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ТЕМАТИЧЕСКИЙ РЕФЕРАТИВНЫЙ СБОРНИК № 22-1

“Complex Radar Signal Processing”
(«Обработка сложных РЛ сигналов»)

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"Fractional QCQP With Applications in ML Steering Direction Estimation for Radar Detection"

This paper deals with the problem of estimating the steering direction of a signal, embedded in Gaussian disturbance, under a general quadratic inequality constraint, representing the uncertainty region of the steering. We resort to the maximum likelihood (ML) criterion and focus on two scenarios. The former assumes that the complex amplitude of the useful signal component fluctuates from snapshot to snapshot. The latter supposes that the useful signal keeps a constant amplitude within all the snapshots. We prove that the ML criterion leads in both cases to a fractional quadratically constrained quadratic problem (QCQP). In order to solve it, we first relax the problem into a constrained fractional semidefinite programming (