may lead to ways to estimate PSL distributions for computationally impractical lengths. Plots of the lower four moments for N between 1 and 45 showed that the moments can be approximated closely by aNk. Histograms for N = 45 were compared to a binomially-distributed PSL PDF model based on statistically independent sidelobes. The independent-sidelobe model agreed closely with truth for middle-to high-PSL values, and only varied significantly from truth for PSLs one or two units away from the lowest achievable PSL. Future work will examine ways to develop the PDF from the moments accurately enough to estimate minimum PSL for a given N, and ways to account for sidelobe dependence in the probabilistic model. [C665]

"An approach for interference detection and rejection from other sensors by using Hough Transform and image processing"

This paper presents some results of studies on radar interference rejection using a Hough-Transform-based technique and image processing. If target detection is done by comparing the magnitude of each bin with a threshold produced by a CFAR algorithm, a number of radar systems operating at the same frequency band can cause reciprocal interference, thereby affecting detection and increasing false alarm probability. In this work we will refer to this interference as to "other sensor interference" (OSI). The goal of this work is the definition of methods to detect and remove the interference patterns from radar raw video images. We show that the substitution of interferences with samples estimated from cells (cross range samples) in close proximity of the OSI-affected samples allows CFAR algorithms performance to be improved. [C666]

"Novel pulse-sequences design enables multi-user collision-avoidance vehicular radar"

A new, so-called chaotic pulse-sequence radar (CPSR) has been developed and implemented for short-range vehicular radar, designed to warn the driver of close-by overtaking vehicles (so-called 'blind-spot' warning). It employs a novel design of randomized signal generation and processing which overcomes problems of long-range returns from large reflecting structures and high-levels of interference from both similar and dissimilar radars in the same frequency channel/band. The new technique involves generation of long, non-deterministic pulse trains, composed of a large number of successive, relatively-short pulse-sequences having specially designed correlation properties, separated by random gaps. The statistically-defined unpredictability of such composite pulse trains required in a multi-user scenario is derived from a very large number of pulse-sequences processed in the radar receiver to obtain near-vehicle range estimates. Field tests of a prototype radar confirm good and reliable performance of the technique, including its interference rejection capabilities. [C667]

"Multistatic SAR image reconstruction based on an elliptical-geometry radon transform"

We propose a geometry and inversion methods for a multistatic, downlooking SAR mode using simple antennas. The resulting generalized Radon transform takes line integrals over ellipses of changing aspect ratio. We apply the method of approximate inverse to the inversion of this transform and show the results of the numerical inversion. [C668]

"Multichannel parametric detectors for airborne radar applications"

We consider the problem of detecting a multichannel signal in the presence of spatially and temporally colored

disturbances. The parametric Rao and GLRT detectors, recently developed by exploiting a multichannel autoregressive (AR) model for the disturbance, have been shown to perform well with limited or even no range training data. The performance of the parametric detectors, however, has been evaluated through the limited computer simulations. The disturbances were generated to follow the exact multichannel AR processes and independently from each other with the same distribution whereas the disturbances in an airborne radar environment do not follow the exact multichannel AR model. In this paper, we evaluate the detection performance of the parametric Rao and GLRT detectors using airborne data obtained from the multi-channel airborne radar measurement (MCARM) database. This data contain typical clutter found in airborne radar systems, and cover a variety of scenarios including dense-target or heterogeneous environment Numerical results show that the parametric Rao and GLRT detectors work well with limited or even no range training data in an airborne radar environment. [C669]

"Design and realization of a distributed vector sensor for polarization diversity applications"

Polarization is one type of waveform diversity that may be exploited to improve both radar and communication systems performance. Analytical results show that in order to obtain the best performance improvements, based upon the use of polarization diversity, knowledge of the full electric and magnetic field components is required. Vector sensor antennas are able to measure these components and thus they enable the exploitation of polarization diversity. This article describes a distributed approach to design a 6D vector antenna in a distributed fashion using both electric dipole and magnetic loops as constitutive elements. [C670]

"Information theoretic radar waveform design for multiple targets"

In this paper we describe the optimization of an information theoretic criterion for radar waveform design. The method is used to design radar waveforms suitable for simultaneously estimating and tracking parameters of multiple targets. Our approach generalizes the information theoretic water-filling approach of Bell. The paper has two main contributions. First, a new information theoretic design criterion for designing multiple waveforms under a joint power constraint when beamforming is used both at transmitter and receiver. Then we provide a highly efficient algorithm for optimizing the transmitted waveforms, by approximating the information theoretic cost function. We show that using Lagrange relaxation the optimization problem can be decoupled into a parallel set of low-dimensional search problems at each frequency, with dimension defined by the number of targets instead of the number of frequency bands used. [C671]

"Target tracking using particle filtering and CAZAC sequences"

When tracking targets in radar, the selection of the transmitted waveform and the method of processing the return signal are two of the design aspects that affect measurement accuracy. Increased measurement accuracy results in enhanced tracking performance. In this paper, we apply sequential Monte Carlo methods to propose matched filtering operations in the delay-Doppler space where a target is expected to exist. Moreover, in the case of thresholding the measurements, these methods are used to form resolution cells that have the shape of the probability of detection contour. These methods offer an advantage over traditional radar tracking methods that form tessellating resolution cells to approximate the probability of detection contours, and exhaustively perform matched filtering operations over the entire delay-Doppler space. With the use of a Bjorck constant amplitude zero-autocorrelation (CAZAC) sequence, a high resolution measurement is attained and the use of thresholding is avoided. This is an advantage over commonly used waveforms such as linear frequency modulated chirps (LFMs). We examine the properties of Bjorck CAZACs and demonstrate improved tracking performance over LFMs in a single target tracking scenario. [C672]

"MIMO noise radar-element and beam space comparisons"

The noise radar concept is extended to an array of K transmit antenna and M receive antenna. When independent noise sources are transmitted from each antenna the approach may be viewed as a special case of MIMO radar. Two transmission approaches, termed element space (ES) and beam space (BS), are considered together with both conventional and MVDR beamforming on receive. [C673]

"Target classification by echo locating animals"

In this paper, the principal mechanisms by which bats are assumed to classify targets are reviewed. Particular attention is paid to the ways in which bats might extract information from echoes. Classification mechanisms differ fundamentally according to signal design. It is shown how bats design their emitted waveforms according to whether they need to classify on the basis of micro-Doppler or range profile information. Throughout, analogies are made with radar (and sonar) systems, drawing attention to some ways in which engineers might learn from the classification mechanisms proposed for echo locating animals. [C674]

"Radar signal design using chaotic signals"

The use of chaotic signals in radar imaging applications present particular advantages as they behave like pseudo noise, have a wide band, and are easy to generate. A chaotic frequency modulated (FM) sine wave is an example of a chaotic signal that can yield higher transmitted mean power when peak-power limited transmitters are used. Unlike the random FM signal, the behavior of chaotic FM signals is not fully understood. In this paper, two approaches for analyzing the spectrum of chaotic FM signals are discussed. The first approach approximates the chaotic signal with noise and the second one, deals with the condition for the chaotic signal to remain chaotic after frequency modulation and consequently have a wide band spectrum. [C675]

"A novel polyphase code for sidelobe suppression"

A binary code sequence attained by modification of a Golay code is proposed. This code has sidelobes which are out of phase with the main lobe, a property which facilitates their removal. Unknown delay-dependent phase terms proclude the multiplexing of a Golay pair in frequency. However the modified Golay code is found to have an autocorrelation whose square is complementary with that of the code's original Golay partner. This enables complementary behavior to be achieved when the modified code is multiplexed at equal offsets both above and below the partner. Applications include sidelobe removal in radar returns. [C676]

"Computationally efficient waveform diversity"

In this paper, a new signal processing approach referred to as simultaneous range-Doppler (SRDreg) is presented. It applies fractional Fourier transforms in a manner that yields projections and slices of the cross-ambiguity function (CAF). Waveform diversity (WD) techniques often require extensive processing resources, thus precluding WD from smaller, more mobile systems, or applications with limited resources. By employing SRDreg, the feasibility of WD in these applications is greatly increased. The projection and slice processing is used to detect targets and estimate their unambiguous range and Doppler in the CAF range-Doppler space. SRDregdetects peaks of the CAF in a processor-efficient manner, thereby reducing the computational load associated with traditional approaches since computing the entire CAF is avoided. The number of required operations is reduced to O(Nlog2(N)) as opposed to O(N2log2(N)). Since SRD* processing load is insensitive to waveform modulation and coding, orthogonal waveforms can be exploited to confer temporal, spatial, and spectral diversity to a sensor system, without incurring any processing penalty. Fundamentally, SRDregoffers waveform flexibility and increased processing efficiency, which can be applied to broaden the scope of applicability of WD to sensor systems. [C677]

"The Strength Pareto Evolutionary Algorithm 2 (SPEA2) applied to simultaneous multi- mission waveform design"

This paper furthers the development of the application of evolutionary computation, specifically genetic algorithms (GAs) to the design of simultaneously transmitted orthogonal waveforms. The goal of the application is to determine a suite of "optimal" waveforms (in the Pareto sense) for a single platform radar system performing multiple radar missions simultaneously. The waveform suite is determined by applying the strength Pareto evolutionary algorithm 2 (SPEA2) developed by Zitzler, Laumanns & Theile (2002) to find waveform parameters that successfully realize a set of objectives particular to a variety of radar missions. The objectives to optimize are dictated by the particular missions of interest. The mapping of these objective functions to actual radar performance parameters is used in the SPEA2 algorithm to determine how best to simultaneously perform multiple radar missions such as GMTI, AMTI, SAR etc. using a single radar system in a Pareto optimal sense. Preliminary results are presented for a scaled down multi-mission multi-objective function scenario. [C678]

"Characterization of diversity approaches for LFM stretch-processed waveforms"

Frequency diversity in linear frequency modulated (LFM) waveforms can introduce unintended range shifts among receive radars in a distributed environment. This can make it difficult to predict where interference will occur in those receive radars, particularly when multipath is considered. This paper introduces the concept of interference region in range-frequency space to characterize the interference levels at a receive radar caused by waveforms transmitted from different radars in a distributed architecture. Linear frequency modulated (LFM) stretch-processed waveforms provide wide bandwidth and high range resolution while imposing only modest demands on the digital processing capabilities of a radar system. For this reason they are the waveform family of choice for many current wideband radar systems, including synthetic aperture radar (SAR) systems. However, LFM waveforms do not easily lend themselves to applications that require orthogonality, such as distributed radar architectures. The widespread use of these waveforms and the processing advantages they provide make it worthwhile to examine schemes for their use in a distributed environment. The paper uses interference region

analysis to assess the effectiveness of frequency diversity, upchirp-downchirp diversity and chirp slope mismatch using LFM stretch-processed waveforms in a distributed environment. [C679]

"Polarization diversity for detecting targets in inhomogeneous clutter"

Polarization diversity has proved to be a useful tool for radar detection, especially when discrimination by Doppler effect is not possible. In this paper, we address the problem of improving the performance of polarimetric detectors for targets in heavy inhomogeneous clutter. First, we develop a polarimetric detection test that is robust to inhomogeneous clutter. We run this polarimetric test against synthetic and real data to assess its performance in comparison with existing polarimetric detectors. Then, we propose a polarimetric waveform-design algorithm to further improve the target-detection performance. A numerical analysis is presented to demonstrate the potential performance improvement that can be achieved with this algorithm. [C680]

"Conditional and constrained joint optimization of RADAR waveforms"

In this paper we describe a methodology of jointly designing waveforms for a semi-cooperative, distributed radar system. Some radars have waveforms which are fixed and cannot adapt. The remainder of the group must optimize their emanations conditioned on the existence of the non-cooperative radars. We term this 'conditional joint optimization.' A special case is termed constrained joint optimization examines the problem when the RADAR configuration is completely cooperative. Only classic constraints such as phase-only, finite energy, etc. are considered. The overall metric that is used in the optimization is signal to interference plus noise ratio (SINR). We will show the results of a number of empirical experiments based on canonical spectra and knowledge aided sensor signal processing for expert reasoning (KASSPER) simulated data that show that a joint conditional design will outperform a non-cooperative, individually optimized RADAR network. [C681]

"Adaptive waveforms for target class discrimination"

This paper compares the performance of two matched-illumination waveform design techniques for distinguishing between M target hypotheses. The waveforms are implemented within a closed-loop, sequential-testing framework. In contrast to our earlier work, in this paper the target hypotheses are statistically characterized by power spectral densities. Thus, the waveforms are matched to the target class rather than to individual target realizations. As the class probabilities change in response to received data, the waveforms are adapted, which leads to faster decisions. [C682]

"Multidimensional waveform encoding for spaceborne synthetic aperture radar systems"

This paper introduces the innovative concept of multidimensional waveform encoding for spaceborne synthetic aperture radar (SAR). The combination of this technique with digital beamforming on receive enables a new generation of SAR systems with improved performance and flexible imaging capabilities. Examples are high-resolution wide-swath radar imaging with compact antennas, enhanced sensitivity for applications like along-track interferometry and moving object indication, or the implementation of hybrid SAR imaging modes which are well suited to satisfy hitherto incompatible user requirements. Implementation specific issues will be discussed and performance examples demonstrate the potential of the new technique for different remote sensing applications. [C683]

"Interferometric radar waveform design and the effective interferometric wavelength"

Interferometric radar systems are used by the research, commercial and military communities for applications ranging from topographic mapping to measuring subtle deformations of the Earth's surface for geophysical processes such as earthquakes, volcanoes and ice motion. These systems operate at a variety of wavelengths from 1 cm to 1 m depending on the application. As the number of users of the spectrum increases it is becoming increasingly necessary for these systems to alter their waveforms to have the necessary interoperable compatibility. In particular, notching of certain spectral bands within the radar transmit band may be required to avoid interference with critical users operating in the same band. For high accuracy applications it is necessary to account for how these waveform differences affect the interferometric phase and correlation. We have developed a formula for the effective interferometric wavelength that accounts for the effect of the transmitted waveform on the effective interferometric wavelength and the way the data is processed. [C684]

"Laboratory experiments for the evaluation of Digital Beamforming SAR features"

Digital beamforming (DBF) technique is a promising technique for future Synthetic Aperture Radar (SAR). In this paper, we present the preliminary experiments and investigate the crucial parameters for the optimization of the DBF SAR. The measurements were accomplished by a ground-based DBF SAR system for a single target. The

demonstrator provides the raw data including the system response. SAR images were reconstructed with numerous spatial sampling distances, not only by DBF SAR processing, but also conventional mono-static SAR processing. The reconstructed images show that the minimum variation of the phase between the receive channel is crucial to obtain the theoretical improvement factor and achieve the wide area observation with fine resolution. [C685]

"Motion compensation for a frequency stepped radar"

A few hundred MHZ synthetic bandwidth requires the transmission of many (~100) frequency stepped pulses when a small instantaneous bandwidth (<10 MHz) is available. The actual trend in radar imaging is towards wide instantaneous bandwidth (>50 MHz) thanks to improved technology. However the need of retrofit of narrow instantaneous bandwidth to HRR (high range resolution) seems to be still cost effective in the industrial context. In this case the processing time, combined with a large synthetic bandwidth, requires a proper motion compensation of radial target velocity and acceleration. Target kinematics parameters are estimated by minimization of a like-autocorrelation cost function; this technique is capable of detecting minima of aliasing created by uncompensated motion condition. Accuracies are estimated by Monte Carlo simulation and compared to those achievable by entropy and contrast based techniques. [C686]

"Waveform design and modulation schemes for impulse communications and radar"

Ultrawideband impulse radio communication is based on the classical principles of pulse time modulation conveniently used for baseband transmission. In this paper, we present the principles of impulse waveform design, impulse time modulation for information transmission process, period-staggering modulation scheme for multiple access applications, and M-ary impulse modulation. Periodic and orthogonal non-sinusoidal impulse waveforms are generated in terms of the periodic and orthogonal sinusoidal waveforms. The conventional analog and digital modulation schemes that are based on the use of sinusoidal carrier waveforms are applied to nonsinusoidal impulse waveforms. As illustrative examples, M-ary impulse modulation schemes are described, i.e., M-ary phase shift keying (M-PSK) and M-ary frequency shift keying (M-FSK). The design of a linear FM "chirp" impulse waveform for radar applications is presented too. [C687]

"Waveform communalities between digital beamforming radar and MIMO"

In this paper an approach to the joint realization of digital beamforming radar and MIMO communications is presented. From a hardware point of view, both radar sensing and digital communications systems are based on similar radio frequency components. It will be shown that through a suitable signal design both applications can be simultaneously realized on one multiple antenna hardware platform. [C688]

"Sector interpolation for 3D SAR imaging with baseline diversity data"

SAR tomography is an emerging technique which can be used to derive full 3D SAR images of the observed areas. It is based on the Fourier elevation focusing of the signal acquired by means of baseline diversity. Unfortunately, the spatial baseline distribution is typically non-uniform, resulting in an unsatisfactory image quality. In this work, we improve the basic elevation focusing technique by reconstructing a set of uniform baselines data exploiting a light a priori information, i.e. the height sector which contains the scatterers. The validity of the method has been evaluated by carrying out simulated analyses for different scenarios. [C689]

"Use of frequency-randomized SAR waveforms for the detection and mitigation of small-motion effects in precision RCS measurement"

The use of SAR and ISAR imaging is an important tool in the laboratory RCS characterization of scattering patterns across signature critical platforms. Despite measures to the contrary, air turbulence and mechanical vibration can produce unwanted complex perturbations of the target during the imaging process. The slow sweep time of many laboratory stepped-frequency CW radars means that a target can undergo significant motion even during a sweep, leading to substantial and time-varying defocusing of range profiles, unsuited to conventional motion-correction schemes. Model code was written to provide simulations of representative complex motions for a string-suspended target. Comparison of images produced using monotonic and randomized waveforms could detail the presence and pattern of very small motion-related changes in RCS. The ability to do this was found to have a complex dependence on the relative lengths of the radar sweep time and the characteristic oscillation period of the motion. When the sweep time and oscillation period are comparable, it may be possible to accurately retrieve the target's entire motion history, from the phase perturbation recoverable from the difference of the monotonic and randomized waveforms in the raw frequency domain. This can then be applied back to the data as a motion correction. [C690]

"Time-reversal waveform preconditioning for clutter rejection"

A time-reversal implementation of a transmit waveform preconditioning scheme for optimal clutter rejection in radar imaging is presented. Waveform preconditioning involves determining a map on the space of transmit waveforms, and then applying this map to the waveforms before transmission. Our work applies to antenna arrays with an arbitrary number of transmit-and receive elements, and makes no assumptions about the elements being co-located. Waveform preconditioning for clutter rejection achieves efficient use of power and computational resources by distributing power properly over a frequency band and by eliminating clutter filtering in receive processing. By our time-reversal implementation we avoid the need to obtain an explicit model for the environment in order to compute the preconditioning operator. [C691]

"Model order estimation for adaptive radar clutter cancellation"

Adaptive waveform design for radar clutter cancellation requires knowledge of the rank of the clutter subspace. In this paper, we compare the computed clutter subspace rank, r, using three methods: (i) the exponentially embedded family (EEF) estimator, (ii) Rissanen's minimum description length (MDL) estimator, and (iii) the statistical ranking and selection method (CWA). [C692]

"Evaluation of a fully self-consistent methodology to correct attenuation and differential attenuation at C-band"

A methodology to correct reflectivity factor and differential reflectivity at C-band for rain attenuation is presented and evaluated. The methodology is based on a full self-consistency condition describing the interrelation between polarimetric measurements and attenuation or differential attenuation along the rain medium. Evaluation is performed both using C-band profiles generated from S-band radar measurements collected by the NCAR S-Pol radar as well as data collected at C-band by the Polar 55 C radar in Italy. Evaluation shows improvement in performance with respect to the available techniques. In particular, it shows the capability to remove any systematic bias that could arise from drop size distribution variability from attenuation and differential attenuation estimates. [C693]

"Signal processing and waveform selection strategies in multistatic radar systems"

The multistatic ambiguity function has recently been used as a tool for analyzing multistatic radar systems. It was demonstrated that the multistatic ambiguity function with proper analytical foundation and corresponding graphic representation can serve as a guideline for developing multistatic radar signal processing rules. In this work we use this newly developed approach to combine optimal selection of weights for fusing signals from multiple receivers with waveform selection strategies in order to meet desired performance goals. We consider configurations with multiple receivers and one transmitter and demonstrate through examples that multistatic system performances can be significantly improved when selection of system parameters is based on shaping of the multistatic ambiguity function. This approach promises to be beneficial especially in scenarios with rapidly changing geometries, such as when the transmitter and/or receivers are moving, and when waveform diversity is applied, since the classical detection theory does not take into account the system geometry and waveform shape. [C694]

"Experimental HF radar trial of real-time STAP"

An alternative multi-static HF radar architecture, known as the Forward-Based Receiver Augmentation (FBRA) system, has been developed and tested by the Defence Science and Technology Organization [1]. The experimental system has performed beyond expectations in a number of trials involving targets of interest. This is not only due to the impressive hardware capabilities, but also the advanced signal processing for clutter and interference mitigation, particularly STAP which was shown to be indispensable for the successful operation of the system. This paper describes the real-time STAP algorithm in the FBRA system, and demonstrates its experimental detection performance on a cooperative aircraft target with flight path "ground truth" data available from on-board GPS logging equipment. [C695]

"Waveform Optimization for MIMO Radar: A CramГґB©r-Rao Bound Based Study"

A MIMO (multi-input multi-output) radar system, unlike standard phased-array radar, can transmit via its antennas multiple probing signals. This waveform diversity offered by MIMO radar enables superior capabilities compared with a standard phased-array radar. We consider MIMO radar waveform optimization for parameter estimation for the general case of multiple targets in the presence of spatially colored interference and noise. Numerical examples are provided to demonstrate the effectiveness of the approaches we consider herein. [C696]

"Adaptive Radar Waveform Design for Multiple Targets: Computational Aspects"

In this paper we describe the optimization of an information theoretic criterion for radar waveform design. The method is used to design radar waveforms suitable for simultaneously estimating and tracking parameters of multiple targets. Our approach generalizes the information theoretic water-filling approach of Bell. The paper has two main contributions. First, a new information theoretic design criterion for designing multiple waveforms under a joint power constraint when beamforming is used both at transmitter and receiver. Then we provide a highly efficient algorithm for optimizing the transmitted waveforms, by approximating the information theoretic cost function. We show that using Lagrange relaxation the optimization problem can be decoupled into a parallel set of low-dimensional search problems at each frequency, with dimension defined by the number of targets instead of the number of frequency bands used. [C697]

"Low-Complexity Method for Transmit Beamforming in MIMO Radars"

MIMO radar is a new concept in which radar employs multiple waveforms to improve its performance. Previously, a transmit beamforming method was proposed for MIMO radars. This method allows optimization of the beampattern by altering the cross-correlation matrix of the transmitted waveforms. The optimization is based on minimization of a cost function, but the use of numerical methods in the algorithm leads to high computational complexity. Here we propose a new cost function for the beampattern optimization. For linear arrays and typical beampatterns, this cost function can be evaluated in closed form, thus reducing the computational complexity considerably. Simulation examples demonstrate that the proposed cost function also leads to faster convergence and lower approximation error [C698]

"Adaptive Polarized Waveform Design for Target Tracking using Electromagnetic Vector Sensors"

We develop an adaptive waveform design method for target tracking. In our method, at each time step, we optimally select the parameters, including the polarization of the transmitted signal waveform to improve the tracking accuracy. An array of electromagnetic vector sensors is employed to fully recover the polarimetric information from the reflected signals. We derive our approach under a framework of sequential Bayesian filtering. We apply a sequential Monte Carlo method to manipulate the nonlinear and non-Gaussian state and measurement models. We design a criterion for the waveform optimization based on a posterior Cramer-Rao bound [C699]

"Characteristic Phase E-Sequences in Efficient Pulse-Compression Methods using Discrete Wavelet Decomposition"

We derive a family of sequences which obey a characteristic-phase constraint as it applies to finite sequences. We show these sequences are special cases of the well-known Welti sequences. We construct a transmit waveform which allows extremely efficient decomposition, whose outputs are simultaneously interpretable as adjacent correlation-filter outputs, and as lossless input signal representations. We discuss implementation of receive and transmit functions. [C700]

"A Subspace Method for MIMO Radar Space-Time Adaptive Processing"

In the traditional transmitting beamforming radar system, the transmitting antennas send coherent waveforms which form a highly focused beam. In the MIMO radar system, the transmitter sends noncoherent (possibly orthogonal) broad (possibly omnidirectional) waveforms. These waveforms can be extracted by a matched interbank. The extracted signals can be used to obtain more diversity or improve the clutter resolution. In this paper, we focus on space-time adaptive processing (STAP) for MIMO radar systems which improves the clutter resolution. With a slight modification, STAP methods for the SIMO radar case can also be used in MIMO radar. However, in the MIMO radar, the rank of the jammer-and-clutter subspace becomes very large, especially the jammer subspace. It affects both the complexity and the convergence of the STAP. In this paper, a new subspace method is proposed. It computes the clutter subspace using the geometry of the problem rather than data and utilizes the block diagonal property of the jammer covariance matrix. Because of fully utilizing the geometry and the structure of the covariance matrix, the method is very effective for STAP in MIMO radar. [C701]

"Filter Design for Steady-State Tracking of Maneuvering Targets with LFM Waveforms"

The equation for the Kalman filter assumes that the model or process noise is white Gaussian. However, for maneuvering targets, the acceleration changes in a deterministic manner, and hence, the process noise is non-white. Therefore, while tracking maneuvering targets, the Kalman filter develops a bias (lag) in its estimates and the state covariance does not accurately represent the error. This paper derives expressions for the sensor

noise only (SNO) covariance matrix and the position and velocity lag parameters due to maneuvers, which are used to perform an RMSE analysis for tracking with LFM waveforms. In doing so, the concept of the deterministic tracking index and its relation to the typical tracking index for random maneuvers is introduced. Using these relations, the paper also proposes a method to calculate the optimal process noise variance to be used in the Kalman filter for a given deterministic tracking index. [C702]

"An X-band Transmission Line Based CMOS VCO with FM Modulation"

An X-band voltage-controlled oscillator (VCO with frequency modulation (FM) capability is realized in a 0.18mum 1P6M CMOS technology. The characteristics of the VCO modulated by a 100KHz triangular waveform are presented and investigated. The passive components of the VCO are implemented by two-dimensional (2-D) complementary-conducting strip transmission lines (CCS TLs), varactors and metal-oxide-metal (MOM) capacitors for substrate coupling consideration. The measured VCO with free running phase noise of -83.2 dBc/Hz at 100KHz offset from the carrier. The compact VCO chip size is 330 times450mum2excluding pads. Furthermore, the modulation bandwidth is up to 400MHz of the proposed VCO with direct FM modulation which could improve range resolution in a radar system [C703]

"Adaptive Pulse Compression: Preliminary Experimental Measurements"

Preliminary experimental results from the adaptive pulse compression (APC) test bed are presented. A recently proposed adaptive processing technique has been shown via simulation to improve upon current pulse compression techniques through a process known as reiterative minimum mean-square error estimation (RMMSE). The RMMSE technique forms the basis of the APC and the Multistatic APC (MAPC) algorithms. In this paper, we present experimental results demonstrating the feasibility of these approaches. Several polyphase waveforms have been implemented in an experimental test bed. Initial results show that small non-linearities in the waveform generation process have only a marginal impact on the estimation performance of the algorithms. A discussion of the APC test bed followed by experimental results demonstrating the performances of the APC and MAPC algorithms are presented. These initial experimental results indicate that the APC approach is able to successfully mitigate pulse-compression sidelobes on measured data, and that the MAPC algorithm can successfully mitigate both the mutual-interference from shared-spectrum radar signals and pulse compression sidelobes on measured data. [C704]

"22-29GHz Ultra-Wideband CMOS Pulse Generator for Collision Avoidance Short Range Vehicular Radar Sensors"

The pseudo millimeter wave 22-29GHz ultra-wideband (UWB) is attractive for the applications in short-range (SR) automotive radar sensors in order to contribute to significant reduction of traffic fatalities. Although CMOS is suitable for the short-range radar since processing units can be implemented in the same chip with the UWB front-end building block, it is difficult to operate CMOS pulse generators at such a high frequency. To realize the pseudo-millimeter-wave band using CMOS, we have proposed a new pulse generator consisting of a series of delay cells and edge combiners with waveform shaping. As a result of measurement using 90nm CMOS technology, 1Gbps pulses are successfully generated with a power consumption of 1.4mW at a supply voltage of 0.9V. This result is the key technology for a one-chip SR cost effective radar sensors. [C705]

"Multiresolution Subspace Beam Formation Using a Partially Coherent Model"

Traditional beam formation and waveform techniques rely on fixed apertures with single frequency assumptions that restrict the geometry of the aperture. This approach results constraints on the functionality of radar systems such as having simultaneous imaging and tracking ability, eliminating complex interference, and working with platforms that have limited bandwidth and processing resources. We propose an adaptive multiresolution orthogonalized sub-space beam formation method (AMOS) that allows optimization of apertures that may have non-uniform spacing with limited bandwidth. We combine this model with a partially coherent electromagnetic wavefront propagation model. We will show how this method compares to similar methods from a theoretical lower bound standpoint. [C706]

"Analysis and Emulation of FM Radio Signals for Passive Radar"

Due to its high power levels provided, and its wide coverage, FM radio could be a good opportunity transmitter for passive coherent location (PCL) radar systems. In this paper we study the effectiveness of FM signals as radar waveforms by means of simulated and real data analysis. To this purpose, an emulation of FM radio transmitter is presented, whose outputs are compared with real FM data collected by an experimental digital receiver. In this way, we also achieve a reliable instrument to optimize target detection performance by a successive adaptive signal processing. To complete the analysis of opportunity waveforms, the signals' self-

ambiguity functions and spectra are evaluated, so it is possible to improve the knowledge of how to select the most appropriate FM channel. Since emulated data differ from real data in means of the transmission channel, a statistical analysis of the real channel is presented. [C707]

"Compression Waveforms for Non-Coherent Radar"

Non-coherent pulse compression (NCPC) was suggested recently. It was described using on-off keying (OOK) signals based on Manchester-coded binary pulse compression sequences (e.g., Barker, Ipatov). The present paper expands the discussion on waveform choice for both periodic and a-periodic cases, and on detection performances of this method. OOK transmitter and a receiver based on envelope-detection, suggested for the NCPC system, are simpler to implement than a binary phase-coded transmitter and a coherent receiver with I&Q synchronous detector, required for coherent pulse compression. NCPC can be used in simple radar systems where Doppler information is not required, in direct-detection laser radar systems and in ultra wide band (UWB) radar. Non-coherent processing has drawbacks in cases of reflections from multi-scatterer targets. The drawbacks and means of mitigating them are considered in section II. [C708]

"Ambiguity and sidelobe behavior of CAZAC coded waveforms"

CAZAC (Constant Amplitude Zero Autocorrelation) sequences are important in waveform design because of their optimal transmission efficiency and tight time localization properties. Certain classes of CAZAC sequences have been used in Radar processing for many years while recently discovered sequences invite further study. This paper compares several classes of CAZAC sequences with respect to both the periodic and aperiodic ambiguity function. Some computational results for different CAZAC classes are presented. In particular, we note the fact that so-called Bjorck CAZACs have sidelobes at different locations when different shifts are considered. We take advantage of this fact by using an averaging technique to lower sidelobe levels. [C709]

"Radar Core Electronics for the European Radar SOSTAR-X-Recent Results"

A Radar Core Electronics (CE) has been developed for the European SOSTAR-X (Stand-Off Surveillance and Target Acquisition Radar) programme. Taking into account the requirements for different SAR modes, MTI modes, and simultaneous SAR/MTI modes, the main functions (frequency genera-tion, radar timing, waveform generation, demodulation, A/D-conversion, digital pre-processing and formatting) have been identified, and a modular, configurable and flexible CE has been designed. Key features are e.g. programmable high resolution waveforms, waveform agility, bursts with different pulse repetition frequencies (PRFs), pulse synchronous and burst synchronous operation, and radar sensor control incl. antenna pointing control. The CE has been integrated and tested and turned out to fully comply with the requirements. After integration with the antenna during the Radar Sensor (RS) integration in the Compact Antenna Test Range in Friedrichshafen, the RS was embedded into the SOSTAR-X demonstration system on a Fokker 100 aircraft. The performed tests and obtained results show the high performance of the CE and proved that the CE performs all tasks as expected. The design of the CE is also suitable for other carriers, like UAVs and satellites. Other programmes like the TerraSAR-X satellite for which EADS also built the Radar Core Electronics show that a small chassis size can be achieved while meeting a similar or even better performance. [C710]

"Characterization of Range Resolution as a Function of Bandwidth and Frequency"

Wideband radar systems typically express range resolution as a function of bandwidth only. This interpretation of resolution is related to the width of a single peak corresponding to a point scatterer, and is analogous to the Rayleigh criterion in optics. However, if one interprets resolution to mean the ability to resolve two closely spaced scatterers in a downconverted, pulse-compressed radar return, then resolution is a function of frequency as well as bandwidth. This paper shows that, for fixed bandwidth, the quality of peak separation in the processed return of two closely spaced scatterers is a nonlinear, nonmonotonic function of frequency and range separation. Simulation results, using full pulse-compression processing of uncompressed waveform returns, plot peak separation quality as a function of frequency. Analytical results show why this frequency-dependent behavior should be expected and how bandwidth figures in the nonlinearity as well. Frequency-dependent resolution of closely spaced scatterers has implication for applications that need high range resolution and also utilize frequency diversity for operation in a multi-radar environment. [C711]

"Tracking High-Speed Targets Using a Pulse Doppler Stepped-Frequency Waveform"

This paper develops a computationally efficient processing technique using fast Fourier transforms (FFT), averaging, and weighted least squares fits to track high-speed targets with a pulse Doppler waveform that is stepped in frequency. The measurements will be unambiguous in Doppler for high-speed targets of interest, but highly ambiguous in range before tracking. First, a range-Doppler matrix is formed using motion compensated

data. Then, the effect of the range, radial velocity, and radial acceleration of the target on the processed data is approximated by a polynomial series, and the parameters are estimated using a weighted least squares fit. Monte Carlo simulations of the algorithm when four or more cpis of data are processed are in reasonable agreement with the theoretical predictions. [C712]

"A Comprehensive Review of Quasi-Orthogonal Waveforms"

Quasi-orthogonal waveforms which exhibit low cross-correlation responses have the potential to enhance radar performance. Intra-pulse, phase coded or frequency modulated waveforms, sharing the same frequency band, are of greatest interest. A review of quasi-orthogonal waveform design and performance is presented including bounds on auto and cross-correlation performance. [C713]

"Some properties of IIR power-symmetric filters"

Power-symmetric IIR filters have in the past been used in two-channel filter banks. If appropriately designed, such filters have allpass polyphase components, and this induces useful properties in the filter bank. For example, IIR orthonormal filter banks have in the past been designed in this way, and generate orthonormal basis functions. In this paper we study some theoretical properties of IIR power symmetric filters in a more general perspective. This includes the derivation of a general analytical form, and a study of pole locations [C714]

"Improving Detection in Sea Clutter using Waveform Scheduling"

In this paper, we propose a method to exploit waveform agility in modern radars to improve performance in the challenging task of detecting small targets on the ocean surface in heavy clutter. The approach exploits the compound-Gaussian model for sea clutter returns to achieve clutter suppression by forming an orthogonal projection of the received signal into the clutter subspace. Waveform scheduling is then performed by incorporating the information about the clutter into the design of the next transmitted waveform. A simulation study demonstrates the effectiveness of our approach [C715]

"Synthetic Aperture Radar Demonstration Kit for Signal Processing Education"

A synthetic aperture radar scale model has been developed to improve signal processing teaching. Based on low frequency ultrasound transmission, it is a low cost demonstration kit. The overall software is directly running on Matlabreg and allows easy and realtime modifications. This educational tool can be used to test different waveforms and show the effects of a real scene on the final image. It can also be used in a more advanced way to test different signal processing in order to improve image focusing or to reduce computation burden [C716]

"Next Generation Intelligent Radar"

A confluence of several recent advances in adaptive radar technologies has created the opportunity for major advancement in "intelligent adaptive radar". Firstly, the appearance of fully digital AESA radars has provided the radar system engineer with unprecedented opportunities for rapid agility and adaptability-including pulse-to-pulse modulation agility/adaptivity. Second, recent advancements in the theory and design of adaptive waveform capability has matured to the point where new radar operating modes can be conceived that exploit the aforementioned fully digital transmit capability. Lastly, real-time knowledge-aided processing for radar has also matured to the point where the adaptivity of the radar (both on transmit and receive) can be intelligently regulated through precise environmental awareness. In this paper, all of these elements are combined to show how a new intelligent radar architecture can be conceived that not only acts "intelligently" on the receive chain, but also on the transmit side-in some ways analogous to nature's own intelligent sonar system: the bat. [C717]

"Radar Sensor Network Design and Optimization for Blind Speed Alleviation"

In this paper we propose orthogonal waveforms and equal gain combination algorithm in radar sensor network (RSN) to alleviate blind speed problem. We also design a fuzzy logic system (FLS) to optimize the number of radars in RSN. Simulation results show that our FLS-based RSN can not only balance the number of radars and QoS in terms of probability of miss detection (PMD), but to some extent achieve constant PMD with different system configuration. [C718]

"Multisensor Dynamic Waveform Fusion"

Speech communication is significantly more difficult in severe acoustic background noise environments, especially when low-rate speech coders are used. Non-acoustic sensors, such as radar sensors, vibrometers,

and bone-conduction microphones, offer significant potential in these situations. We extend previous work on fixed waveform fusion from multiple sensors to an optimal dynamic waveform fusion algorithm that minimizes both additive noise and signal distortion in the estimated speech signal. We show that a minimum mean squared error (MMSE) waveform matching criterion results in a generalized multichannel Wiener filter, and that this filter will simultaneously perform waveform fusion, noise suppression, and crosschannel noise cancellation. Formal intelligibility and quality testing demonstrate significant improvement from this approach [C719]

"Cancellation of Doppler Distortion in Pulse Compression for Targets Moving in an Arbitrary Direction"

It can be shown that the hyperbolic frequency modulated waveform is Doppler-invariant only when the Doppler factor is a constant number, i.e., the target has a constant velocity and along the direction from the radar to the target. If the target moves in an arbitrary direction, the degradation of the pulse compression caused by the mismatch between the reflected signal and the matched filter may still exist. In this paper we demonstrate that the Doppler effect caused by the moving target in an arbitrary direction can be approximated by a target with an initial velocity and a constant acceleration along the direction from the radar to the target, which results in a frequency shift in the reflected waveform. Therefore a bank of matched filters with pre-selected values of frequency shifts can be utilized to compensate for the Doppler effect. Numerical examples with target moving in an arbitrary direction are presented to illustrate this effect, which have been successfully compensated by shifting the frequency response of the matched filter. [C720]

"Optimal Beampattern Synthesis of a Polarized Array"

Utilizing the polarization information in waveforms about targets enables improving the performance of radar systems. We consider the optimal synthesis of the polarized beampattern of an array of antennas, each having two orthogonal electricdipole elements. We control the amplitudes and phases of the electric fields emitted from these dipole antennas to synthesize the electromagnetic beam with desired power and polarization patterns. The problem is formulated in a convex form which is thus efficiently solvable. We compare the performance of two synthesizing methods: (i) separate design of the two co-aligned dipole antenna sub-arrays; and (ii) joint design of the cross-dipole antenna array. Our results indicate that these two separate designs have the equivalent capability of suppressing the sidelobe power density, whereas the joint design has the additional advantage of controlling the beam polarizations. The results are also demonstrated by numerical examples. [C721]

"MIMO Radarwaveform Design"

Recently the radar community has been discussing "multiple-input multiple-output (MIMO) radar" that utilizes multiple transmitters to transmit independentwaveforms. MIMO radar offers the potential for significant gains, e.g., diversity gain and spatial resolution gain. Since the employed radar waveform plays a key role in determining the accuracy, resolution, and ambiguity in performing tasks such as determining the target range, velocity, shape and so on, it is meaningful to investigate waveform design specially for this newly proposed MIMO radar. This paper summarizes some of our recent results on MIMO radar waveform design, mainly for identification and classification of extended radar targets. Our waveform design considers optimizing two criteria: maximization of the mutual information (MI) and minimization of the minimum mean-square error (MMSE). In this process, we are also interested in identifying the relationship between the waveforms obtained under the two criteria, given different a prior knowledge of the target's second-order statistics. [C722]

"Doppler Resilient Golay Complementary Pairs for Radar"

We present a systematic way of constructing a Doppler resilient sequence of Golay complementary waveforms for radar, for which the composite ambiguity function maintains ideal shape at small Doppler shifts. The idea is to determine a sequence of Golay pairs that annihilates the low-order terms of the Taylor expansion of the composite ambiguity function. The Prouhet-Thue-Morse sequence plays a key role in the construction of Doppler resilient sequences of Golay pairs. We extend this construction to multiple dimensions. In particular, we consider radar polarimetry, where the dimensions are realized by two orthogonal polarizations. We determine a sequence of two-by-two Alamouti matrices, where the entries involve Golay pairs and for which the matrix-valued composite ambiguity function vanishes at small Doppler shifts. [C723]

"Prototype of a Reconfigurable 94GHz Smart Radar Sensor"

With the introduction of millimetre wave radar systems in various commercial applications, including collision avoidance, cruise control, autonomous navigation and imaging, it is now clear that a "one size fits all" approach to radar system development is not effective. This paper describes the implementation of a reconfigurable millimetre wave system comprising a coherent 94 GHz front end, a fast arbitrary waveform generator based

modulator and a fast digitiser which, with their associated software, will allow for the development and evaluation of modulation and signal processing techniques which can be adapted to various radar based tracking and imaging requirements. [C724]

"Maximizing Detection Performancewithwaveform Design for Sensing in Heavy Sea Clutter"

In this paper, we consider a radar system capable of adaptively adjusting its transmitted waveform to mitigate the effect of the environment and improve detection performance. We thus bring the potential of waveform agility to bear on the challenging problem of target detection in heavy sea clutter. Using a two-stage procedure, we first estimate the statistics of the sea clutter in the vicinity of a predicted target. A phase-modulated waveform is then designed and transmitted so as to maximize the generalized likelihood ratio at the predicted target location, thus improving the signal-to-clutter ratio (SCR). Employing the compound-Gaussian (CG) model, we exploit a subspace-based approach to further mitigate sea clutter and deliver improved detection performance. Simulations illustrate the effectiveness of our method. [C725]

"Time Reversal Target Classification from Scattered Radiation"

This paper proposed the M-ary hypothesis testing algorithm for classifying radar backscatter signals from hidden targets in a rich scattering environment using time reversal. The target recognition algorithm is to be designed to distinguish measurements of the radar backscatter from an unknown object as belonging to one of a set of M classes. The proposed time reversal target classifier is, in essence, a correlator that calculates the cross-correlation of the normalized target signature waveforms with a data dependent quantity obtained from measurements. The algorithm requires a priori empirical statistical knowledge of the scattering channel, which is dependent of configurations of the scatterers in the environment. By incorporating time reversal, the proposed algorithm provides a significant performance improvement compared with the conventional method. Proof of concept is provided using electromagnetic data collected in a laboratory environment. [C726]

"Agenda-at-a-glance"

{no data available} [C727]

"Time-orthogonal-waveform-space-time adaptive processing for distributed aperture radars"

Distributed aperture radars represent an interesting solution for target detection in environments affected by ground clutter. Due to the large distances between array elements, both target and interfering sources are in the near field of the antenna array. As a consequence the characterization of both the target and the clutter is complicated, combining bistatic and monostatic configurations. Using orthogonal signaling the receivers can treat the incoming signals independently solving separately bistatic problems instead of the initial multistatic problem. Recent works have demonstrated the benefits of the use of frequency diversity space time adaptive processing for distributed aperture radars. This paper modifies the waveform diversity signal model, resorting to a time orthogonal signaling scheme, which does not present the coherence loss exhibited by frequency diversity. [C728]

"The benefits of matched illumination for radar detection of ground based targets"

This paper compares the radar detection performance of a narrow band rectangular pulse, linear chirp and nonlinear stepped frequency waveform approximating to a matched target illumination against two target types (a farm tractor and a main battle tank) in the presence of clutter (soil/sand, rocks and woodland). [C729]

"Waveform Diversity and Electromagnetic Compatibility"

Waveform diversity in multistatic radar systems can enhance distributed radar system performance. Dynamically changing the electromagnetic emanations of radar and communications systems however poses an electromagnetic compatibility (EMC) challenge. Data are provided illustrating how waveform diversity improves multistatic radar system performance. An approach for maintaining EMC in a dynamically changing environment is also provided. [C730]

"Effect of In-band Intermodulation Interference on Direct-Sequence Spread Spectrum (DSSS) Communication Systems for Electromagnetically Diverse Applications"

The goal of this paper is to analyze the effect of nonlinearities on the performance of direct-sequence spread spectrum systems in the context of electromagnetically diverse applications. Inter-modulation products due to nonlinear amplification are analyzed and the effect of nonlinearities is illustrated by means of a computer

simulation result. For the performance measure, bit-error rate (BER) is considered to assess the effect of in-band intermodulation interference. The findings of this study will be of benefit to the waveform diversity community. This community concerned with assessing the effects of multiple RF sensor and communication systems used for enhancing cooperative target tracking and engagement. This involves multiple radars and communication systems that process acquired information in real time. The optimum performance, operation and availability of these systems are assured through the application of adaptive spread spectrum waveforms and electromagnetic diversity schemes derived for the RF communications problem. [C731]

"Improved Methods for Frequency Measurement of Short Radar Pulses"

A method for measuring the frequency of short radar pulses is presented. In our experiment, two frequency synthesizers were used as a signal source, a double balanced mixer as a phase detector and a fast sampling oscilloscope (1 Gs/s) was used for data acquisition/display. Therefore our method is relative in nature. Since this method is based on waveform measurements, also even shorter pulses and their frequency deviations can be measured or at least detected and evaluated. In our test setup, 18 ns pulses can be produced. A waveform of such short pulses cannot be measured using a conventional oscilloscope, but a dedicated high-speed sampling device. [C732]

"An ECCM Scheme for Orthogonal Independent Range-Focusing of Real and False Targets"

This article develops a radar signaling scheme providing full immunity against a repeat jammer. Resistance against the jammer is achieved by employing the concept of pulse diversity where the radar continuously emits either modified version of previous waveforms or new pulses following a specific orthogonal structure. This structure enables the radar to successfully separate the signals being reflected off the real targets and the false reflectors being emulated by the jammer, resulting in full independent range-focusing. The method permits combination of various types of pulses and also offers waveform diversity. [C733]

"A Full Waveforminversion Algorithm for Interpreting Crosshole Radar Data"

Ground-penetrating radar (GPR) is a useful tool for civil and environmental engineering fields because of its high resolving power and non-destructive measurements. This paper presents a method of full-waveform inversion of borehole GPR data for imaging permittivity structures. The inversion algorithm is based on a conjugate gradient search for the minimum of an error functional relating to the difference between measured and predicted data. A small model perturbation in the functional can be efficiently calculated by propagating the data error back into the model in reverse time and correlating the field generated by the back-propagation with the corresponding incident field at each point. A finite difference time domain (FDTD) method is used for solving Maxwell's equations to obtain incident electromag-netic wavefields. Back-propagated wavefields satisfy adjoint Maxwell's equations, which are stable in reverse time and can be solved by the same FDTD scheme. The imaging scheme is applied to crosshole radar configuration, thereby demonstrating its capability to reconstruct permittivity structures. Tests on a two-dimensional synthetic model produce good images of target scatterers and show stable convergence. [C734]

"Direction of Arrival Estimation using Advanced Signal Processing"

Accurate estimation of signal direction of arrival (DOA) has many applications in communication and radar systems. For example, in defense application, it is important to identify the direction of possible threat. One example of commercial application is to identify the direction of emergency cell phone call such that the rescue team can be dispatched to the proper location. DOA estimation using a fixed antenna has many limitations. Its resolution is limited by the mainlobe beamwidth of the antenna. Antenna mainlobe beamwidth is inversely proportional to its physical size. Improving the accuracy of angle measurement by increasing the physical aperture of the receiving antenna is not always a good option. Certain systems such as a missile seeker or aircraft antenna have physical size limitations; therefore, they have relatively wide mainlobe beamwidth. Consequently, the resolution is quite poor. Also, if there are multiple signals falling in the antenna mainlobe, it will be difficult to distinguish them. Instead of using a fixed antenna, an array antenna system with innovative signal processing would enhance the resolution of signal DOA. It also has the ability to identify multiple targets. Two types of signal processing methods, model based and eigen-analysis estimation techniques, are presented in this paper. The model based approach models the observed data as the output of a linear shift invariant system driven by zero mean white noise. The signal's DOA can be estimated by evaluating the model parameters. This approach has properties similar to the maximum entropy spectrum estimation. Some of the problems in the maximum entropy method, such as the line splitting effect, are also observed in this method. Two different processing algorithms are used to obtain the model parameters, and they are: 1. least mean square (LMS) and 2. sample matrix inversion (SMI). The eigen-analysis method based on temporal averaging

has been investigated by many authors in the past (Sc- hmidt, 1986). However, temporal averaging requires average over multiple time samples to estimate the covariance matrix. Sometimes, the radar system prefers to have an estimated covariance in a single snapshot. We propose eigen-analysis based on spatial smoothing so that we can have estimated covariance in a single snapshot. Performances based on several different spatial averages are discussed in this paper. Extensive computer simulations are used to verify the processing algorithms. For narrowband signals, both processing algorithms provide enhanced resolution and have ability to resolve multiple targets as long as the number of targets is less than the system's degree of freedom. SMI provides better performance than the LMS method due to the fact that this method is relatively immune to excessive mean square error. However, for multiple wideband waveforms, sometimes the array antenna has difficulty to resolve them, especially if signals are impinging the antenna with narrow spatial separation. This problem can be solved by extending the array antenna to a space time adaptive processor (STAP) (Guerci, 2003). STAP is basically replacing the single weight at the output of each array element by an adaptive filter. Statistical analysis of the performance of the processing algorithms and processing resource requirements are discussed in this paper. [C735]

"Spatially Waveform Diverse Radar: Perspectives for High Frequency OTHR"

The application of multi-input multi-output (MIMO) radar concepts to HF over-the-horizon radar is considered to improve radar timeline management flexibility and to permit adaptivity on transmit. MIMO radar concepts in the literature are inconsistent and in this paper the taxonomy of MIMO radar is clarified and distinctions between different MIMO radar types drawn. The term "spatially waveform diverse radar" is introduced, and performance equivalences between element-space and beamspace orthogonality discussed. Finally, we outline significant constraints on the design of waveform sets for the case of transmit arrays where (at least for some part of the operational regime) the array inter-element spacing is less than one half wavelength. [C736]

"High Resolution Frequency MIMO Radar"

The frequency MIMO radar synthesizes a wideband waveform by transmitting and receiving multiple frequency signals simultaneously. This paper provides the efficient transmitter array configurations and signal processing methods to improve the cross range resolution and range resolution of the frequency MIMO radar after receiving beamforming. The key is to properly apply the weightings to the multiple subband returns to compensate the delay differences and phase shifts between them. To eliminate the ambiguous images, the nonuniform array and the auxiliary array layout are employed, and the round robin transmission scheme is utilized on the basis of the configuration of the main array plus the auxiliary array. Among them the "round robin" transmission scheme can obtain the best cross resolution at cost of decreasing the pulse repeat frequency. In the "round robin" transmission scheme, spatial diversity technique can be used to combat the target RCS scintillation. [C737]

"Polarization Diversity Using Mutual Information"

An information-theoretic criterion is introduced for waveform polarization type selection in a synthetic aperture radar (SAR) configuration. The criterion is based on the concept of mutual information (MI). Specifically, the MI criterion (MIC) minimizes the MI between the radar return signal at two distinct instants of time: one is the just-received return due to the last-transmitted pulse with known polarization type, and the other is the to-be-received return due to the pulse to be transmitted next with to-be-determined polarization type. In that manner, the polarization type selected for the pulse transmitted next will result in the collection of the largest amount of new information, as measured by a formal criterion. The MIC involves the radar system model and the probabilistic definition of the clutter, interference, and noise processes. In particular, when all these processes are proper Gaussian processes, the MIC attains a simple analytic form. The formulation and simulation-based results are presented in the context of a first-order radar system model, for simplicity, but the MIC can be extended to cover more complex models in a straightforward manner. In addition, the MIC is applicable to other radar modes and sensor types. The results presented show that the MIC is an effective method for polarization type selection in a SAR. [C738]

"Ka-Band Ground-Based Noise Waveform SAR"

We present main results of design and investigations of Ka-band ground based interferometric SAR which uses continuous noise waveform as a probe signal and may operate in both monostatic and bistatic regimes. Synthetic aperture antennas enable to design a portable, light weight, easy to mount device with high speed of operation suitable for SAR imaging in quasi-real time while Ka-band noise waveform signals provide all-weather high resolution, high electromagnetic compatibility and interference immunity. Experiments have shown a rather high stability and repeatability of the measurements due to both the high quality of the equipment and advanced signal processing methods. The SAR system designed is an innovative instrument for solving new tasks of

precise remote monitoring of various large objects, such as sealing of big halls, dams, bridges, TV towers, hangars, etc. [C739]

"DCT Local Adaptive Filtering of Images Corrupted by Fluctuative Noise with a Priori Unknown Statistical Properties"

A DCT based locally adaptive filter has been proposed and applied for processing of real and imaginary components of bispectrum for solving a problem of unknown signal shape (waveform) reconstruction. The bispectrum is a 2-D complex function and in its real and imaginary components a strongly non-stationary noise is present. Thus, the filter designed can be also effectively applied to processing different kind of images for which non-stationary noise with a priori unknown local statistical properties is present. The modifications of DCT based filters have been successfully used for removal of pure multiplicative, speckle and film-grain noise. [C740]

"Minimax Robust Waveform Design for MIMO Radar in the Presence of PSD Uncertainties"

In this paper, we consider the problem of mini-max robust waveform design for multiple-input multiple-output (MIMO) radar based on mutual information (MI) and minimum mean square error (MMSE) estimation for target identification and classification. Recognizing that a single, precise characterization of target power spectral density (PSD) is rare in practice, we assume the PSD lies in an uncertainty class of spectra bounded by known upper and lower bounds, which markedly relaxes the required target a priori knowledge. Based on this band model, we develop minimax robust waveforms for MIMO radar under both MMSE and MI criteria. These robust waveforms bound the worst-case performance at an acceptable limit, and also could insure performance will be sufficiently good for any PSD in the uncertainty class. Our findings also indicate that the MI and MMSE criteria lead to a different minimax robust waveform solutions, which is in contrast to the case of the perfectly known target PSD. [C741]

"Solving Multi-path Time Delay Estimation Problem in the Presence of Additive White Gaussian Noise Using a Genetic-Algorithm"

In practical world, there always exist problems of multi-path time delay estimation (MTDE) and it is an important problem in the fields of sonar, radar, digital communication and geophysics. We consider the problem of estimating the arrival times of overlapping ocean-acoustic signals from a noisy received waveform that consists of attenuated and delayed replicas of a known transient signal. We assume that the transmitted signal and the number of paths in the multipath environment are known. Many existing time-delay estimation algorithms perform poorly due to converging to local optimum points. In this paper, an efficient genetic-algorithm (GA) is applied to deal with the above problem. To the best of our knowledge this study is the first attempt to solve time delay estimation (TDE) using an evolutionary technique, genetic-algorithms. The performance of generic-algorithm is examined for different signal-noise scenarios. Our simulation results show that the time delays are estimated well based on the genetic-algorithm. [C742]

"Two-Dimensional Generalized Partial Response Equalizer for Bit-Patterned Media"

The use of bit-patterned media is one of the approaches being investigated to extend magnetic recording densities to 1 Tbit/in2and beyond. In patterned media, track pitch may be small causing adjacent tracks to have significant interference on the replay waveform from the main data track. To mitigate the effect of such inter-track interference (ITI), we propose the use of a two-dimensional (2D) generalized partial response (GPR) equalizer. We select both the equalizer and the partial response target using the minimum mean squared error (MMSE) criterion. However, we avoid the need for a 2D Viterbi algorithm by imposing a constraint on the 2D target that forces the adjacent track contributions (in the ideal case) to zero. Simulation results show that this 2D equalizer significantly improves the bit error rate (BER). In this work, the effect of a 2D GPR equalizer on the performance of a patterned media system in the presence of track misregistration (TMR) is also investigated. Based on the simulation results, the 2D equalization method appears to be more tolerant to TMR than the conventional GPR The main drawback of the proposed method is the need for simultaneously acquiring the signals from three adjacent tracks. [C743]

"Investigation on Genetic Algorithm for Countermeasure Technique Generator"

Development of successful electronic countermeasure (ECM) techniques against target track radars is a time-consuming and expensive process. Recently, Nunez et al. reported a genetic algorithm (GA) optimization method for ECM techniques generation; this paper outlines the current effort to implement the approach with an operational radar system and to establish a methodology for arbitrary ECM signal generation in a closed-loop system. While this effort employs GA, the method applies equally to other optimization techniques. After defining

the GA fitness function for a generic range gate pull off (RGPO) technique, the ECM signal is implemented with a very fast digital arbitrary waveform generator. The RGPO signal is injected into the radar environment, and the tracking radar response is measured and scored for optimization. The method is suitable for more sophisticated ECM signals and will be studied in future work. [C744]

"Orthogonal waveform support in MIMO HF OTH radars"

HF skywave radar performance and flexibility can benefit from transmission of multiple orthogonal waveforms in a multiple-input, multiple-output (MIMO) radar architecture. Several practical limitations need to be considered in such a design. One issue is that many HF radar transmit arrays are over-sampled spatially to allow for operation over a significant portion of the HF band. Transmission of orthogonal waveforms in this case can result in large reactive power and consequent equipment damage. Another issue is the ability to generate orthogonal waveform sets with sufficient cardinality at the low time-bandwidth products typical of aircraft surveillance operation. There are likely to be fewer waveforms than transmit elements and so some form of spatial rank expansion, from waveform to radiated signal, is required. Both of these issues are examined using Maric-Titlebaum frequency-hop codes as one example of an orthogonal waveform set. [C745]

"MIMO Radar: Joint Array And Waveform Optimization"

In this paper, techniques for the optimization of multiple-input multiple-output (MIMO) radar waveform correlations and array geometries are investigated. The primary focus of this study is improved angle-estimation performance. This performance can be characterized by the Cramer-Rao angle- estimation bound and by the threshold point. The threshold point indicates the signal-to-noise ratio (SNR) at which the angle- estimation performance of an estimation statistic deviates from the Cramer-Rao bound performance. Approximation techniques for estimating the threshold are introduced. Examples of joint waveform and array geometry optimization are presented. [C746]

"Time Reversal Synthetic Aperture Radar Imaging In Multipath"

Conventional spotlight synthetic aperture radar (SAR) assumes a single reflection of transmitted waveforms from targets [1]. Multiple reflections of targets due to surrounding scatterers appear as ghosting artifacts in conventional SAR images, which obscures true target image and leads to poor resolution. In this paper, we develop image formation techniques using time reversal, time reversal SAR (TR-SAR), to remove ghosting artifacts and achieve high resolution. The TR-SAR algorithm is tested using phase history data collected by a rail-mounted SAR sensor operated by Raytheon. [C747]

"Doppler Resilience, Reed-MГґBjller Codes and Complementary waveforms"

While the use of complementary waveforms has been considered as a technique for providing essentially perfect range sidelobe performance in radar systems, its lack of resilience to Doppler is often cited as a reason not to deploy it. This work describes and examines techniques both for providing Doppler resilience as well as tailoring Doppler performance to specific aims. The Doppler performance can be varied by suitably changing the order of transmission of multiple sets of complementary waveforms. We propose a method which improves Doppler performance significantly in specific Doppler ranges by arranging the transmission of multiple copies of complementary waveforms according to a suitable choice from the first order Reed-Muller codes. We provide both a theoretical analysis and computer simulations of the Doppler response of waveform sequences constructed in this way. [C748]

"On Data-Adaptive Waveform Design for MIMO Radar"

We consider the problem of signal design for MIMO radars, where the transmit waveforms are adjusted based on the characteristics of the radar scene. A model for the radar returns which explicitly incorporates the transmit waveforms is presented. The waveforms are designed to optimize the estimation of the radar scene. An adaptive design can provide improved estimation performance compared to fixed designs such as the one employing a set of orthogonal waveforms. [C749]

"MIMO Radar Ambiguity Optimization Using Frequency-Hopping Waveforms"

Recently, the concept of MIMO (multiple-input- multiple-output) radars has drawn considerable attention. In traditional SIMO (single-input-multiple-output) radar, the transmitters emit coherent waveforms to form a focused beam. In MIMO radar, the transmitters emit orthogonal (or incoherent) waveforms to increase the spatial resolution. These waveforms also affect the range and Doppler resolution which can be characterized by the ambiguity function. In traditional (SIMO) radars, the ambiguity function of the transmitted pulse characterizes the

compromise between range and Doppler resolutions. In the MIMO radar, since many transmitting waveforms are involved, their cross-ambiguity functions enter into the signal design problem. In this paper, frequency hopping codes are used to generate these orthogonal MIMO radar waveforms. A new algorithm for designing the frequency hopping codes is proposed. This algorithm makes the energy in the corresponding ambiguity functions evenly spread in the range and angular dimensions. [C750]

"Slow-Time MIMO STAP with Improved Power Efficiency"

This paper concerns a multiple-input multiple- output (MIMO) generalization of space-time adaptive processing (STAP) to mitigate radar clutter subject to multipath propagation between transmit and receive arrays. Slow-time MIMO transmit channels are phase-coded to be orthogonal post-Doppler processing at the receiver (";slow-time";) and are easily implemented without receiver modification before range pulse-compression. Slow-time MIMO STAP methods coherently combine orthogonal received waveforms, steering virtual transmit nulls in cone angles responsible for multipath clutter [1]. A potential problem with MIMO STAP is the occurrence VSWR peaks over the course of a dwell. Herein, we consider sub-array designs that improve power efficiency by reducing VSWR. [C751]

"Hybrid Adaptive Receive Processing for Multistatic Radar"

For multiple radars operating within the same spectrum, the resulting mutual interference can severely degrade sensitivity. Recently, the multistatic adaptive pulse compression (MAPC) algorithm has demonstrated the ability to partially suppress multistatic interference to better estimate the illuminated range profiles. This estimation is accomplished by jointly determining, in an MMSE sense, the range cell complex amplitudes associated with each of the received radar waveforms. As the number of received radar signals increases, the residual error after the application of MAPC increases as well. However, instead of jointly estimating all the received signals, one may wish to selectively minimize the residual error for a particular received radar (e.g. the monostatic returns from the co-located transmitter). In this paper, selective error minimization is achieved by utilizing a MAPC-based variant of the CLEAN algorithm. The resulting hybrid CLEAN algorithm is shown to provide significant sensitivity improvement over MAPC alone. [C752]

"Adaptive Sensing of Dynamic Target State in Heavy Sea Clutter"

We propose an adaptive estimation method for the spatio- temporal covariance matrix of sea clutter. The motivation is to enable adaptive detection approaches that rely on accurate estimation of this matrix. The method involves vectorization of the equations for the dynamical system model governing the temporal evolution of the clutter matrix followed by a multiple particle filtering approach to deal with the high dimensionality of the formulation. The estimated sea clutter covariance matrix is applied to the problem of detection of a small target in heavy clutter; effectiveness is demonstrated via simulations. [C753]

"Adaptive Transmit/Receive Schemes for Mimo Radar"

In this paper we consider the issue of adaptive transmission and detection for MIMO radars operating under clutter with unknown covariance. In particular, we show that the availability of a set of secondary data allows defining constant-false-alarm rate (CFAR) receivers starting upon a family of previously known non-adaptive structures. We also show that, if the clutter correlation remains constant in several scans, an adaptive waveform selection procedure can also be implemented. The results show that the adaptive transmit/receive structures perform satisfactorily in comparison to their non-adaptive counterparts, the loss being in the order of 2-3 dB's for customary values of the system parameters. [C754]

"Waveform Diversity for Different Multistatic Radar Configurations"

The multistatic ambiguity function has recently been proposed as a tool for analyzing and designing multistatic radar systems. It was demonstrated through examples that multistatic radar system performances can be improved by shaping the multistatic ambiguity function through waveform selection and adequate weighting of different receivers during pre-detection fusion. In this work we study sensor repositioning as a third way of shaping the multistatic ambiguity function. We provide some preliminary simulation results that illustrate how significant improvements in radar system performances can be achieved by combining waveform selection, receiver weighting and sensor placement strategies. These results can serve as a guideline for future multistatic fusion rule development. [C755]

"Waveform Design for MIMO Radar with Space-Time Constraints"

We consider the problem of designing waveforms for MIMO-radar, where both the temporal and spatial

characteristics of the waveform need to be determined. In other words, we design a set of different waveforms transmitted by different antennas. In previous works design procedures were presented where the resulting waveforms were constrained only by transmit power. Here we extend this work to include arbitrary linear constraints in the form of a space-time basis for the waveforms. We demonstrate that properly selecting and applying these constraints leads to waveforms with better temporal and spatial response (e.g., range response and beam pattern) than using previously proposed design procedures. [C756]

"Time Reversal Transmission in MIMO Radar"

Time reversal explores the rich scattering in a multipath environment to achieve high target detectability. MIMO radar is an emerging active sensing technology that uses diverse waveforms transmitted from widely spaced antennas to achieve increased target sensitivity when compared to standard phased arrays. In this paper, we combine MIMO radar with time reversal to further improve the performance of radar detection. We establish a radar target model in multipath rich environments and develop likelihood ratio tests for the proposed time-reversal MIMO radar (TR-MIMO). Numerical simulations demonstrate improved target detectability compared with the commonly used statistical MIMO strategy. [C757]

"Re-tracking of SAR altimeter ocean power-waveforms and related accuracies of the retrieved sea surface height, significant wave height and wind speed"

This paper describes the simulation of the power- waveforms acquired in by a radar altimeter operating in SAR mode over ocean surfaces, including the effects of the radar transfer function and of the geophysical ocean parameters, namely the sea surface height(SSH), the sea surface wave height (SWH) and the surface wind speed (WS). The performances of the SAR mode with respect to the retrieval of the ocean geophysical variables (SSH, SWH, WS) are then computed using the Cramer-Rao estimation bounds. It is shown that the radar to ocean range estimation provided by the SAR mode is improved by more than a factor of two compared with conventional Ku band altimeters. Improvements on SWH and wind speed are also discussed. [C758]

"The RA-2 individual echoes processing description and some scientific results"

The RA-2 in its nominal operation provides averaged waveforms at the rate of 18 Hz (one averaged waveform over 100 individual echoes, every 0.0557 seconds). It has also the capability to provide limited bursts of individual, unaveraged echo sample data in phase (I) and quadrature (Q), at the full PRF rate. In this concept the full-rate data are stored, for a short burst, into an internal buffer memory, in parallel to the normal averaging and other functions of the instrument. The buffered data are subsequently read out at a much lower rate and appended to the normal science data. These Individual Echoes (IE) are, therefore, not processed onboard in the same way that the nominal RA-2 waveforms are.Recent studies have demonstrated that through the full rate data it is possible to discover some behaviour than cannot be seen with the averaged data. Moreover, it is the first time in altimetry that we have echoes that contain the information of the phase. This is a great potential for new science studies. This paper describes the algorithm applied on-ground to the IE of the RA-2 Burst Waveforms to reproduce the same process done by the instrument on-board (except for the averaging). Once this algorithm is applied to the IE they will be in the same condition than the normal RA-2 telemetred average waveform, but at 100 time higher surface sampling and with the phase information. The final objective of this work is the use of the IE fully processed and instrument calibrated for calibration, validation and science exploitation purposes. We will present results of studies carried out using these IE. The blurring on the averaged waveforms depends on the total movement of the range window [1], which in turn depends on slope of the terrain, the orbit slope and ultimately, how well the on-board tracker tracks that particular waveform shape. In early studies using ERS data, the blurring on the averaged waveforms has been estimated by simulating the ERS range window movement during-tracking. Using individual echoes there is no longer the need to do so, we can directly use these echoes. The IE will be averaged in the correct way and compared to the averaged waveform provided in the nominal RA-2 product. Changes on the retracked epoch and slope of the leading edge can be assessed for different type of waveforms over different surfaces. In particular we will present results of the analysis of the behaviour of IE over the "Salar D'Uyuni" in Bolivia, to better understand biases in retracking of specular echoes. The results can be used to improve the current understanding of retracked elevations over sea ice and help to improve tuning of current sea ice retracking schemes for the EnviSat RA-2 instrument. ESA has run a study on this topic to seed the use of individual echoes by scientists. This study is completed and reconstructed echoes will be made available for the first time to the scientific community. Final results from the technical and scientific application of individual echoes and S band data are described in [3]. [C759]

"Waveform coding for dual polarization weather radars"

Polarimetric variables are an essential part of algorithms for improved rainfall rate estimation, attenuation

correction and hydrometeor identification. In such systems the transmit polarization state changes according to some fixed pattern that is repeated. The simultaneous mode and alternating mode waveforms are commonly used in weather radars. In the simultaneous mode of operation the horizontal and vertical polarization states are transmitted simultaneously and samples of both horizontal and vertical co-polar return are obtained A drawback of the current implementation of simultaneous mode is its inability to measure cross-polar parameters such as linear depolarization ratio. In this paper a technique to estimate cross- polar signals with a simultaneous mode waveform is presented. In this method, the horizontally and vertically polarized transmit waveforms are coded with orthogonal phase sequences. The performance of the phase coded waveform is determined by the properties of the phase codes. This paper presents the performance of the cross-polar and co-polar parameter estimation based on the simulation as well as data collected from CSU- CHILL radar. [C760]

"Evaluation of first generation CASA radar waveforms in the IP1 testbed"

The Center for Collaborative Adaptive Sensing of the Atmosphere (CASA), an engineering research center (ERC) established by the National Science Foundation (NSF) deployed its first generation network of four low-power, short-range, X- band, dual-polarized Doppler weather radars known as NE- TRAD. The short range CASA radars will have range overlay and velocity folding problems with conventional pulse-pair processing. The first testbed of X-band radar systems (developed within the ERC) in central Oklahoma called IP-1 (Integrated Project 1) have a low unambiguous velocity due to their short wavelength, and increasing the PRF will result in multiple trip overlays since storms can extend over a large distance. In addition the radar observations at short ranges are contaminated by ground clutter. This paper describes the waveforms for the individual radar nodes based on NETRAD operational requirements such as scan speeds, volume coverage pattern and system/hardware limitations to resolve range and velocity ambiguities. A dual PRF waveform has been suggested for operational use based on a simulation study. This paper presents an evaluation of the waveform from data collected by the first generation CASA radars. [C761]

"What optech's bathymetric LiDAR sees underwater"

This article presents early results of the FUDOTERAM project using bathymetric LiDAR data acquired with the SHOALS-3000, the latest bathymetric LiDAR system from Optech. The survey area is in the coastal zone along the northern shore of Chaleurs Bay, in the western Gulf of St. Lawrence, Canada. The project aimed to apply the SHOALS- 3000 to geological mapping, sedimentary process monitoring and marine habitat mapping. This paper focuses on the sedimentological part of the study and presents the early raw data obtained to produce a bottom type classification based on some simple parameters, roughness, slope angle and direction. Two methods are evaluated for analysis of the SHOALS-3000 waveforms, the Moment Method and the Gaussian Mixture Model, and the latter is used as an approach to model the bottom type signal. [C762]

"Statistical classification methodology of SHOALS 3000 backscatter to mapping coastal benthic habitats"

The scanning hydrographic operational airborne LiDAR survey (SHOALS) consists of a bathymetric LiDAR system which provides high precision measurements of water depth. Even though the acquisition is focused on depth accuracy, the return signal, i.e. waveform, contains other relevant information because of integration signatures from the water surface, the water column and the sea-bed. This paper highlights the benthic characterization in extracting statistical parameters derived from the bottom backscatter. In applying multivariate analysis (K-means), it is significantly proven that signals derived from habitat, described as statistically homogeneous throughout ground-truth analysis, are (1) similar within an intra-habitat view, while they are (2) different between themselves. [C763]

"Copyright"

The following topics are dealt with: radar systems; multistatic radar; detection and tracking; synthetic aperture radar; target recognition; waveform design; ECCM; antennas; passive radar; and space-time adaptive processing. [C764]

"Oral Session 3b: Waveform Design"

First Page of the Article [C765]

"Signal Covariance Matrix Optimization for Transmit Beamforming in MIMO Radars"

MIMO radars use multiple waveforms simultaneously to improve performance. A beamforming method that exploits this waveform diversity has been proposed previously. This method works by optimizing the covariance

matrix of the waveforms to obtain an approximation of a desired beampattern. The previous method uses gradient descent to optimize the beampattern with the constraint on the power of each antenna element. We show how this method can be extended to obtain rank-deficient covariance matrices and also to handle the total power constraint. The conjugate gradient method is used in addition to the gradient descent. In this paper, we also propose converting the constrained beampattern optimization problem into an unconstrained one. This can be done by using the method of Lagrange multipliers, but also removing all constraints and then scaling the result so that the total power constraint is satisfied. Using this approach, the beampattern optimization can be written as a least squares problem. [C766]

"Error analysis of ICESat waveform processing by investigating overlapping pairs over Europe"

Full waveform laser altimetry is a recently developed method to obtain a complete vertical profile of the height of objects in the footprint as illuminated by a laser pulse. The richness of the signal also complicates the processing. One way to improve the processing strategy is to analyze differences of waveforms that should be very similar because they were obtained at approximately the same time and location. Such waveform pairs are still difficult to find. Here it is shown how to use the archive of ICESat space-borne altimetry data over Europe to determine a set of tenths of thousands of at least partial overlapping waveform pairs. The differences in the values of the waveform parameters, median energy, waveform extent, relative returned energy and intensity distribution are determined and discussed. As a case study, three typical pairs of almost perfectly overlapping waveforms are shown, were considerable differences are still occurring. In all three cases an explanation for these differences is found and discussed. Further analysis of the waveform pairs in this database is expected to considerably improve automatic processing of full waveform data. [C767]

"Multidimensional radar waveforms a new paradigm for the design and operation of highly performant spaceborne synthetic aperture radar systems"

This paper introduces and analyses the innovative paradigm of multidimensional waveform encoding for space-borne synthetic aperture radar (SAR). The combination of this technique with digital beamforming on receive enables a new class of highly performant SAR systems employing novel and highly flexible radar imaging modes. Examples are adaptive high-resolution wide-swath SAR imaging with compact antennas, enhanced parameter estimation sensitivity for applications like along-track interferometry and moving object indication, and the implementation of hybrid SAR imaging modes that are well suited to satisfy the hitherto incompatible user requirements for frequent monitoring and detailed mapping. Implementation specific issues will be discussed and examples demonstrate the potential of the new technique for different remote sensing applications. [C768]

"3D map generation for biometric applications using a network of multi-static radar sensors"

In this paper, we describe a novel algorithm based on diffraction tomography for 3D map generation using the received backscattered radar electro-magnetic (EM) field from different spatially distributed multi-static radar sensors. Each sensor at a given time will transmit a radar waveform and the other sensors including the one transmitted will receive the waveform that is backscattered from the objects. A data cube of received data will be created at each sensor by changing the location of sensors. This data cube is used in generating the 3D object profiles at each sensor and then the fused 3D map will be outputted which will contain the fused 3D object profiles or structure obtained from each sensor. If there are more than one object in the field of interest there would be inter object backscattering. This would result in receiving mixed signals. This mixed signal might cause problems in the generation of the 3D map/structure. So to reduce the effect of inter object backscattering we use the probabilistic based blind source separation (BSS) technique for convolutive mixture separation. Before applying the mixture separation technique, we estimate the number of sources. For this we have developed a technique. In this paper, all these techniques are described and also results using real radar backscattered data are provided. A description of how this 3D maps can be used for biometrics is also provided. [C769]

"Waveform Preconditioning for Clutter Rejection in Multipath for Sparse Distributed Apertures"

The idea of preconditioning transmit waveforms for optimal clutter rejection in radar imaging is presented. Waveform preconditioning involves determining a map on the space of transmit waveforms, and then applying this map to the waveforms before transmission. The work applies to systems with an arbitrary number of transmit- and receive-antenna elements, and makes no assumptions about the elements being co-located. Waveform preconditioning for clutter rejection achieves efficient use of power and computational resources by distributing power over a frequency band in an effective way and by eliminating clutter filtering in receive processing. [C770]

"Frequency coded waveforms from chaotic time series"

This paper discusses the construction of frequency coded radar waveforms formed by using a chaotic time series for the frequency coding. These codes provide wide bandwidth, and, hence, high range resolution, and also provide orthogonality. The paper uses simulation results to investigate the properties of these waveforms, including spectral properties, sidelobe levels, range resolution and orthogonality. This study was motivated by the need for a system of coded waveforms that provide both cross-correlation orthogonality and high range resolution. An advantage of these frequency coded waveforms over phase coded waveforms is that bandwidth (and hence range resolution) is independent of pulsewidth. [C771]

"Waveform diversity: Past, present, and future"

This paper reviews important aspects of waveform diversity development, and discusses how waveform diversity, distributed processing, spatial diversity, and knowledge-based processing can be integrated for optimum surveillance system performance. A next-generation surveillance concept is proposed, which is composed of a distributed constellation of autonomous sensors. [C772]

"A new method of the high-resolution wide-swath SAR"

A new method of the high-resolution wide-swath SAR is advanced in this paper. It realizes high resolution and wide swath SAR imaging at the same time. It is based on waveform diversity SAR technique and improves the integrated range ambiguity ratio. It also eliminates the blind zones. Moreover the data rate isn't increased. [C773]

"Range Doppler correlation for time-orthogonal distributed aperture radars"

Distributed aperture radars represent an interesting solution for target detection in environments affected by clutter. Due to the large distances between array elements, both target and interfering sources are in the near field of the antenna array. Recent works have demonstrated the benefits of combining frequency diversity and space time adaptive processing for distributed aperture radars. Using orthogonal signaling the receivers can treat the incoming signals independently, solving several bistatic problems instead of the initial multistatic problem. However, a well known problem in bistatic radar is the dependency of the clutter Doppler center on range. We analyze the benefits of joint use of waveform diversity and adaptive techniques to counteract the non-stationarity of the clutter Doppler. [C774]

"Waveform diversity for distributed and layered sensing"

Waveform diversity in distributed radio frequency (RF) sensor systems offers the potential for breakthrough performance enhancements in the detection and identification of natural and manmade objects. This paper discusses advances in relevant technology and emerging applications to radar. [C775]

"Radar and communication waveform: Wideband ambiguity function and narrowband approximation"

Aiming for a system combining radar and communications, along with high performance requirements, imposes a waveform characterized by a large time-bandwidth product. The assumption of a wideband signal model for the radar problem and wideband ambiguity function seem then a forced solution, but it is then relevant to identify the exact conditions and the sustainable degradation of performance that allow instead the use of the narrowband approximation. The need to use wideband representation depends on the waveform parameters bandwidth and duration. Certain types of future state-of-the art radar should take into account this representation. [C776]

"Low cost networked radar and sonar using open source hardware and software"

Experimental and educational applications of radar and sonar hardware would often be facilitated by access to a flexible, digital transceiver. This hardware should be easily reconfigured to implement different transmit waveforms, and sampling requirements. It would be possible to compromise very wide bandwidth in such an environment. This paper reports on the development of a digital transceiver based on Open Source hardware and software from the GnuRadio project. [C777]

"Multidimensional waveform encoding for synthetic aperture radar remote sensing"

This paper introduces and analyses the innovative concept of multidimensional waveform encoding for spaceborne synthetic aperture radar (SAR). The combination of this technique with digital beamforming on receive enables a new class of highly performant SAR systems employing novel and highly flexible radar imaging modes. Examples are adaptive high-resolution wide-swath SAR imaging with compact antennas, enhanced parameter estimation sensitivity for applications like along-track interferometry and moving object indication, and

the implementation of hybrid SAR imaging modes that are well suited to satisfy the hitherto incompatible user requirements for frequent monitoring and detailed mapping. Further advantages arise for fully polarimetric operation where it becomes possible to reduce the PRF by a factor of two. Implementation specific issues will be discussed and examples demonstrate the potential of the new technique for different remote sensing applications. [C778]

"The architecture and operating characteristics of a multi-frequency hf surfacewave radar-part one"

To successfully operate a High Frequency Surface Wave Radar (HFSWR) the current understanding of the HF environment dictates a holistic approach to the problems encountered. The use of a Multiple-Input Multiple-Output (MIMO) architecture combined with strong frequency management techniques and multi-frequency operation can provide the quality of data required for robust tracking. The use of COTS technology, especially wideband HF digital receivers and digital waveform generators allows for the implementation of the required techniques in a practical system. Part one of this paper describes the basic MIMO system architecture, general operational characteristics and the tracking performance of an operational multi-frequency monostatic HF surfacewave radar. Part two of the paper exploits the quality of the tracking performance of the radar to extract target RCS characteristics. Other technical details of the multi-frequency operating characteristics are also presented. [C779]

"Digital pulse compressor design for ultra-low range sidelobes for use within the eclipsed region"

A novel pulse compression technique is described, which allows extremely low range sidelobes to be maintained within the eclipsed regions of a pulse Doppler radar. The technique allows more efficient use of the radar's time, by allowing data to be recovered from the eclipsed regions, reducing the need for multiple waveforms to provide complete surveillance coverage. Theoretical modelling results are presented. [C780]

"Eliminating ghost images for stepped-frequency train of LFM pulses"

Range ambiguity due to inappropriate frequency step size between successive pulses and "ghost image" phenomenon due to pulse expansion in single pulses, are two drawbacks of stepped-frequency waveforms (SFWF) in obtaining synthetic high range resolution (HRR) profiles. A new Least Square (LS) synthetic range profiling algorithm is proposed in this paper. Compared with the traditional algorithms, it can reduce range ambiguity, restrain ghost images, and decrease the signal-to-noise ratio (SNR) loss as well. The field experimental profiling results are also presented. [C781]

"Target detection using orthogonal netted radar system (ONRS)"

An Orthogonal Netted Radar System (ONRS) is a networked system consisting of multiple radars, each of which uses an orthogonal set of coding waveforms, and operating at the same carrier frequency. ONRS can simultaneously operate in a monostatic and a multistatic mode, and thus possesses the advantages offered by both a monostatic and a multistatic radar system. The principles and structure of ONRS are described in this paper. The detection schemes using ONRS and an initial performance analysis is carried out. [C782]

"Passive radar detection using wireless networks"

We report the first results of simulation and experiments on the utilisation of 802.11 wireless network transmissions in a passive radar system. Target detection of a range of objects has been simulated and then experimentally demonstrated. Waveform analysis shows that some of the modulations used within the transmission sequence have suitable properties for target localisation. These initial results suggest this technique has a high potential for the basis of a widely available low cost passive surveillance system. [C783]

"DRM signals for HF passive bistatic radar"

The concept of using digital HF signals in a passive radar configuration is discussed. Ambiguity functions of these signals are presented and a comparison of the waveform's properties is made with other signals of interest in passive radar in terms of their radar parameters. The ambiguity functions show no ambiguities, approach the ideal thumbtack shape and are thus potentially very useful for passive radar applications. For 5 s integration times the signals have a processing gain in excess of 40 dB. Expected coverage is examined in terms of the signal to interference ratios expected for an array of receivers and compared to the coverage obtained using a single surveillance channel. It is concluded that to support the detection ranges of which HF is capable, a phased array surveillance receiver is required to reduce the effects of interference from the transmitter. [C784]

"Characterisation of an L-band digital noise radar"

This paper experimentally evaluates the dynamic range of a digital radar at L-band employing both direct digital synthesis and direct RF sampling, thus minimizing analogue components. Noise-like radar waveforms and pulse to pulse waveform agility are utilized to improve the signal to noise ratio and reduce the sidelobe levels to improve the dynamic range of the radar system. [C785]

"Resolution of Closely Spaced Deterministic Signals with Given Success Rate"

Fundamental limitations on estimation accuracy are well known and include a variety of lower bounds including the celebrated Cramer Rao Lower Bound. However, similar theoretical limitations on resolution have not yet been presented. We exploit results from detection theory for deriving fundamental limitations on resolution. The results are general and are not based on any specific resolution technique and therefore hold for any method and for any resolution success rate. We show that for signals with additive white Gaussian noise the resolution is given by a simple expression related to signal to noise ratio, the signals waveforms and the resolution success rate. As an example, we discuss the resolution of two sinusoids with closely spaced frequencies. The result is compared with the empirical performance of the Akaike information criterion, and the Minimum Description Length criterion for model order selection. [C786]

"Interrupted SAR waveforms for high interrupt ratios"

SAR operations typically require long flight lengths to provide the coherent sequences needed for cross-range imaging. For multi-function radars with SAR modes it is usually necessary to interrupt the SAR data collection sequences to support other essential radar modes. These data interruptions can require interruptions totalling up to 50% of the radar timeline. This paper analyses the simulation of antenna patterns at rates of data interruption, typically with 50% data loss. This paper compares the effects of high data interruption on SAR antenna patterns for both periodic and randomly spaced data interruptions. For spotlight mode SAR, the use of pattern averaging can be used to reduce the pattern sidelobes for the cases of randomly spaced data interruptions. [C787]

"Ionospheric clutter modelling for VHF passive radars operating at high latitudes"

Passive VHF and UHF radars which prosecute FM and television broadcasts above 50 MHz at latitudes greater than 40 degrees will occasionally be subject to large amounts clutter from the ionosphere. Conventional pulsed, active radars can mitigate against auroral clutter by appropriate gating of the transmtter waveforms and receiver samples. However, passive radars, as CW systems cannot. In this report we describe the basic features of meter scale ionospheric clutter, describe how its magnitude can be estimated, and how its effects may be mitigated. [C788]

"Optimal fast-time beamforming with linearly-independent waveforms"

Optimal radar transmitter and receiver architectures are proposed for increasing the degrees of freedom for beamforming optimisation by transmitting linearly independent waveforms from each element of a phased array radar. This effectively encodes clutter returns with a spatial signature which enhances clutter-rejection performance in the spatial processing. The theory which enables the exploitation of these additional degrees of freedom is developed for a general set of linearly independent waveforms and considered in the context of both conventional beamforming applications as well as novel applications. [C789]

"Digital radar"

A radar architecture is described in which radio frequency (RF) pulse waveforms are generated digitally in the transmitter and target returns are digitised without analogue down-conversion in the receiver, thereby eliminating most of the analogue components found in typical radar systems. This architecture, which has a number of important advantages over conventional radar systems, can be implemented using broadband digitisation technologies developed recently for the communications industry. [C790]

"Maximising the benefits of sophisticated electronic countermeasures systems"

As electronic countermeasure systems become more complex, the time taken between the equipment being specified, designed, developed and eventually fielded has lengthened significantly. During this development, advances in radar processing are likely to change the requirements for countermeasure waveforms, and the original specification from which the system was designed may no longer be appropriate. The hardware within modern countermeasure systems is designed in a flexible manner that will support the generation of waveforms not explicitly defined during the specification process. However, the functionality of this hardware is constrained by the inflexible nature of the support tools that prevent novel waveforms from being defined within the system.

This paper provides background to the evolution of countermeasure systems and their support tools, and continues to discuss more flexible approaches to the definition of countermeasure waveforms such that maximum benefit can be gained from modern technology in an ever-changing environment. [C791]

"Analaysis of calibrated sea clutter and boat reflectivity data at C- and X-band in South African coastal waters"

The temporal characteristics of low grazing angle sea clutter and boat reflectivity are considered for both fixed and stepped frequency waveforms under a range of environmental conditions and geometrical configurations. Detectability of boats using an asymptotically optimal detector is evaluated empirically, as well as the influence of the local sea on boat reflectivity. Measurements were conducted with a calibrated, coherent, staring, pulsed radar system at C- and X-band frequencies ranging from 6.9 GHz to 10.3 GHz. [C792]

"UHF radar system tested on the Bridge of Yangtze River"

This paper presents a field test of UHF radar system on the Bridge of Yangtze River in China. Recently a set of UHF radar system has been developed for vessel surveillance and estimation of surface velocity profile across the river. The radar operates at 300MHz to match the dimension of water wavelengths. Another aim of ship surveillance is to protect the pier against ship collision. The transmit power of the radar is under 5W and the maximum range is 2km. This paper gives the design methods and waveform parameters of the system, some results of field test are also presented. [C793]

"Through-the-wall radar using multiple UWB antennas"

In this paper, we present a study of short range radar for through-the-wall detection and tracking of human beings. New concepts envisaged here are based on an Ultra Wide Band (UWB) waveform and on the use of numerous separated antennas. A full wave 2D simulator using the FDTD method has been performed in order to deliver synthetic data for studying signal processing algorithms. These algorithms, although well known in some other contexts, are here applied to UWB TTW imaging and detection and some quasi real time formulations are proposed. Results are presented on a test configuration computed by the simulator. [C794]

"Design Considerations For An Atmospheric Imaging Radar"

This paper describes the design requirements, tradeoffs and simulations involved with the design specifications of an Atmospheric Imaging Radar (AIR). Design constraints are discussed including size and portability. Radar details include the range of meteorological targets detectable, maximum range, and other criteria needed for the weather radar equation. A dual pulse repetition time waveform is used to improve the maximum unambiguous velocity and range. The trade-offs in volume, sensitivity and pulse integration are described in the radar design. Calculations are made and and initial plots showing at least 15 dBZ sensitivity at 10 km are shown for a radar that will image a cone 16.5deg wide and 40 km long. [C795]

"UWB-GPR Data Processing for Identification of Anti-personnel Landmines under Rough Ground Surface"

A process for finding buried landmines by using GPRs is divided into two stages, detection and identification. In the detection stage, all buried objects including the desired landmines together with other clutter objects are detected. In the identification stage, the detected objects are classified and the landmines are differentiated from the other objects. In this research, we focus on the identification stage and propose a GPR data processing for identification of shallow!) buried antipersonnel landmines. After suppressing the ground surface reflection, we extract features related to waveform correlation from the GPR data. As an identification algorithm, an approach based on a matched filter is employed. In order to check the identification performance, Monte Carlo simulations are carried out using dataset generated by a 2D-FDTD method. Results are shown in the form of ROC curves and AUC values, and effects of soil condition (i.e. ground surface roughness, inhomogeneity, and moisture in soil) on identification performance are assessed. [C796]

"Narrowband Interference Suppression in UWB Impulse Radar for Human Being Detection"

Narrowband interference (NBI) is a major source of performance degradation in human being detection applications using impulse radar and stroboscopic samplers. Implementation of notch filters results in undesired ringing of the target response. Four methods are developed and their performance analysed: two variations of the approach that extracts the NBI and subtracts its contribution and two variations of the approach that filters the NBI out and restores the missing spectrum. NBI is modelled as modified GSM signal. It is shown that latter methods perform better both in terms of NBI suppression, but also in terms of signal waveform and energy

preservation. [C797]

"Autodyne Signal at Reflection Factor Value Modulation"

Considered in this paper is the problem of signal generation on the amplitude variation taking into account frequency variations in autodyne oscillator under the influence of electromagnetic wave reflected from the object under control with reflection factor modulation. It is shown that autodyne response waveform may essentially differ for the modulation function law. The results of the theoretical analysis are confirmed by experimental investigation of the oscillators designed on the basis of hybrid integrated modules "Tigel-08" and "Tigel-08M" in millimeter waveband. Theoretical analysis carried out and experimental investigations results show that autodyne signal waveform with amplitude modulation of the electromagnetic wave reflected from the stationary object may essentially differ from the modulation function law. This feature should be taken into account at radio physical investigations of various substance features, in radio spectroscopy, as well as in short-range radar. [C798]

"Addition and Multiplication Statistics for Orthogonal Signal Processing in Multiple Antennas System"

Multiple configuration antennas system using ultra wideband orthogonal noise waveforms is considered for testation radar applications. System Signal Function of MIMO radar is determined using the time domain back-projection algorithm with addition and multiplication statistics. [C799]

"Digital Implementation of Pulse Compression Technique for X-band Radar"

The performance of conventional pulsed radars is limited by its "time-bandwidth" product. In order to get high range resolution, a narrow pulse is required to be transmitted. However, this reduces the average transmit power resulting into shorter detection range. To mitigate this limitation of "time-bandwidth" problem, pulse compression technique is used. Pulse compression technique can be broadly classified as, FM chirp and phase coded. In FM chirp method, a longer duration frequency modulated pulse is transmitted, and on the receiver side matched filter is used to compress the echo signal. This also resolves the targets which may have overlapping returns. Earlier implementation of pulse compression was done using analog circuitry, which has its own limitations. With the availability of high speed digital equipment, it is now possible to implement it in digital domain. This paper presents a digital implementation of LFM pulse compression technique in X-band. Here, we used an arbitrary waveform generator to generate LFM pulse (chirp) at lower frequency band, which is up-converted to X-band by mixing with a carrier of 9.375 GHz for transmission. On receiver side, after translation to lower frequency band, data is acquired by analog to digital converter card and pulse compression algorithm was implemented in computer using MATLAB tool. Various tests were performed to verify pulse compression technique. [C800]

"A Framework for the Analysis of Multistatic Radar Systems with Multiple Transmitters"

The multistatic ambiguity function can be used as a tool for analyzing multistatic radar systems. It has been demonstrated that the multistatic ambiguity function can serve as a guideline for developing multistatic radar signal processing rules and waveform selection strategies in system configurations with a single transmitter and multiple receivers. In this work we extend the development of multistatic ambiguity function to radar systems with multiple transmitters and multiple receivers. [C801]

"Constrained Partially Observed Markov Decision Processes for Adaptive Waveform Scheduling"

The dynamic programming approach is applied to a partially observed constrained Markov decision process problem with both total cost and probabilistic criteria. The Markov decision process is partially observed, but it is assumed that the constraint costs are available to the controller, i.e., they are fully observed. The problem is motivated by an adaptive sequential detection application. The application of the dynamic programming results to optimal adaptive truncated sequential detection is demonstrated using examples involving the optimization of radar detection processes. [C802]

"Closed-Loop Radar with Adaptively Matched Waveforms"

Adaptive and knowledge-based radar focus on improving the performance of the radar receiver through signal processing However, rather than develop transmission waveforms and signal-processing techniques independently, it is useful to consider a closed-loop system complete with an adaptive radar transmitter. In this paper, we summarize and demonstrate a framework being developed at the University of Arizona for implementation of closed-loop radar with adaptive waveforms. This framework integrates a Bayesian channel representation, matched illumination techniques, and sequential hypothesis testing. The result is a closed-loop system that modifies its understanding of the channel based on measured data, customizes waveforms to hasten

understanding of the channel, and draws conclusions (such as target classification) when sufficient understanding of the propagation channel is achieved. [C803]

"Limits on the Resolution of Closely Spaced Multipath Signals"

Fundamental resolution limits of multipath replicas are presented. The results are not based on any specific resolution technique and therefore hold for any method. The resolution limit is a function of signal to noise ratio, signal waveform and the resolution success rate. As a specific example we consider the resolution of a radar chirp signal. We compare the limit with empirical results obtained by employing the Akaike Information Criterion and the Minimum Description Length criterion for model order selection. [C804]

"Adaptive Waveform Radar Enabled by S2-material Based Photonic Signal Processing Hardware"

An S2-material based photonic signal processor can perform wideband pulse compression over tens of GHz of instantaneous bandwidth in real-time. We utilize these capabilities to demonstrate wideband mismatched filtering showing 14 dB improvement in the peak-to-sidelobe-ratio when compared to the matched filter case. We proposed the utilization of this technology for adaptive waveform radar signal processing. [C805]

"Diversity Aspects of Radar-Embedded Communications"

This paper discusses aspects of intra-pulse radar-embedded communications whereby a tag/transponder illuminated by a radar converts the illumination waveform into one of a set of K communication waveforms with which to convey information to a spatially separated receiver. Initial work based upon an expansion of the radar spectrum has demonstrated the potential for significant data-rate improvement relative to previous inter-pulse approaches while still maintaining a low probability of intercept. In this work, a general mathematical formulation for intra-pulse radar-embedded communications is presented. This formulation provides insight into options for even higher data-rates by utilizing additional degrees-of-freedom. [C806]

"Electromagnetic Pulse Shaping and Applications"

Electromagnetic pulse shapers based on optical pulse processing techniques provide unparalleled waveform agility. By allowing user control of both the RF spectral amplitude and phase, we demonstrate these systems can compensate for electrical distortions experienced by broadband waveforms (here, from radiation from a broadband antenna). We believe these pulse shapers to be an enabling technology for airborne applications such as impulsive radio and radar. [C807]

"Shared-spectrum multistatic radar: Preliminary experimental results"

In this paper we present preliminary experimental results demonstrating the ability of the multistatic adaptive pulse compression (MAPC) algorithm to suppress the mutual-interference generated by shared-spectrum radar signals, thus enabling shared-spectrum radar. The MAPC algorithm, a waveform diversity technique wherein multiple known transmitted waveforms are adaptively pulse compressed using reiterative minimum mean-square error (RMMSE) estimation, has been shown to successfully suppress both range sidelobes and interference from multiple radars operating in the same spectrum. In this paper, we present initial experimental results from the adaptive pulse compression (APC) test bed that demonstrate the ability of MAPC to mitigate both the mutual interference from multiple radars and pulse compression range sidelobes when applied to measured data. [C808]

"Implementation and Design of Auto Ranging System with Risk Estimation for Vehicles"

Based on the theory of optical-mechanical-electrical automatic ranging system of vehicles, paper has a discussion and research of the implementation and design of auto ranging system with risk estimation and decision. The hardware is based on MPC5200. And paper includes the design of hardware architecture, software architecture and key techniques, of hardware development, etc. The system adopts the laser-lidar ranging method to get a high precision. Paper focused on the signal processing of laser-lidar and waveforms selection of the detection system. [C809]

"Adaptive Space-time-waveform Processing for MIMO Radar"

This paper presents a preliminary investigation into space-time-waveform adaptive for multiple input multiple output (MIMO) radar. Existing space-time adaptive processing (STAP) algorithms are extended to the waveform-time-space adaptive processing (WTSAP) case. We develop the signal model required to generate simulated data. Simulation results show a significant improvement in processor performance as compared to conventional phased array radar. [C810]

"Concurrent operation and cross-radar interference cancellation of two over-the-horizon radars"

It is known that improved target characterizations can be achieved by concurrently using multiple over-the-horizon radars (OTHRs) as compared to a single OTHR operating alone. However, a key limitation with OTHR radar is the selection of an appropriate operating frequency, given the rising demand on radar waveform bandwidth commensurate with the range resolution requirements. The authors have considered concurrent operations of two OTHR systems that use the same frequency band with different chirp waveforms, and a cross-radar interference cancellation technique has been developed. The purpose of this paper is to examine the performance of cross-radar interference cancellation in the presence of multiple target returns from both auto- and cross-radar reception modes. It is shown that, the interference between target returns corresponding to the same radar is negligible, whereas the residual error of cross-radar interference cancellation in the presence of signal returns corresponding to different radars takes a low value in a typical application scenario. [C811]

"A new method to create a virtual third antenna from a two-channel SAR-GMTI system"

Two-channel SAR-GMTI systems are suboptimal for moving target motion parameter estimation. Indeed, the ATI phase estimate of the across-track velocity component for a moving target is biased to lower values depending on the target signal to clutter ratio and the target across-track velocity. Additional antenna diversity can introduce additional degrees of freedom that can eliminate the bias problem. Aperture switching is an accepted method to virtually increase the number of channels without adding new hardware. One such mode is the RADARSAT-2 toggle mode (S. Chiu and C. Gierull, 2006). This paper proposes a new processing method to create a similar effective phase center configuration as the RADARSAT-2 Toggle mode from already recorded two-channel SAR data. This is achieved by delaying and combining the recorded two-channel measurements. The combination operation manifests not only a third phase center halfway between the phase centers of the two-channel system, but also a different antenna length of the virtual third antenna which requires a modification of the DPCA-ATI processing algorithm. The DPCA-ATI performance of the new mode is assessed and compared to ATI from the original two-channel mode. [C812]

"Continuous coded waveforms for noise radar"

This paper describes a new class of continuous waveforms for noise radar that can be processed using earlier developed methods for reducing pulse compression sidelobes and equalizing compressed pulses before Doppler filtering. The proposed waveforms are based on codes that modulate sub-pulses which define the bandwidth of the waveform. For constant amplitude waveforms the codes are phase codes and the sub-pulses can consist of rectangular pulses with constant phase or linear phase. The proposed waveforms use many short codes to produce a code with a length that is the product of the shorter code lengths. The resulting long code can be arbitrarily long by introducing new shorter codes iteratively. The codes can be random or deterministic with low mismatch losses in the processing at the expense of a quasi-periodic but unpredictable waveform. [C813]

"Using Polynomial Phase Signal Modeling against Range False Targets"

A novel approach of extracting a true target component from radar superposing echoes on the premise of that a repeater jammer is detected, when radar is suffered from range false targets jamming, is presented based on multicomponent polynomial phase signals (mc-PPS's) modeling. For linear frequency modulation (LFM) waveform, the differences of the echoes' polynomial phase coefficients between a true target and a false target are analyzed first. Parameter estimation of the true target by using product high-order ambiguity function (PHAF) is described. After the desired parameters be estimated, the true target signal can be reconstructed. Validity of the method is verified by simulation results. [C814]

"Multicarrier Coherent Pulse Shaping for Radar and Corresponding Signal Processing"

A new pulse shaping approach based on coherent superposition of multiple carriers in radar is introduced, by which a shorter efficient pulse width waveform can be formed. At the receiver end, breaking the echo into multiple corresponding frequency components, multiple series can be taken from those individual components, then recombining these components to achieve the signal processing gain. Three processing approaches are proposed for multicarrier Doppler processing, which will provide better Doppler estimate performances than that of conventional pulse Doppler radar. [C815]

"Radar Reflected Signal Process of High Spinning Rate Projectiles"

By slotting at the bottom of the projectiles, the target characteristics such as the spinning rate and the attitude can be obtained by Doppler radar. The reflection of spin projectile is a nonstationary AM-FM signal. The index of

AM represents the attitude of the projectile. And the modulation frequency shows the spinning rate. The model of the reflected waveform is given. Chirp-Z transform (CZT) is adopted to improve the measurement precision. The process approach and the complexity of CZT are present. Its time cost is in the same grade to FFT Simulation results and perspective are also given. [C816]

"Noise-Linear Frequency Modulation Shared Waveform for Integrated Radar and Jammer System"

This paper presents an integration of radar and Electronic Warfare (EW) utilizing Noise-Linear Frequency Modulation (NLFM) waveform, which is capable of simultaneous operation of radar and EW function for target detection and jamming against the Linear Frequency Modulation (LFM) Pulse Compression (PC) radar. The basic properties, detection and jamming capability of the NLFM waveform are investigated. Analysis indicates that the NLFM waveform has better range resolution and sidelobe suppression than LFM PC and random signal waveform, and that it has higher jamming efficiency against LFM PC radar than normal noise jamming waveform. [C817]

"Optimization of Orthogonal Discrete Frequency-Coding Waveform Based on Modified Genetic Algorithm for MIMO Radar"

A modified genetic algorithm (GA) is proposed to numerically design orthogonal discrete frequency-coding waveforms (DFCWs) which have good aperiodic autocorrelation and cross-correlation properties for orthogonal multiple input multiple output (MIMO) radar. Some of the designed results are presented, and their correlation properties are better than other known in the literature. The effect of Doppler frequency shift on the performance of these signals and ambiguity function are investigated. The simulation results and comparisons show that the proposed algorithm is more effective for the design of DFCWs with superior aperiodic correlation. [C818]

"Wide-Band High Resolution Homing Sonar Echo Detect Based On Spread Spectrum Technology"

This paper propose and analyze high resolution auto-navigation sonar system based on DS/SS technology. Compare to traditional auto-navigation sonar system, the system have big time and frequency range, can provide high distance and speed resolution and good anti-interference capability. Paper discuss the principle of waveform design and enduce ambiguity function of DS/SS modulation signals. In the case of high-speed target, paper provided and proved a algorithm using CZT which can estimate Doppler frequency offset and target speed in very low SNR condition. [C819]

"An experimental independent bistatic radar system for wideband application"

The aim of this research is to develop techniques for bistatic ISAR as applied to target imaging. A scheme of an independent bistatic receiving system without dedicated data links was carried out under the support of national science foundation. The research defined a system configuration and assesses its potential performance via modeling. It was developed to support pulse compression of wideband waveforms for applications. The associated implementation issues introduced by electro-optical component characteristics were discussed. Coherent detection was used to implement difference mixing for subsequent digital processing. This system is independent since it requires no timing control signals for synchronization provided by illuminators, but the necessary reference signal is intercepted from the radar's sidelobe emissions. [C820]

"ISAR Imaging with LFM waveforms"

This thesis demonstrates a technique involving Linear Frequency Modulation (LFM) waveform and Inverse Synthetic Aperture Radar (ISAR) processing to develop two-dimensional radar images of a missile target. The processing is combination of two high-resolution processes: development of a high-range resolution (HRR) profile in down range using LFM waveform, and the development of high-resolution profile in cross-range using the ISAR technique. With these two techniques complementing each other, images of targets' dominant scatterers can be extracted, processed and displayed. This method is a practical method to process LFM radar data, in order to imaging the target. And it is useful in checking various interference methods to ISAR imaging. [C821]

"The design of waveform-generation applied to wide-band high resolution imaging radar"

Linear frequency modulated (LFM) signal is widely used in radar duo to its good characteristic. Aimed at transmitted waveform design of SAR system, a scheme of the wide-band LFM signal based on DDS technique is presented in this paper. Some factors affecting its compressed performance are also discussed. Finally, experiments results show that the proposed scheme is available. [C822]

"Stepped frequency chirp signal SAR imaging"

To achieve high range resolution using the stepped frequency chirp signal, two or more chirp waveforms are sequentially transmitted and received at stepped carrier frequencies in the whole bandwidth. An advantage of the approach has no increase in instantaneous bandwidth of the radar system. In this paper phase incoherent factor among sub-pulses trains produced by down frequency conversion mixer is put forward and analyzed. Which must be took into account when range bandwidth synthesis is processed. Frequency domain bandwidth synthesis is applied to SAR imaging combining with the phase incoherent factor estimate and compensation based on contract optimization autofocusing. Simulation results show the validity of the method. [C823]

"SAR deceptive jamming signal simulation"

Based on SAR jamming geometry model and radar waveform, the signal model on SAR deceptive jamming is presented, and the simulation method which is feasible in project is verified. The jamming signal is produced to protect single point or multi-points target, and is validated by SAR imaging algorithm. The method that is discussed in the paper isn't a limit to the occasion which the jamming station and the protective zone are situated in the main lobe, and it has practicality. [C824]

"Using MODIS and GLAS data to develop timber volume estimates in central Siberia"

Mapping of boreal forest's type, structure parameters and biomass are critical for understanding the boreal forest's significance in the carbon cycle, its response to and impact on global climate change. The biggest deficiency of the existing ground based forest inventories is the uncertainty in the inventory data, particularly in remote areas of Siberia where sampling is sparse, lacking, and often decades old. Remote sensing methods can overcome these problems. In this study, we used the moderate resolution imaging spectroradiometer (MODIS) and unique waveform data of the geoscience laser altimeter system (GIAS) and produced a map of timber volume for a 10degx12deg area in Central Siberia. Using these methods, the mean timber volume for the forested area in the total study area was 203 m3/ ha. The new remote sensing methods used in this study provide a truly independent estimate of forest structure, which is not dependent on traditional ground forest inventory methods. [C825]

"Exploiting full-waveform lidar data and multiresolution wavelet analysis for vertical object detection and recognition"

A current challenge in performing airport obstruction surveys using airborne lidar is lack of reliable, automated methods for extracting and attributing vertical objects from the lidar data. This paper presents a new approach to solving this problem, taking advantage of the additional data provided by full-waveform systems. The procedure entails first deconvolving and georeferencing the lidar waveform data to create dense, detailed point clouds in which the vertical structure of objects, such as trees, towers, and buildings, is well characterized. The point clouds are then voxelized to produce high-resolution volumes of lidar intensity values, and a 3D wavelet decomposition is computed. Vertical object detection and recognition is performed in the wavelet domain using a multiresolution template matching approach. The method was tested using lidar waveform data and ground truth collected for project areas in Madison,Wisconsin. Preliminary results demonstrate the potential of the approach. [C826]

"Multi-waveform radar for ice sheet measurements and classroom demonstration"

The Center for Remote Sensing of Ice Sheets (CReSIS), at the University of Kansas, is a Science and Technology Center established by the National Science Foundation (NSF) in 2005, with the mission of developing new technologies and computer models to measure and predict the response of sea level change to the mass balance of ice sheets in Greenland and Antarctica. As part of a senior undergraduate capstone design course we designed and simulated a wideband, push-broom, multi-waveform radar for fine-resolution airborne ice sheet surface elevation measurements. A prototype of this system was developed and its response was measured. The prototype will serve as a teaching tool and a design platform for the final instrumentation package to be used on an uncrewed aerial vehicle (UAV) being developed at the University of Kansas. In this paper we will present the objectives of the project, design details, simulation results, and testing results from experiments delay line and point targets. [C827]

"Performance results of the SHARAD instrument"

SHARAD (SHAllow RADar)is a subsurface sounding radar provided by ASI as a Facility Instrument to NASA's 2005 Mars Reconnaissance Orbiter for the characterization of the upper part of the Martian crust. The design of the instrument reflect a balance of scientific requirements versus SHARAD mission and Hardware constraints.

One of the most difficult point in SHARAD design was the choice of the radar wavelength, since longer wavelengths have the potential for deeper subsurface penetration at the expense of depth resolution. Shorter wavelengths enhance the ability to generate surface images and accurate profile. A radar sounder needs a system requirements for large dynamic range and precise sidelobe control. Very low range side-lobes are mandatory to allow detection of weak sub-surface echoes in presence of the strong surface return. The approach of limiting to the minimum the amount of processing performed on-board was selected in order to allow the pulse compression process (critical from the point of view of range side-lobes) to be performed on ground, using the computed instrument Point-Target-Response (PTR) as correlation reference waveform. One of the main goal of this paper is to describe the design of the experiment design of SHARAD and the selection of the instrument parameters. An assessment of radar performance has been obtained by using both on-ground and on- flight measurements. Some preliminary results from the mars mission have been reported. [C828]

"An investigation of PN sequences for multistatic SAR/InSAR applications"

This paper investigates the performance of pseudo-noise (PN) sequences as pulse compression waveforms in the radar imaging of distributed targets. Multiple transmitter schemes such as multi-static synthetic aperture radar (SAR) and multi- baseline interferometric SAR (InSAR) provide high resolution images for remote sensing applications at lower costs. PN sequences are a natural choice for such systems. The performance of different PN coding schemes such as the maximal length sequences (m-sequences), Gold sequences and shifted m-sequences are compared. [C829]

"On the Far-Field Calculations Using AWE and the Method of Moments"

In this paper, the problem of wideband radar cross section (RCS) calculations with asymptotic waveform evaluation (AWE) accelerated method of moments is considered. The traditional formulation, with RCS obtained independently for each frequency, based on Pade approximation of the current distribution is compared to the formulation where rational functions are used to directly approximate far fields. It is shown that an additional approximation used in the second attitude, may reduce the resulting bandwidth of the model. [C830]

"24GHz Software-Defined Radar System for Automotive Applications"

A software-defined measurement system is proposed and described in this work. The system makes use of a hybrid radar scheme of frequency modulation continuous wave (FMCW) and pseudorandom (PN) code pulse techniques. In this system, the FMCW measurement technique is deployed in obtaining the range value of a target while the PN code pulse radar technique is used to determine the inter-vehicle radar information for communication purpose. Different waveforms are generated in direct digital synthesizers (DDSs) and processed by different algorithms in a single digital signal processor (DSP). The switching between the PN code pulse and FMCW functions is controlled by software to improve the parametric resolution and ensure the communication function. Measurement results of our designed and fabricated K-band (24 GHz) prototype radar validate the proposed software defined radar system. The results of the radar compared with those of a reference laser meter suggest an accuracy of range value around 15 centimeters. The PN code information reflected from target is well collected and recovered. The work has demonstrated unique and reliable combined functions of the FMCW and PN code pulse platforms for automotive applications. [C831]

"Simulation studies of forest structure using 3D lidar and radar models"

The use of lidar and radar instruments to measure forest structure attributes such as height and biomass are being considered for future Earth Observation satellite missions. Large footprint lidar makes a direct measurement of the heights of scatterers in the illuminated footprint and can yield information about the vertical profile of the canopy. Synthetic Aperture Radar (SAR) is known to sense the canopy volume, especially at longer wavelengths and is useful for estimating biomass. Interferometric SAR (InSAR) has been shown to yield some forest canopy height information. There is much interest in exploiting these technologies separately and together to get important information for carbon cycle and ecosystem science. More detailed information of the electromagnetic radiation interactions within forest canopies is needed and backscattering models can be of much utility here. A three-dimensional (3D) coherent radar backscattering model and a 3D lidar backscatter models were used to investigate the use of large footprint lidar, SAR and InSAR for characterizing realistic forest scenes. The tree height indices derived from lidar waveform and heights of InSAR phase centers were compared. Results will address the possible synergies between lidar and radar data in terms of forest structural information. [C832]

"Design and implementation of a golay-based GPR system for improved subsurface imaging"

A bench-top prototype GPR using Golay codes has been designed and implemented. The preliminary

experimental results show a reasonable good improvement in terms of SNR. This work is still in progress. Improvements related to some of the other components and subsystems are underway. In particular, we are experimenting with innovative antenna designs having minimum influence on the transmitted waveform, and improved image processing algorithms. [C833]

"Wideband Sonar Waveform Design using Linear FM Signals and Hermite-Rodriguez Functions"

A new approach for the design of wideband sonar waveforms using linear FM signals and Hermite-Rodriguez functions is proposed. The use of Hermite-Rodriguez functions make it possible to formulate the waveform design problem as an optimal parameter selection problem with a positive definite objective function and linear and bilinear constraints. Such a formulation is quite flexible and can accommodate both frequency and time domain design specifications and constraints. The approach used to solve the optimization problem is to convert the nonlinear and nonconvex complex-domain constraints to simple linear and bilinear real-domain constraints by introducing extra optimization variables. Some preliminary numerical results are presented to illustrate the effectiveness of the proposed method. [C834]

"Analysis of the signal model for forward scattering radar in case of a small target"

This paper presents the signal model for forward scattering radar (FSR) in the case of a small target and presents the analyses of this model. The equations and graphs for waveform, instantaneous frequency, energy, autocorrelation function and spectrum are given. The empirical modes and Hurst parameter were also calculated and plotted. [C835]

"Digital beamforming and multidimensional waveform encoding for spaceborne radar remote sensing"

This paper describes an active electronically scanned array (AESA) FMCW radar with eight transceivers. Each transceiver has its own direct digital synthesizer (DDS) for signal generation which enables digital beamforming on transmit as well as on receive. The coherent operation of the eight transceivers and the capability to perform digital beam forming on transmit and receive is demonstrated. [C836]

"Maximally Frequency Selective Wavelet Packets Based Multi-Carrier Modulation Scheme for Cognitive Radio Systems"

In this paper we demonstrate the operation of a wavelet packet based multi-carrier modulation (WP-MCM) scheme in the context of cognitive radio. The wavelet packets are derived from multistage tree-structured paraunitary filter banks. The emphasis is on the design and development of maximally frequency selective wavelets derived from a modified Remez exchange algorithm. To enable the WP-MCM cognitive radio system to co-exist with other licensed users a common spectrum pool is maintained and the WP-MCM transmission waveform characteristics are shaped to communicate in the idle time-frequency gaps of the licensed user. This is achieved by dynamically deactivating wavelet packet carriers in and near the region of the licensed user spectrum. Through simulation results, we demonstrate the efficacy of the proposed wavelet packet based mechanism in seamlessly cohabiting with licensed users. The bit error rate (BER) performance is shown to be comparable, and even at times better, to conventional Fourier based OFDM system. [C837]

"High Performance Waveform Generator Design for Full-Coherent Millimeter-Wave Radar"

Millimeter-wave radar has attracted much attention as a replacement of some infrared or laser systems currently in use. In this paper, an approach of developing high performance waveform for full-coherent millimeter-wave radar is proposed. With good frequency configuration and optimal utilization of DDS (direct digital synthesizer), PLL (phase locked loop) and FPGA (field programming gate array), the developed radar waveform generator implemented with low complexity has the good performance of both spectrum purity (phase noise and spur level) and switching speed. The measurement results show that, in S/C band, the local oscillator's bandwidth is 480MHz and the minimum frequency step is 15MHz, the spur level is better than -65dBc, the phase noise level is better than -94dBc/Hz@1kHz, the maximum frequency switching time is less than 15mus. [C838]

"Chaotic signals in radar?"

Chaotic signals add to the design repertoire for radar. This paper discusses the properties of chaotic signals, their generation and use, including transmitter hardware and efficiency, with reference to results in communications research and recent theoretical and practical results in sonar, and development throughout the world for radar. Practical issues arising from the unique properties of chaotic systems are considered. Phase locking and target identification benefits are also suggested. Results of sonar experiments and trials to support

prediction from simulation findings are given. It is concluded that chaotic signals have the potential to offer exciting additional capabilities [C839]

"A Hybrid Approach to Modulation Recognition for Intentional Modulation on Pulse (IMOP) Applications"

In this paper, a hybrid approach to modulation recognition is proposed for classifying unmodulated CW, narrow-band FM, wide-band FM, triangular FM, BPSK, DSB-SC and AM as well as noise. The algorithm is based on the use of decision theoretic and pattern recognition techniques. The decision theoretic approach is used to separate noise from signals, constant-envelope from varying-envelope waveforms, unmodulated CW from waveforms with phase information, and the two varying-envelope waveforms from one another. The pattern recognition technique is used to distinguish the three FM and BPSK waveforms. Computer simulations are used to demonstrate the performance of the proposed algorithm [C840]

"Computation of Far-Field Impulse Response of an X-band Waveguide Slot Array using the Finite-Difference Time-Domain Method"

The waveform in the far field of an antenna array can be obtained using the convolution of the input signal and the antenna far-field impulse response. Since it is very difficult to measure an antenna far-field impulse response, a numerical approach, i.e., the finite-difference time-domain (FDTD) method, is used in this paper to calculate an antenna far field impulse response. It is well known that the FDTD method models electromagnetic problems in both spatial and temporal domains. In conjunction with the time domain near-to-far field transformation, the FDTD method can be used to compute an antenna far-field radiation waveform at any angular location. With the far-field waveform computed by the FDTD method, this paper presents the deconvolution procedure to obtain an antenna far-field impulse response. A 54-element waveguide slot array of X-band navigation radar is used as an example. Its far-field impulse response as a function of the radiation angle is computed using the FDTD method. The far-field waveforms of an FM pulse transmitted by the waveguide slot array are calculated using the convolution of the FM pulse and the array far-field impulse response. The instantaneous frequencies of these far-field waveforms at different radiation angles are examined in details. It clearly shows from analysis results that the instantaneous frequencies at the leading and trailing edges of the received pulse have been distorted. The amount of frequency shift is related to the antenna radiation pattern at different radiation angles [C841]

"Combined-Waveform Design Method and Its Application in Ultra-Wideband Pulse Shape Multiple Access"

In impulse radio ultra-wideband (IR-UWB) systems, Rayleigh pulse and Gaussian monocycle are usually the waveforms used to transmit data. However when all the users in a system transmit an identical waveform, the effects of multi-user interference (MUI) are great and therefore the system bit error rate (BER) is high. In order to reduce the effects of MUI, orthogonal waveforms based pulse shape multiple access (PSMA) is proposed. In this paper, combined-waveform the novel orthogonal waveforms design method based on orthogonal wavelet, is presented and utilized to realize multiple access with time hopping (TH) sequence. Meyer wavelet is used as an example to illustrate how to design a set of orthogonal waveforms by this method. Simulation results show that PSMA using combined-waveform can be used to reduce MUI, decrease receiver complexity compared to other orthogonal waveform based PSMA and reach the goal of adaptive spectrum envelope at the same time [C842]

"UWB Array-Based Radar for Landmine Detection"

In this paper, the development of an UWB array-based time-domain radar sensor is described. The radar sensor is designed to be used within a vehicle-mounted multi-sensor system for humanitarian demining. The main novelty of the radar lies in the modular approach, design of the antenna system and waveform of the transmit antenna feeding pulse. The radar has focusing capability via near-field beamforming in cross-scan direction and migration in along-scan direction [C843]

"MIMO Radar, Techniques and Opportunities"

MIMO techniques have been well studied for communications applications where they offer benefits in multi-path fading environments. This terminology is now appearing in the radar literature, but in several forms causing some confusion. Much of the existing work has focused on multistatic radars with sufficient spatial separation to de-correlate target RCS fluctuations, and where the data from the radars are combined incoherently. Another form of MIMO radar, closer to the communications technique, is where multiple orthogonal signals from the individual transmitter elements of a phased array are coherently combined on reception to form multiple beams.

This paper presents a simple understanding of this within-aperture MIMO technique. We show how a filled array of "phantom" elements can be formed from relatively few physical elements. We explain the phantom element concept and extend it to the synthesis of various antenna array configurations, covering one, two and three dimensional geometries. The paper describes a range of waveform and signal processing options and discusses the implications of these radar capabilities [C844]

"Multicomponent Chirp Demodulation using Discrete Fractional Fourier Analysis"

The multicomponent chirp model finds numerous applications in biomedical signal processing, radar problems, and in the modeling of biological waveforms such as bat and whale echolocation signals. The problem of demodulating these signals is straight-forward when the components are distinct, however, when the components overlap spectrally or when one of the components is stronger than the others existing multicomponent demodulation algorithms run into singularity problems and are unable to effect signal separation and demodulation. In this paper, we present a method of multicomponent chirp demodulation using the recently introduced multiangle-centered discrete fractional Fourier transform. We specifically demonstrate that the proposed algorithm is effective in the aforementioned difficult situations where other algorithms fail [C845]

"Automatic Target Recognition Based on High-Resolution Range Profiles with Unknown Circular Range Shift"

In this paper, an automatic aircraft target recognition (ATR) framework is presented, which is based on the high resolution range profiles (HRRP) of aircraft targets. This work is divided into two major parts. First, we consider the generation of the HRRP, which includes the modeling and simulation of radar cross section (RCS), the design of step frequency waveform (SFW), and IFFT processing for HRRP synthesis. In practice, a possible circular shift of the received HRRP relative to the template HRRPs in target library may exist. In such a situation, we resort to the statistical classification technique to develop an ATR algorithm, which begins with using the Neyman Pearson criterion to determine whether a target is present or not, under a constant false alarm rate constraint. Then the circular correlation is used to estimate possible circular range shift, as well as the unknown phase shift and attenuation. Moreover, we adopt the Gram-Schmidt orthogonalization (GSO) procedure to construct a signal space, and then project the received HRRP onto the signal space. Finally, the target classification can be done in terms of maximum a posteriori (MAP) decision rule. Simulation results are also included to demonstrate the feasibility of this approach [C846]

"Robustness of Arrays with Different Waveforms"

This paper examines the robustness of the basic waveform of UWB antenna arrays and Gaussian modulated sinusoidal pulse against failure of element. Simulation for circular arrays shows that pattern of Gaussian pulse is more robust and does not change for failure of elements and there is some condition that radiation of Gaussian pulse in sidelobes is zero. For Gaussian and GMS (T), the direction of maximum radiation never changes. According to tables, circular array for both GMS has better energy radiation percent than Gaussian but for linear array only GMS (T) is better. The results of the previous analysis show that significant improvement in the performance of antenna arrays patterns is possible if one is willing to abandon simple narrow-band sinusoidal signals and instead work with time gated ultra-short pulses and wavelets. The GMS is better than Gaussian in angular resolution in both modes T and 2T and it is suitable for radar applications. GMS pulse in case of element failure generates sidelobes but amplitudes of these sidelobes are smaller than Gaussian's radiation [C847]

"An Alternative Target Density Function For Radar Imaging"

In this paper, an alternative target density function (TDF) is proposed to image the radar targets in a dense target environment. It is produced by wavelet theory considering a new range and angle plane different from the conventional methods. It is shown that wavelet theory can be used as approach to imaging by active sensors by transmitting a waveform which is a kernel for this transform such as a window function. Although the imaging is obtained via the phased array radars, the problem associated with beamforming in linear phased array radar system is bypassed in this new algorithm [C848]

"Congruence Method for Sidelobe Control in SAR images"

A new method for nonlinear processing of synthetic aperture radar (SAR) images is experimentally approved. The method was suggested and is based on nonlinear processing of two different SAR images generated from the same raw data. One of these images is SAR image with low sidelobes while the second one has Ltarray blindnessGt at the target direction. The method essentially suppresses impulse response sidelobes with no mainlobe widening. Description of the processing algorithm is given. SAR images generated using noise

waveform SAR are presented [C849]

"Weighted Norms of Ambiguity Functions and Wigner Distributions"

In this article new bounds on weighted p-norms of ambiguity functions and Wigner functions are derived. Such norms occur frequently in several areas of physics and engineering. In pulse optimization for Weyl-Heisenberg signaling in wide-sense stationary uncorrelated scattering channels for example it is a key step to find the optimal waveforms for a given scattering statistics which is a problem also well known in radar and sonar waveform optimizations. The same situation arises in quantum information processing and optical communication when optimizing pure quantum states for communicating in bosonic quantum channels, i.e. find optimal channel input states maximizing the pure state channel fidelity. Due to the non-convex nature of this problem the optimum and the maximizers itself are in general difficult find, numerically and analytically. Therefore upper bounds on the achievable performance are important which will be provided by this contribution. Based on a result due to E. Lieb, the main theorem status a new upper bound which is independent of the waveforms and becomes tight only for Gaussian weights and waveforms. A discussion of this particular important case, which tighten recent results on Gaussian quantum fidelity and coherent states, will be given. Another bound is presented for the case where scattering is determined only by some arbitrary region in phase space [C850]

"Waveform Design and Diversity in Radar Sensor Networks: Theoretical Analysis and Application to Automatic Target Recognition"

In this paper, we perform some theoretical studies on constant frequency (CF) pulse waveform design and diversity in radar sensor networks (RSN): (1) the conditions for waveform co-existence, (2) interferences among waveforms in RSN, (3) waveform diversity combining in RSN. As an application example, we apply the waveform design and diversity to automatic target recognition (ATR) in RSN and propose maximum-likelihood (ML)-ATR algorithms for nonfluctuating target as well as fluctuating target. Simulation results show that our waveform diversity-based ML-ATR algorithm performs much better than single-waveform ML-ATR algorithm for nonfluctuating targets or fluctuating targets. Conclusions are drawn based on our analysis and simulations [C851]

"A Real Time Signal Processing for an Anticollision Road Radar System"

This paper describes the real time processing unit used for an anticollision road radar system. This radar based on a numerical correlation between the transmitted signal and the received signal is under development. The signal uses orthogonal codes to ensure a multiple access communication between all vehicles in near area. In this paper, a real time processing unit associated to an original anticollision radar is presented. The studied radar is based on spreading spectrum coded radar waveforms at 76-77 GHz and a numerical correlation receiver. This sensor associated to other sensors like Lidar and Camera will be used on-board vehicles for more safety on road. The studied receiver computes the numerical crosscorrelation between the received signal and a replica of the transmitted code to allow an optimal detection. The appropriate coding and processing have been used to implement a laboratory radar mock-up. The real time processing is tested in order to show their performances and disadvantages when applied to obstacles detection. The main idea is to achieve an efficient real time detection using a simple and low cost system. [C852]

"Waveform Libraries for Radar Tracking Applications: Maneuvering Targets"

In this paper we extend the idea of adaptive waveform selection for radar target tracking to interacting multiple model (IMM) trackers to permit the modelling of maneuvering targets by allowing multiple possible dynamical models. We develop a one step ahead solution to the problem of waveform selection, which is designed to decrease dynamic model uncertainty for the target of interest. It is based on maximization of the expected information obtained about the dynamical model of the target from the next measurement. We also discuss the design of waveform libraries for target tracking applications. [C853]

"Collaborative Signal Processing Using Radar Sensor Networks"

In this paper, we propose a collaborative signal processing framework using waveform diversity in radar sensor networks (RSN). We study waveform diversity using constant frequency (CF) pulse waveform and linear frequency modulation (LFM) waveform, and compare their performance in automatic target recognition (ATR) with delay-Doppler uncertainty. Simulation results show that CF pulse waveform and LFM waveform can achieve very similar performance in ATR with delay-Doppler uncertainty using radar sensor networks. The ATR performance can tremendously be improved with larger number of radars in RSN [C854]

"Enhanced Discrimination for Boundary and Material of Buried Objects in Concrete Structure using

Microwave Subsurface Radar"

In this report, a novel signal and image processing method for microwave subsurface radar is proposed, which enables to estimate the internal construction in concrete structures. By using proposed method, enhanced information of buried objects such as boundary and material are discriminated. As the objects are buried near the concrete surface, signal processing is complicated because a reflected wave is often interfering with a transmitting wave in an observed signal. In order to reduce an influence of the interference, transmitting wave subtracting method is adopted, which calculates the difference between the observed signal and a typical transmitting waveform identified from the observed signal without buried objects, and boundary and material of the buried objects are discriminated precisely. Next, a boundary back projection histogram method is newly proposed. The boundary model fitness whose shape is the normal distributions having characteristics of the original model fitness is introduced to sharpen the boundary on electrical characteristics in propagation medium (which represents the boundary of the buried object). The boundaries of the buried object are discriminated clearly in the back projection images calculated by using boundary model fitness. An effectiveness of these proposed methods has confirmed by experimental application to several concrete structure samples [C855]

"22-29GHz CMOS Pulse Generator for Ultra-Wideband Radar Application"

The pseudo-millimeter-wave ultra-wideband (UWB) is attractive for applications in short-range automotive radar systems using 22 to 29GHz in order to realize road safety and intelligent transportation. Although CMOS is suitable for the short-range radar since processing units can be implemented in the same chip with the UWB front-end building block, it is difficult to operate CMOS pulse generators at such a high frequency. To realize the pseudo-millimeter-wave band using CMOS, the paper have proposed a new pulse generator consisting of a series of delay cells and edge combiners with waveform shaping. As a result of measurement using 90nm CMOS technology, 1Gbps/bit pulses are successfully generated with a power consumption of 1.4mW at a supply voltage of 0.91V. This result is the key technology for a one-chip short-range radar system [C856]

"Spatial-Temporal-Frequency Diversity in Radar Sensor Networks"

In this paper, the spatial-temporal-frequency diversity to improve the detection performance of Radar Sensor Networks (RSN) in the presence of certain types of interference (clutter, jamming, noise and interference between radar sensors) is studied. In order to reduce the interference between radar sensors and maximize the signal-to-interference-plus-noise ratio (SINR), we propose a method using the orthogonality criterion to design waveforms for radar sensors in the network. Besides the interference between radar sensors, performance of the network depends largely on other interference, especially clutter, which is extended in both angle and range, and is spread in Doppler frequency. By using the spatial-temporal diversity, we can suppress effects of these interference. In this paper, we also propose a receiver for diversity combining in RSN. As an application example, we apply the spatial-temporal-frequency diversity scheme to improve the detection performance or reduce the missdetection probability at a low false alarm probability. Simulation results for both non-fluctuating targets and fluctuating targets show that the performance of our proposed scheme is superior to that of the single radar with the spatial-temporal diversity only. [C857]

"Generating Costas Arrays to Order 200"

Number-theoretic generators of Costas arrays and generalizations in the literature and some presented here produce 526,908 of the known 663,703 known Costas arrays for orders up to 200. For orders higher than seven, there are more Costas arrays than the generators produce. A spin generalization is observed to find new Costas arrays for orders up to about 50, but none of higher order. This, and early work on the occurrence of Costas arrays, indicates that most, or all, Costas arrays are known, or are generated by known generators and their generalizations. [C858]

"Frequency Coded Waveforms for Adaptive Waveform Radar"

We consider the use of frequency coded sequences for adaptive waveform radar. In particular, we investigate the joint use of stepped frequency chirps, Costas sequences, and pushing sequences to form an effective signal set for adaptive waveform radar. [C859]

"Waveform Design for MIMO Radar Based on Mutual Information and Minimum Mean-Square Error Estimation"

This paper addresses the problem of optimum radar waveform design for both radars employing a single transmit and receive antenna and the recently proposed multiple-input multiple-output (MIMO) radar. A random target impulse response is used to model the scattering characteristics of the target, and both point and

extended radar targets are considered. Assuming the constraint on waveform power, two radar waveform design problems have been investigated. The first one is to design waveforms that maximize the conditional mutual information (MI) between the random target impulse response and the reflected waveforms given the knowledge of the transmitted waveforms. The second one is to find transmitted waveforms that minimize the minimum mean-square error (MMSE) in estimating the target impulse response. Our analysis indicates that under the same total power constraint, these two criteria lead to the same solution for a matrix which specifies the essential part of the optimum waveform design. The solution employs water-filling to allocate the limited power appropriately. We also present an asymptotic formulation which requires less knowledge of the statistical model of the target. [C860]

"A Doppler statistic for zero autocorrelation waveforms"

There are several natural constructions of constant amplitude zero autocorrelation (off the DC-component) waveforms. We adopt a construction for waveforms of length K, where K is a non-square-free integer. This property of K is used in the derivation of a frequency shifting (Doppler) detection algorithm which we derive. There are number theoretic properties which account for the properties of this algorithm, as well as for analogous but different properties in the square-free case. A variety of relevant examples is given along with the technical rationale for the algorithm. [C861]

"Waveform-Agile Sensing for Tracking Multiple Targets in Clutter"

In this paper, we consider the problem of scheduling the waveform transmitted by waveform-agile radar sensors to track multiple targets in clutter. A number of generalized frequency modulated chirps with trapezoidal envelope form the library of waveforms available to the sensors, which obtain measurements using a nonlinear observation model. A joint probabilistic data association filter is used to track the target, and the waveform selection is made so as to minimize the predicted mean square tracking error. We provide simulation results to show that the scheduling improves the tracking performance of multiple targets even in the presence of clutter. [C862]

"Space-Time-Waveform Adaptive Processing for Frequency Diverse Distributed Radar Apertures"

This paper reviews recent developments in the field of adaptive processing for frequency diverse, distributed, radar apertures. The large baseline of such a distributed radar results in angular resolution that is orders of magnitude better than the resolution of a single large radar. This capability comes at the cost of grating lobes (multistatics with evenly spaced apertures) or high sidelobes (multistatics with randomly spaced apertures). This paper presents some of the issues specific to such a radar and develops the notion of frequency diversity and presents the outlines of a data model that addresses the specific nature of frequency diverse distributed apertures. [C863]

"Information Theoretic Radar Waveform Design for Multiple Targets"

In this paper we use information theoretic approach to design radar waveforms suitable for simultaneously estimating and tracking parameters of multiple targets. Our approach generalizes the information theoretic water-filling approach of Bell. The paper has three main contributions: a new information theoretic design criteria for single transmit waveform with a receiving array using a weighted linear sum of the mutual informations between targets' radar signatures and the corresponding received beams (given the transmitted waveforms), we provide a family of design criteria that weight the various targets according to priorities. Then we generalize the information theoretic design criteria for designing multiple waveforms under joint power constraint when beamforming is used both at transmitter and receiver. Finally we provide a highly efficient optimization algorithm for optimizing the transmitted waveforms both for single target and multiple targets. We show that the optimization problem in both cases can be decoupled into a parallel set of low dimensional search problems at each frequency, with dimension defined by the number of targets, instead of the number of frequency bands used. The power constraint is forced through the optimization of a single Lagrange multiplier for the dual problem. We end with comments on the generalization of the proposed technique for other design criteria, e.g., for the linearly weighted MMSE design criterion. [C864]

"An Effective Deconvolution Algorithm for Time-Domain Near-Field ISAR Imaging"

In this paper, we present a deconvolution algorithm for time-domain near-field ISAR imaging. Due to its impulse-like waveform, the backscattering waveform from an electrically large conducting sphere is adopted as the system response to restore the impulse response, and to reconstruct the images. The deconvolution is discretized into a matrix equation, and the least-squares solution is implemented by the conjugate gradient method. Furthermore, the Coifman wavelet (Coiflets) of the 6th order is employed to replace the system function

of the 1st and 3rd derivatives of a Gaussian function. The resulting images are clean with most smearing removed. Owing to the orthogonality and compact support of the Coiflets, the deconvolution process is accelerated 22 times without sacrificing the image quality [C865]

"Towards radar-enabled sensor networks"

Ultra wideband radar-enabled wireless sensor networks have the potential to address key detection and classification requirements common to many surveillance and tracking applications. However, traditional radar signal processing techniques are mismatched with the limited computational and storage resources available on typical sensor nodes. The mismatch is exacerbated in noisy, cluttered environments or when the signals have corrupted spectra. To explore the compatibility of ultra wideband radar and mote-class sensor nodes, we designed and built a new platform called the radar mote. An early prototype of this platform was used to detect, classify, and track people and vehicles moving through an outdoor sensor network deployment. This paper describes the sensor's theory of operation, discusses the design and implementation of the radar mote, and presents sample signal waveforms of people, vehicles, noise, and clutter. We demonstrate that radar sensors can be successfully integrated with mote-class devices and imbue them with an extraordinarily useful sensing modality [C866]

"Passive detection suppression of cyclostationary phase coded waveforms"

A disadvantage of using pulse compression coded waveforms in radar is that the transmitted signal has features that can be easily detected by enemy passive detection equipment. One of these detectable features is the carrier frequency. Presence of the carrier frequency in coded waveforms gives rise to cyclostationary properties that are exhibited in the form of spectral lines in a nonlinearly transformed signal. This paper focuses on suppression of cyclostationary properties present in a transformed Welti coded CW waveform with the nonlinear transformation being that of the quadratic type [C867]

"Design of synthetic waveforms with low sidelobes"

We propose a new systematic approach for designing pulse trains with nonuniform frequency shifts between the center frequencies of the consecutive subpulses. We suggest specific relationships between the frequency shifts so that the waveform's matched filter response would have a desired sidelobe level. Our approach can be also used for designing Doppler tolerant waveforms. We show that waveforms generated by our algorithm exhibit improved performance when compared with traditional synthetic waveforms [C868]

"Nonquadratic regularization for waveform optimization"

An adaptive algorithm for eigen-based waveform optimization is presented. The algorithm is capable of improving the matched filter signal-to-interference-plus-noise ratio (SINR) of a radar operating in a colored interference environment while simultaneously constraining the shape of the matched filter response. To arrive at the algorithm cost function, the asymptotic behavior of the interference covariance matrix is examined, and a p-norm regularization term is considered. The resulting cost function consists of one term to improve SINR, and another term to constrain the shape of the matched filter response. This provides the waveform designer with a means of trading between SINR performance and matched filter response for a given application. The simulated performance of various steepest descent algorithms applied to waveforms in a colored interference environment is presented. These results show that a low-complexity stochastic gradient algorithm (in the spirit of LMS) is capable of improving radar performance in band-limited interference. [C869]

"An approach for multiple moving targets detection and velocity estimation"

The purpose of range tracking and velocity estimating for multiple moving targets is to accurately track the location of the targets and their differential changes. In this paper, an approach for multiple moving targets detection and velocity estimation in radar is proposed. By using transformable periods and symmetrical LFM (TPS-LFM) waveform, multiple moving targets detection is possible. Since this radar waveform will increase the complexity of signal processing. To resolve this problem, an effective algorithm based on discrete match Fourier transform (DMFT) is proposed for chirp rate estimation and used to overcome the difficulty of parameter estimation for multiple moving targets. The signal model and the detection method are discussed and some simulations are performed. Theoretic derivation and computer simulations show that multiple moving targets can be easily detected with high range resolution and high velocity resolution, and under certain conditions, the false detections of unnecessary targets and failures to detect necessary targets, which used to be major problems in detection performance, can be substantively reduced. Its usefulness in multiple moving targets detection and velocity estimation in various radar, such as automotive collision avoidance radar (ACAR) and moving target indicator (MTI) radar, are confirmed. [C870]

"A rate distortion method for waveform design in RF target detection"

Conventional RF image formation relies on a fixed waveform set that is based largely on obtaining maximum resolution for a given amount of bandwidth present in a waveform. However, the correlation process for a given waveform set varies widely depending on the cross correlation properties of the waveform and the geometry of the aperture interrogating the object to be detected. We propose a method that maximizes quality of the object being detected by first using an orthogonal basis to minimize the unwanted correlation response for the waveform. We then shape the frequency and temporal correlation response of the waveform for a given target using a rate distortion criteria and demonstrate the imaging and detection performance of the method [C871]

"Implementation of method for operating multiple high frequency surface wave radars on a common carrier frequency"

The increasing use of high frequency surface wave radar (HFSWR) for the surveillance of coastal regions is faced with the problem of limited channel availability in the electromagnetic spectrum. Thus there is a need for multiple radars to share a common frequency channel. Proof-of-concept work is presented here for a method to operate multiple radar systems on a common carrier frequency. A review is provided of an existing concept where a common waveform is modulated by tones varying by a few hertz across the different radars. The signals from the different radars are separated by either pulse-domain filtering or Doppler processing. An experiment has been performed that demonstrates the feasibility of the method. Limitations of the method are considered in terms of the linearity of the propagation channel. [C872]

"A waveform strategy for detection of targets in multiplicative clutter"

Conventional radar signal processing techniques approximate multipath as a linear process. Unfortunately, such an approach results in poor detection performance and because the model for the interference does not accurately represent the physical scattering process. We instead propose a method that uses the flexibility of waveform design for a given aperture to linearize the physical scattering phenomenon. This allows us to successfully detect targets using a Wiener matched filter approach in high multipath conditions. [C873]

"Improved high range resolution profiling of aircraft using stepped-frequency waveforms with an S-band phased array radar"

A signal processing scheme based upon stepped-frequency waveforms is presented which enables high range resolution (HRR) profiles of targets to be formed of potentially sub-meter resolution, and extent of several kilometers, using an S-band (3 GHz) radar system. This 'Hybrid' method is a significant improvement upon conventional ('Classical') HRR techniques, which have severely limited range unambiguous range extents. Successful aircraft trials and static experiments have been conducted using the MESAR2 phased array multifunction radar. Phased array time delay effects resulting from the reception of off-boresight target reflections were overcome without the need for calibration at every azimuth angle. Key application advantages are the potential to form high resolution range profiles of multiple target raids in an air defense scenario and extended threat clouds in ballistic missile defense. [C874]

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{no data available} [C875]

"Multi-mission multi-mode waveform diversity"

Previously, the authors presented a novel method for achieving range-dependent beamforming through the use of a frequency diverse array. The frequency diverse array concept was developed using a quasi-stationary waveform assumption. This concept can be extended to non-continuous wave signals for narrowband and wideband applications such as moving target indication (MTI) and synthetic aperture radar (SAR). Alternative implementations are described, which offer the potential for achieving MTI and SAR simultaneously. [C876]

"Multistatic radar systems signal processing"

In this paper, a multistatic radar system with multiple receivers and one transmitter is analyzed. We address the rules for selecting the weights for fusing multiple receivers in order to meet pre-specified performance goals. A multistatic radar ambiguity function is used to relate different radar performance measures to system parameters such as radar geometry and radar waveforms. Simulations are used to demonstrate that different performance criteria can lead to different rules for combining the signals from multiple receivers. [C877]

"A general class of stepped frequency trains"

For uniform frequency stepped pulse trains, there can be undesirable peaks of the autocorrelation function, known as "grating lobes". In this paper, we address this issue, using an approach, which allows us to suppress grating lobes below a desired threshold level in the case of appropriately chosen stepped frequency waveforms, i.e., sequences of narrowband pulses that span the desired bandwidth. We will introduce a multiparametric generalization of a stepped frequency train, and by exploiting a factorization of the autocorrelation function, will be able to effect a useful tradeoff between competing properties of the factors by careful choices of relevant parameters. We provide a detailed description of the method applied to a representative data set. [C878]

"Single-Stage Waveform Selection for Adaptive Resource Constrained State Estimation"

We consider the problem of optimal waveform selection. We would like to choose a small subset from a given set of waveforms that minimizes state prediction mean squared error (MSE) given the past observations. This differs from previous approaches to this problem since the optimal waveforms cannot be computed offline; it requires the previous observations. Since the optimal solution to this subset selection problem is combinatorially complex, we propose a convex relaxation of the problem and provide a low complexity suboptimal solution. We present a specific model and show that the performance of this suboptimal procedure approaches that of the optimal waveforms [C879]

"Advanced Optical Processor for Arbitrary Waveform Radar Imaging"

Essex has developed a prototype hybrid optical/digital processor for range-Doppler image formation using wideband arbitrary waveforms. The processor is called the advanced optical processor (AOP) and is a hybrid acousto-optic/digital processor that generates high dynamic range, range-Doppler images from wideband radar returns in real time. The AOP was first tested at a U.S. Government facility in November 2005. The AOP is currently scheduled to be tested with a range radar in April 2006. The laboratory testing included three waveform types and verification of all the necessary trigger control signals. The range radar testing will include collection and processing of the same three waveform signals to demonstrate arbitrary waveform capability. The AOP supports high resolution processing necessary for target discrimination and kill assessment by enabling the use of true arbitrary wideband waveforms. The selected architecture combines the advantages of both optical signal processing for the front-end receiver and high-speed digital signal processing for the real-time processing. Its size is a 6U form-factor and fits within the 6U electronic chassis [C880]

"Signal Waveform's Optimal Under Restriction Design for Active Sensing"

We consider signal waveform's optimal under restriction design (SWORD) for active sensing. In the presence of colored interference and noise with known statistical properties, waveform optimization for active sensors such as radar can significantly increase the signal-to-interference-plus-noise ratio needed for much improved target detection. However, the so-obtained optimal waveforms can result in significant modulus variation, poor range resolution, and/or high peak sidelobe levels. To mitigate these problems, we can constrain the waveform optimization problem by restricting the sought-after waveform to be similar to a desired waveform, which is known to have, for example, constant modulus as well as reasonable range resolution and peak sidelobe level. One example of the desired waveform is the widely used linear frequency modulated waveform or chirp. We will provide a detailed solution to the constrained optimization problem and explain how it is related with the existing waveform optimization methods [C881]

"Parallel Post-Processing Techniques for Fast Radar Cross-Section Computation"

Parallel processing methods for accelerating radar cross-section (RCS) calculation for general 3D conducting targets are investigated and evaluated. The main focus of this work is to develop methodologies that exploit the use of parallel computing environments during the post-processing phase of general method of moments (MoM) programs used for surface integral equations. The primary objective of this research is to examine the processor requirements incurred when multiple processors are used to solve for an overall RCS in a parallel manner. A secondary goal of this study is to evaluate the solution accuracy of asymptotic waveform evaluation (AWE) based techniques used in conjunction with this parallel post-processing approach. A selection of illustrative and informative computational examples for benchmark RCS targets are solved and compared to direct MoM reference solutions using the CLUMEQ Supercomputing Centre at McGill University [C882]

"Ultra Wideband Multibeam Optical Coherent Transient Radar"

In this paper, we present an electro-optic radar receiver for wide bandwidth, high time-bandwidth-product radar

returns that simultaneously performs parallel beamforming across arrays with thousands of antenna elements. This analog technique allows for correlation times of approximately 10 mus across 30 GHz of bandwidth without the use of extremely fast digitizing circuits or digital processors. To perform this technique, we upconvert the return waveforms from the antenna array onto an array of optical fibers by using an array of electro-optic modulators. From here, we can use a single lens as a Fourier optical beamformer. The frequency scaled beams are formed into a optical coherent transient (OCT) crystal along with an optically upconverted copy of the transmitted waveform. The OCT crystal correlates the return with the reference signal across all squinted beams. A chirped readout laser probes the spectrum of the correlation at each frequency bin across all beams while a synchronized zoom lens compensates for the frequency scaled location of the beams. The resulting beam spectra is Fourier transformed across time to generate the correlation peaks of the return signal. Pulse-to-pulse correlation peaks can be achieved using spatial multiplexing within the crystal or temporal multiplexing of the readout of the signal. We motivate such a system by calculating the digital processor requirements of a similar system, followed by a detailed description of the architecture [C883]

"Information Theoretic Criterion for Waveform Selection"

A novel criterion for waveform selection in adaptive radar and other sensing applications is presented that is based on the information theoretic concept of mutual information. In addition, its application to the area of waveform diversity for synthetic aperture radar (SAR) systems is examined. Mutual information is a measure of the information (in the sense of Shannon) in a random variable or vector about another random variable or vector. It is shown herein that such a framework provides the basis for a conceptually simple and powerful criterion for context-dependent evaluation of candidate waveforms, as well as context-dependent design of waveforms. Furthermore, in the special case of zero-mean Gaussian-distributed clutter, interference, and noise, the criterion attains an analytically simple form-a scalar function of the singular values of a specific cross-covariance matrix. The criterion can be used in distinct optimization contexts (minimization or maximization) as a function of the problem to be addressed. In addition, the criterion inherently includes the statistical information of the sensed parameters. More specifically, in the context of a SAR system the criterion includes the covariance matrix of the set of illuminated ground scatterers. The formulation and simulation-based results are presented in the context of a first-order radar system model for simplicity, but the approach can be extended in a straightforward manner to cover more complex models. Results presented show that the criterion is an effective means for waveform selection in an adaptive SAR system [C884]

"Distributed Coherent Aperture Measurements for Next Generation BMD Radar"

This paper describes the distributed coherent aperture work being carried out at MIT Lincoln Laboratory in support of the next generation radar (NGR) program under the direction of the Radar Systems Technology (RST) group within the Missile Defense Agency/Advanced Systems (MDA/AS) Directorate. The NGR concept achieves transportability and high-radar sensitivity by coherently combining multiple distributed radar apertures in a building block manner. The operational concept uses orthogonal noise-like waveforms and multiple-input multiple-output (MIMO) techniques for cohere-on-receive operation and for adaptively estimating the transmit coherence parameters. In cohere-on-transmit mode, like waveforms are used and the relative phase and transmit time of each transmit pulse is adaptively adjusted so that the transmitted pulses arrive at the target in-phase and at the same time. In cohere-on-receive mode, an N2signal-to-noise ratio (SNR) gain is achieved over a single aperture when the orthogonal waveforms are combined coherently. In cohere-on-transmit mode, full coherence is achieved on both transmit and receive for an N2SNR gain over a single radar. The NGR concept and recent highly-successful distributed aperture measurement campaigns are described. These measurements were carried out at the white sands missile range (WSMR) using the Lincoln Laboratory Wideband MIMO Distributed Aperture Test System in July 2005 and at the Air Force Research Laboratory (AFRL) Ipswich Antenna Range Facility in August 2004. Wideband coherence on transmit and receive was demonstrated at X-band in real time against live targets. A performance analysis, including comparison to the Cramer-Rao bounds, is given for the coherence parameter estimators during the presentation. Future plans are briefly discussed, including experiments with more radar channels and plans to demonstrate additional benefits of using MIMO techniques with distributed apertures and through spatial-- diversity [C885]

"A Comparison of Back-Projection and Range Migration Algorithms for Ultra-Wideband SAR Imaging"

Ultra-wideband waveform and large integration angle benefit the synthetic aperture radar (SAR) with very high range and azimuth resolutions. However, at the same time, more new complexities and challenges are brought to the conventional SAR imaging algorithms. The back-projection algorithm and range migration algorithm are two newly developed algorithms that can be used in ultra-wideband SAR imaging. The back-projection algorithm originates from the medical imaging reconstruction technique called computer-aided tomography whereas the

range migration algorithm is derived from seismic migration techniques. In the application to SAR imaging, the performance comparison is made in this paper based on theoretical analysis, simulation and experimental data. The analysis and processing results show that both algorithms are suitable for ultra-wideband SAR imaging and the theoretical resolution performances can be achieved. In addition, some practical issues of implementation and performance difference about these two algorithms are addressed as well [C886]

"Optimal Polarized Waveform Design for Active Target Parameter Estimation Using Electromagnetic Vector Sensors"

We develop optimal design methods of polarimetric radar signals that improve the estimation accuracy of the target parameters. A weighted sum of the Cramer-Rao bound (CRB) of the parameters of interest is used as the cost function of the optimization. We employ an array of electromagnetic vector sensors to fully recover the polarization information from the target returns. Simulation examples illustrate the improved system performance [C887]

"Waveform Scheduling in Wideband Environments"

The time-variation due to Doppler scaling effects, coupled with scattering due to multipath propagation, can severely limit the performance of wideband systems. In this paper, we examine the dynamic configuration of transmitted waveforms for agile sensing to increase tracking performance in wideband environments. Using wideband frequency modulated waveforms, we present an algorithm for predicting the mean square tracking error and selecting the waveform that minimizes it in a target tracking application with a nonlinear observations model. The algorithm is based on the Cramer-Rao lower bound on the measurement errors that is computed using the wideband ambiguity function. Using simulations, we demonstrate the improved performance provided by scheduling over fixed configurations [C888]

"SBR waveform and processing parameters as a function of array distortion"

Structural distortions in large antennas have impact on antenna gain, sidelobe level and adaptive interference rejection. Partial compensation for the distortion of space-based radar (SBR) phased-array antennas and array-fed reflectors can be achieved by adjusting the phase-shifter settings to compensate for the distortion, if it can be accurately measured. This approach is effective in regaining the antenna gain and sidelobe levels, but the adaptive rejection of interference and clutter is much more complex. This paper addresses the ground moving target indication (GMTI) performance for a large active electronically scanned array (AESA) at a medium-earth orbit (MEO) altitude of 10,000 km, and a maximum sinusoidal mechanical distortion of 10 cm modeled across the horizontal aperture. To evaluate the impact of mechanical distortion on GMTI performance, the full-dimension space-time adaptive processing (STAP) matched filter (MF) and the reduced-dimension joint-domain localized (JDL) algorithms were evaluated using signal-to-interference-plus-noise ratio (SINR), SINR loss and minimum discernable velocity (MDV) as the GMTI performance metrics [C889]

"Adaptive Techniques for MIMO Radar"

By transmitting independent waveforms via different antennas, the echoes due to targets at different locations are linearly independent of each other, which allows the direct application of many adaptive techniques to achieve high resolution and excellent interference rejection capability. In the absence of array calibration errors, we discuss the application of several adaptive algorithms including Capon, APES and CAPES. When array errors are present, we apply the robust Capon beamformer (RCB) and doubly constrained robust Capon beamformer (DCRCB) approaches to the MIMO radar system to achieve accurate parameter estimation and superior interference and jamming suppression performance [C890]

"MIMO Radar Space-Time Adaptive Processing for Multipath Clutter Mitigation"

This paper describes a multiple-input-multiple-output (MIMO) generalization of space-time adaptive processing (STAP) to mitigate radar clutter subject to multipath propagation between transmit and receive arrays. Multipath clutter can occur when surface returns are multiply scattered, causing significant Doppler frequency and wavenumber spreads. In the worst case, multipath propagation may cause Doppler spread clutter to return via the receiver mainlobe. In such situations, conventional STAP cannot mitigate Doppler spread mainlobe clutter without also suppressing the target. MIMO radar techniques using orthogonal waveforms have been proposed for increasing radar coverage rate often at the expense of employing significantly larger radar time-bandwidth products. In this paper, we consider a MIMO approach wherein conventional radar waveforms are phase-coded to be orthogonal after Doppler processing at the receiver, i.e. in "slow-time". Slow-time MIMO has the advantages of being bandwidth efficient and easily implemented without the need to modify the receiver before range pulse-compression. In this paper, the mathematical formulation of MIMO STAP is developed for both

direct-path and multipath clutter scenarios. At each slant range, the MIMO STAP processor operates on a receive sensor, transmitted pulses, and slow-time phase code channel data cube. Coherent combination of the decoded slow-time channels at the receiver permits effective control of the transmit array pattern by receive post-processing as a function of slant range. Simulation results demonstrate SNR gains when a transmit null is steered in the outbound direction towards the multiply scattered clutter [C891]

"Radar Waveform Design using Minimum Mean-Square Error and Mutual Information"

This paper addresses the problem of radar waveform design for target identification and classification. Both the ordinary radar with a single transmitter and receiver and the recently proposed multiple-input multiple-output (MIMO) radar are considered. A random target impulse response is used to model the scattering characteristics of the extended (nonpoint) target, and two radar waveform design problems with constraints on waveform power have been investigated. The first one is to design waveforms that maximize the conditional mutual information (MI) between the random target impulse response and the reflected waveforms given the knowledge of transmitted waveforms. The second one is to find transmitted waveforms that minimize the mean-square error (MSE) in estimating the target impulse response. Our analysis indicates that under the same total power constraint, these two criteria lead to the same solution for a matrix which specifies the essential part of the optimum waveform design. The solution employs water-filling to allocate the limited power appropriately. We also present an asymptotic formulation which requires less knowledge of the statistical model of the target [C892]

"MIMO Radar Medical Imaging: Self-Interference Mitigation for Breast Tumor Detection"

In this paper, an application of multiple-input multiple-output (MIMO) radar techniques to medical imaging is investigated. MIMO radar, which can be viewed as a form of microwave tomography for medical imaging geometries, offers an alternative to current X-ray technology. Of particular interest is the detection of cancerous tumors in breast tissue. Previously, ultrawideband radar techniques have been considered. Here, an intermediate bandwidth is assumed, which enables the digitization of the entire baseband signal. However, this comes with the cost of self-interference because of transmitting and receiving simultaneously. Because the scattering response of tumors is weak compared to self-interference, mitigation of the direct transmitter-to-receiver signal is important to detection. In this application, three interference suppression techniques are considered: temporal mitigation, receive-array mitigation, and transmit-waveform optimization. Mitigation residuals, caused by calibration errors and signal nonlinearities, are included in the analysis. A system concept is introduced, and results from simulations using a simplified physical model are presented. [C893]

"Instantaneous Radar Polarimetry with Multiple Dually-polarized Antennas"

Fully polarimetric radar systems are capable of simultaneously transmitting and receiving in two orthogonal polarizations. Instantaneous radar polarimetry exploits both polarization modes of a dually-polarized radar transmitter and receiver on a pulse by pulse basis, and can improve the radar detection performance and suppress range sidelobes . In this paper, we extend the use of instantaneous radar polarimetry for radar systems with multiple dually-polarized transmit and receive antennas. Alamouti signal processing is used to coordinate transmission of Golay pairs of phase codes waveforms across polarizations and multiple antennas. The integration of multi- antenna signal processing with instantaneous radar polarimetry can further improve the detection performance, at a computational cost comparable to single channel matched filtering. [C894]

"Adaptive Waveform Design for a Multi-Antenna Radar System"

We consider a radar system which uses an array of antennas, and is capable of adjusting the waveform transmitted through these antennas based on target and clutter statistics, on a pulse by pulse basis. A model for the radar returns which incorporates the transmit waveforms is developed. The target detection problem is formulated for that model. An algorithm is derived for designing the transmit waveform so as to optimize detection performance. [C895]

"Ultra Wideband Wireless Communication on the Base of Noise Technology"

The process of ultra wideband (UWB) data transmission on the base of noise continuous waveforms is considered. The new method of code spectral modulation is proposed for data insertion onto noise continuous carrier. The spectral compression of received ultra wideband waveforms is performed by means of double spectral processing. Experimental results of quadrature correlation measurements in 3.1-4.1 GHz frequency range with successive selection of transmitting data are discussed. [C896]

"Power Amplifier Linearization and Efficiency Improvement Techniques for Commercial and Military

Applications"

This paper presents some recent developments in the area of power amplifier (PA) linearization and efficiency improvement techniques. Advanced digital pre-distortion (DPD) architectures implemented with digital signal processing (DSP) are discussed. Various results of improvements in intermodulation distortion (IMD) when applied to high power RF amplifiers are presented. Crest factor reduction (CFR) has been shown to substantially increase the power output, and hence the efficiency of PAs operating with high peak-to-average waveforms. The combination of DPD and CFR is shown to improve both efficiency and linearity to levels previously unachievable with analog technologies alone for commercial wireless applications. Independent of these signal processing techniques, polar transmitter circuit architectures have been proposed to improve PA efficiency. A combination of a polar transmitter architecture operating in combination with DPD and CFR is proposed in this paper to address more demanding military wireless communications applications. [C897]

"A Novel Beamformer Robust to Steering Vector Mismatch"

It is well know that the performance of the minimum variance distortionless response (MVDR) beamformer is very sensitive to steering vector mismatch because of the signal cancellation. Such mismatches can occur as a result of direction-of arrival (DOA) errors, local scattering, near-far spatial signature mismatch, waveform distortion, source spreading, imperfectly calibrated arrays and distorted antenna shape. In this paper, an adaptive beamformer which is robust against the DOA mismatch is proposed. This method imposes two quadratic constraints such that the magnitude responses of two steering vectors exceed unity. Then a diagonal loading method is used to force the magnitude responses within a range of the arrival angles to exceed unity. The diagonal loading factor can be computed systematically by a proposed algorithm. Numerical examples show that this method has a significantly better SINR performance compared to previously published methods (including the MVDR), and a complexity comparable to the standard MVDR beamformer. [C898]

"Beamforming issues in modern MIMO Radars with Doppler"

In traditional beamforming radar systems, the transmitting antennas send coherent waveforms which form a highly focused beam. In the MIMO radar system, the transmitter sends noncoherent (possibly orthogonal) broad (possibly omni-directional) waveforms. These waveforms can be extracted by a matched filterbank at the receiver. The extracted signals can be used to obtain more diversity or improve the clutter resolution. This paper focuses on space-time adaptive processing (STAP) for MIMO radar systems which improves the clutter resolution. The size of the MIMO STAP steering vector can be much larger than the traditional SIMO STAP steering vector because of the extra dimension. An accurate estimation of clutter rank for the subspace method is developed, and is a generalization of Brennan's rule to the MIMO radar case. A data independent method for estimating the clutter subspace is also described. [C899]

"A new approach for long low autocorrelation binary sequence problem using genetic algorithm"

Distinguishing reflected waveforms from two separated targets which are very close to each other is an important challenge in radar signal processing. Pulse compression is a technique used for accounting for this problem. There are several methods for compressing such as phase coding waveform and the goal of this paper is finding these optimal codes. In this paper, by combining several contents, a new optimum method based on Genetic algorithm is suggested. This method has low computational operation and its speed is faster than the other ordinary algorithms. This method is belonged to local or partial search methods and has following advantages: 1. It uses branch-and-bound strategy; 2. It's search logic, avoids codes redundant relative to three PSL-preserving operations and upper order of allomorphic forms of a code; 3. Although it is a partial search method, but it does not involved in local minimums; 4. It can be implemented by a simple scheme for partitioning and parallelizing the search by the fixed upper bound on PSL. 5. By using genetic algorithm, it is possible to optimize found codes by several factors simultaneously included in fitness coefficient like as PSL and Merit Factor, The efficiency and effectiveness of the algorithm is exhibited by resulted for code length 126 [C900]

"Technique of Doppler compensation for phase-coded signal pulse compression"

Codes used in phase-coded pulse compression waveforms suffer from Doppler mismatch. Based on an analysis of the effects of Doppler mismatch on quasiphase-coded waveforms and the performance results, a new technique of Doppler compensation is proposed. This technique solves the problem of the sensitivity of phase-coded signal to Doppler. It is proved that pulse compression performance is quite well by using this technique, and it meets the project's requirement very well [C901]

"On Scheduling the Dwells of a Multifunction Radar"

Among several other tasks, the radar of a fighter has to search, track and identify potential targets. The waveforms used by the radar for each of these tasks are most often incompatible and hence, cannot be processed simultaneously. Moreover, these tasks are repeated several times in a cyclic fashion. Altogether, this defines a complex scheduling problem that impacts a lot on the quality of the radar's output In this paper, we define a formal framework for this real time scheduling problem and we introduce a local search method to compute efficient schedules for the radar. We also describe a set of lower bounds for the scheduling problem. Simulated results are provided [C902]

"MIMO Radar Ambiguity Functions"

Multiple-input multiple-output (MIMO) radar has been shown to provide enhanced performance in theory and in practice. MIMO radars are equipped with the ability to freely choose their transmitted waveforms at each aperture. In conventional radar systems Woodward's ambiguity function is used to characterize waveform resolution performance. In this paper we extend the idea of waveform ambiguity functions to MIMO radars. MIMO ambiguity functions are developed that simultaneously characterize the effects of array geometry and transmitted waveforms on resolution performance. Overall resolution performance is shown to be governed by a space- time covariance function that can be controlled by the system on transmit using waveform diversity. Visual examples are provided to illustrate the resolution enhancement possible using MIMO technology. [C903]

"Study on HPRF Pulsed Doppler Stepped Frequency Radar System"

Stepped-frequency radar has the ability of high range resolution. It normally adopts frequency time transformation (IDFT) processing to get the range profile of targets. Alternatively stepped frequency radar can also use time-frequency transformation (DFT) processing, with which it is regarded as a kind of Doppler (PD) radars. Through parametric design and signal processing methods, DFT method can achieve both unambiguous velocity and high resolution ranging in a single dwell under HPRF mode. This paper gives parameter design principle for HPRF PD stepped-frequency radar system, and its system implementation methods. Both theoretical analysis and simulation result prove that this radar scheme can simultaneously achieve unambiguous velocity and high resolution ranging [C904]

"A New Method of Improving Range Resolution Based on Waveform Characteristic Identification"

As an important index of radar, the range resolution is mainly limited by bandwidth of radar system. In this paper, a new method of improving radar range resolution is proposed based on waveform characteristic identification techniques. The results of data simulation and real test of flight show that the range resolution can be improved markedly with the proposed new method, and for the radar with 2 MHz bandwidth, its range resolution can reach about 80 m, which is twice as much as that using the conventional method [C905]

"Analysis of Amplitude Limiter Application for Suppressing Spurious Signals"

The paper is dedicated to the analysis of influence of amplitude limiting on main signal which contains spurious signals. A mathematical analysis of the limiting process was done. The analysis was divided into two approaches. First is based on operations on the signal waveform in the time domain. The second relies on the approximation of an ideal limiter characteristic by the 15-th degree polynomial and excitation by superposed sine signals. The obtained results show a possibility of improving the main signal to spurious signal power ratio up to 6 dB. [C906]

"Acoustic Random Noise Radar Using Ultra Wide Band Waveforms"

Ultra wideband noise radar gives high range resolution and the range ambiguity is suppressed as a result of the non-periodic waveform. Random noise waveforms could also be applied in acoustic radar (Sodar/Sonar). Both wave generation and signal processing can then be performed on a PC. As a result, some signal processing algorithms used in random noise radar/sodar can be tested simpler using sound waves. This paper presents basic relationships and algorithms for signal processing in random noise radar/sodar, and the noise floor generated by the randomness of the transmitted signal is defined. A PC-controlled acoustic radar with ultra wide band random noise waveform (1-8 kHz) was implemented to test some of the algorithms described Measurements were carried out on both moving objects and stationary scenes. Moving target indication using stretched time processing (Doppler) and change detection algorithms were tested as well. Recording from a bridge shows the potential use of the technique for water level indication as an example. [C907]

"Radar Design Using Noise/Random Waveforms"

Theoretical and experimental evaluations of potential capabilities of Noise Radar Technology (NRT) in design

and development of radar sensors are presented. Derivation of Ambiguity Function for Pulsed Noise Waveform is given. Theoretical basis for Noise Radar design and three different methods for coherent processing of Noise Radar returns are briefly described. Interference immunity and probability of interception for NR as well as current and future applications of NRT are presented. In concluding remarks, the methods and existing technologies for design and development of NRT key components are listed and the nearest tasks for NRT developments are pointed out. [C908]

"Simple Sea Clutter Canceller for Noise Radar"

In the last decade the noise radar technology is intensively investigated. The low transmitting power and nonspecific waveform makes that the noise radar has very god LPI properties. The simultaneous emission and reception of signals in such kind of radars make them sensitive to near-far problem. Strong echoes, originated from ground clutter can completely mask the weak target return. In case, when the radar is placed on a vessel, except of zero-Doppler ground returns the dominant part of return power consists of Doppler-spread sea cutter echoes. The papers present a simple adaptive sea clutter canceller, which can be used to mitigate near-far problem "on the sea". [C909]

"The Joint Radar Targets Detecting and Communication System"

The combined radar system architecture for joint radar target detection and communication is considered. In this system we use complex quasi-continuous waveform of the big time-bandwidth product and duration with the combined modulation. This waveform is used in interrupted continuous wave radar technique. With reference to mariner radar [1] for a radar-location and communication it is offered complex coherent radar waveform with phase and linear frequency modulation. Problems of waveform synthesis, performance characteristic of the combined system are discussed. [C910]

"Inverse Filtering for Noise Radar Processing"

This paper proposes pulsed noise-like or noise waveforms to be able to perform pulse compression with inverse filtering operations to get high resolution, low sidelobes and possibly super resolution. The processing is based on the earlier developed methods to reduce sidelobes and to equalize the response from each processed pulse. This impacts the clutter filtering and allows better clutter suppression. The proposed method can also handle pulse to pulse agility with different pulse lengths and different pulse repetition intervals. [C911]

"The Use of Frequency-Randomised Waveforms with Intelligent Processing for UAV SAR Imaging"

A stepped-frequency continuous wave (SF-CW) synthetic aperture radar (SAR), with frequency-agile waveforms and real-time intelligent signal processing algorithms, is proposed for operation from a lightweight UAV platform. An SF-CW radar offers some distinct advantages over a pulsed radar. It measures the frequency response of the scene across a set of discrete frequencies over the bandwidth of interest, at each element position along the synthetic aperture. This means the individual frequency measurements are low power, but which are then integrated to simulate a much higher-power pulsed system. This is a cost effective way of providing radars with a low probability of interception (LPI), operating across wide frequency bands to obtain high image resolutions. In contrast, pulsed radars require large peak powers. Low power operation, and associated simple SF-CW circuitry, provides significant savings in the mass and size of the SAR sensor. To alleviate any bandwidth restrictions imposed by the spatial sampling requirements along the aperture, an approach is outlined using frequency randomised waveforms which allows the bandwidth to be greatly under-sampled before the appearance of significant sampling artefacts. This also provides benefits to the LPI performance of the radar. For a fixed transmit power, omission of frequencies naturally produces a decrease in target signal. However, an intelligent frequency selection scheme is proposed to alleviate signal drop-off, such that signals can be maintained 3dB above the level that might otherwise be expected. [C912]

"Wideband modelling and measurement of trans-ionospheric radar waveform propagation"

A propagation model has been developed to simulate the corruption of wideband radio waveforms (such as radar chirps) as they pass through a non-homogeneous ionosphere. The ionosphere is modelled by a series of phase changing screens and a split-step Parabolic Equation method is used to describe the propagation of the complex electromagnetic field in planes normal to the propagation vector. Wideband characteristics of the channel are calculated by propagating spectral components of the waveform spectrum through the phase screens and then reconstituting the signal at the ground via a Fourier transformation into the time (delay) domain. By estimating the ionospheric drift velocity, the channel scattering function (signal power vs Doppler frequency and time delay) is calculated for a given satellite orbit and pulse repetition frequency (PRF). [C913]

"A Radar Sensing Algorithm by Gabor Theory"

In this paper, an alternative target density function (TDF) is proposed for narrowband radar model. This is achieved by estimating a new target density function by Gabor theory. It is shown how Gabor transform can be used to obtaining wideband target density function by transmitting a waveform which is a kernel for this transform. The windowing characteristics of this theory is plausible to reaching an accurate result. The presented wideband target density function is developed in a various manner different from the conventional methods. [C914]

"Waveform Design for First Generation CASA Testbed"

The first testbed of X-band radar systems deployed by the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA), in central Oklahoma called IP-1 (Integrated Project 1) will have a low unambiguous velocity due to their short wavelength, and increasing the PRF will result in multiple trip overlays since storms can extend over a large distance. The range-velocity ambiguity is more severe for X-band radars compared to the conventional S-band. However, low cost radars limit the ability to support complex waveforms due to hardware requirements. In addition the radar observations at short ranges are contaminated by ground clutter. This paper describes the waveforms for the individual radar nodes based on operational requirements such as scan speeds, volume coverage pattern and system/hardware limitations to resolve range and velocity ambiguities along with clutter suppression. [C915]

"Inversion of Combined Radiative Transfer Models for Imaging Spectrometer and LIDAR Data"

The spectral information domain provided by imaging spectrometers contains information about the biochemical composition of a vegetation canopy such as foliage chlorophyll and water content. The spectral information content also enables indirect assessment to the biophysical parameters LAI and fractional cover. On the other hand, the information domain observed by LIDAR provides direct measurements of the vertical and horizontal canopy structure describing the canopy height and the vertical distribution of canopy elements. The leaf optical properties, which are directly related to the foliage biochemistry, scale to the canopy as function of canopy structure and spatial arrangement of canopy elements. Further, the spatial heterogeneity and canopy structure dominate the radiative transfer especially within forest stands. Consequently the LIDAR signal, e.g. recorded as full waveform, can improve the accuracy and robustness of forest canopy parameter retrieval by reducing uncertainties related to the canopy structure. On the other hand the accurate interpretation of the LIDAR signal depends on the spectral properties of canopy elements as well as the background. The two sensors and their different information domains are thus mutually dependent but also complement each other. A synergistic exploitation of the information domains observed by Imaging Spectrometry and LIDAR based on radiative transfer modeling will therefore provide a new approach to optimize the retrieval of forest foliage biochemical composition and the canopy structure. [C916]

"HF radar receiver designed for surface current radar system"

The paper presents the design methods of the HF radar receiver for the short-range Ocean State Measuring and Analyzing. The radar system adopts Frequency Modulated Interrupted Continuous Waveform (FMICW) and operates at 12 14MHz. The receiver has only once mixing and band-pass sampling structure. After sampling the data, a new DDC (Digital Down Converter) algorithm is used during the demodulation. It is a modified DDC algorithm, in which no filter is used. The receiver uses cross-loops/monopole as receiving antenna, and the radar signals are generated by DDS chips. The structure of the system is quite simple and the antenna is portable. It proved that all modules of the system worked well during the field test of the radar system. [C917]

"Comparison of Small-footprint and Large-footprint Waveform Lidar for Terrestrial Surface Characterization"

First Page of the Article [C918]

"Model Based Terrain Effect Analyses on ICEsat GLAS Waveforms"

First Page of the Article [C919]

"Waveform Diversity in Intelligent Sensor Systems"

Waveform diversity in distributed radio frequency (RF) sensor systems offers the potential for breakthrough performance enhancements in the detection and identification of natural and manmade objects. This paper discusses advances in relevant technology and emerging applications to radar [C920]

"Programme"

{no data available} [C921]

"Commentary"

{no data available} [C922]

"50 Million Years of Waveform Design"

Echo locating mammals such as bats, whales and dolphins have been using waveform diversity for over 50 million years. They vary the PRF, the power and the frequency content of the transmitted waveforms. This has enabled them to evolve highly sophisticated navigation techniques and the ability to forage for food. Moreover, recent developments in technology means that it is now possible to replicate many of the methods employed by mammals in synthetic systems such as radar and sonar. Thus echo locating mammals potentially offer valuable insights that might allow improvements in these synthetic sensor counterparts enabling autonomous navigation of platforms and automatic target classification. In this paper the authors examine the waveforms used by bats as a function of orientation and intent. The information is presented in terms forms well known to the radar community and includes, power spectra, ambiguity functions. From this analysis the authors are able to derive understanding as to how bats are exploiting waveform diversity and how this can be copied in radar and sonar systems [C923]

"Utilising signal absence in SAR imagery for moving target detection"

SAR images of moving targets are blurred, defocused and displaced from their true location making them difficult to detect from their direct energy returns. This paper presents an alternate technique for detecting such targets by exploiting the phenomenon that the shadow projected by the target produce a null in the SAR imagery. The target shadow is presented at its true location and tracks the target as it moves along in the scene. A change detection technique has been developed that processes a sequence of highly overlapped SAR images. Initial detections thus obtained then seed a shadow delineation process that simultaneously delineates the shadows of the moving targets over multiple images. The technique has been successfully demonstrated on real SAR imagery for detecting and locating moving targets [C924]

"The Diversity of Chaotic Waveforms in Use and Characteristics"

This paper serves to provide a thorough introduction to chaotic signal generation and chaotic radar waveform modulation, emphasizing the diversity and ease of variation of such waveforms. Results of their adaptation to a specific waveform performance objective are presented as is their potential use as target matched waveforms [C925]

"Range Resolution Improvement in Passive Coherent Location Radar Systems Using Multiple FM Radio Channels"

Passive coherent location (PCL) radar systems that use single FM radio channel signal as illuminator of opportunity have limited range resolution due to low modulation bandwidth and high dependence on the content that is being broadcasted from the FM station. An improvement in range resolution is obtained by using multiple adjacent FM channels, emitted from co-sited transmitters, which is often the case in large towns in countries, where the FM channel allocations are relatively weakly regulated. The proposed scheme computes the autocorrelation function of the signal directly received from the FM co-located transmitter, and compares it to the cross-ambiguity function, obtained from direct and target scattered signals. The geometry of the problem is like in the case of monostatic radar. The range information is obtained by the delay between the cross-ambiguity function and the autocorrelation function. It is shown that down to -37dB signal to noise ratio (SNR) the autocorrelation function of 7 FM channels with different contents can be successfully extracted from the cross-ambiguity function. The detection of the time delays is a linear estimation problem. The issue of time-delay estimation is a known topic of research. A powerful estimator can be found [C926]

"HYCAM: A RCS Measurement and Analysis System for Time-Varying Targets"

The measurement of the radar cross section (RCS) of time-varying targets, which variation of reflectivity are caused by geometrical or radioelectrical deformations has to tackle sever constraints. Indeed the measurement time must be short enough so that the phenomenon under study can be considered as stationary. Besides, the frequency bandwidth of the system has to be wide enough for a fine analysis of the phenomenon. Both

constraints induce thereby an increasing amount of data to be processed. However recent evolutions of digital high speed technologies enable to overcome these difficulties. An ultra-wideband digital system, named HYCAM, and dedicated to the measurement and the realtime analysis of the RCS of time varying targets, has been designed. The transmitted waveform is an OFDM (orthogonal frequency division multiplexing) phase coded signal, which minimizes the ratio between the peak power and the mean power. An instantaneous indoor measurement of a time varying target has been carried out by an experimental system [C927]

"Spectral Efficiency and Spectral Sharing for Civil Radar Systems"

This study investigated the practical issues for implementing radar filters, techniques to reduce radar emissions, waveform based techniques to improve spectral sharing in share bands, and concepts for reducing radar emissions to CW like bandwidth. This study performed the ground work for spectral sharing and increasing future civil radar efficiency. In addition the costs, reduced spectral usage and other benefits were quantified [C928]

"On Scheduling a Single Machine to Minimize a Function of Distances Between Pairs of Tasks: Scheduling a Multifunction Radar"

Among several other tasks, the radar of a fighter has to search, track and identify potential targets. The waveforms used by the radar for each of these tasks are most often incompatible and hence, cannot be processed simultaneously. Moreover, these tasks are repeated several times in a cyclic fashion. Altogether, this defines a complex scheduling problem that impacts a lot on the quality of the radar's output. In this paper, we define a formal framework for this real time scheduling problem and we introduce several techniques to compute efficient schedules for the radar. We also describe a set of lower bounds for the scheduling problem. Experimental results are provided [C929]

"Target Classification for Air Defence Radars"

Radar is evolving rapidly from being a sensor which detects and tracks targets to a high resolution imaging sensor with target classification capabilities. This paper addresses the techniques being developed for air defence radars. The application of target classification functions in fire control radars which support missile systems and multi-function phased array radars is discussed. The main high resolution techniques employed are range profiling, ISAR, frequency/spectral analysis and range-frequency imaging. Typical aircraft images measured are presented. The level of maturity of the hardware and signal processing technology to support these modes is discussed. The key technical, operational and practical issues which drive the design and application of high resolution modes for these types of radars are presented. Factors which determine the type of target classification mode which can be employed include the: operational frequency of the radar, time available for the application of the high resolution waveform, pulse repetition frequency, radar bandwidth available, basic architecture of the radar, and mission of the radar system. The other critical issue for the practical employment of target classification modes is that of the target signature database. Classifier algorithms are used to provide the match between the signature measured by the radar and reference signatures of targets of interest held in a database to provide an estimate of the target class. The assembly and maintenance of the target signature database is discussed and techniques employed are presented [C930]

"Copyright page"

{no data available} [C931]

"The Institution of Engineering and Technology Forum on Waveform Diversity and Design in Communications, Radar and Sonar"

The following topics are dealt with: waveform diversity; radar; sonar, navigation; radio channels; target tracking; MIMO communication; UWB communication [C932]

"Target Classification by Radar"

Target classification by radar has enormous potential with many important applications. So far, with a couple of notable exceptions, this has proved to be an extremely challenging problem with no obvious solution. The chief method for improving the quality of information gathered has been to improve resolution in both range and cross-range dimensions. Recent advances, chiefly in digital technology means that radar systems are now able to operate varying parameters such as frequency, waveform, PRF, bandwidth on a pulse by pulse basis. Additionally, there is emerging evidence that geometric diversity when gathering measurements to be used for classification is an equally important factor. This paper will examine the relationship between radar design parameters and data collection strategies as a basis for solving the problem of radar target classification [C933]

"Study on Reducing False Targets for Anti-collision Radar in Intelligence Transportation System"

A novel waveform named double-slope symmetrical saw-tooth wave is presented and its corresponding algorithm is also introduced to resolve the problem of multiple targets detection for automotive anti-collision radar. The method by using the proposed waveform and algorithm improves the response characteristic of radar system and reduces false targets in detection process. Computer simulation results and theoretical analysis prove that the method is effective and practical for multiple targets detection in intelligence transportation system [C934]

"Adaptive combined bispectrum-filtering signal processing in radar systems with low SNR"

The application of adaptive techniques for obtaining bispectrum estimates in additive Gaussian noise and random shifts of received signals is considered. An approach using joint adaptive robust forming of bispectrum estimates and processing of complex-valued signal Fourier spectrum estimates by discrete cosine transform-based filtering with local variance estimation within each block is proposed. The advantages of the proposed approach in comparison to the conventional signal waveform recovery from bispectrum are illustrated by computer simulations [C935]

"The Application of Spatial Diversity to Target Location"

The application of multi-rate processing to target location is considered in this paper. This technique is shown to refocus the corresponding ambiguity function, giving rise to the possibility of enabling diversity to be used for the benefits of enhancing both accuracy and resolution of a target. Attention is paid to the geolocation of radio frequency (RF) emitters; however, this technique can be applied to either passive or active target location, and in a range of different environments including satellite, airborne and terrestrial intercept. This work extends a former study which had presented the notion of the generalised correlation function (GCF), a technique which readily enables a smeared ambiguity function to be re-focused. An example is provided to illustrate the impact of motion between sensors upon the ambiguity function and the corresponding refocusing, through the use of multi-rate sampling, is presented [C936]

"Maximum Entropy Method for Angular Estimation"

In order to suppress angular glint in monopulse radar system, a novel method for angular estimation basing on spectrum entropy maximization is presented in this paper. Spectrum widen of difference beam echoes due to the pattern modulation is investigated. Basing on the relations between the spectrum widen, target angular motion center and waveform entropy, a novel method by searching maximum waveform entropy for angular estimation is presented to suppress angular glint. Compared with high-range-resolution angular estimation method available, the novel method performs more conspicuously in angular glint suppression. Simulations show the effectiveness of the new method [C937]

"Synthesis of the Optimal Discriminator for a FMCW Radar with the Beat Signal"

The algorithm of optimal data processing for linear frequency modulated continuous waveform (LFM CW) radar is considered. It is shown that such algorithm can be performed by means of tracking range measurement consisting of the non-linear discriminator and linear averaging circuits. The structure of discriminator is synthesized and fluctuations of spectral density for optimal discriminator realizing the algorithm of correlation processing w.r.t high-frequency LFM-signal as well as discriminators used in practical radar-altimetry is compared in this research [C938]

"Optimum M-sequence Search via Immune Clonal Selection Algorithm"

The binary pulse compression codes such as the Barker code or m-sequences have been widely used in modern radar systems. The selection of the initial shift register of m-sequence, whose pulse compression waveform has low peak power and large compression ratios, is a key technique in pulse compression waveform design. Based on the antibody clonal selection theory of immunology, we propose the immune clonal selection algorithm (ICSA) to select the best initial shift register of m-sequences. Compared with the standard genetic algorithm (SGA) and a hybrid genetic algorithm (HGA), the approach we used can overcome the prematurity availably and has higher searching results. Experimental results prove the feasibility and validity of this algorithm [C939]

"Simultaneously Velocity Measuring and HRR Profiling with a Novel CSF Sequence"

High radial velocity of radar targets is an important reason of HRRP (high range resolution profile) distortion in synthetic HRR pulse radar and it can be measured by transmitting high PRF sequences. Therefore, high PRF synthetic HRR sequence has the potential to acquire accurate radial velocity besides of accurate range and undistorted HRRP. In this paper, a new waveform called CSF (cross stepped frequency) sequence is proposed. The carrier frequencies of the first half pulses and the second half pulses in one CSF sequence are stepped with two opposite stepping slopes, making the CSF sequence achieve much higher range-Doppler 2D resolution than normal SF sequence. The principle of velocity estimation in high PRF mode is derived based on phase compensating and profile correlating process. After that, twice bandwidth of each half is synthesized by echo sequence re-ordering, which makes CSF sequence much more attractive than TSF (triangle stepped frequency) sequence. Simulation results show that much less velocity estimation error exists by utilizing CSF sequence than SF sequence in high PRF mode, and that HRRP after twice-bandwidth-synthesis has great correlation coefficient with ideal HRRP of twice bandwidth. Thus, high PRF CSF sequence has a good perspective in utilization [C940]

"Interference-Mitigating Waveform Design for Next-Generation Wireless Systems"

A brief historical perspective of the evolution of waveform designs employed in consecutive generations of wireless communications systems is provided, highlighting the range of often conflicting demands on the various waveform characteristics. As the culmination of recent advances in the field the underlying benefits of various multiple input multiple output (MIMO) schemes are highlighted and exemplified. As an integral part of the appropriate waveform design, cognizance is given to the particular choice of the duplexing scheme used for supporting full-duplex communications and it is demonstrated that time division duplexing (TDD) is substantially outperformed by frequency division duplexing (FDD), unless the TDD scheme is combined with further sophisticated scheduling, MIMOs and/or adaptive modulation/coding. It is also argued that the specific choice of the direct-sequence (DS) spreading codes invoked in DS-CDMA predetermines the properties of the system. It is demonstrated that a specifically designed family of spreading codes exhibits a so-called interference-free window (IFW) and hence the resultant system is capable of outperforming its standardised counterpart employing classic orthogonal variable spreading factor (OVSF) codes under realistic dispersive channel conditions, provided that the interfering multi-user and multipath components arrive within this IFW. This condition may be ensured with the aid of quasi-synchronous adaptive timing advance control. However, a limitation of the system is that the number of spreading codes exhibiting a certain IFW is limited, although this problem may be mitigated with the aid of novel code design principles, employing a combination of several spreading sequences in the time-frequency-and spatial-domain. The paper is concluded by quantifying the achievable user load of a UTRA-like TDD code division multiple access (CDMA) system employing loosely synchronized (LS) spreading codes exhibiting an IFW in comparison to that-of its counterpart using OVSF codes. Both systems' performance is enhanced using beamforming MIMOs [C941]

"Transmit Notched Bandwidth Waveforms"

First Page of the Article [C942]

"Self-Phased & Retrodirective Array: Radar Applications for Ultra-fast Cueing & Re-acquisition"

In this article, phase conjugation in radar is studied. A method developed by ONERA (Van Atta, 1955) is used and then the performances of the process are evaluated. Comparisons between phase conjugation and classical radar processes are established [C943]

"Multi-User UWB-IR Systems with Interleaved Coding-Modulation on Multipath Fading Channels"

Interleaved coding-modulation (ICM) is a recently proposed method for ultra-wideband impulse radio (UWB-IR) systems. ICM exploits the concept of chip interleaving, allowing to alleviate the problem of inter-symbol and inter-pulse interference commonly present in high data rate UWB-IR systems. In this paper, the authors extend previous work on ICM to scarcely populated multi-user scenarios. The authors propose a design of a deterministic chip interleaver based on time-hopping hyperbolic congruence sequences. The authors also review the main parameters of the random and hyperbolic interleavers. Our results indicate that the proposed type of interleaver yields similar performance to random interleavers but with the advantage of simpler implementation [C944]

"Novel FEC Schemes for UWB: Design, Modelling and Performance Analysis"

In this paper, the authors present the design and modelling aspects of UWB turbo codes and UWB SCCCs, along with their performance analysis in comparison with the FEC method recommended by the UWB specifications. The authors consider both the direct spread and multi-carrier versions of UWB in the presence of additive white Gaussian noise (AWGN) channel as well as IEEE 802.15.3 channel models. The results obtained

show that UWB turbo codes yield a coding gain of 3-4 dB at an error floor of 106compared to the convolutional encoding and Viterbi decoding (CEVD) method. In addition, UWB SCCC yields a coding gain of 1-2 dB at an error floor of 10-3in comparison with the UWB turbo codes. However, convolutional codes perform better than turbo codes at higher signal-to-noise ratios and turbo codes seem to yield a better performance than SCCCs at lower input block sizes [C945]

"Diversity: On the Evolution to MIMO and Beyond"

This paper considers the evolution to multiple input, multiple output (MIMO) communications, which has its origins in both spatial processing and temporal processing. In the context of this paper, the term 'spatial processing' is taken to include classical/adaptive beamforming and sub-space analysis, whereas the term 'temporal processing' is taken to include the subjects of error control coding, interleaving and equalisation. The objective of this paper is therefore to provide an outline of some of the principal developments within both spatial processing and temporal processing, in order to relate MIMO to the prior art. The emphasis on this paper is on the results which steered this notion of diversity to yield MIMO. The benefits of MIMO have been achieved by integrating the functionality contained within both spatial processing and temporal processing. As shown within this paper, historically, the original motivation within spatial processing was to enhance target location and accuracy in terms of resolution and bias. Temporal processing, in the case of communications engineering, however, was driven by the need to control the number of digital errors between the transmitter and receiver. Each of these two subjects was for a significant number of years treated independently, and excellent process had been made in both. However, a significant barrier within each of these two subjects was the limitation of system processing capability, particularly in terms of both speed and memory. Improvements in the categorisation of physical phenomena associated with a range of wireless channels, and the processing power of recent hardware have enabled the realisation of MIMO to be achieved. As hardware capabilities improve and greater effort is made at the integration of the functionality between the various layers within a communications system, system efficiency and performance can be maximised. The technologies which will be instrumental in achieving this goal are likely- to include techniques as diverse as artificial intelligence, higher order statistics and the synthesis of natural phenomena (e.g., the use of chaotic models) [C946]

"Point target imaging simulation using chaotic signals"

Chaotic FM signal is similar to random signal. It has good electronic counter-countermeasure (ECCM) capabilities. In this paper, chaotic FM signal is used to improve the ECCM capabilities of synthetic aperture radar (SAR). A kind of chaotic series was generated using n-way Bernoulli map. The signals modulated by this kind of series have ideal auto-correlation property. High resolution image can be achieved using these signals. However, the waveform is very hard to estimate. In this paper, the chaotic FM signal model is discussed, and point target imaging is simulated. The simulation result shows that ideal point target image can be achieved using chaotic FM signal, which has good prospects to be applied in imaging radar system. [C947]

"Generation of raw stepped-frequency waveform echoes using RCS chamber measurements"

Complicated microwave scattering characteristics of non-point targets are often examined using radar cross section (RCS) chamber measurements. These measurements are designed to be waveform independent. Attempting to gather waveform dependent data on complex target responses typically requires a robust (and expensive) waveform generation and sampling capability beyond that of most RCS chambers. This paper introduces a technique to convert standard RCS chamber measurements into raw stepped-frequency waveform echoes. By controlling the construction and processing of these echoes, many waveformdependent target effects can be examined. After demonstrating the validity of the proposed technique using both 1-D range profiles and 2-D inverse synthetic aperture radar (ISAR) images, the paper examines the effects of linear frequency modulation (LFM) waveform filtering mismatches on an RCS chamber target. [C948]

"Non-self-embedding context-free grammars for multi-function radar modeling-electronic warfare application"

Multi-function radars (MFRs) exploit flexible and sophisticated software control algorithms that enable them to perform multiple functions (tracking, acquisition, range resolution and search) virtually simultaneously. They can engage multiple targets at once, and employ complex hierarchical signal waveforms to achieve these goals. From the standpoint of the field of electronic warfare (EW), MFRs present a very serious threat. Traditional EW radar signal processing algorithms are not well suited for the level of structure and complexity found in MFR signals. In this paper, we present a new MFR modeling methodology. We consider the signals from an MFR to be strings from some formal language that can be modeled by a compact syntactic representation called the non-self-embedding context-free grammar (NSE CFG). We then describe a procedure that allows conversion of such an

NSE CFG model of the radar into a finite state machine. Thus, the rich and well-established theory of finite-state automata can be directly applied to the EW signal processing of MFRs. [C949]

"Joint utilization of incoherently and coherently integrated radar signal in helicopter categorization"

Radar signal based helicopter categorization is a challenging task for all types of radars. Airborne pulse Doppler radar with an appropriate digital signal processing unit has a good potential to perform categorization or even classification, providing that radar parameters are carefully selected. This paper presents a helicopter categorization method, which is based on estimation of the main rotor blade tip velocity and the time interval between two successive main rotor blade flashes. Both incoherent integration and conventional coherent integration play an important role in the new method. Joint utilization of both integration types makes the method feasible without using unrealistic radar waveform parameters. Based on the L/N-quotient helicopter classification method, a new categorization procedure was developed. Compared to the original L/N-quotient method, the new method exploits both incoherent and coherent integration. Combined use of both integration types enables it to use effectively potential of dwell time and PRF. In addition, the new method includes a certain kind of moving windows edge detection algorithm that was found to improve the performance of the edge detection compared to the one introduced with the original L/N-quotient method. [C950]

"Cylindrical array beamforming based on ultra-wideband signals"

Conformal array antennas are very attractive for many applications interest, especially in space-born radar, navigation, and radio communications, where the allowable space for antenna platform is very limited. One type of conformal array antennas is the cylindrical array which can provide wide angular coverage in both the azimuth plane as well as the elevation plane. In this paper, the principle of cylindrical array beamforming based on ultra-wideband impulse (UWBI) waveforms is introduced. Antenna patterns, such as amplitude pattern and energy pattern, are derived for the cylindrical array as functions of array dimensions and signal bandwidth. [C951]

"Thunderstorm tracking system using neural networks and measured electric fields from few field mills"

The paper presents a novel system to asses quickly the direction of thunderstorm by using a few field mills on the ground. As opposed to traditional methods using expensive radar systems to detect thundercloud movement, the presented method simply uses the electric waveforms detected by the field mills and, by using a neural network of suitable complexity, can determine the thundercloud's direction with reasonable accuracy. The neural system is trained with data obtained from the simulation of thundercloud dynamics using parameters observed through experiments. Through extensive testing, it is found that the presented system can reasonably track the direction of the thunderstorm as it propagates while dynamically changing its parameters, and, thus, offers the possibility of creating a practical system. Two types of neural networks are developed and their efficiencies compared. [C952]

"A high-resolution imaging algorithm based on scattered waveform estimation for UWB pulse radar systems"

{no data available} [C953]

"High-speed, electronic arbitrary waveform generation using time-domain processing of ultrashort optical pulses"

Ultra wideband (UWB) microwave signals are receiving much attention for their potential use in both radar systems and high-speed data links. The currently available arbitrary waveform generation (AWG) devices operates up to only a few gigahertz. The desire to create UWB signals with carrier frequencies in the 10s of GHz and fractional bandwidths approaching 100% suggests investigating microwave-photonic approaches. In this paper, the authors demonstrate a method for electrical AWG with independent envelope and carrier control though the manipulation of wide bandwidth optical pulses in a time-domain processor. [C954]

"Development of laser waveform digitization for airborne LIDAR topographic mapping instrumentation"

{no data available} [C955]

"A novel method to identify multi-target by transformable periods LFM waveform"

A novel method to identify multi-targets for automotive collision avoidance radar (ACAR) by using transformable

periods and symmetrical linear frequency modulation (TPS-LFM) waveform is proposed. In addition, a method to generate the signal source based on a triple tuned frequency synthesizer (TTFS) is discussed. Theoretical derivation shows that the false detections of unnecessary targets and failures to detect necessary targets, which used to be major problems in detection performance, have been substantially reduced, and the high resolution of range and velocity for the target may be obtained simultaneously. Its usefulness in eliminating the false targets is confirmed. [C956]

"Fusion of SHOALS bathymetric lidar and passive spectral data for shallow water rapid environmental assessment"

The simultaneous estimation of seafloor and water column information from a combination of bathymetric lidar and passive spectral data represents an evolution in shallow water mapping. Here, we demonstrate recent progress on the use of SHOALS waveforms and depths to constrain inversion algorithms for passive spectral data. We use these inversions within a data fusion paradigm to achieve 3-dimensional benthic mapping, while simultaneously describing horizontal spatial variations in water column optical parameters. [C957]

"Adaptive pulse compression repair processing"

It is well known that the standard matched filter used in radar pulse compression generates range sidelobes in the vicinity of large targets which can result in the masking of smaller nearby targets. Recently, pulse compression repair (PCR) was proposed as a means of suppressing the range sidelobes after matched filtering has taken place. This is especially applicable to in-service radar systems, where one may not have access to the received signal prior to standard pulse compression or where it may not be feasible to replace the current pulse-compression system. The PCR algorithm adaptively operates on the output of the standard matched filter, thereby treating the autocorrelation of the received waveform as if it were the transmitted waveform. This paper examines the effects of the Doppler mismatch on the PCR algorithm in which the resulting correlation between the transmitted waveform and the Doppler-shifted received waveform is mismatched to the waveform autocorrelation. It is shown that PCR degrades gracefully as Doppler mismatch increases, even in dense target scenarios. [C958]

"Non-myopic approaches to scheduling agile sensors for multistage detection, tracking and identification"

The paper addresses the problem of sensor scheduling for simultaneous target detection, tracking and identification. We consider sensors with agility in waveform and pointing direction. Scheduling decisions are made using an information based approach, where the merit of competing actions is judged by the information expected to be gained when taking the action. We focus on non-myopic scheduling, where the long-term ramifications of scheduling decisions are accounted for in decision making. Since an exact non-myopic solution is computationally prohibitive, we investigate two approximate approaches: direct approximation of Bellman's equation; reinforcement learning. We show, via simulation, that both techniques provide substantial gains over myopic scheduling. [C959]

"Multi step ahead beam and waveform scheduling for tracking of manoeuvering targets in clutter"

Modern radar systems have considerable flexibility in their modes of operation. In particular, it is possible to modify the waveform on a pulse to pulse basis, and electronically steered phased arrays can quickly point the radar beam in any feasible direction. Such flexibility calls for new methods of scheduling, both of the waveform and the beam direction so as to optimize the radar performance. We consider a radar system capable of rapid beam steering and of waveform switching. The transmit waveform is chosen from a small library. The operational requirement of the radar is to track a number of manoeuvring targets while performing surveillance for new potential targets. Tracking is accomplished by means of an LMIPDA (linear multitarget integrated probabilistic data association) tracker. An interacting multiple models (IMM) method is used to model manoeuvering targets in the tracker. LMIPDA provides a probability of track existence, permitting adoption of a "track-before-detect" technique. "False alarm" tracks are maintained until the probability of track existence falls below a threshold. Our aim is to maintain the tracks of the existing targets to within a specified accuracy as determined by the absolute value of the track error covariance matrix. However, this has to be done within the time available, given that a full scan has to be performed within a prescribed interval. We give an algorithm for scheduling revisits to measure the targets while maintaining surveillance. [C960]

"Active sensor waveform design for motion insensitivity"

Waveforms for active sensors (e.g., radar or active sonar) are often designed to maximize sensitivity to target

motion to enhance tracking performance. The paper addresses the complementary problem of waveform design to maximize insensitivity to motion. Insensitivity is desirable in cases where motion is a nuisance to the sensor system. The motion insensitivity problem has been approached in the past using the trajectory diagram, related concepts of trajectory ambiguity, and generalized ambiguity functions. The paper discusses motion insensitivity in terms of both trajectory ambiguity and the generalized ambiguity function. The relationship between trajectory ambiguity and motion insensitivity via a generalized ambiguity function is described mathematically. The hyperbolic FM (HFM) signal is used as an example of a velocity insensitive signal. [C961]

"Optimal Design of Analog Signal Sets for Multiuser CDMA Communications"

We investigate the design of an optimal set of analog signals with prescribed magnitude spectrum and quadratic phase structure such that the maximum cross correlation between signals in the set is minimized. Such a set of signals can be used as signature waveforms in multiuser CDMA communications. It is also useful in a number of signal processing applications. In this paper, we first summarize some recently derived analytic results for the maximum cross-correlation between two signals. Then, we present some illustrative numerical design examples to show the effectiveness of the proposed approach [C962]

"2005 IEEE International Conference on Acoustics, Speech, and Signal Processing"

{no data available} [C963]

"Relationships between radar ambiguity and coding theory"

We investigate the theory of the finite discrete Heisenberg-Weyl group in relation to the development of adaptive radar. We contend that this group can form the basis for the representation of the radar environment in terms of operators on the space of waveforms. We also demonstrate, following recent developments in the theory of error correcting codes, that the finite discrete Heisenberg-Weyl group provides a unified basis for the construction of useful waveforms/sequences for radar, communications and the theory of error correcting codes. [C964]

"Measurement and analysis of ambiguity functions of passive radar transmissions"

Passive coherent location (PCL) radar systems make use of broadcast or communications 'illuminators of opportunity' in a bistatic configuration. In order to understand the performance limitations of this type of radar it is necessary to know the ambiguity properties of these waveforms, and how they vary with the form of modulation and with the bistatic geometry. This paper presents and analyses the ambiguity functions of a set of off-air measurements of signals that might be used for PCL systems. We find that the ambiguity behavior of analog modulation formats, such as FM radio or analog television, depend significantly on the instantaneous program content, and can be very poor, for example during pauses in speech. Digital modulation formats, in contrast, are much more favorable and much more constant with time. This suggests that the choice of signals to be used for PCL may be made on a dynamic basis, according to the modulation and bistatic geometry. [C965]

"Optimization design of NLFM signal and its pulse compression simulation"

To meet the requirement of modern radar, a kind of NLFM signal is designed in this paper based on Taylor window function, which has the low PSLL and high Doppler tolerance. The methods to synthesize and optimize waveforms are presented. Simulation results of pulse compression for different Doppler frequencies are provided. The proposed signal has been applied to the practical engineering. [C966]

"Increasing the effective bandwidth of an SF-CW SAR using frequency agility"

The use of a frequency-agile waveform is proposed as a way of providing significantly increased bandwidth for a stepped frequency continuous wave (SF-CW) SAR, than is provided by traditional imaging schemes. The range resolution is set by the bandwidth of the transmitted waveform, and is built up as a set of monotonically increasing stepped frequencies. As these frequencies are sampled sequentially, a constraint with SF-CW waveforms is the time restriction available to build up the bandwidth, imposed by the spatial sampling requirements along the aperture to avoid grating-lobe effects. To address this problem, an approach is outlined which allows the frequency spectrum to be greatly under-sampled to provide a greater effective bandwidth. It was found that randomizing the set of frequencies omitted from sweep to sweep allowed significant thinning before the appearance of significant unwanted image artifacts due to the under-sampling. This scheme allows great flexibility in the choice of bandwidths that can be realized for a particular imaging scenario. Their application is considered from the point of view of operation from UAV SAR platforms. [C967]

"Waveform-space-time adaptive processing for distributed aperture radars"

This paper presents the preliminary development of adaptive signal processing for distributed, waveform diverse, antenna arrays. The long term goal is to develop practical waveform-time-space adaptive processing algorithms for distributed apertures. A crucial issue identified in previous works is that, in practice, the target and interfering sources are not in the far-field of the antenna array. Recent work by the authors develops the model required to generate simulated data. This paper extends this work, focusing on using the model to formulate adaptive signal processing algorithms specifically for waveform diverse distributed apertures. [C968]

"Aspects of multistatic adaptive pulse compression"

It is well known that two or more radars operating in close proximity, at the same time, and in the same spectrum can severely interfere with one another despite the use of low cross-correlation waveforms. Recently, an approach was proposed called multistatic adaptive pulse compression (MAPC) based on a minimum mean-square error (MMSE) formulation which has been shown to suppress both range sidelobes and cross-correlation ambiguities to the level of the noise. This paper examines the performance of the MAPC approach under the effects of Doppler mismatch. It is demonstrated that for relatively high Doppler the MAPC approach experiences some Doppler-induced sidelobes around large targets yet is still substantially superior to the standard matched filter. [C969]

"Waveform Recognition in Pulse Compression Radar Systems"

In this paper a system for recognizing pulse compression radar waveforms is introduced. The waveforms considered in this study are the linear frequency modulation (LFM), Costas codes, binary phase codes, and the Frank, P1, P2, P3, and P4 codes. A feature vector based on instantaneous signal properties, second- and higher-order statistics, and time-frequency distributions is computed from the received signals. Cyclic correlations are used in symbol rate estimation. Information theoretic measure is used to remove redundant components from the feature vector. The discrimination capability of the features is evaluated using an ensemble averaging early-stop committee of multilayer perceptrons. Bayesian MLP classifier is considered as well. In simulation the classifier attains over 97 % overall correct classification rate in signal-to-noise ratio (SNR) of 6 dB [C970]

"COBRA 94-ultra broadband experimental radar for ISAR applications"

For airborne reconnaissance day/night/all-weather capability and high resolution of imaging radar sensors is mandatory. For the development of related processing algorithms an experimental, polarimetric 94-GHz radar has been developed using a FM/CW waveform with a bandwidth of 4000 MHz resulting in a resolution [C971]

"Waveform based detection of anti-personnel mines with an UWB radar"

The present paper deals with feature-based landmine detection by means of UWB ground penetrating radar (GPR). A waveform of target response is used as a discriminative feature for two feature-based detection schemes. The output of each DPS is a confidence map obtained by means of energy projection of a 3D distributed feature onto a 2D surface. An automated detection is made over the obtained confidence maps and mines detectability is analyzed on the basis of the receiver operation characteristic curves. Performances of the feature- and energy-based data processing schemes (DPS) applied to the experimental data are compared. It is shown that suggested waveform based detection is stable to the change of the environment. [C972]

"Broadband Photonic Signal Processing of LIDAR Noise Waveforms"

We present a novel broadband photonic signal processor, capable of sensing and processing a wide variety of waveforms including analog optical noise, for coherent LIDAR range processing. The device relies on the spectral and spatial sensing capabilities of rare-earth ion doped crystals to perform correlative signal processing. The processed results are extracted using a highly-coherent, actively-stabilized low-power frequency-swept laser, allowing broadband information to be detected and digitized at low bandwidths with high dynamic range. Time-of-flight resolution of 450 ps, signal-to-noise ratios of > 40 dB and up to 1us delays are demonstrated using 8 ms long waveforms. The optical noise waveforms are created by modulating RF noise onto the carrier, using up to 6 Gbps pseudo noise coding and 2 GHz analog noise waveforms. [C973]

"Multi-dimensional aperture design and analysis for SAR using the Cramer-Rao theorem"

We are applying the Cramer-Rao theorem to synthetic aperture radar (SAR) processing in order to establish flight paths that permit height estimation and minimize errors in reflectivity measurements. The Cramer-Rao bound (CRB) establishes a lower bound on the error variance of unbiased estimates. Error bounds are

developed for multi-dimensional synthetic apertures that improve the overall performance and efficiency of monostatic, single-pass SAR missions. A computationally efficient means for the design and analysis of SAR waveforms is proposed using simulated scattering models that are limited in size. A comparison made with the error bounds for standard SAR show that estimates of scatterer range and cross-range positions are sufficiently accurate for multi-dimensional aperture SAR, even with the additional estimator for height. [C974]

"Ground penetrating radar antenna system analysis for prediction of earth material properties"

The electrical properties of the ground directly beneath a ground penetrating radar (GPR) antenna very close to the Earth's surface (ground-coupled) must be known in order to predict the antenna response. In order to investigate changing antenna response with varying ground properties, a series of finite difference time domain (FDTD) simulations were made for a bistatic (fixed horizontal offset between transmitting and receiving antennas) antenna array over a homogeneous ground. We examine the viability of using an inversion algorithm based on the simulated received waveforms to estimate the material properties of the earth near the antennas. Our analysis shows that, for a constant antenna height above the earth, the amplitude of certain frequencies in the received signal can be used to invert for the permittivity and conductivity of the ground. Once the antenna response is known, then the wave field near the antenna can be determined and sharper images of the subsurface near the antenna can be made. [C975]

"SAR/ISAR imagery from gapped data: maximum or minimum entropy?"

In UWB synthetic aperture radar (SAR) or inverse SAR (ISAR) imagery, there are several special cases leading to the collections of fragmented (or gapped) data. Both spectrally fragmented waveforms and interrupted SAR data collection result in data gaps, which in turn lead to sidelobe severely corrupted radar images. In these cases, innovative image processing techniques must be developed to recover the degraded images. Different algorithms have proposed in the past. We concentrate on radar imagery from randomly gapped data. Two image processing algorithms based on either maximum or minimum entropy, namely, the Burg algorithm and the alternative iteration deconvolution based on minimum entropy (AIDME) are compared. The performance comparison of the two algorithms suggests a new processing procedure to combine the merits of both techniques for optimal SAR/ISAR imagery from gapped data. [C976]

"A novel stepped fat monopole antenna for precision location system using impulse waveform"

This paper presents a novel planar stepped fat monopole antenna for ultra wideband (UWB) applications. A drawback of a planar fat monopole antenna, relatively narrow bandwidth is overcome using stepped arms, and then UWB behavior of the antenna is obtained. For an easy feeding, a coplanar waveguide technique is used. For optimum design in terms of return losses and constant gain, the antenna is simulated with a commercial EM simulation tool. For verification, a prototype antenna is fabricated. From the numerical and measured results, the antenna has better than 10 dB return loss in the bandwidth between 2.2 GHz and 7 GHz. [C977]

"Utilization of human-computer interaction in wireless transmission of arterial pulse waveforms"

The shape of the arterial pulsations depends upon the thickness of the blood vessels and contractility of the heart as well as the state of the vascular smooth muscle in the vessel wall. Photoplethysmography (PPG) is by definition an optoelectronic method for measuring and recording changes in volume of a body part. The shape and stability of the PPG waveform can be used as an indication of possible motion artifacts or low perfusion conditions. Furthermore, the photoplethysmogram reveals circulatory depression and arrhythmia. In the paper, we propose a system that allows wireless transmitting of peripheral arterial pulse waveforms with use of a GPRS network. Selected examples of results, which were obtained during investigations made on a number of real PPG signals, are presented. [C978]

"Adaptive Waveform Distortion Compensation"

Radar receivers use low sidelobe matched filtering techniques to separate closely spaced targets. Ideally, low sidelobes can be achieved through either waveform selection or through spectral weighting of the matched filter. In practice, however, the minimum achievable sidelobe levels are determined by the presence of waveform distortion. Such distortion can be unintentional (e.g., as the result of hardware errors in the radar's transmitter or receiver) or intentional. This paper presents several non-iterative adaptive processing techniques for canceling coherent waveform distortion. Moreover, these techniques also potentially super-resolve closely spaced targets [C979]

"Waveform Shaping for Time Reversal Interference Cancellation: A Time Domain Approach"

In this paper, we present a time domain interference cancellation scheme using time reversal, in time reversal, a signal, for example, transmitted by a weak source through a dispersive medium, is received by an array, time reversed, power normalized, and retransmitted through the same medium. If the channel is reciprocal, and the clutter is sufficiently rich, the retransmitted waveform refocuses on the original source. This focusing effect implies that a significant portion of the received signal energy concentrates in a very small time/space, support compared with the rest of the signal components. In this paper, we consider the opposite problem: rather than refocusing, we reshape the retransmitted waveform to reduce the returned echo, i.e., to mitigate the clutter returns. Proof of concept is provided using experimental electromagnetic data and wave propagation simulations [C980]

"Waveform Correlation and Optimization Issues for MIMO Radar"

{no data available} [C981]

"A Subspace Framework for Adaptive Radar Waveform Design"

{no data available} [C982]

"Optimal adaptive waveform selection for target tracking"

Modern phased array radars, with flexible waveform generation and beam steering capability, are able to adaptively modify their performance to suit a variety of environments. This power has not yet been fully exploited, in part because of the lack of suitable scheduling algorithms. This paper describes an optimal adaptive waveform selection algorithm for target tracking. An adaptive scheduling algorithm that selects the waveforms to be used in future epochs based on current estimates of the environment has the potential to significantly improve tracking performance. This paper describes such a scheduling algorithm, which is designed by posing the problem of adaptive waveform scheduling for target tracking as a stochastic dynamic programming problem. The result is a scheduling algorithm that minimises target tracking errors. The performance of the algorithm is illustrated by comparing the tracking errors produced by this approach in comparison to a fixed waveform schedule. [C983]

"Range-Doppler Imaging Using an Analog Optical Signal Processor with Agile Waveform Sets"

A range-Doppler radar signal processor based upon a spatial-spectral holographic analog optical signal processor is discussed. Such a system has a variety of advantages over conventional range-Doppler signal processors including increased instantaneous bandwidths (> 20 GHz), enhanced dynamic range over those bandwidths, and the ability to process a variety of wideband radar waveforms directly at the radar carrier frequency without down conversion. Range-Doppler ambiguity functions are measured showing range resolution < 15 cm, Doppler resolution < 130 Hz, and > 15 dB enhanced imaging due to agile waveform sets. [C984]

"The Spectral Products Created by Nonlinear Intersymbol Interference in NRZ Data"

In two-level noise-shaped D/A conversion, a delta-sigma modulator quantizes a bandlimited discrete-time signal into a binary drive for a two-level D/A converter that then outputs a nominally clean NRZ data waveform with the quantization-noise spectrum shaped to be very low in the signal band. Nonlinear intersymbol interference in the final two-level conversion can, however, corrupt the signal band with intermodulation noise. Here a nonlinear model of that two-level conversion is used to derive its output spectrum for test data that are either periodic or random with i.i.d. bits, results that can enable laboratory measurement of model parameters and guide needed circuit improvements [C985]

"Test Bed for a Smart Millimetre Wave Radar Sensor"

With the introduction of millimetre wave radar systems in various commercial applications, including collision avoidance, cruise control, autonomous navigation and imaging, it is now clear that a "one size fits all" approach to radar system development is not effective. This paper describes the implementation of a test bed millimetre wave system comprising a coherent 94GHz front end, a fast arbitrary waveform generator based modulator and a fast digitiser which, with their associated software, will allow for the development and evaluation of modulation and signal processing techniques which can be adapted to various radar based tracking and imaging requirements. This research is aimed primarily at the development of a single, intelligent, adaptive radar system that is capable of performing many of the short and medium range sensing roles required by the airborne and ground based autonomous systems under development at the ACFR. [C986]

"Coherent lidar range processing of broadband optical noise waveforms"

We present proof-of-concept results for coherent 'time-of-flight' lidar range processing of broadband analog optical noise waveforms using the spectral sensing material Tm:YAG. Time-of-flight resolution of 450 ps with 30 dB of signal-to-noise ratio is demonstrated. [C987]

"Microwave signal processing with spatial-spectral holography"

Recent advancements in the use of spatial-spectral holographic processors to perform a variety of microwave signal processing operations are reviewed. Applications include range-Doppler radar, microwave spectrum analysis, lidar, true-time-delay, beamforming, and arbitrary waveform generation. [C988]

"An arbitrary waveform generator for SAR test-bench application"

Function and performance simulation is an effective method for the development and verification of modern radar modes. Gathering radar raw data during flight trials is an essential but expensive way. In order to minimize such costs, synthetic radar raw data at an early system design stage is adopted widely. In this paper, an arbitrary waveform generator for synthetic aperture radar (SAR) test-bench application is presented. This waveform generator uses high speed multi-DSPs to accelerate the processing to obtain a near real-time baseband echo signal of SAR, and a DDS based frequency synthesizer is used to shift the signal to the operating band. By this way, a lot of system parameters and different target features is simulated and verified. Some result waveforms gained with data created for certain test scenarios by this generator are presented. [C989]

"Digital-RF linearizer for improved broadband multi-carrier power amplifiers"

In both communications and radar, the system performance is limited by the linearity of the high power amplifiers in the transmitters. Nonlinear power amplifiers create distortion that limits the dynamic range and causes interference. Efforts to correct this problem decrease the amplifier efficiency while increasing the hardware complexity and cost. While it is the RF waveform that gets distorted, the conventional corrective measures (such as a compensating predistortion equalizer) are applied on the baseband signals instead due to speed limitation of traditional semiconductor electronics. Such baseband schemes are fundamentally constrained to partial correction of weak nonlinearity. It would be preferable to perform the corrections on the RF waveform directly for two major reasons: (1) near-perfect correction to even strong amplifier nonlinearity and (2) substantially simpler signal processing circuitry. This improved performance has been verified in detailed simulations. Only ultra-high speed superconducting electronics are fast enough to perform digital predistortion directly on the RF waveform to improve linearity and dynamic range to unprecedented levels. This technology will pave the way for future broadband, low-distortion, multi-carrier transmitters, utilizing cheaper, more efficient high power amplifiers. This will result in enhanced system performance as well as lower cost and operating expenses of radar and communication signal transmitters. [C990]

"Design and realization of a compact, low-cost, ultra wideband ground penetrating radar system"

The ground penetrating radar (GPR) is currently one of the most convenient sensors used for the detection of the dielectric objects buried under the ground. Ultra wideband (UWB) GPR has a significant advantage due to benefit from both low and high frequencies, which means long-range detection with better resolution respectively. In this paper, a compact, low cost GPR using an impulse waveform is developed. The UWB GPR system is mainly composed of an impulse generator, UWB transmitting and receiving antennas, timing circuit, signal conditioner, high accuracy digitizer, and a laptop computer for data storage and image processing. An experimental UWB GPR system is designed and tested. [C991]

"DOA estimation of ultra wide band impulse radio signal"

For ultra wide band impulse signal direction of arrival estimation, conventional wide band algorithms need to divide the wide band frequency into narrow band bins, but the time width of an impulse is about a nano second and the collected signal duration to do Fourier transform is about a few nano seconds, does the frequency resolution satisfy the narrow band condition? We show that the narrow band assumption also hold. We also obtain the signal noise ratio loss when only one frequency bin data is used to do DOA estimation. When impulse waveform is known, a subspace-based high resolution joint DOA delay estimation algorithm is obtained. [C992]

"Blind multiuser detection for DS-CDMA systems with signature mismatch"

The performance of blind multiuser detection in ds-cdma systems is often very sensitive to signature waveform mismatch. In this paper, a robust blind linear multiuser detector based on a robust capon beamforming technique is proposed. The detector belongs to the class of diagonal loading approaches, but the amount of diagonal

loading can be precisely calculated based on the given uncertainty set of signature waveform. It turns out that the presented method exhibits improved performance on bit error rate, the ratio of signal to interference plus noise, and asymptotic multiuser efficiency. [C993]

"A waveform generate unit suitable for software defined HFSWR"

A new radio frequency waveform generate unit is presented for software-defined high frequency surface wave radar (HFSWR). Since HFSWR operates in congested band, to suppress interference and clutters, together obtain the optimal combined sequence of waveform parameters, the radar system should be designed based on software radio principle. In this paper we discuss a software defined HF radar system-OSMAR2003, and focus on design and implementation of waveform generate unit for it. The proposed waveform generation unit integrates a frequency synthesizer with low phase noise and high signal to noise rate and a re-configurable synchronization control unit. The design is started with examination of requirements of the waveform and then optimize architecture of the combination of the synthesizer technology to satisfy the system requirements. Followed is the FPGA (field programmable logic array) based synchro unit controlled by VXI-bus. The measurement shows that the transmitted signal can be synthesized quickly with phase noise less than -109 dBc/Hz at 1-kHz off carrier and spur suppression greater than 65 dBc, While the waveform parameters can be set by VXI-bus. The signal generate unit becomes an important part of the software defined HFSWR and field experiments provide the validity. [C994]

"Resolution and precision of a delay-Doppler radar altimeter"

A conventional radar altimeter incoherently averages successive radar returns to form measurement waveforms. In contrast, a delay-Doppler radar altimeter combines coherent processing and incoherent averaging. This near-optimum approach leads to significantly improved measurement precision and footprint resolution than are possible from a conventional incoherent altimeter. These factors enable a new standard for oceanic altimeter applications, especially marine geodesy. [C995]

"Wideband digital beamforming when using LFM waveform"

This paper presents a new method on wideband digital beamforming and jammer ing using linear frequency modulation (LFM) waveforms with stretch processing and subarrays technique. The approach eliminates quantization style errors of conventional analog time delay units method and improves beamforming performance by using full digital processing. While subarrays technique reduces the cost, complexity and computation. Moreover, we can realize wideband jammer ing by changing digital phase-weight within each subarray when there existing wideband interferences. [C996]

"The asymptotic waveform evaluation technique based on lifting wavelet transform"

The asymptotic waveform evaluation (AWE) technique based on fast lifting wavelet transform (LWT) was applied to the method of moments to solve combined-field integral equation (CFIE). The wide-band radar cross section of arbitrarily shaped two-dimensional perfect electric conducting objects was calculated. The employment of CFIE eliminates interior resonance problem. The numerical results presented in this paper were compared with the results obtained by the method of moments. It was shown that the computational efficiency was improved greatly. [C997]

"A super-resolution method for extraction of modal responses in wideband data"

The paper presents a spectral estimation method to process coherently the wideband frequency domain field data of any object, and extract specific modal responses associated with wave propagation along the object. The problem is formulated in terms of well-known range processing used in radar waveform analysis. Thus, the data is modeled in terms of complex sinusoids, whose phase yields the decay/growth constants and the range associated with discrete scattering centers. Unlike previous approaches, the resulting amplitude and decay/growth constants are made frequency-dependent to capture the dynamic wideband behavior of the scattering mechanism. The method is illustrated by application to mode extraction for a cylindrically stratified scatterer. [C998]

"Development of an ultra wideband ground penetrating radar (UWB GPR) for nondestructive testing of underground objects"

A compact ground penetrating radar (GPR) using an impulse waveform is developed. The UWB GPR system is composed of an impulse generator, ultra wideband transmitting and receiving antennas, high speed digitizer, and a laptop computer for data storage and image processing. By considering the maximum measuring depth and

soil properties, a proper impulse generator is made and then a novel compact traveling wave monopole antenna is designed to transmit the impulse and receive the reflected signal. Also, image processing for visualization of buried targets is performed. For verification, a UWB GPR prototype is built and tested. It is shown that the system has very good depth and spatial resolution. [C999]

"Direct position determination of narrowband radio transmitters"

The most common methods for location of communications or radar transmitters are based on measuring a specified parameter such as signal angle-of-arrival or time-of-arrival. The measured parameters are then used to estimate the transmitter location. These methods are sub-optimal since they are indirect and involve two separate estimation steps. We propose a technique that uses exactly the same data as the common methods but the estimation of location is based on maximum-likelihood and the location determination is direct. Although there are many stray parameters, including the attenuation coefficients and the signal waveform, the method requires only a two-dimensional search. Monte-Carlo simulations indicate that the accuracy is superior to angle-of-arrival, time-of arrival and their combination. [C1000]

"Frequency hopping ultra wideband inter-vehicle radar system using chirp waveforms"

In this paper we propose a inter-vehicle UWB ranging system using chirp waveforms instead of the conventional UWB-IR ranging system that uses modulated Gaussian pulses. In the proposed system, the transmitted signal consists of a linear combination of chirp signals with the same time duration but different frequency bands. It is assumed that the channel model of the inter-vehicle communication system is a two-path channel model. The proposed system and conventional UWB-IR ranging system is evaluated in such a two-path channel model. The proposed system achieves better performance. [C1001]

"Estimation of radar target reflectivity in ultrawideband regime-a group theoretic approach"

The paper presents a fundamentally new mathematical framework based on group representation theory for the modeling and processing of signals in the ultrawideband (UWB) regime. A group theoretical approach is motivated by the fact that in the UWB regime, the underlying mathematical structure of the inverse scattering is governed by the affine group. In particular, a received echo can be viewed as the affine Fourier transform of the range-Doppler image evaluated at the transmitted waveform. Based on group representation theory and a novel Wiener filtering method over the affine group, we derive a regularized closed form analytical estimate of the range-Doppler target reflectivity density in the presence of nonstationary noise and clutter in the UWB regime. This estimate also leads to a method of data fusion to form synthetic UWB high resolution images from multiple radars with narrowband transmission. [C1002]

"A wideband radar depth sounder for measuring the thickness of glacial ice"

We developed a wideband coherent radar depth sounder (WCORDS) system developed to measure glacial ice thickness and map internal layers with high resolution. The radar operates over a frequency range of 50-200 MHz, providing a resolution of about 1 m in ice. A high-speed arbitrary waveform generator (AWG) is used to generate a chirp from 50-200 MHz over a very small pulse width to obtain high sensitivity needed to sound 5-km thick cold ice and map internal layers high resolution. It also consists of a two-channel receiver to obtain very high dynamic range. The low-gain channel is used to map the shallow internal layers and the high-gain channel provides ice sheet thickness and bedrock properties up to a depth of 5000 m. The gain in both the channels can be adjusted to obtain optimum performance. A high-speed data acquisition system is used to digitize and perform necessary real time processing on the data before transferring it to the storage device. The radar and data-acquisition systems have been significantly miniaturized using the latest RF and fabrication technologies. The entire system is designed to fit into multiple compact-PCI cards. Laboratory tests show that the radar system has the required sensitivity to map 5000-m-thick ice. Considerable improvement in sidelobe performance was achieved. The radar system will be tested during the summer 2004 field experiment at the Summit Camp, Greenland. [C1003]

"Correlation time analysis of delay-Doppler waveforms generated from ocean-scattered GPS signals"

The ocean-scattered Global Positioning System (GPS) signal can be used, in a bistatic radar configuration, for estimating the ocean surface roughness. This requires fitting a scattering model to the distribution of reflected power in delay and Doppler. The delay-Doppler map, or waveform, is generated through the cross-correlation of a local copy of the pseudorandom noise (PRN) code assigned to each GPS satellite with the reflected signal over increments in Doppler frequency equal to the pre-detection bandwidth. The correlation time of the reflected signal voltage sets an upper limit on the pre-detection integration time. Correlation time was estimated from

experimental data through fitting a model Gaussian function to the magnitude of the complex autocorrelation of the time series of the waveform. Range bins were taken 1.1 chips prior to the averaged waveform peak in the leading edge and 2.5 chips after the averaged waveform peak in the trailing edge. Doppler bins were set at -500, 0, and +500 Hz relative to the Doppler frequency of the corresponding direct GPS signal. The direct GPS signal was tracked using a frequency locked loop (FLL). Results showed that maximum correlation time occurs approximately 0.72 code chips prior to the averaged waveform peak. The correlation time was found to vary with the elevation angle of the satellite, with lower elevation satellites showing longer correlation time. Some experimental results were compared with model predictions. A good comparison was usually found for delay bins near the specular point and both the model and experiment showed a decrease in the correlation time for longer delays. In the higher range bins the model tended to predict longer correlation times than those observed in the experimental data [C1004]

"Waveform selection for spaceborne sparse aperture MTI radar"

Sparse aperture MTI radar has several potential advantages, but challenges associated with grating lobes, coverage area, and system timing must be overcome. Waveform selection, especially in the form of waveform diversity, provides methods for mitigating these issues. We present a detailed overview of issues involved in waveform selection applied to sparse arrays. We also present processing flows for waveform diversity and some supporting numerical results. [C1005]

"Through-the-wall wideband synthetic aperture beamformer"

A coarray-based aperture synthesis scheme using subarrays and post-data acquisition beamforming is presented for through-the-wall wideband microwave imaging applications. The wall causes wave refraction and a change in the propagation speed; both effects alter the travel time between the transmitter, the target, and the receiver. Coherent combining of the pulse waveforms emitted by the different transmitters and incident at the receivers through reflections from targets and clutter requires incorporation of wall effects into the beamformer design. Simulation results verifying the proposed synthetic aperture technique for a TWI system are presented. [C1006]

"Adaptive algorithm for Doppler ambiguity resolution in multiple target situations"

An adaptive algorithm for velocity ambiguity resolution in coherent pulsed Doppler imaging system using multiple repetition frequencies (PRFs) is presented. The fast implementation of this unambiguous estimation procedure is based on the fast Fourier transform (FFT) of the nonuniformly sampled data using two consequently changed PRFs. The proposed algorithm resolves the multiple undersampled waveforms and can be easily processed in the real-time Doppler processing. [C1007]

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{no data available} [C1008]

"Recovery of badly motion-degraded SAR imagery by the use of frequency-randomized waveforms"

The use of SAR imaging is an important tool in the laboratory RCS characterization of signature critical platforms. Despite measures to the contrary, air turbulence and mechanical vibration can produce complex perturbations of the target during the imaging process. Model code was written to provide simulations over a wide range of representative target motions and imaging schemes. The slow swept-frequency data collection schemes of many laboratory radars mean that the target can undergo significant motion during and between pulses, leading to substantial and time-varying defocusing of range profiles. Conventional motion-correction schemes cannot be used as they rely on the presence of clearly defined range profiles which can be tracked over the imaging process. It was found that replacement of a monotonically increasing frequency waveform with one in which the frequency sampling order was repeatedly randomized could produce a significant recovery of the imagery, especially in combination with data averaging. The pattern of the image degradation was found to have a complex dependence on the radar waveform scheme and target motion characteristics. [C1009]

"Use of fractional autocorrelation in efficient detection of pulse compression radar signals"

In the recent past, fractional cross-correlation and autocorrelation operations associated with the fractional Fourier transform (FrFT) have been formulated. A detection statistic based on fractional autocorrelation has been employed for detection of linear frequency modulated (LFM) signals. In this paper, we extend the utility of the detection statistic based on fractional autocorrelation for detection of pulse compression radar waveforms. In

particular, we consider the step LFM signal and the waveforms of Frank code and P4 code. [C1010]

"Adaptive Doppler filtering applied to modern air traffic control radars"

This paper presents an analysis of the Doppler processing technology currently in use in the USA's terminal airport surveillance radars, and examines possibilities for performance improvement, particularly in the presence of moving clutter. The research focuses on five- and eight-pulse waveform methodologies and their respective detection capabilities given clearly defined rain clutter scenarios. Performance with fixed coefficient filters similar to those used in the existing radars is calculated, followed by performance using an adaptive Doppler filtering technique. Performance is quantified in terms of signal-to-interference ratio at the output of the Doppler filters and resultant probability of detection given a specified probability of false alarm. The results show that a substantial improvement in detection in the vicinity of rain clutter is realized for both the five- and eight-pulse waveforms when using the adaptive coefficient Doppler filters as compared to the performance observed with the fixed coefficient filters. For constant filter weights, the eight-pulse Doppler filters give significantly better performance in most diverse rain clutter than the five-pulse Doppler filters. [C1011]

"Combinatoric collaboration on Costas arrays and radar applications"

Costas arrays are permutation matrices that also provide a frequency indexing sequence that permits at most one coincident tone in cross-correlations of FSK waveforms. As such, they have obvious application as frequency indexing sequences in radar and communications when long codes with bounded autocorrelation are required or when Doppler is a significant portion of the transmitted bandwidth. All Costas arrays for orders less than 25 are known, with those for N=24 disclosed in the paper. Higher orders are found through number-theoretic generators and partial searches. [C1012]

"Adaptive thresholding of non-homogeneity detection for STAP applications"

An adaptive thresholding algorithm is presented that can be used in conjunction with the multi-pass generalized inner product (GIP)-based editing method to eliminate non-homogeneities from the training data used for STAP applications, such as adaptive radars. The algorithm exploits a property of the generic structure of the ordered GIP statistic, along with a single user-specified parameter related to the type I error of incorrectly excising target-free training data, to determine adaptively the thresholds for excising target-contaminated training data. The performance of the method is demonstrated using high-fidelity site-specific simulated data, with both ideal and realistic waveforms, as well as measured data from the multi-channel airborne radar measurement (MCARM) experiment. [C1013]

"Generators, antennas and registrator for UWB radar application"

The paper describes the basic elements developed for realization of UWB radar: generators, antennas and registrator. Generators produce UWB signals of nano- and picosecond duration, having the form of a step-like function, a monopulse, or a pulse in the form of sine wave single period (monocycle). Fulfillment of FCC radiation requirements means filtering the UWB signal spectrum, which results in distortions of the waveform. It is shown that filtering sine wave single period pulses of 0.2 ns duration provides slight distortion. A description of a TEM broadband shielded horn antenna with low side and back pattern lobes is given. The registrator for reception of UWB signals and software for secondary signal processing are described. [C1014]

"Adaptive pulse compression"

Pulse compression is essentially an estimation procedure in which the complex amplitude for a given range cell is to be estimated while mitigating the interference from neighboring range cells that results from the convolution of the transmitted waveform with the range swath of interest. Traditionally, matched filtering is employed to estimate the range returns whereby the neighboring range cells are suppressed by a fixed amount that is dictated by the range sidelobes of the matched filter. However, matched filtering is a misnomer in that the receive filter is matched only to the transmitted waveform and not to the actual received signal. The paper extends the previously proposed reiterative minimum mean-square error (RMMSE) algorithm for adaptive pulse compression whereby the true matched filter for each individual range cell is estimated based upon the actual received signal resulting in range sidelobes that are adaptively suppressed to the level of the noise floor. The convergence of the RMMSE algorithm is addressed along with the Doppler tolerance. [C1015]

"A spectrally clean transmitting system for solid-state phased-array radars"

Navy radar operations are being curtailed in a littoral environment. This is due to two factors: the encroachment of cell phone systems into the naval radar bands; in-band interference from other radars. The spectral width of

most pulsed radars is significantly wider than necessary with present modulation schemes. Most radars utilize some form of constant envelope pulse with phase or frequency modulation. This causes the spectrum to broaden to several times the information bandwidth. If both the amplitude and phase of the transmitted signal are allowed to change, a significantly narrower bandwidth can be achieved. The paper presents a method to create waveforms with instantaneous bandwidths of 20 MHz confined within -100 dB. The theoretical spectral results of three popular phase modulation schemes (phase shift keying, minimum phase shift keying and derivative phase shift keying) are compared with the spectrally clean results. In addition, the Chireix out-phasing method is presented as an alternative to generating amplitude and phase modulated waveforms. The Chireix method provides a way of improving the efficiency compared to the conventional class A power amplifier. Preliminary results are shown for a spectrally clean waveform. [C1016]

"Waveform generation and signal processing for a multifunction radar system"

A multifunction, single platform RF sensor capable of performing target acquisition and tracking, combat identification, high data rate communications, and active protection is of interest to the USA army. The sensor ultimately must tie affordable and the size minimized to meet the demands of a rapidly deployable force. To address these needs, the Army Research Laboratory has built and tested a multifunction radar test bed capable of performing multiple tasks simultaneously at Ka-band. The system has integrated high-end RF components together with commercial-off-the-shelf (COTS) signal processing technology. Key elements of the test bed are a commercial direct digital synthesizer (DDS) for adaptable waveform generation, multiple COTS field programmable gate array (FPGA) processors for real-time data acquisition and signal processing, a COTS FPGA based multi-port input/output (I/O) board programmed for radar timing and control, and an electronically scanned antenna (ESA) based upon a Rotman lens beam-former with active elements for multi-beam generation. The radar is capable of transmitting and receiving two simultaneous and independent beams in azimuth with up to 3 GHz of bandwidth and up to 8 watts of average power. The current configuration uses one beam for a radar target acquisition function and the other for a high data rate communication channel. The emphasis of this paper is on the radar's waveform generation and signal processing capability. [C1017]

"The study on a new radar waveform with high rang resolution"

A phase coded stepped frequency (PCSF) radar waveform is an improvement of linearity stepped frequency (SF) radar waveform. By combining intra-pulse phase and inter-pulse frequency modulations, the PCSF enables larger frequency step sizes than SF. With same system effective processing bandwidth, PCSI technique makes the bandwidth traverse much faster, shorter time of sent pulse cluster, and low data rate higher and Doppler sensitivity. A low stage pulse compression process is employed to achieve a variable range resolution. The results of the simulation for the characteristic mentioned above are presented to illustrate the properties of the PCSF. [C1018]

"A sidelobes suppression technique for spectra discontinuous HF radar signal"

Over-the-horizon high frequency (OTH-HF) radars operate in HF (high frequency) band, it is quite difficult to find a clear frequency band for radar system requirements in this band due to heavy interferences. The adoption of a discontinuous spectra waveform can mitigate the interferences influence and, as a result, it gives rise to high range sidelobes and thus a low signal dynamic range. This kind of sidelobes cannot be suppressed by traditional spectral weighting. In this paper, we introduce a new signal processing technique based on frequency extrapolation to lower the sidelobes associated with discontinuous spectra signals. Simulation results show significant range sidelobe reduction using this new algorithm. [C1019]

"Modeling and simulation of video target echo and clutter for HLA-based radar system"

In this paper, we investigate the modeling and simulation of the target echo and K-distributed clutter echo for radar. In output of the simulator, velocity and distance of a moving target are simulated by delaying the video waveform and linearly shifting the phase of carrier wave, angle of a moving target is simulated by the angle gain of the antenna. Clutter is used as disturbance. [C1020]

"Real-time simultaneous assessment of wall distension and wall shear rate in carotid arteries"

A novel ultrasound (US) system has been developed to make possible the real-time assessment of both blood velocity profile and wall displacements in human arteries. The system consists of a modified US machine and a custom PC add-on board based on a high-speed DSP board. The software has been customized to make possible the simultaneous selection of two independent M-lines. In the B-mode display. With respect to the artery of interest, such lines can be set at optimal angles for wall detection and blood velocity detection, respectively. When switched to PW-mode, the system fires the elements of the linear array probe in such a way

that US bursts are alternatively transmitted into one of the two selected M-line directions. Quadrature demodulated echo signals produced along both such lines are sent to the DSP board, which allows the corresponding blood velocity profile and wall displacement (or distension) waveforms to be calculated and displayed in real-time. From the velocity profile, the wall shear rate (WSR), i.e. the spatial velocity gradient close to the blood-wall interface, is extracted. The system has been preliminarily tested in the common carotid arteries of 11 healthy volunteers. Results of simultaneous diameter distension and WSR measurements are reported. [C1021]

"A sidelobes suppression technique for spectra discontinuous HF radar signal based on spectra compensation algorithm"

The discontinuous spectra frequency hopped pulse waveform (DS-FHPW) signal is employed to combat spectra congestion in radar and other radio services to evade external interference in high-frequency (HF) and ultrahigh-frequency (UHF) bands. However, the spectral discontinuity of the signal gives rise to high range sidelobes when matching the reflected echo, which is much more difficult for target detection. The technique for radar range sidelobe suppression by a spectral compensation algorithm is introduced in detail. By estimating the signal at polluted frequency bands and filling the actual received signal with the estimated signal, The discontinuities of the received signal can be diminished, thus the range sidelobes can be suppressed. Simulation results show that the range sidelobes of a DS-FHPW radar signal can be suppressed significantly by the algorithm. [C1022]

"Bandwidth and bits: new AWG design achieves both"

This paper describes the architecture and application of a new modular, dual channel arbitrary waveform generator (AWG) capable of generating a 1 GHz IQ modulation bandwidth. Each channel supports a signal fidelity of over 65 dB of spurious-free dynamic range (SFDR). The key technology consists of two Agilent-developed digital-to-analog converters (DAC) operating at 1-25 gigasamples per second (GSa/s) clock frequency and 15 bits of vertical resolution. The new design supports advanced waveform sequencing and triggering for event-based pulse building. This new level of performance gives designers the ability to generate not only wide-bandwidth pulse compression radar signals, but also to add interfering radar and EW signals into the signal scenario. When combined wide-bandwidth IQ and pulse modulators, real-world signatures can be realized at microwave frequencies. [C1023]

"Study on reducing false targets for automotive radar"

New waveform for millimeter-wave automotive anti-collision radar is proposed. It greatly improves the response characteristic of radar system and partly reduces the false alarm of the radar. The effective algorithm is introduced to further eliminate false targets in multiple targets circumstances. Simulation results show that the method is effective. [C1024]

"Blind parameter estimation of low probability of intercept waveforms"

A novel algorithm to estimate the parameter of low probability of intercept waveforms is presented, based on RAT, de-chirp and FRFT. Except for carrier frequency and chirp rate of triangular linear frequency modulation continue waveform (TLFMCW), modulation bandwidth and modulation period are also given. Finally the simulation results indicate that this method can provide good estimation performance even in low SNR. [C1025]

"A new chirp-coded radar waveform"

A new chirp-coded radar waveform (ICC-2) is introduced, relative to the old type intra-pulse chirp-coded (ICC-1) waveform described by Xu Qing (Syst. Eng. and Elect., vol.12, p.7-8, 2000). The waveform forming, ambiguity function and match filter output are discussed. From the discussion, it is found that the ICC-1 can achieve higher resolution than chirp and phased code waveforms and ICC-2 is not suitable for target position radar. The reasons are given by analyzing the spectrum, ambiguity function and match filter output. Finally, it is indicated that through some restructuring, ICC-2 can achieve good performance by stepping frequency etc. It is useful in radar target identification applications. [C1026]

"Motion compensation based on entropy-like function optimization for MMW Costas frequency hopped radar"

Motion compensation is the key technology for MMW Costas frequency hopped (FH) radar to realize high range resolution. By defining the waveform entropy for the 1-D range profile of Costas FH radar using an entropy-like function, motion compensation was translated into a one-dimensional optimization problem. A one-dimensional accurate search method based on simulated annealing algorithm was developed and applied to motion

compensation of Costas FH radar simulations show that this method is robust, globe and independent of the gradient. High-range-resolution 1-D range profiles of moving targets can be obtained even when the signal to noise ratio (SNR) is nearly 0 dB. [C1027]

"Novel method for ambiguity elimination in the linear FMCW radar"

Aiming at solving the distance and velocity decouple problem for moving target in linear FMCW (LFMCW) radar signal processing, a multiple repetition frequency waveform is adopted and a Doppler frequency cluster (DFS) algorithm is proposed, which is capable of recovering true velocity from the coupled velocity estimation directly. Aiming at solving resolution of multiple targets, a match algorithm based on mean square error is also proposed. The combination of the above two methods realizes distance and velocity decoupling for multiple moving targets. The result of simulation verified the effectiveness of the methods, the velocity estimate performance of DFS algorithm improve 2.5 dB contrast to Chinese remainder theorem. [C1028]

"A novel LPI radar signal based on hyperbolic frequency hopping combined with Barker phase code"

In tins paper we address the problem of low probability of intercept (LPI) techniques. Previous LPI signals are first reviewed, and then the characteristic of frequency hopping techniques and barker phase code is investigated. A new LPI signal called PR-FH is brought forward by combining the Barker sequences and hyperbolic frequency hop code and compared with the PSK Costas-frequency hopping signal. Auto- and cross-ambiguity functions are used to research the characteristics of PR-FH, the result shows that the novel waveform has low cross correlation and good resolution of both range and Doppler. [C1029]

"Application of entropy minimization to motion compensation of MMW Costas frequency-hopping radar"

The Doppler performance of MMW Costas frequency-hopping (FH) radar was analyzed briefly. By defining waveform entropy for the 1D range profile of this radar, motion compensation was converted into a 1D optimization problem. Based on simulated annealing algorithm (SAA), a 1D search algorithm was presented and applied to motion compensation of Costas FH radar. Simulations show that this method is robust and globe. Satisfying results can be obtained even in the low-SNR case. [C1030]

"Advantages of the wideband and ultra wideband signals in the remote sensing"

Some aspects of the wideband and ultrawideband signals usage considered. Essential aspects of the processing techniques as well as models of the input process represented and discussed. The term efficiency bandwidth and principle of the waveform selection represented. Concept of the wideband signals in the synthetic aperture radar presented. Results which show advantages of these signals are shown. [C1031]

"Wideband noise radar for detection of slow moving objects"

The results of the theoretical and experimental researches of L-band short-range radar, with correlation processing of random noise sounding waveforms, are presented. It proposes the approach of inter-survey subtraction of clutters to detect and localize slow moving objects. [C1032]

"Implementation of new technologies in radar systems"

Future radar systems employ new RF and digital technologies that increase their functionality and performance. These changes in the radar system design include zero-IF receivers, software radio implementations and employ computationally intense radar data processing. New functionalities of the radar include high resolution imaging, new multiple waveform designs, resource management and new radar system designs employ digital T/R modules. To investigate the feasibility of utilizing new digital technologies in a radar system, a low demand modulation scheme of a SSR (secondary surveillance radar) system was chosen. The receiver was realized with a CMOS gain controlled 110 dB amplifier, zero-IF quadrature mixer along with a software radio detection design that was implemented with a flexible FPGA (field programmable gate array), also implemented in CMOS. This type of work allow the adaptation of computationally intense requirements of active digital array radars empowering radar system designers to implement new detection schemes, increase dynamic management of RF energy and processing resources thereby enhancing nominal radar performance. [C1033]

"Simultaneous laser and radar altimeter measurements over land and sea ice"

Elevation data derived from space-based altimeter measurements over landand sea-ice are key to understanding

the Earth's ice mass balance. This importance is recognized by both NASA, as expressed in the laser altimeter GLAS on ICESat, and ESA, as expressed in the radar altimeter SIRAL on CryoSat. The JHU/APL Delay-Doppler Phase-monopulse (D2P) radar altimeter has shown its value as a scientific/calibration/validation instrument, and has participated in two airborne field campaigns sponsored by NASA and ESA to collect simultaneous radar and laser altimeter measurements over land and sea ice. These measurements are unique; they provide colocated, cross-calibrated, and high-precision altimetry data over a variety of geophysical ice conditions in two very different frequency regimes. In this paper, we give an overview of the CryoVEx field campaign in 2003 including basic system parameters, flight tracks, and sample waveforms from the airborne experiment. [C1034]

"Effects of forest spatial structure on large footprint lidar waveform"

Large footprint lidar has demonstrated its great potential for accurate estimation of many forest parameters, e.g., forest height, forest biomass and vertical structure of forest canopy. In addition to the canopy vegetation, many factors such as atmosphere, underlying surface, the shape of crown, et al., influence the lidar waveform. The illuminating intensity of the laser beam across the lidar footprint is a Guassian distribution and reduces from 1.0 to e-2 from the center to the edge of the footprint. Hence the forest stand structure plays an important role in the lidar waveform. The contribution of each tree to the lidar waveform varies with its location in a forest stand. This paper simulated the random, uniform and clumped tree distribution patterns in a stand. Then waveforms were simulated using a three dimensional lidar waveform model developed by Sun and Ranson. The results show that the tree distribution patterns affect the lidar waveform profiles. The area (or energy) under the waveform from vegetation (AWAV) and the height of median energy (HOME) were used to estimate the effects. Following trends have been revealed from the simulation: for AWAV and HOME, uniform > random > cluster. There is no obvious difference between regular and random. The waveform area (AWAV) varies much more than HOME. For the clumped case, the number of clusters does not have much effect on the lidar waveform [C1035]

"An algorithm to acquire the average height of land surface"

For an airborne altimeter, an algorithm to acquire the average height of the land surface is suggested based on the return waveform. Through the origin analysis about each point of return, scattering from assured distance reflects the corresponding information of incident scope. In the difficult situation of how to decide the single characteristic point, the technique built in the theory can be handled easily in practice. Otherwise, we validate our model by simulation in a good way. [C1036]

"High range resolution using a Wigner distribution deconvolution algorithm"

To achieve high range resolution of scatterers, radar systems transmit wideband signals. This paper presents a new technique for resolving scatterers using a narrowband transmitted waveform. This technique exploits the fact that the spectrum of the returned signal is the product of the spectrum of the transmitted signal and the Fourier transform of the impulse response of the target. The range profile of the target is determined using the Wigner distribution of the transmitted and received signals in a deconvolution algorithm. It is shown that the achievable resolution of scatterers in range by this method is well beyond the conventional range resolution of the transmitted signal. [C1037]

"Joint space-time clutter and interference covariance estimation for non-chirped radar"

We investigate the problem of clutter covariance estimation from multichannel radar data with non-specific waveforms. This differs from other similar algorithms in that they are typically tailored for a specific transmitted waveform, in most cases an LFM chirp. We also consider the possibility that there is interference, within the data, caused by a spatially localized source that is independent of the transmitted signal. We frame the problem of estimating the space-time covariance matrices of both the clutter and interference separately as one of maximum-likelihood estimation, and obtain a solution via the expectation-maximization algorithm. Results with simulated data are presented. [C1038]

"SDR approach to 3G cellular/PCS and position location services"

In the past few years. third generation (3G) mobile communication systems, where the spectrum of the services now extend up to 60 MHz to 75 MHz, have emerged. In this process, new communication waveforms, such as WCDMA (TDD and FDD) cdma2000 and TD-SCDMA. are now joining the legacy communication waveforms such as GSM/EDGE/GPRS and cdmaOne, to form a large set of services that are used throughout the world. CellularWS manufacturers are now facing various challenges in supporting multiple services as these services have different frequency, bandwidth and protocol structures. Furthermore, in 2001, USA FCC has mandated the E911 requirements for user location services. To meet these requirements radio manufacturers have investigated methods of position location for user equipment. The main objective is to develop the position location solution

that is synergistic with the cellular/PCS technology while minimizing the change of current base station infrastructure. In this paper, the SDR architecture for 3G cellular/PCS services and location services is addressed along with the technologies that make this advanced architecture feasible. [C1039]

"Signal design for MIMO diversity systems"

This paper addresses the problem of waveform design for general diversity systems. The paper firstly introduces a general model for such systems, and then considers linear and nonlinear cases. Examples of each case are given n the linear case, the MIMO communications design problem; in the nonlinear case, the MIMO radar waveform design problem. In the latter case, a simulation example is provided which illustrates the potential benefits, which might be obtained. Finally, the paper concludes with a brief discussion of the MIMO radar tracking problem. [C1040]

"MIMO radar theory and experimental results"

The continuing progress of Moore's law has enabled the development of radar systems that simultaneously transmit and receive multiple coded waveforms from multiple phase centers and to process them in ways that have been unavailable in the past. The signals available for processing from these multiple-input multiple-output (MIMO) radar systems appear as spatial samples corresponding to the convolution of the transmit and receive aperture phase centers. The samples provide the ability to excite and measure the channel that consists of the transmit/receive propagation paths, the target and incidental scattering or clutter. These signals may be processed and combined to form an adaptive coherent transmit beam, or to search an extended area with high resolution in a single dwell. Adaptively combining the received data provides the effect of adaptively controlling the transmit beamshape and the spatial extent provides improved track-while-scan accuracy. This paper describes the theory behind the improved surveillance radar performance and illustrates this with measurements from experimental MIMO radars. [C1041]

"Multiple-input multiple-output (MIMO) radar: performance issues"

The application of multiple-input multiple-output (MIMO) techniques to multistage radar offers a number of advantages, including improved resolution and sensitivity. Depending upon the radar's mode of operation, the array design and the environment, these advantages may or may not be significant. In this paper, a simple analytic model for ground moving target indicator (GMTI) radar detection is presented and its predictions are compared with simulation. Conventional single-input multiple output (SIMO) and MIMO GMTI radars are compared in terms of minimum detectable velocity, area-search rates and array sidelobes. Optimal waveform cross-correlation matrices are identified for MIMO radars, given different performance criteria. Finally, bounds are developed for MIMO arrays with uniformly sampled virtual apertures. [C1042]

"Ultra wide band 24 GHz automotive radar front-end"

The recent approval granted by the FCC for the use of Ultra Wide Band (UWB) signals for vehicular radar applications has provided a gateway for production of these sensors as early as in 2004. However, the rules governing the allowable spectral occupancy create significant constraints on the sensors operation. The implications for waveform design and the consequent limitation on system architecture, including antenna design and receiver architecture are discussed. Other practical considerations such as available semiconductor technology with low-cost plastic packaging are reviewed. This is developed into a methodology for developing a single board sensor with integrated antenna. Results are presented for a specification compliant antenna, and a low-cost plastic package for 24 GHz ICs. Finally, the required IC architecture for a transceiver is presented, along with measured results of a single-chip homodyne I/Q down-conversion receiver fabricated in SiGe. [C1043]

"Radar target recognition based on orthogonal range profile extraction"

In this paper a novel approach to use orthogonal range profiles for effective real-time target recognition is proposed. The proposed system is based on the two netted monostatic radars located at different locations. The two radars simultaneously send two different specially designed wideband radar waveforms to generate a pair of orthogonal range profiles of the target from different incident angles at the same moment. The two-dimensional target scattering feature is thus extracted from the two orthogonal range profiles for efficient target recognition. The wideband waveforms used by the two radars are designed such that they do not correlate to each other, i.e. their cross-correlation function is almost zero, and each of them has thumbtack-like autocorrelation function. Therefore, the matched filter at the receiver of one of the radars outputs a strong processing result only with the input including the coding waveform transmitted by the same radar; while the target echo scattered from the waveform transmitted by the other radar is mismatched at the receiver and behaves like a noise signal. [C1044]

"A novel direct-imaging radar sensor with frequency scanned antenna"

The principle, design and experimental results of a simple direct imaging radar sensor are presented. The FM-CW radar principle and a frequency scanned antenna are combined with waveforms of different frequency slopes in such a way that angular and range information are provided by the amplitude envelope of a fixed video frequency. The sensor architecture uses a minimum of active RF components and digital signal processing. With low cost frequency scanned antennas, this architecture can be applied in radar surveillance stations or automotive side looking sensors. [C1045]

"Waveform synthesis via splines"

As it currently stands, waveform generators are being employed in many diverse areas such as communication systems, radar applications, simulation, and testing. Thus, the objective here is to develop an algorithm for a waveform generator capable of synthesizing analog signals from a specified collection of discrete signal points, and polynomial splines are employed to develop a smooth curve (continuous derivatives) connecting these points. Texas Instruments recently released its 720 MHz digital signal processor (world's fastest), and the purpose of this brief paper is to add to the body of knowledge associated with splines and digital to analog conversion. [C1046]

"A multiuser detector based on blind signal separation"

Conventional RAKE receiver distinguishes each user by crosscorrelation of the spread sequences and achieves detection of the desired user. In practical applications, however, the performance of receiver is much degraded due to the so-called near-far problem. Based on the theory of blind signal separation (BSS), this paper presents a new multiuser detector, which substantially enhances the near-far resistance ability of the receiver. The proposed method solves the order ambiguity inherent in the BSS problem by utilizing the structure information of the effective signature waveform. Finally, computer simulations confirm its performances. [C1047]

"Artificial intelligence and waveform diversity"

Future US Air Force sensor systems must be able to adapt to changing environments in real time. A capabilities-based modeling approach offers a new method for building the next generation weapon system. To accommodate this model based approach, the Department of Defense (DoD) is promoting the use of waveform diversity for active radar systems. Building a weapon system including one or more systems with waveform diversity will require the use of artificial intelligence (AI) tools and techniques. We provide a model of how an aircraft sensor system can be retrofitted to accommodate radars employing waveform diversity without causing fratricide. [C1048]

"Artificial intelligence and sensor fusion"

Future US air force sensor systems must be able to adapt to changing environments in real time. A capabilities-based modeling approach is a new method being promoted for the building of the next generation weapon systems. To accommodate this modeling approach the Department of Defense (DoD) is promoting the use of waveform diversity for radar systems. Building a weapon system including one or more radar systems with waveform diversity will require the use of artificial intelligence (AI) tools and techniques. We investigate leveraging the AI tools being developed by the Semantic Web, DARPA's DAML program and, specifically, the building of ontologies and resource description framework (RDF) for sensor systems so that they can efficiently communicate and share their data. [C1049]

"Ultra wideband ranging system using improved chirp waveform"

In this paper we propose a novel chirp signal for UWB radar systems instead of the conventional Gaussian monocycle. In the proposed scheme, the transmitted signal consists of a (linear) combination of chirp signals with the same time duration, but different frequency bands. The proposed technique can suppress the peak power and to accomplish the same range resolution of the conventional UWB radars. Moreover, the proposed system can achieve single user ranging error performance. [C1050]

"Noise reduction by multiplicative waveforms decomposition"

This paper introduces a novel multiplicative noise reduction method based on a particular association of structural and statistical analysis. The structural analysis is performed by a new, multiplicative matching pursuit decomposition (MMPD), that decomposes images containing the intrinsic variation into a nonlinear expansion of

waveforms selected from a dictionary of functions. This selection is made in such a way to match best the image local structures. Local statistics evaluation is associated to the MMPD convergence scheme ; then an adaptive algorithm framework for multiplicative noise is deduced. An application to speckle reduction in synthetic aperture radar (SAR) images is described. [C1051]

"Signal waveform reconstruction from noisy bispectrum estimations pre-processed by vector filters"

The reconstruction of 1-D signal waveform from noisy bispectrum estimations in case of a limited ensemble realization number and low input SNRs leads to considerable output errors. In order to improve the signal bispectrum estimations we propose to smooth the obtained bispectrum estimations. The methods based on vector filter application to 2-D complex valued bispectrum processing are considered in this paper. The influence of input SNR, the filter type and the used norm selection on signal reconstruction system performance is analyzed using computer simulations. It is shown that the proposed methods decreases both fluctuation error and bias of reconstructed signal. [C1052]

"Measurement of S band clutter statistics using quasi-deconvolution filter for a phase coded waveform"

This paper describes a signal processing technique by which radar clutter data collected with a derivative phase modulated waveform was used to evaluate sea clutter statistical parameters. Two processing options for recovering full bandwidth clutter samples from the radar return signal are matched filter and deconvolution. Both processors may be implemented in the form of a transversal filter (finite impulse response or FIR). The FIR matched filter output contains certain errors, such as filter time sidelobe responses, which are not present at the output of a pure deconvolution process. A transversal filter approximation to deconvolution, quasi-deconvolution, contains similar errors but greatly reduced in magnitude. We have shown that the use of quasi-deconvolution (QD) filters make it possible to accurately estimate two key amplitude distribution statistics for surface clutter: mean and mean/median ration. [C1053]

"Sidelobe response of antennas to short pulse signals"

We consider the waveforms of signals received in the sidelobe region of antenna, when the signals are of very short duration. It is shown that the output signal waveforms can be very different from those of the input signal. An analytical theory is presented to explain these effects, and several examples are presented to illustrate the effects and to show the validity of the analysis. A number of applications are suggested. [C1054]

"Mitigating the effects of chaff in ballistic missile defense"

In this paper, an algorithmic (schema) approach for detecting and tracking targets in highly cluttered environments is presented. The approach is to accurately track the centroid of the chaff cloud using a combination of medium band (MB) and wide band (WB) range resolution radar waveforms. At moderate pulse repetition frequencies (PRFs), differential target velocities (about the centroid of the chaff cloud) are detected and tracked via Doppler banks of transversal filters that are tuned to detect the target velocity differences. Through sensitivity analysis using Matlab models, the theoretical lower bound on detectable differential target velocity as a function of the chaff cloud composition (e.g., clutter cross section, clutter spectral width, number of dipoles, and clutter velocity standard deviation) and radar related parameters (e.g., waveform frequency, bandwidth, integration times, PRFs, and signal-to-clutter ratio) is presented. [C1055]

"Multi-Waveform SFCW radar"

A Stepped Frequency Continuous Wave radar for detecting flush buried and surface laid anti personnel landmines was designed and built. The system covers a frequency band from 400 MHz up to 4845 MHz. The range resolution is 3.4 cm and the maximum unambiguous range is 4.3 m. The antenna set up is a bi-static one with two Archimedean spirals with opposite sense of rotation. A particular property of the radar is that it transmits and receives a set of eight frequencies at the same time. The system parameters are particularly aimed at imaging algorithms exploiting the phase evolution over the antenna footprint. An example of the result achieved after Synthetic Aperture Radar processing is presented. [C1056]

"Simultaneous detection and parameter estimation of multiple linear chirps"

The paper describes a new method for the simultaneous detection and parametric estimation of multiple chirped waveforms using a method based on evolutionary algorithms. Unlike traditional time-frequency analyzers, which provide a distribution of the signal spectrum over a period of time, but do not inherently provide chirp parameters, this new method detects and provides as an output the start and stop frequencies of each chirp, its

starting phase and amplitude. The new method is capable of detecting and characterizing multiple chirps which may be overlapping (in time and frequency) and in the presence of significant noise. [C1057]

"Studies of ground penetrating radar antennas"

Virtually all systems that have been developed in recent years to detect landmines and buried unexploded ordinance (UXO), have included the ground-penetrating radar (GPR) as one of the principal subsystems. Much of the effort reported to date in evaluating these GPRs has focused on obtaining overall end-to-end detection performance metrics (Pd, Pfa). These studies have been useful but they provide little insight into the functioning of individual GPR components and the limitations they may impose on system performance. By contrast, this project concentrates on investigating performance characteristics of the GPR antenna, which is perhaps the most critical component in determining GPR system performance. Some of the antenna issues that remain unresolved are: determination of the most useful bandwidths, defining the role of polarization and polarization diversity, minimizing the effects of self-clutter (also known as "ringdown" or "reverberation"). Over the course of this ongoing program, we plan to investigate a variety of GPR antenna subsystems, including the spiral, the sinuous log-periodic, various dipoles, the TEM horn, the TEM rhombus, tapered slots and forms of the impulse radiating antenna (IRA). In this paper, we report some initial experiments carried out on a transmit-receive pair of Archimedean spiral antennas. To characterize these antennas, we carried out measurements in a conventional radio frequency (RF) laboratory using a vector network analyzer to synthesize waveforms covering the frequency range from 500 MHz to 5.5 GHz. Transformation of these data to the time domain allows us to gate out extraneous laboratory clutter beyond a 1.5-m (10 nsec) range. The principal measurements reported here are: the gain and phase properties, noise and clutter levels, and the antenna system spatial response footprint. The spatial patterns were measured by raster-scanning a stainless steel sphere through a two dimensional grid located 17 cm (a range typical of GPR applications) from the aperture of the transmit/receive antenna pair. [C1058]

"Neural networks trained by scattered electromagnetic data for GPR applications"

This paper is intended to give a presentation of the first results we have achieved in the field of reconstructing buried objects starting from the data extracted from the time-domain waveform of the scattered electromagnetic field which can be available at the receiving terminals of a GPR equipment. To this aim, neural network methodologies are exploited to face the inverse scattering problem. The main attention has been devoted to identify sets of data that can be "easily" extracted from the transient field. These data, however, represent the "electromagnetic signature" of the investigated scenario and thus they be chosen to be closely related to the geometric as well as the dielectric properties of the target. Preliminary results are shown concerning the localisation of the target and the reconstruction both of its dimension and of its relative dielectric permittivity. [C1059]

"Feasibility analysis of GSM signal for passive radar"

Passive radar makes use of an 'illuminator of opportunity' already present in the environment for other purposes (TV transmission, broadcast systems, etc) to detect targets as well as estimating target parameters. This radar has the merit of being a completely covert radar system, which does not advertise the presence of either the receivers or transmitting stations. One such existing radio transmission that may be utilize for this purpose is that of the GSM system. This paper is intended to access the feasibility and suitability of using the GSM downlink signals from the GSM base station as the 'transmissions of opportunity' in an experimental passive radar system. The analysis of the GSM signal as a radar waveform for the passive radar systems design and its associate signal processing scheme is investigated. Simulations and preliminary experimental results demonstrate that the detection of ground moving targets can be indeed be achieved, affirming that this system is indeed viable and for certain does offer a novel and unique kind of passive detection that is outside the scope of other current approaches. [C1060]

"Adaptive space/frequency processing for distributed aperture radars"

This paper deals a preliminary investigation into space-time-waveform adaptive processing for waveform diverse distributed apertures. The large baseline of such a distributed radar results in angular resolution that is orders of magnitude better than resolution of a monolithic system (single large radar) with the same power-aperture. This capability comes at the cost of grating lobes (multistatics with evenly spaced apertures) or high sidelobes (multistatics with randomly spaced apertures). This paper develops some preliminary solutions to these drawbacks associated with distributed apertures. In particular, the use of approximately logarithmic spacing with each aperture transmitting orthogonal waveforms provides excellent detection performance. [C1061]

"High fidelity modeling of space-based radar"

Space based radar design are becoming more affordable given new technologies of solid state active apertures and advanced digital signal processing. However, it is important to be able to synthesize the design of the system with sufficient detail to anticipate the radar system's operation and interference effects expected in a space environment. This includes simulation of site specific clutter with realistic Earth rotation and statistical variation, wideband propagation of the signal from multiple phase center aperture, and impact of channel match and errors on adaptive processing for detecting targets. The research laboratory space time adaptive processing (RLSTAP) has been developed as a variable fidelity radar simulation tool to captures these effects. The paper will describe results of modeling an L-band multimode space based radar, including effective of ambiguities from antenna subarrays, and range and Doppler waveforms on adaptive processing. [C1062]

"Bayesian computer-intensive methods for statistical signal processing"

Summary form only given. The talk discusses various computational techniques for solving complex inference problems in signal processing. The focus of the talk would be Monte Carlo methods, and in particular the sequential Monte Carlo methods which are currently proving extremely powerful for non-linear/non-Gaussian sequential environments. The author review the basic formulation of the sequential Monte Carlo framework, or particle filter, from the perspective of sequential updating of a general probability distribution, such as the posterior distribution of a hidden state or signal parameter. These methods, in their most basic forms, have proved very powerful for solving of non-linear problems in radar tracking, financial time series, communications, robotics and computer vision. In recent years increases in available computer power and memory have facilitated substantial algorithmic advances in these methods, allowing for more accurate inference and solution of more complex problems. In the second part of the talk the author describe some of these recent advances in sequential Monte Carlo, including Monte Carlo smoothers and trans-dimensional filters, which allow for on-line model selection. The methods described would be illustrated with examples from radar tracking, audio signal extraction and inference of musical beat from an audio waveform. [C1063]

"Novel radar technology and applications"

The behaviour of electromagnetic waves as described by the fundamental equations developed by James Clerk Maxwell around 1864, are governing the performance of radar technology and applications, along with appropriate signal waveform design, generation and processing. Novel radars are utilizing innovative modulation methods through digital signal generation and processing, with powerful data handling techniques and all-solid-state electronics, to realise the radar principles. Contemporary radar applications are particularly focused on (vehicle) traffic supervision and control, subsurface exploration, industrial measurements and automation processes, in addition to more sophisticated military applications. [C1064]

"The SAR train concept: required antenna area distributed over N smaller satellites, increase of performance by N"

The concept implements the coherent combination of the N SAR flying along a same arc as seen from the ground. A particular case is with N SAR in visibility and a single transmit. A "Signal Cleaning" SAR Train keeps unchanged the maximum antenna area of each individual SAR and brings a factor N advantage on both the SNR and the ambiguity protection. The main formation constraint is the width of the tube containing the satellite trajectories on an earth frame. An "Antenna distributing" SAR Train enables the distribution of an unchanged total minimum antenna area into N smaller elementary antennas, together with the multiplication by N of the merit factor (swath over azimuth resolution ratio). Application for N >2 requires very tight along track SAR spacing accuracy. Use of appropriate spread spectrum waveforms instead of conventional pulse waveforms removes the major part of the extra orbit constraints induced by "Antenna distributing" and enables it for any value of N. A Train of N SAR in visibility eases the metrology of the formation (DGPS) and the global energy efficiency is increased by N since with only single transmit SAR the same performance is achieved. Moreover, the orbit constraints are relaxed by 2. As part of its application, the concept can circumvent the matter of huge antenna size for SAR mission in P band or at very high altitude, all the more as in these cases the tube width constraints are reduced (function of λ and altitude). [C1065]

"The delay-Doppler radar altimeter: robust and improved measurement capabilities"

A delay-Doppler radar altimeter exploits coherent signal processing in addition to incoherent waveform averaging to achieve significantly better measurement precision and instrument efficiency than are possible from a conventional incoherent instrument such as TOPEX or Jason-1. The required processing can be built into the on-board system, whose output waveforms yield geophysical parameters with the analysis algorithms already developed for conventional altimetric data. The approach enables new architectures, ranging from a single-

frequency geodetic instrument (Abyss-Lite), to a three-satellite constellation of TOPEX-class altimeters (WITTEX) small enough to fit into one launch vehicle. [C1066]

"Improved global marine gravity by retracking altimeter waveforms"

We present a new global marine gravity anomaly model with errors nearly a factor of two lower than our previous global models. This improvement is achieved by re-tracking the raw echoes of the ERS-1 radar altimeter. Ocean surface waves are a fundamental limitation to the recovery of gravity anomalies from satellite altimeter profiles. For example, to recover the gravity field at an accuracy of 1 mGal at 20-km full wavelength requires measuring the ocean surface height change over a 10-km horizontal distance to a precision of 1 cm. Standard processing of altimeter data provides a height precision of only about 5 cm at this length scale. These standard products are optimized for recovery of ocean surface height, significant wave height and wind speed and are based on tracking algorithms having at least three unknown parameters. The most precise retracking algorithms are heavily weighted to match the onset time of the leading edge but we show this onset time is nearly perfectly correlated with the wave height parameter. If one assumes the wave height changes only slowly with distance, re-tracking can be performed with a more precise, two-parameter model. Repeat cycles across the South Pacific (area of high sea state) show improvement in along-track slope error from 6.39 microradian to 3.34 microradian and there is a corresponding improvement in resolution from 40 km to 31 km. In addition there are improvements in ocean coverage, especially near coastlines and on the shallow continental margins. The quality of the retracked ERS-1 data are superior to non-retracked Geosat geodetic mission data suggesting the Geosat data can be improved as well. [C1067]

"Optimization of waveforms for UWB disk antenna arrays"

The optimization of basic pulse waveform for disk array is considered. Numerical results show that energy patterns of optimized waveforms have much narrower main lobes than those of corresponding Gaussian waveforms and achieve considerably improvement in angular resolution. [C1068]

"Topics in passive bistatic remote sensing"

This paper presents a succinct overview of a research effort involving passive bistatic remote sensing. Included were antenna analysis, direction of arrival estimation analysis, waveform analysis, direction of arrival error analysis, and receiver location analysis. [C1069]

"Seasonal polarimetric measurements of soil moisture using tower-based GPS bistatic radar"

The results of GPS L-band (L1, λ = 19 cm) surface reflection measurements observed using multiple polarizations and receiving antenna gains are described. The measurements were performed using the 300 m tall ETL Boulder Atmospheric Observatory (BAO) tower during summer through fall of 2002. In this experiment, the first seasonal measurements of bare soil moisture from a stationary location using bistatic reflection of signal of opportunity were performed. Several receiving antennas offering various gain and polarization sensitivities were used. Theoretical modeling of bistatic surface scattering shows that the magnitude and width of the reflected waveform depend on the dielectric permittivity of the soil, vegetation cover, and soil roughness. By observing from a fixed tower over low grass, the roughness of the reflecting area remains constant, hence variations in the signal are uniquely related to changes in the dielectric permittivity, and therefore, to soil moisture. To investigate polarization sensitivity of the reflected signal to soil moisture, four endfire (12 dB) antennas with complete circular and orthogonal polarization sensitivities were used. The high-gain antennas increased the received dynamic range and reduced surface multipath radio wave interference. Seasonal retrievals of soil-moisture content from multi-polarization GPS reflection data is presented and compared with in-situ soil moisture measurements. [C1070]

"Multi-waveform full-polarimetric GPR for landmine detection"

A full-polarimetric ultra wideband GPR front-end has been developed in IRCTR especially for landmine detection application. A number of new ideas have been implemented in the design. A principally new antenna system design and an ability to perform quasi-simultaneous measurements with two transmit polarization and in two different frequency bands are main novelty aspects of the radar. Additionally in comparison with commercially available video impulse GPR systems the front-end has considerably larger bandwidth, ability to measure polarimetric structure of the scattered field and very high precision of scattered field measurements. [C1071]

"Anisotropy in reflected GPS measurements of ocean winds"

The probability density function (PDF) of the ocean surface slope can be estimated from the code-correlation

waveform of reflected GPS signals. Anisotropy in this PDF is found to correspond to the local near surface wind direction, suggesting the ability to resolve this direction using scattered signals from two or more GPS satellites. A two-stage estimation process was applied to sets of waveform data collected from an airborne delay-mapping GPS receiver. First, an isotropic normal distribution was assumed for the PDF. The mean square slope (MSS) was fit to the measured waveform data for each satellite independently. Differences between the MSS estimates from two satellites at different azimuths were observed. In the second step, a bidirectional normal PDF was used with MSS constrained to that obtained in the first step, and an assumed value was given for the ratio of upwind to crosswind slopes. The direction of the principal axes was then varied to minimize the total residuals for both satellites. The results were compared with buoy recordings of the local wind direction. [C1072]

"Noise radar using random phase and frequency modulation"

Pulse compression radar is used in a great number of radar applications. Excellent range resolution and high ECCM performance can be achieved by wide-band modulated long pulses, which spread out the transmitted energy in frequency and time. By using random noise as waveform, the range ambiguity can be suppressed as well. The same limit in Doppler resolution is achieved as for a coherent Doppler radar when the time compression of the reference is tuned to that of the target. Mostly, the random signal is transmitted directly from a noise generating HF-source. A sine wave, which is phase or frequency modulated by random noise, is an alternative giving similar performance but higher transmitted mean power when peak-limited transmitters are applied. A narrower modulation noise bandwidth can also be applied to generate the same output bandwidth. For phase modulation, the bandwidth amplifying factor is simply the rms value of the phase modulation, and for a frequency modulating waveform, the output rms bandwidth equals the rms-value of the frequency modulation. The results also show that the range sidelobes can be highly suppressed compared with the sidelobes of the modulating signal. The mean and variance of the correlation integral are derived in terms of the autocorrelation function of the modulation. The combined effects of low range sidelobes and enhanced range resolution make frequency and phase modulation attractive. [C1073]

"An estimation method of target location and scattered waveforms for UWB pulse radar systems"

This paper presents a method of estimating target location and scattered waveforms, whose accuracies are interdependent. The technique relies on iterative improvements of estimated dominant-frequency waveforms. Description of the algorithm is followed by statistical simulation examples. The performance of the technique is contrasted with conventional methods and statistical bounds in terms of target locationing accuracy. Results indicate that our proposed method has a remarkable performance, which is close to the theoretical limit. [C1074]

"Complexity feature extraction of radar emitter signals"

Because the intra-pulse modulation laws of radar emitter signals reflect directly on the signal waveform, a novel approach is presented to extract the complexity features (CFs) of radar emitter signals. CFs, including Lempel-Ziv complexity (LZC) and correlation dimension (CD), can measure the complexity and irregularity of radar signals effectively. To show the effectiveness and feasibility of the introduced approach, CFs of 10 typical radar emitter signals are extracted in our experiments. The results demonstrate that the CFs have good characteristics for clustering the same radar signals and separating different radar signals, which indicates that CF can simplify the design procedure of classifiers and greatly heighten the identification accuracy rate of radar emitter signals. [C1075]

"Multi-waveform SFCW radar"

A stepped frequency continuous wave radar for detecting flush buried and surface laid anti personnel landmines was designed and built. The system covers a frequency band from 400 MHz up to 4845 MHz. The range resolution is 3.4 cm and the maximum unambiguous range is 4.3 m. The antenna set up is a bi-static one with two Archimedean spirals with opposite sense of rotation. A particular property of the radar is that it transmits and receives a set of eight frequencies at the same time. The system parameters are particularly aimed at imaging algorithms exploiting the phase evolution over the antenna footprint. An example of the result achieved after synthetic aperture radar processing is presented. [C1076]

"2003 IEEE Conference on Ultra Wideband Systems and Technologies (IEEE Cat. No.03EX759)"

First Page of the Article [C1077]

"A programmable ultra wideband signal generator for electromagnetic susceptibility testing"

Under Phase I of the Defense Advanced Research Projects Agency (DARPA) Networking in Extreme

Environments (NETEX) initiative, Multispectral Solutions, Inc. (MSSI) was tasked with the development of a general purpose, ultra wideband hardware simulator capable of reproducing a wide variety of ultra wideband (UWB) waveforms. The simulator, with UWB outputs from baseband through millimeter wave, was to be used for the purpose of electromagnetic susceptibility testing of legacy military radio, radar and positioning systems. The ultimate goal of this portion of the Phase I program was the quantitative determination of those UWB parameters (e.g., frequency, power, pulse rate, pulse shape, dithering, etc.), which had the least impact on the operational performance of legacy designs. This paper describes the development of the MSSI NETEX UWB simulator (BFPI000). [C1078]

"Multiple scale correlation of chirp signal by discrete wavelet transform"

Chirp signal, a finite duration pulse with linear frequency modulation (LFM) is the signal waveform widely used for coherent image formation. Coherent imagery is derived essentially as a 2-dimensional correlation of received, delayed chirp waveform with a 2-dimensional matched filter. There is wide and active research interest in analyzing coherent imagery at multiple scales for multiresolution speckle reduction, clutter separation from desired targets and other low level vision requirements such as multiple scale segmentation, etc. This paper attempts to address these requirements during the image formation process; i.e., obtaining multiple resolution imagery by signal correlation at multiple scales. We derive a shift and scale invariant DWT algorithm, which functions as the cornerstone for such multiple scale correlation. We also briefly discuss implications of this image formation algorithm with particular attention to speckle reduction. [C1079]

"An S-band digital array radar testbed"

Future naval radars will perform a combination of functions including volume search, track, and high resolution imaging. These radars, which must operate in littoral regions (i.e., near coastlines), will need to contend with strong clutter and jamming. As such, digital phased array technology, wherein transmit and receive signals are digitized at (or near) the antenna element, can offer significant advantages. However, it appears that digitizing a large wideband microwave phased array has never before been attempted. Directly fielding such a system would come with some perceived risks; many of these risks can be mitigated through the development of a small scale testbed. Recently, MIT Lincoln Laboratory funded the development of a wideband digital array radar testbed. The system consists of a 14' reconfigurable digital linear array aperture, 500+MHz imaging bandwidth, 90+dB dynamic range, and element-level digital recording. The initial system configuration uses direct digital waveform synthesis, analog signal distribution, and stretch processing at the receivers. Digital downconversion, time-delay beamsteering, and space-time adaptive processing (STAP) are performed by an offline processor. This paper provides an overview of the testbed's design and construction. Initial test results are also presented. [C1080]

"STRAAP: space-time-radiating array adaptive processing"

This paper provides an overview of the physical and mathematical approach to the synthesis and analysis of a multidimensional adaptive radar system. Using a paradigm of distributed sensors, the characterized concept leverages the dimensional advantages gained in such a system by exploiting the inherent, space, time, and waveform domains for adaptive processing. Execution of space-time-radiating array adaptive processing (STRAAP) makes use of the full parametric domain. Data analysis within this extended space suggests system performance advantages in radar target detection, object isolation, and scenario depiction. [C1081]

"The use of random frequency-hopped waveforms for the recovery of motion-degraded SAR imagery"

There is a conflict between the requirement of a very low RCS target support system, and the need for high stability and accurate target setting during the SAR imaging of signature-critical targets. To meet the ideal of measuring targets in free space, multiple string suspension systems from overhead gantries have been devised. Despite measures to the contrary, air turbulence and mechanical vibration can produce complex perturbations of the target during the SAR imaging process. Model code was written to provide representative motion models. Simulations were made over a wide range of motion patterns to assess the effects on the imagery. The pattern of the image degradation has a complex dependence on the frequency sampling rate and characteristic period of the oscillation. A comparison is made between monotonically stepped-frequency waveforms and random frequency-hopped waveforms, and the benefits to image recovery of the latter discussed. [C1082]

"Optimal adaptive waveform selection for target detection"

Modern phased array radars are able to adaptively modify their performance to the environment. To make full use of this capability, scheduling algorithms need to be designed. This paper poses the problem of adaptive waveform scheduling for detecting new targets in the context of finite horizon stochastic dynamic programming.

The result is a scheduling algorithm that minimises the time taken to detect new targets, detecting these targets in accordance with importance, while minimising the use of radar resources. [C1083]

"Use of STAP techniques to enhance the detection of slow targets in shipborne HFSWR"

This paper addresses the detection of low velocity targets from a shipborne HFSWR (high frequency surface waves radar). In a shipborne configuration, as a consequence of the ship motion, the first order of Bragg lines is spread in the useful Doppler interval where detections of a ship target are expected to appear. Space time techniques like STAP, usually studied for airborne radar purposes, are candidates to reduce the effect of ship motion. The influence of pitch and roll components is also discussed. Simulations of STAP techniques are given, based on a conventional architecture of processing. Estimation of the clutter covariance matrix is studied with respect to the characteristics of the radar waveform. Interleaving between the classical HFSWR waveform and a wide band learning waveform is proposed, to enable the covariance estimation. [C1084]

"PulsON P200 UWB radio: simulation and performance results"

In 1999, Time Domain (TDC) introduced the first ultra-wideband (UWB) radios using the PulsON P100 chipset. In 2002, a second-generation chipset, the PulsON P200, was introduced. It consists of a P200 timer (T2), P200 correlator (C2) and P200 digital baseband (DBB) chip. The chipset has been incorporated into the P200 UWB radio platform. The P200 radio is architected as an 8-correlator transceiver. The correlators are configured to minimize acquisition time, provide rake receiver gain, enable higher order modulation, provide ing of in-band jammers and provide a means to record the entire received waveform (waveform capture). The radio relies on coherent signal processing. Energy from up to 1024 pulses can be coherently summed thereby providing 30dB of process gain. Additional process gain is realized from duty cycle as the 0.5 ns waveform is transmitted once every 104ns. As part of the design process, the radio was well simulated and a link budget was produced. Upon completion, the radio performance was compared to the predicted values. The radio has been tested as a communications system, a ranging system and as a mono-, bi- and multi-static radar. This paper summarizes the radio architecture, modulation, link budget, simulation, and performance results. [C1085]

"2003 Proceedings of the International Conference on Radar (IEEE Cat. No.03EX695)"

First Page of the Article [C1086]

"Radar the next generation-sensors as robots"

One can easily envisage future military operations and emerging civilian requirements (e.g. intelligent unmanned vehicles for urban warfare, intelligent manufacturing plants) that will be both complex and stressing and will demand innovative sensors and sensor configurations. The goal of our research into sensors as robots is to develop a cost effective and extendable approach for providing surveillance for a variety of applications in dynamically changing military and civilian environments. We discuss the development of a futuristic intelligence, surveillance and reconnaissance concept utilizing the innovative integration of cutting edge technologies such as: knowledge-based signal processing; robotics; wireless networking; waveform diversity; the semantic Web; advanced computer architectures and supporting software languages. This concept is projected as an autonomous constellation of air, space, and ground vehicles that would offer a robust paradigm to build toward future deployments. [C1087]

"Conditions to the radar vector signal providing simultaneous measurements of all back-scattering matrix elements"

The properties of the illuminating waveforms and conditions of the signals, forming orthogonal (by polarization) vector sounding signals are discussed. These signals are needed in order to estimate the back-scattering matrix (BSM) of real media and objects. It is shown that the correct BSM estimation of fluctuating objects, having a-priori unknown ranges and radial velocities, is possible only when complicated orthogonal signals are being used. The principles of forming the needed radar waveforms as well as principles of backscattered vector signal processing, assuming Gaussian noise at the receiver is formulated. [C1088]

"Adaptive bow-tie antenna with variable current distribution"

In this work we have demonstrated the possibility to adapt a GPR antenna to different environments using electrically controlled reactive loads. It was shown that it is possible to vary the antenna transfer function spectrum as well as the main pulse amplitude and the antenna ringing. It is suggested to use an antenna with controlled internal resonances for post-processing synthesis of pulses with special waveforms to suppress parasitic reflections from the environment. [C1089]

"Automatic segmentation of pavement condition data using wavelet transform"

We present a new algorithm based on wavelet transforms for automated segmentation of pavement (road surface) condition data. We developed a denoising scheme to remove random noise caused by the collection device and random extreme distress in the pavement while essentially preserving the important information followed by a singularity detection-based segmentation algorithm. During the segmentation stage, singularities of the smoothed waveform are detected, and they are marked either as isolated singularities or border points. Isolated singularities are suppressed and the remaining singularities are used as border information to segment the pavement-condition data into regions that exhibit similar characteristics. The proposed approach follows the envelope of the original pavement data and the resulting segments semantically and objectively (in the mean square error sense) represent the original data better than the previous methods. [C1090]

"A fuzzy approach for tracking of low-altitude target in the presence of multipath propagation"

To process tracking low-altitude targets with the multipath propagation is a difficult task. The difficulty derives from a large number of uncertain knowledge (parameters) such as the radar waveform frequency, the specific signal processing, the surface reflectivity, and the actual target elevation and range, ... etc. This paper offers a technique based on the fuzzy logic to solve the uncertain measurement error by the multipath propagation. And we apply the quantitative analysis presenting the degree of multipath effect to achieve the goal we mentioned ahead. Meanwhile, the tracking filter estimation is used to reduce the measurement error by the multipath propagation. After the simulation, the fuzzy-logic-base technique not only can simplify the process of the model building by IMM but also can promote the tracking accuracy. [C1091]

"Surface roughness estimation from GPS sea reflections"

The research reported in this paper was motivated by a Global Positioning System (GPS) data set collected by researchers at The Johns Hopkins University, Applied Physics Laboratory (JHU/APL) in May 1999. Raw GPS signal data were collected from an aircraft equipped with two downlooking antennas for receiving both left-hand circularly polarized (LHCP) and right-hand circularly-polarized (RHCP) GPS reflections from the ocean surface. Concurrent measurements of the local wind and wave conditions were collected from a nearby research vessel. The measured (LHCP) waveforms were similar to those already reported. The reflected RHCP waveforms were about 10 dB below those from the LHCP antenna. As far as we know, detection of the (depolarized) RHCP waveform has not been previously demonstrated. Models for GPS surface scattering based on geometrical optics or the Kirchhoff approximation predict a very weak depolarized return. We have recently developed a general bistatic scattering model that yields the proper cross section for both the specular and resonant (Bragg) scattering limits and also predicts depolarization for scattering out of the plane of incidence. Comparison of this scattering model with the cross section obtained by exact integration of Maxwell's equations shows good agreement even for relatively rough surfaces. [C1092]

"Electromagnetic field simulation of target detection by high-resolution radar"

The electromagnetic field simulation of the target detection by high-resolution radar is performed by incorporating the asymptotic waveform evaluation (AWE) technique and the compression technique of a chirp signal. The electromagnetic field simulation is very helpful for revealing the multi-scattering mechanism of wide-band radar signal between targets or within a target. Our current simulation involves three major steps, in the first step, AWE technique is used to calculate the scattering far field over a wideband at which a radar is operated; in the second step, the frequency response of scattering field is multiplied by the spectrum of the chirp signal transmitted by radar to get the frequency response of radar system; in the third step, the system response is multiplied by the conjugate of the spectrum of the chirp signal and then transformed into time domain by inverse FFT. In this way the target detection by chirp radar can be accurately simulated using electromagnetic field. Numerical examples are presented. [C1093]

"A super-resolution locationing algorithm for ultra-wideband phased-array radars"

Super-resolution direction finding algorithms such as MUSIC or ESPRIT methods inherently assume narrow-band signals, which are not applicable to ultra-wideband radars such as GPR (ground penetration radar). We developed a time-domain algorithm to determine the time and direction of arrival pulses with an order higher resolutions than the nominal resolution determined by the aperture size. The received signal waveform at each array element is first analyzed by the recursive nonorthogonal decomposition using a dictionary of basic waveforms. After the delay time of the echoes in each element of the receiving array is determined, the number of targets and their locations are determined by analyzing variation of the delay time over the array with the aid of a Hough transform. The robustness of the proposed algorithm is confirmed by numerical simulations. [C1094]

"Approximating sensor signals: a rough set approach"

This paper presents an approach to approximating sensor signals. In classical rough set theory, set approximation is carried out in non-empty, finite universes of objects. In contrast, we carry out set approximation inside non-empty, uncountable sets (universes) of points. This study is motivated by an interest in classifying sample values for various types of sensors. The result of this study is the introduction of a family of discrete rough integrals based on rough set theory. The discrete rough integrals have practical implications, since these integrals serve as an aid in approximate reasoning and in pattern recognition relative to segments of continuous signals. In the context of approximate reasoning, discrete rough integrals provide a basis for determining the relevance of sensors over a particular sampling period. In the context of pattern recognition, discrete rough integrals can be useful in doing such things as classifying radar weather data, vehicular traffic patterns, and waveforms of power system faults. By way of illustration, one form of discrete integral is used to assess the accuracy of set approximation of a sensor signal. [C1095]

"A new complementary waveform technique for radar signals"

A new phase coding technique for radar signals is introduced which uses novel complementary waveforms constructed to have optimal sidelobe performance. The waveforms are constructed using a modification of the Prometheus orthonormal set (PONS) technique. An advantage of a PONS matrix is that it allows for many complementary pairs of waveforms to choose from as well as allowing for multiple pairs to be used simultaneously. It is shown that sets of waveforms which are complementary in quartets can also be applied for more flexibility. Results showing improved ambiguity properties versus other radar waveform coding techniques are given. [C1096]

"Radar breadboard for DSP scatterometer"

The design and test results for the radio frequency (RF) portion of a breadboard polarimetric scatterometer operating at 13.402 GHz are presented. To evaluate the feasibility of a programmable digital signal processing (DSP) approach for a follow-on scatterometer similar to SeaWinds an integrated breadboard has been developed at the Jet Propulsion Laboratory (JPL). Early breadboards of this type have been identified as valuable assets in developing effective subsystem requirements for the eventual flight instrument. Many compatibility and partitioning issues between the RF and DSP hardware are addressed with empirical results derived from the aforementioned breadboard. The RF portion of the breadboard consists of a dual channel receiver, heterodyning the received signal of 13.402 GHz down to an IF of 37 MHz and a single channel transmitter, that converts the I/Q baseband transmit waveform up to Ku band. The breadboard makes provision for emulating capabilities such as programmable attenuators, loop-back calibration, and saturation effects in an actual instrument's power amplifier. It also provides control interfaces to allow early verification of software control algorithms. [C1097]

"Multifractal features of sea clutter"

Sea clutter refers to the backscattered returns from a patch of the sea surface illuminated by a transmitted radar pulse. Since the complicated sea clutter signals depend on the complex wave motions an the sea surface, it is reasonable to study sea clutter from nonlinear dynamics, especially chaos, point of view, instead of simply based on random processes. In the past decade, Dr. Simon Haykin's (1997) group at the McMaster University of Canada carried out analysis of some sea clutter data using chaos theory, based on the the assumption that a chaotic attractor is fully characterized by a non-integer fractal dimension and a positive Lyapunov exponent. Thus, they concluded that sea clutter signals are chaotic. In other words, the complicated sea clutter waveforms are generated by nonlinear deterministic interactions of a few modes (i.e., number of degrees of freedom). However, a numerically estimated non-integral fractal dimension and a positive Lyapunov exponent may not be sufficient indication of chaos. Cowper and Mulgrew (see Proc. UCNN, vol.4, p.2633, July 1999), Noga (see Ph.D thesis, Cambridge University, 1998), and Davies (1994) separately have questioned the chaoticness of the radar sea clutter. We show, using the direct dynamical test for deterministic chaos developed by Gao and Zheng, which is one of the more stringent criteria for low-dimensional chaos, a two minute duration sea clutter data is not chaotic. We also carry out a multifractal analysis of this sea clutter data set, and find that the original sea clutter amplitude signal is approximately multifractal, while the envelope signal, formed by picking up the successive local maxima of the amplitude signal, thus measuring the energy of successive waves on the sea surface, is well modeled as multifractals. These behaviors determine that the amplitude signal follows approximately log-normal distribution while the envelope signal, and thus the energy of the successive waves of the sea surface, is log-normally distributed. Approximate log-normal distributions for the amplitude signal has been observed earlier. However, by using the multiplicative multifractal theory, there is theoretical justification for the log-normal distribution of sea clutter, as discussed. The implications of the multifracta- l nature of sea clutter may have relevance for the detection of point targets on the sea surface. [C1098]

"Hilbert filter for double-layer perpendicular recording media"

Summary form only given. Readback waveforms from GMR heads in perpendicular magnetic recording are completely different from the regular longitudinal recording waveforms. Proper signal equalization is therefore critical. For this purpose a Hilbert filter is discussed. This filter is known to transform the dipulse response from a single layer perpendicular media into a longitudinal signal, however, for double layer perpendicular media with a soft magnetic underlayer its properties have not been reported yet. In this paper the authors discuss the performance of the Hilbert filter for double-layer perpendicular recording media. [C1099]

"A spline function, DSP based mixed-signal arbitrary waveform generator"

As it currently stands, waveform generators are being employed in many diverse areas such as communication systems, radar applications, simulation, and testing. The arbitrary waveform generator introduced in this paper consists of a DSP (Digital Signal Processor), a FIFO memory, a video palette, and a PC interface. A program running on the PC creates a digital representation of a waveform according to user parameters and sends it to the DSP's RAM. The DSP algorithmically converts the digital representation to a point-by-point representation of the desired analog signal. The data points are sent to the FIFO buffer, which latches the data to the video palette that serves as the digital to analog converter. The system uses JTAG and a high-speed serial port interface to communicate with the PC, to allow for readily programmed signals. In addition to the production of traditional signals such as sinusoids and squarewaves, a mathematical tool known as splines will be employed to aid in the development of customized arbitrary waveforms. A picture of our new device is presented in the paper, in addition to laboratory measurements. [C1100]

"Ultra wideband radar systems: advantages and disadvantages"

This review paper discusses the differences of ultra wideband (UWB) radars from conventional narrowband radars. The features are shown of generation, radiation and processing of UWB radar signals evoked by change of signal waveform in the process of location, by appearance of the mutual dependence between signal waveform and antenna directivity and others. The opportunity of reception of the target radioimage is shown. [C1101]

"2002 IEEE Conference on Ultra Wideband Systems and Technologies (IEEE Cat. No.02EX580)"

First Page of the Article [C1102]

"Model function development for GPS reflection measurements"

Empirical model functions are derived for the retrieval of surface winds from the post-correlation waveform of scattered GPS signals. A geometric optics model is applied to generate model waveforms from the the surface slope probability density function (PDF). Batches of experimentally recorded waveforms are then processed to estimate parameters defining the PDF (ie., up-wind and cross-wind slope variances and the direction of the principal axes). A nonlinear least squares method is used to perform this estimation. Experimentally measured PDFs from this method are then compared with independent measurements of surface wind conditions obtained from the TOPEX altimeter. Linear and a logarithmic forms are assumed for the functional dependence of apparent slope moments on wind speed. The coefficients of each of these functions are determined by weighted linear least squares. The limitations and uncertainty in these models are discussed. [C1103]

"Estimating the power spectral density of ultra wideband signals"

Ultra wideband (UWB) signals are being considered for a number of applications including short range/high throughput communications, ranging and high resolution radar. One of, the primary concerns in the design and deployment of UWB systems is the interference generated by UWB systems on other co-located UWB systems and more importantly on narrow band (NB) systems such as GSM and GPS. The interference power levels are a function of (1) the power spectral density(PSD) of the UWB signal over the bandwidth of concern; (2) the spatial density of the UWB transmitters, and the (3) the traffic characteristics of the NW of UWB transmitters. This tutorial paper addresses the spectral properties of the UWB signals. [C1104]

"Extraction of multiple-bounce artifacts in tomographic imaging"

This analysis develops an innovative image formation technique for reflection tomography based upon the extraction of multiple-bounce (MB) ghosting artifacts. The basic concept is that the time-of-flight between the transmission and reception of a waveform includes the realistic effects of MB interactions. An enhanced quality

image can be constructed by utilizing only the single-bounce (SB) contributions of the measured phase history data. In addition, the MB ghosting artifacts are projected into a series of auxiliary images that can be applied to enhance the performance of object identification. These novel methods can be applied to the many domains of reflection tomography, including: (a) real aperture radar, (b) synthetic aperture radar (SAR), (c) inverse SAR (ISAR), (d) active sonar underwater acoustic mapping, (e) active geographic acoustic exploration, and (f) ultrasonic medical imaging. [C1105]

"Joint optimal Tx-Rx design for multiple target identification problem"

A design methodology for jointly optimizing the transmit waveform and receiver filter for multiple target identification is presented. The methodology is applied and illustrated for various multi- 'target' ID problems. The resulting probability of correct classification is significantly better than that achieved by a conventional chirp or any other waveform. Unlike the classical radar case, the choice of transmit pulse shape can be critically important for the identification of extended targets in presence of additive channel noise. [C1106]

"A measurement model for Cartesian coordinate tracking with linear FM chirp waveforms"

This paper provides a measurement model for linear FM (LFM) chirp waveforms in Cartesian coordinate. The model is derived by first incorporating the Doppler shift term into the measurement model in radar coordinate, and then transform it to Cartesian coordinate. The proposed model is then applied to a simple airplane tracking problem. The simulation result shows better tracking performance than the case with ordinary measurement model. It is also shown that up chirp radars has better tracking performance than down chirp radars. [C1107]

"Ku-band receiver and transmitter for breadboard DSP scatterometer"

The design and test results for the Radio Frequency (RF) portion of a breadboard polarimetric scatterometer operating at 13.402 GHz are presented. An integrated breadboard has been developed at the Jet Propulsion Laboratory (JPL) to evaluate the feasibility of a programmable Digital Signal Processing (DSP) approach for a follow-on scatterometer similar to SeaWinds (scheduled for launch in winter 2002). Early breadboards of an integrated system have been identified as valuable assets in developing effective subsystem requirements for the eventual flight instrument. Many compatibility and partitioning issues between the RF and DSP hardware are addressed with empirical results derived from the aforementioned breadboard. The RF portion of the breadboard consists of a dual channel receiver, heterodyning the received signal of 13.402 GHz down to an IF of 37 MHz prior to the analog to digital conversion, and a single channel transmitter, that converts the I/Q baseband transmit waveform up to Ku band. The breadboard makes provision for emulating capabilities such as programmable attenuators, loop-back calibration, and saturation effects in an actual instrument's power amplifier. It also provides control interfaces to allow early verification of software control algorithms. [C1108]

"Bistatic radar denial by spatial waveform diversity"

The purpose of this paper is to introduce and evaluate a number of techniques to prevent a radar being used by an adversary as a bistatic illuminator of opportunity. These are all based on the idea of radiating a so-called "masking signal" which is arranged to be orthogonal, both in a spatial sense and in a coding sense, to the radar signal, and of a level sufficient to mask the radar signal to an adversary, and hence to deny a reference for bistatic operation. The overall performance of the scheme is quantified in terms of two parameters: (i) the degree of masking of the radar signal by the masking signal, and (ii) the degree of suppression of echoes (from targets or from clutter) of the masking signal in the channels of the radar receiver. The choice of waveforms is considered, followed by a description of two approaches to the choice of radiation patterns, and then the results of some simulations of the overall performance are presented. [C1109]

"Optical arbitrary waveform generator for radar applications at high frequency resolution"

In future radar systems, highly complex synthetic waveforms are needed to perform sophisticated signal processing functions at high speed. An opto-electronic arbitrary radar waveform generator is proposed. It permits one to generate predefined waveforms by driving phase-amplitude distributions of optically carried microwave signals. [C1110]

"Performance indications of a novel chaotic-signal FM-CW radar for multi-user applications"

Emerging requirements for several radar applications call for highly-specialised signal processing algorithms displaying good multi-user capability. This paper presents some results of tests and measurements from an experimental chaotic-signal radar (CSR) test bed where a novel, yet simple, signal-processing algorithm, called implicit sampling averaging has been implemented. The CSR has a very large processing gain and hence

provides high resistance to external noise and interference. Furthermore, it is also highly resistant to mutual interference from similar systems, since the random or chaotic-signal generator in each system produces a unique signal. As an initial verification of the theory, a standard 77 GHz FM-CW radar receiver was specially adapted to facilitate the novel CSR scheme. A digitising oscilloscope was used as a signal processor for reconstructing and visualising the characteristic bipolar waveform (so-called S-curve) indicating the obstacle position. First results agree well with theory and stimulate further development of this new approach. [C1111]

"Ambiguity suppression in a multiple beam radar"

Phased array radars facilitate beam-scanning versatility that was not possible with traditional mechanically scanned radars; specifically, that the advent of electronic beam steering has allowed antennae to scan a wider angular volume per unit time than was previously achievable. This paper develops an idea proposed by DERA Malvern in which this beamforming versatility is exploited by insertion of further pulse trains in the otherwise redundant pulse repetition interval (PRI). Associating these pulse trains with spatially diverse transmit beams formed by such a phased array results in a stare-while-scan (SWS) radar, in which the multiplicity of beams allow the radar to observe a number of directions simultaneously. Such a system would bring the twin advantages of considerable gain with integration of pulses and the provision for realisation of new detection strategies. SWS systems, however, suffer from severe ambiguities caused by imperfect spatial separation between beams, rendering a multiple beam system ambiguous even if its constituent beams contain range unambiguous pulses. Fortunately, these ambiguities can be mitigated by employing a combination of spatial, waveform, frequency and time diversity. The techniques for ambiguity suppression in a multiple beam radar system are the focus of this paper, and are discussed with reference to a conceptual system. The WEFTDAR (Waveform Enhanced in Frequency and Time with Direction of Arrival), as it was termed, achieved beam-to-beam ambiguity suppression of 35 dB by the use of a combination of these diversity techniques. Further increases in this figure are thought to be possible with the use of the AD-MUSIC direction of arrival (DOA) technique. [C1112]

"Velocity compensation methods for the conical scan step-frequency waveform"

This paper analyzed the velocity interferences on the conical scan step frequency waveform and gave some velocity compensation methods. The holistic velocity compensation (HVC) is effectual for the accurately known velocity. The excursive velocity compensation (EVC) is fit for the case of inaccurate estimated velocity. [C1113]

"An airborne low-cost SAR for remote sensing: hardware design and development"

An airborne low-cost synthetic aperture radar (SAR) is under development at the University of Nebraska-Lincoln. The SAR system is an X-band, stepped-chirp frequency modulation (SCFM) radar system. One of its unique features is that the waveform generation consists of a timing-controlled D/A converter and VCO arrangement to synthesize the SCFM signal, whereby allowing for less design complexity and a much lower overall system cost. In this paper, we present a brief description of the system and some computer simulation results. [C1114]

"Identification of transmitting wave form for deconvolution process. A study on high resolution microwave subsurface radar image. 1"

A subsurface radar is applied broadly for detection such as cavities, water pipes and gas pipes. However since the vertical resolution is not enough, it is difficult to grasp correctly the position and form of buried object. Then, this research describes the shape of transmitting waveform that is important in deconvolution process. It checks that vertical resolution improves by proposing method. [C1115]

"Radar measurements of ice sheet thickness of outlet glaciers in Greenland"

We have conducted airborne measurements over the Greenland ice sheet from the NASA P-3B aircraft using a 150-MHz coherent radar depth sounder to obtain extensive ice sheet thickness measurements. Simultaneous measurements of ice sheet elevation were also made using a laser altimeter. In outlet glacier areas along the ice sheet margin, the ice surface is characterized by a very rough, crevassed surface near the calving front. The rough ice surface generates signal clutter, which can mask the bottom echo. We are developing a technique to remove the surface clutter component from the signal to reveal the bottom echo, providing a complete ice thickness survey to the calving front of outlet glaciers. This technique makes use of a dense array of ice surface elevation measurements provided by the laser altimeter to characterize surface roughness. Surface roughness parameters are then used in a backscatter model to characterize the clutter waveform, which can be subsequently removed from the radar signal. [C1116]

"Modeling lidar and radar returns of forest canopies for data fusion"

Radar backscatter and lidar waveform models, which are based upon a common three-dimensional forest stand structure, are parameterized using realistic forest physical stands to produce a dataset of forest structural parameters and lidar/radar responses. This paper briefly describes some preliminary results in the studies of the sensitivities of models to forest spatial structure, the relationship between radar backscattering and the lidar measurements for various forest stands, and the potential of radar and lidar data fusion for forest structure characterization and biophysical parameter estimation. [C1117]

"An airborne CryoSat prototype: the D2P radar altimeter"

Through airborne flight tests over the ocean and the ice of southern Greenland, we have successfully demonstrated the technical viability and waveform characteristics of an innovative radar altimeter concept (D2P), the first of its kind. The D2P takes advantage of range-curvature-corrected, multi-look Doppler processing along-track, and interferometric angle measurement across-track. The radar's performance met or exceeded expectations. The D2P radar serves as an airborne prototype of CryoSat. [C1118]

"Passive coherent location radar demonstration"

This paper describes a passive coherent location (PCL) radar system developed by Dynetics, Inc. This system uses commercial FM broadcast signals for the radar waveform. This paper presents a technical description of the system and performance data. [C1119]

"Analysis of radial velocity effect on synthetic range profile of stepped-frequency waveform"

The stepped-frequency waveform is able to obtain large effective bandwidth by sequentially changing the carrier frequency in steps over pulses. However, this waveform is very sensitive to the radial velocity between the radar and the target. In this paper, the effect of the radial velocity on the synthetic range profile is discussed first, and then the range spread in terms of the processed range bin is defined differently from others, which is validated by the simulation. Furthermore, the relation between the processed range bin and the range resolution is also discussed. [C1120]

"A multiwavelength airborne polarimetric lidar for vegetation remote sensing: instrumentation and preliminary test results"

Several spaceborne and airborne lidar systems have been launched for vegetation canopy studies. Previous research has shown that lidars are useful tools for remote sensing of vegetation architecture. To support its Airborne Remote Sensing Program, the University of Nebraska has developed a multiwavelength airborne polarimetric lidar system. This system employs a Nd:YAG laser which emits radiation at two wavelengths: the fundamental at 1064 nm and the frequency-doubled at 532 nm. Both laser beams are highly linearly polarized (100:1 extinction ratio) and have a beam divergence angle of 4 mrad. The receiver consists of four channels, which enable dual-wavelength and dual-polarization detection. In addition to the polarimetric information that could be gathered, this lidar system also has ranging capability and is able to record the whole lidar waveform. Thus, our lidar is capable of performing studies of vegetation canopy structure as well as characterization of vegetation depolarization. The system has been packaged to fly aboard a Piper Saratoga aircraft from a height of 1000 m. In this paper, we will present the details of the lidar system design, instrumentation, the system alignment and preliminary ground test results. [C1121]

"Using SHOALS LIDAR system to detect bottom material change"

Bathymetric lidar systems, e.g., the Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) have a proven capability to measure water depth accurately. Although the system is optimized for depth retrieval, there is much more than depth information since the data stream (waveform) includes backscatter from the water surface and water column as well as the bottom return. This paper uses the amplitude of the bottom return signal to characterize the illuminated bottom materials. It is found that, while there are changes in the bottom return that clearly correlate with changes in bottom type, the bottom slope and surface waves have significant effects on the bottom return. These factors can distort the recorded waveforms and alter the apparent reflectance of illuminated materials, and must be accounted for if changes in bottom type are to be detected. [C1122]

"Optimal sampling of linear FM and conversion to digitized waveform having predictable sidelobe patterns"

Several advantages are achieved when discrete phased codes are used instead of continuous waveforms. The

discrete structure of the phase code signal enables one to increase the freedom of waveform design when pulse compression scheme is considered. This may lead to an arbitrary design of the resultant sidelobe patterns and possibly wide dynamic range responses can be achieved for various applications. This paper shows how a particular sampling rate for linear FM signals may lead to a significant reduction of the peak sidelobe level (PSL) as well as the integrated sidelobe level (ISL) in pulse compression operation [C1123]

"Radar waveform design and target detection using wavelets"

The projection of the conventional radar waveform in wavelet space is comparatively complex, which complicated the wavelet decomposition of the radar waveform. A novel radar waveform design method is proposed. The proposed approach uses the wavelet function of a specific scale as the waveform and thus the inter-dependency of the wavelet coefficients in different subspaces is reduced. Better detection performance is achieved when only two wavelet decomposition coefficients are used. Through theoretical analysis and simulation results it is shown that the proposed approach has improved adaptation to non-stationary noise and the echos of the large target has a smaller negative effect on the adjacent range cell [C1124]

"A comparison of PRN and LFM waveforms and processing in terms of the impact on radar resources"

The radar resource impact of using either linear frequency modulation (LFM) or pseudo-random noise (PRN) waveforms is investigated for the case when the radar duty is a limiting factor. It is shown that for large time-bandwidth and low range sidelobe (RSL) requirements, a PRN waveform can be selected that will not increase the radar duty, while LFM will always increase the radar duty. For low time-bandwidth product and moderate RSL requirements LFM will generally have less impact on radar duty than PRN. For moderate time-bandwidth product requirements the impact will be scenario dependent and the difference in radar duty may be outweighed by other considerations [C1125]

"Doppler properties of polyphase pulse compression codes under different side-lobe reduction techniques"

Polyphase codes derived from linear-frequency-modulation, such as P3 and P4 codes, are a common class of pulse compression waveforms. Several side-lobe reduction techniques have been proposed which can be used for those codes. This paper shows and compares the Doppler response performances of P3 and P4 codes when several different side-lobe reduction techniques are employed, including the output peak side-lobe level (PSL) and the signal-to-noise ratio (SNR) loss. Some simulation results are shown [C1126]

"Pole patterns of radar-target scattering model based on ultra-wideband Gaussian pulses"

Time domain and frequency domain analysis of a radar-target scattering model based on ultra-wideband Gaussian pulses are presented. The scattering model is a useful tool for computing the range profile, or image, of a complex target that is illuminated by electromagnetic impulses. Computer plots of range profiles and pole patterns are obtained for a complex target that is composed of a finite number of scattering centers. The range profiles and the pole patterns are valuable information for radar-target classification and identification [C1127]

"A novel transmit signal based on high range-resolution concept for FLAR or AICC system applications"

In this paper, a coded stepped-FMCW signal for mm-wave automotive collision warning radar (FLAR or AICC systems) applications is proposed, which offer high range resolution and multiple target detection probability, and good anti-interference capability can be obtained as well. The waveform is easy to generate digitally and its signal processing reduces the requirement of computational speed compared to conventional high resolution radars. We also suggest an error approach algorithm for multiple vehicle target detection and confirm its usefulness in eliminating false targets by computer simulation [C1128]

"Analysis and experimental results on sparse-array synthetic impulse and aperture radar"

Sparse-array synthetic impulse and aperture radar (SIAR) is a new concept of 4D radar, based on the use of a transmit array, simultaneously radiating a set of orthogonal waveforms, and of a reception array, delivering sampled signals to a processing equipment, dedicated to Doppler filtering, time-space beamforming (including a transmitting beam and a receiving beam by calculation), and target extraction, thus, it can isotropically radiate. This radar adopt sparse arrays to improve its angle resolution. This paper introduces the principle of the SIAR, discusses some questions (including optimization of the frequency coding of the transmitting signal. to eliminate the coupling effects between distance and angles, a low-range-sidelobe technique based on frequency-coding

agility among these frequencies and application of large time-bandwidth signals) and presents a description of the experiment system. Finally, some experiment results are given. Moreover, the strong agreement observed on both experiment and theoretical results [C1129]

"New anti-jamming waveform designing and processing for HF radar"

In this paper several typical HF radar waveforms are synthetically analyzed and compared. To improve the low system resolution and weak anti-jamming ability that the conventional HF radar meets with, a new waveform with interrupted spectra is presented. By cutting off the interference band based on the results of the spectrum surveying system before transmitting, the HF radar could make use of some fractional silent spectra. Processing such a waveform using the method of FFT would result in a very high sidelobe and thus may greatly degrade the HF radar's performance. We introduce a new signal processing method based on the least square technique to lower the sidelobe. It is easy for processing and application. Simulation results show that this method could successfully suppress the sidelobe with high resolution in the congested electromagnetic environments [C1130]

"Use ultra wideband radar systems for increase information about target"

This review paper discusses the differences of ultra wideband (UWB) radar from conventional narrowband radar. The generation, radiation and processing of UWB radar signals evoked by change of signal waveform in processing of location, by appearance of the mutual dependence between signal waveform and antenna directivity are shown. The reception of the target radioimage is shown [C1131]

"Improved wideband time delay beam-steering"

Radars use wideband waveforms for high-resolution imaging. To avoid bandwidth dispersion effects, time delay beam-steering must be used to steer large arrays to off-broadside angles. Unfortunately, analog time delay units (TDUs) traditionally used for this purpose can be costly and bulky. Furthermore, they typically require temperature stabilization, and deliver only quantized delays. This paper describes a method for implementing time delay beam-steering without analog TDUs. Our method works at narrowband digital processing rates, leading to affordable wideband arrays. In essence, our method is a multichannel extension of the well-known "stretch processing" technique. It improves upon other published extensions by eliminating their range-dependent losses. This latter characteristic is crucial in applications wherein high resolution images are desired across extended range regions [C1132]

"Adaptive power-managed FMCW emitter detection performance against low-RCS ships"

The design of a modern 9.3 GHz homodyne triangular-FMCW emitter for detection of low radar cross section (RCS) ships is described. Both searchand track-mode processing are described including a description of transmit and receive waveforms. Tradeoffs in emitter design are examined as a function of the modulation bandwidth. To predict target detection capability, clutter and target models are developed as the emitter is flown at 300 m/s in a scenario that starts at a range of 15 nmi from the target. To evaluate the feasibility of detecting low RCS ships at the horizon, a low-RCS ship design is examined. Each sea state (0-4) is characterized by using a second-order polynomial that describes the normalized mean sea backscatter coefficient as a function of the grazing angle. The emitter transmit power is adapted in time to measure the target characteristics. The emitter transmit power level is consistent with the RCS and range to the target while keeping a target-to-clutter power ratio at 20 dB. For detection analysis, 50, 100 and 500 m2 RCS values are considered [C1133]

"Neural Method for Two Dimensional (2D) High Contrast Imaging in Pulsed Laser Radar"

In this paper we have developed a new imaging method which can obtain the grey levels directly from the output waveform of Pulsed Laser Radar (PLR). A simple digital signal processing technique and multi layer perceptrons (MLP) type neural network (NN) have been used to obtain the grey level information from the pulse shapes. The method has been implemented in a real PLR to improve contrast and speed of 2D imaging in PLR. For comparison with the standard method, a picture consisting of 16 grey levels (from 0 for black to 1 for white) using both methods. Because of the ability of NNs in extracting the information from nonlinear and noisy data and pre-processing of the noisy input pulse shapes to the NN, the average and maximum errors in the grey levels in comparison with standard method more than 88.5% and 72.6% improved, respectively. Because in this method the effect of the noise is decreased, it is possible to make to image at the same resolution as in standard method with lower averaging in the sampling unit and this dramatically increases speed of the measurements. [C1134]

"A low voltage portable system using modified Golay sequences"

For outstanding portability, recently proposed handheld, portable ultrasound systems, which provide excellent image quality as well as portability and patient accessibility, employ the battery-powered devices. However, they suffer from low signal-to-noise-ratio (SNR) due to limited transmit power. In this paper, we propose a low voltage portable system using modified Golay sequences which can increase SNR. To verify the proposed system, we modified a commercial ultrasound scanner to derive coded waveforms and to acquire rf-data. We performed. experiments using Modified Golay sequences and conventional pulse-echo signals and images from mimicking phantom were acquired. For Modified Golay sequences with length 8 (2.1 μsec), experimental results showed that actual SNR gain was about 10.03 dB compared to conventional pulse-echo system with the same voltage (VPP=10 V). Compared to a conventional one with high voltage transmit (VPP=80 V), the proposed system using the Modified Golay sequences with length 32 (8.3 μsec) provided a comparable SNR and penetration depth with low peak voltage (VPP=10 V) [C1135]

"Efficient radar target classification using modular neural networks"

A radar target classifier based on modular neural networks is presented and its performance compared with that of a classifier based on non-modular neural networks. In this classifier, the response from an unknown target is sent to several waveform predictors that are BP neural networks trained by responses from known targets. The predictor errors are then sent to a classifier using the rule of maximum a posteriori or the rule of modified minimum squared errors. The simulation shows that the new classifier has a good performance on radar target recognition. The method also has other advantages such as easy realization, clear structure and easy expansion [C1136]

"Filtering coded waveforms-the effect and correction"

This paper examines the effect of filtering a coded waveform, and develops methods for correction of errors that the filter introduces. The spectral response of coded waveforms have significant spectral components outside the half power bandwidth, these components are corrupted when filtered by a typical radar receiver. Radar receiver digitisers generally sample such coded waveforms at the same rate as the code, which creates ambiguities in the spectral response and hence complicates correction. This paper analyses the effect that a filter has on coded CW radar waveforms with perfect periodic correlation functions by examination of the resultant sampled response and the correlation function. Techniques to derive simple spectral correction masks are then examined and results are produced for measured and theoretical filter responses [C1137]

"Design and implementation of an ultra-wide band pulse compression signal generation system"

The generation of ultra-wide-band pulse compression signals is a very important technology for microwave imaging, buried targets detection, and target identification. Direct digital waveform synthesis (DDWS) enables the waveform agility to be realized easily, and the signal bandwidth can be enlarged by additional orthogonal modulator and double frequency chain circuits. An ultra-wide-band pulse compression signal generation system is introduced, which generates LFM/NLFM signals with a 400 MHz bandwidth at 1200 MHz radio frequency. The test results show that spurious components and harmonics below -55 dB and -50 dB respectively [C1138]

"Effects of RFI on UWB-SAR using LFM waveforms"

The dual requirement of ultra-wide band synthetic aperture radar (UWB-SAR) for high range resolution and low frequency penetration proposes the problem of radio frequency interference (RFI) suppression. Although careful design of the receiver hardware can reduce this difficulty, a great amount of RFI will still distort the actual target returns. The effects of RFI on both of the design of hardware and the task of signal processing are studied. We focus our analysis on the basic pulse compression in linear frequency modulated (LFM) UWB-SAR. The output of a typical sinusoidal RFI after pulse compression is derived and proved to be closely related to the frequency of the RFI. Computer simulations successfully verify our conclusions [C1139]

"Conical scan step-frequency radar signal processing"

The conical scan step-frequency radar waveform has the ability of both high range resolution and angle measurement. The characteristics and structure of this waveform are discussed in detail, and the close coupling process method which can estimate the angles of close range targets is given. This is proved by computer simulation and practical experiments. The effects of noise and velocity are also discussed [C1140]

"Coherence time and statistical properties of the GPS signal scattered off the ocean surface and their impact on the accuracy of remote sensing of sea surface topography and winds"

A GPS transmitter-receiver pair forms a bistatic radar for ocean remote sensing when the receiving platform

carries a down-looking antenna capable of collecting the GPS signal scattered off the ocean surface. The average received power versus time is derived as a function of viewing geometry, system parameters and ocean state. This waveform is crucial for the derivation of the sea surface topography (from its leading edge) or wind speed and direction (from its trailing edge). In predicting the accuracy of either measurement it is important to understand how accurately the average power can be determined in practical situations. This starts with the determination of the coherence time of the scattering, over which the received signal can be integrated for optimal signal to noise ratio. Additionally, the real signal is affected by self-noise which introduces variability from one sample to another. This work examines the coherence properties of the modeled received power as a function of sea state and scattering geometry. In particular the coherence time variability between leading and trailing edges is addressed, and its impact on the accuracy of either sea surface topography or wind speed and direction measurements is addressed. In particular, having determined the integration time necessary to produce independent samples, the incoherent summation time required for a given measurement accuracy is derived. Furthermore, the lag-to-lag correlation is addressed, leading to a covariance analysis formulation for the formal error in height retrieval [C1141]

"Best management of FM waveform by a missile-borne pulsed Doppler radar during high-manoeuvring target tracking in strong clutter environment"

Referring to the application of missile-borne pulsed Doppler radars, the use of a radiofrequency HPRF-FM seeker, having a monopulse tracking processing, is considered in scenarios with a low altitude flying high-manoeuvring target. During target tracking the seeker has to solve the situations when the clutter signal occupies the target frequency positions and tracking can be lost. The algorithm that is presented shows how to dynamically choose an optimum FM factor, so to reduce clutter disturbing effects and to maintain a stable target tracking [C1142]

"Selection of the radar waveform from tracking considerations"

The conventional approach for tracking system design is to treat the sensor and tracking subsystems as completely independent units. However, the two subsystems can be designed jointly to improve system (tracking) performance. It is known that different radar signal waveforms result in very different resolution cell shapes (for example, a rectangle versus an eccentric parallelogram) in the range/range-rate space, and that there are corresponding differences in overall tracking performance. We develop a framework for the analysis of this performance. An imperfect detection process, false alarms, target dynamics and the matched filter sampling grid are all accounted for, using the Markov chain approach of Li and Bar-Shalom (1991). The role of the grid is stressed, and it is seen that the measurement-extraction process from contiguous radar “hits” is very important. A number of conclusions are given, perhaps the most interesting of which is the corroboration in the new measurement space of Fitzgerald's (1974) result for delay-only (i.e., range) measurements, that a linear FM upsweep offers very good tracking performance [C1143]

"Families of waveforms with good auto and cross ambiguity properties"

We address the problem of constructing frequency hop pulse trains for use in multiuser radar and sonar systems. We suggest a new construction of a family of frequency hop waveforms with nearly ideal autoambiguity function and low crossambiguity properties across the entire family of waveforms [C1144]

"Using neural networks for high resolution distance measurements in pulsed laser radar"

We have developed a new distance measurement method which can obtain distance information directly from the output waveform of pulsed laser radar (PLR). A simple digital signal processing technique and multilayer perceptrons (MLP) have been used to recognize the pulse shape and to obtain the distance information. The method has been implemented in a real PLR for high resolution distance measurements to improve the resolution and to decrease the nonlinearity error. Because of the ability of neural networks in decreasing the noise and preprocessing of the noisy input pulse shapes to the neural network, resolution and nonlinearity were greatly improved. Distance deviation of 53 μm-168 μm, full width at half power (FWHP) of 70 μm-190 μm and non-linearity of 187 μm have been achieved. All the measurements in the same situation has been performed by using the standard method to extract the distance information from time interval between the reference pulse and the reflected pulse. In comparison with the standard method, resolution in the best case and non-linearity were improved by 86% and 6.5% respectively. In this method if the PLR system is reasonably stable during the measurement, it is possible to use only the reflected pulse from the target to extract the distance information and this makes PLR simpler in hardware. Because the neural network decreases noise, it is possible to make the measurements with the same resolution of standard method but with the lower averaging in sampling unit and this dramatically increase the speed of the measurement [C1145]

"A numerical waveform design approach to decorrelate target and noise"

Traditional radar detection relies on predefined models for assessment of probability of detection and probability of false alarm. These models assume a target uncorrelated with clutter or other sources of interference. This assumption concerning decorrelation between the target and interference is not strictly true. We propose an iterative approach to design “optimal” waveforms that maximally decorrelate target and clutter returns while still keeping target signal-to-interference-plus-noise ratios (SINR) levels maximized [C1146]

"Clutter suppression in radar by quasi-continuous complex signal and processing algorithm structure optimization"

The synthesis algorithm of a pair of signal-linked filters for navigational radars with one antenna using a complex amplitude-phase modulated waveform of long duration with coherent processing in the receiver is considered. A harmful influence of the ambiguity function (AF) sidelobes on target detection and parameter measurement is a significant obstacle to using the long pulse duration complex modulated waveform in marine radars. We discuss waveforms and linked processing for clutter suppression by means of AF sidelobe reduction. Some relationships for the quasi-continuous complex signal synthesis of amplitude-phase modulated waveform (APW) are given. The received signals are processed by a mismatch filter. The synthesis criterion of the mismatch filter structure was a root mean square minimization of the output signal sidelobe level. The computer synthesis software of the quasi-optimum mismatch processing structure has been developed. We give some examples of the waveform and mismatch algorithms of their professing which could be used in marine and coastal radars for surveillance of surface targets and navigation [C1147]

"MFR surveillance optimisation-a pragmatic systems engineers' approach"

This paper summarises a study undertaken as a segment of an MOD Corporate Research Programme project run by the then-named DERA. A multi function radar (MFR) offers great opportunity to vary radar parameters, waveforms and signal processing, in real time, in response to the environment and the required performance, in order to optimise the use of energy and time. Many experts in the field of radar take a view that this optimisation process is extraordinarily challenging because there are many, inter-related parameters that can be varied. This study postulates that such a view might be overly pessimistic and that performance is relatively insensitive to many of the parameters so that "fine tuning" is unnecessary. We set out, therefore, to determine which parameters are the most rewarding ones to adjust on a continuous basis. Having determined these, we attempted to define rules of thumb or empirical relationships that could be employed as simple system rules. It was, therefore, a pragmatic, systems engineers' approach to solving a potentially complex problem. [C1148]

"Waveform optimisation for efficient resource allocation in airborne AESA radar systems"

In an AESA radar, highly efficient search and track operations can be achieved when the agile beam-steering capability of the E-scan antenna is used to implement an alert-confirm target detection and acquisition strategy, and dynamic management is employed to optimise the resources devoted to track maintenance. The full operational benefits are best realised when multiple waveforms, individually optimised for search detection, for target confirmation/track formation and for track maintenance are employed. Furthermore, an appropriate balance in characteristics and performance must be established between these waveforms in order that radar resources are used efficiently. Criteria guiding the choice of waveforms for air-to-air search, target confirmation and tracking functions in an airborne AESA radar are discussed, and an approach to determining the optimum balance of waveform sensitivities described. The level of performance improvement possible is illustrated for a typical example, using results from an AESA radar simulation and performance model. [C1149]

"A digital signal processor for Doppler radar sensing of vital signs"

A voltage waveform signal containing respiration and heartbeat signatures is low-pass filtered (0.7 Hz) for the respiration and band-pass filtered (1.0-3.0 Hz) for the heart signal. The autocorrelation function is used to calculate the rate per minute for each of these signals. To make the processor more robust, several signal processing techniques are applied. One of these techniques, a method commonly used on audio signals for formant removal, is called center clipping. Another technique is the use of a Hanning window. To reverse the distinct shape left by the Hanning window an "undo" window is applied. The processor is programmed in LabVIEW. [C1150]

"Optimal waveforms and processing for sparse frequency UWB operation"

Spectrum notching on transmit is crucial to the deployment of UWB FOPEN SAR radars. However, it results in

high peak and integrated sidelobes, which translate to loss in received image quality. In order to recover the image quality, we “fill-in” the effects of the frequency notches using the Burg algorithm, before the final image formation [C1151]

"Bistatic surveillance concept of operations"

Space-based radars are being considered for civilian and military surveillance of ground and air moving vehicles because of their worldwide field of regard, and their inherent potential for surveillance of locations denied to other radars for political or geographical reasons. Monostatic radars will provide detection and tracking of moving objects, but are limited by affordable aperture sizes to large target cross sections or infrequent revisit rates. Several authors have postulated that bistatic operation between a space-based illuminator and airborne receiver is one effective method of improving on these limitations. However, the ability to fully utilize the area coverage rate of the bistatic hybrid space-based radar is limited by a small receiver footprint as compared to the spaceborne transmitter. This paper develops the bistatic area coverage radar range equation, as compared to the monostatic equivalent. A description of multibeam receiver operation is presented along with the radar signal processing to provide the necessary signal-to-noise ratio for target detection. Finally, a first-order consideration of the waveform design approach to enable bistatic STAP processing for target detection is presented [C1152]

"Bistatic radar denial/embedded communications via waveform diversity"

Use of an interferometer along with a host radar is proposed for simultaneously achieving coherent reference denial and embedded communications. To prevent self-jamming, spatial orthogonality is achieved between the interferometer antenna pattern and main beam of the host radar. Costas and orthogonal frequency division multiplexing (OFDM) signals are suggested for the host radar and interferometer, respectively. The effectiveness of the interferometer masking signal on a non-cooperative bistatic radar is discussed [C1153]

"Ultra-wideband for navigation and communications"

Precision coordinated maneuvering of multiple space vehicles would offer significant performance advantages to both commercial and scientific missions by increasing the versatility and potential capabilities of the formation. Ultra-wideband systems can provide centimeter level accuracy ranging measurements over distances of kilometers, using only milliwatts of power from an omni-directional transceiver no bigger than a pager. Using these precise range measurements between the vehicles, it is possible to resolve the relative geometry of the entire formation. The ultra-wideband (UWB) system presented in this work is not RADAR; it is active ranging over a code divisible multiple access (CDMA) communications channel with no carrier frequency. Each transceiver is given a unique pseudo-random noise code, which is broadcast using pulse position modulation (shifting pulses or monocycles forward or backward in time relative to an constant rate pulse train), in a type of call and return scheme to measure time of flight between vehicles. As a byproduct of CDMA encoding, a UWB navigation system could also provide a megabit per second communications channel to each vehicle, providing further savings of power, weight, and cost. A simple ranging experiment has been designed as a proof of concept. The experiment includes bench top equipment for sending and receiving ultrawideband monocycles and post processing algorithms for determining range. To implement the system, it was necessary to design and develop ultra-wideband antennas to efficiently propagate the monocycle pulses with minimal distortion. These antennas were tested in an anechoic chamber constructed for the ranging experiment and data on their characterization is presented in this paper. This paper presents the experimentally derived ranging accuracies and compares them to theoretically derived ranging accuracies for the UWB based measurement. It also provides a characterization of the distortions encountered in the pulse waveform during transmission and reception from our custom antennas. UWB ranging systems offer a robust solution to relative vehicle navigation in a variety of space mission configurations [C1154]

"Suppressed ambiguity in range by phase-coded waveforms"

In Doppler radar for surveillance and remote sensing, the ambiguities in range/Doppler are usually solved by varying the pulse repetition frequency. In this paper, two alternative methods are discussed based on phase-coding and orthogonal waveforms. The first one distributes a phase code over a pulse sequence with only one phase step per pulse. The received pulses are correlated with the phase code sequence, and by varying the delay of the phase code, the subintervals in range are scanned and reflector responses outside the focused range interval become highly suppressed. The alternative method that was studied applies a set of near-orthogonal phase codes, which modulate the pulses transmitted. In the receiver, the different subintervals in range are scanned, or detected in parallel, by correlating the signal from the scene by the delayed code sequence of the pulse transmitted. Because orthogonal codes are used, a strong suppression is achieved for signals originating outside the focused subinterval in range [C1155]

"Optimization of waveform and detection threshold for target tracking in clutter"

We formulate an optimization problem to obtain the combined sequence of waveform parameters (pulse amplitudes and lengths, and FM sweep rates) and detection thresholds for optimal target tracking in clutter. The optimal combined sequence minimizes a tracking performance index under a set of parameter constraints. The performance index can include the probability of track loss and the estimation accuracy. The effect of the false alarms and clutter interferences is taken into account in quantifying the performance index. A measurement model is developed based on the resolution cell in the delay-Doppler plane for a Gaussian pulse. Numerical experiments were performed to solve the optimization problem for several example problems [C1156]

"Satellite altimetry-implied sea ice distribution in the Weddell Sea, Antarctica"

We investigated the distribution of sea ice using Topex/Poseidon(T/P) and ERS-1 radar altimeter data in the northwest Weddell Sea, Antarctica, between the area 45-75°W and 55-66°S. Using the Geo_Bad_1 flag of the Merged GDR of Topex/Poseidon, we classified the surface into ocean, land, and sea ice based on the return waveforms. A total of 257 cycles of altimeter measurements between Oct. 1992 and Sep. 1999 (for nearly 2570 days) were analyzed to visualize the distribution of sea ice. We then calculated the surface area of ice coverage using SUTM20 map projection to quantify the periodic variations. Each year, the maximum and minimum coverages of sea ice were found in early October and March in the study area, respectively. We also studied the sea ice distribution using ERS-1 altimeter data between 45-75°W and 55-81.5°S. Using the valid/invalid flag of the ocean product, we studied the sea ice distribution between March and August of 1995, which showed very good coherence with the T/P measurements [C1157]

"A synthetic moving target generator for calibration of Radarsat 2 Moving-Object Detection Experiment (MODEX)"

The Moving-Object Detection Experiment (MODEX) of the Radarsat 2 platform will allow object motion extraction and measurement by partitioning the radar antenna into fore and aft apertures. Accurate extraction of object motion requires compensation to produce two equivalent radar channels. Calibration of MODEX signals is best accomplished by a transponder that receives and measures the signal transmitted by the satellite and uses the captured radar waveform to generate moving point-target signals with precisely known properties. We are proposing to use a computed approach to implement a synthetic target generator (STG) as a transponder for the motion calibration of Radarsat 2 MODEX. With this approach, the incoming pulses are digitized, manipulated using a fast digital signal processor (DSP) to synthesize signals simulating moving point-targets, and then converted back to analog for transmission. This paper reviews theoretical considerations for the synthesis of moving-object signals, demonstrates the concepts with simulations, and discusses implementation issues [C1158]

"A new estimator of the sea state bias using a three frequency radar altimeter"

This work deals with the estimation of the sea state bias (SSB). We performed a method to compute an altimeter return waveform from a deterministic sea surface [Amarouche et al. 2000]. To simulate the SSB, the sea surface characteristics and the electromagnetic model have been modified in agreement with statistical and physical theories and observations [Amarouche et al. 2000]. The conclusions of this study allow us to propose an estimator of the SSB using three frequency bands. Our simulator is tested using the performance budgets of Poseidon-2 (C and Ku bands) and AltiKa (Ka band) radar altimeters. The SSB is estimated with a bias of the order of about one millimeter and a noise of the same order of magnitude as the height estimation noise. The importance of the significant wave height estimation in determining the SSB, led us to propose a method to improve this estimation by studying the point target impulse response approximation by a Gaussian shape in the waveform model [C1159]

"Reduction of cardinal effects in SAR imagery of densely populated urban areas by suppressing strong multiple returns"

In SAR imagery, strong returns from a group of man-made reflectors obscure adjacent target areas leading to a significant loss of information. The wide dynamic range of response levels from urban area is the source to degrade the SAR image characteristic. In this paper, we explore a way to interpret this problem in SAR imaging and propose a waveform design technique to improve target detection performance [C1160]

"Synthetic aperture sonar-the modern method of underwater remote sensing"

Synthetic aperture processing-the coherent combination of data from multiple returns-has revolutionized radar

imaging over the past 35 years. Sonar is in the early stages of the same revolution. Synthetic aperture sonar (SAS) data can be processed into images with resolution independent of range. Additionally, within diffraction limits, the resolution is frequency independent. Such characteristics make SAS a useful tool for applications such as bottom searching and mapping, mine hunting, or submarine detection, for near ranges (~50 m), mid-ranges (several hundreds of meters), and far ranges (several tens of kilometers) respectively. We have SAS-processed data collected by eleven different hardware suites at frequencies ranging from 240 kHz down to 600 Hz; physical array sizes ranging from half a meter to 256 meters; and with range-independent azimuthal resolutions ranging from 2.5 cm at 50 m for the high frequency systems to ~6 m resolution at 26 km for the lowest frequency system. Our results demonstrate that phase coherence can be maintained in spite of severe vehicle motion, medium fluctuations, and multipath propagation. For instance, we imaged the interior structure of a sunken airplane at 350 m and at 1,000 m with similar cross-range resolution, despite the rays having suffered a bottom bounce on both the transmit and return paths for the 1,000 m range data. The same imaging technology is applicable to cross-track interferometry (for resolving vertical features), bottom penetrating sonar, and wideband waveforms [C1161]

"Markov modeling of transient scattering and its application in multi-aspect target classification"

Transient scattered fields from a general target are composed of wavefronts, resonances and time delays, with these constituents linked to the target geometry. A classifier applied to transient scattering data requires a statistical model for such fundamental constituents. A Markov model is employed to characterize the transient scattered fields-for a set of target-sensor orientation over which the transient scattering is stationary-utilizing a wavefront, resonance, time-delay "alphabet". The Markov model is utilized in a classifier developed for multi-aspect transient scattering data, with a hidden Markov model (HMM) employed to address the generally non-stationary nature of the multi-aspect waveforms. Each state of the HMM is characteristic of a set of target-sensor orientations for which the scattering statistics are stationary, the statistics of which are characterized via the Markov model. The wavefront, resonance and time-delay features are extracted via a modified matching-pursuits algorithm [C1162]

"Training the children wavelets to recognise waveforms within non-stationary signals"

Many authors have developed methods for automatic recognition and classification of signal patterns based on wavelet transforms and wavelet theory. However so far a method to find the wavelet family that best fits a particular class of signals is yet not evolved. We present a new method based on a combination of wavelet analysis and the training method used in the field of artificial neural networks. We define a training process applied to a family of wavelets and intended to optimise the pattern detection and location capabilities when applied to a particular class of signals. We also demonstrate how this method is used to detect and localise the interictal epileptic spikes within human EEG bio-signals [C1163]

"Non-iterative GPR imaging through a non-planar air-ground interface"

It is often advantageous to acquire pulse-echo ground penetrating radar (GPR) measurements from antennas that are offset from a non-planar air-ground interface by a non-negligible distance, either because the ground surface is rough, or because measurements must be collected remotely. To compensate for a non-planar air-ground interface, a modification of the plane-to-plane backpropagation algorithm is formulated for surface variations that are relatively smooth with respect to the radar waveform wavelengths. To facilitate this method, a technique for inferring the surface topography from the radar returns is developed. Finally, examples are given to demonstrate the improvement offered over other non-iterative imaging techniques [C1164]

"Simulation of wind speed retrievals from an orbiting bistatic GPS receiver"

Monte Carlo simulations were performed to predict the statistical errors in satellite based wind speed measurements using bistatic GPS signals. A scattering model based upon geometric optics and empirical ocean surface slope variances was used to simulate the mean post-correlation waveform. Synthetic Rayleigh scattered and thermal noise signals were generated. Batches of between 50 and 1000 independent samples were used in these simulations. The surface resolution was set to a radius of approximately 50 km through selection of range and Doppler bins [C1165]

"A wavelet packet basis optimization approach to radar waveform design"

We describe the process of convolving a transmitted wide bandwidth chirp signal with a simulated target and then show how the result of this convolution can be decomposed using a basis optimization approach algorithm. We then show how the wavelet packet basis set can prioritize the bandwidth in the chirp signal to those frequencies that represent the target while removing other frequencies that might contain clutter and noise.

Finally we compare the resulting radar signal to the signal not prioritized by the basis optimization and show improvements in the detection performance of the target at the reduced bandwidth [C1166]

"Wigner distribution detection and analysis of FMCW and P-4 polyphase LPI waveforms"

This paper examines the performance of the Wigner distribution in the detection of two low-probability of intercept (LPI) radar emitter waveforms: a triangular frequency modulation continuous wave (FMCW) and a P-4 polyphase code CW signal. Detection performance for signal-to-noise ratios (SNRs) of +10 dB, 0 dB, -10 dB, and -20 dB are examined. Results indicate that time-frequency processing can provide good detection of LPI waveforms even in the presence of a moderate amount of noise. [C1167]

"Detection and analysis of FMCW and P-4 polyphase LPI waveforms using quadrature mirror filter trees"

This paper investigates the performance of a quadrature mirror filter (QMF) in detecting two low-probability of intercept (LPI) emitter waveforms: a triangular frequency modulation continuous wave (FMCW) waveform and a P-4 polyphase code CW waveform. Detection performance for signal-to-noise ratios (SNRs) of +10 dB, 0 dB, -10 dB, and -20 dB is examined. Signal features that can be extracted are also quantified. Results indicate that QMF processing can provide good detection of LPI waveforms even in the presence of a moderate amount of noise. [C1168]

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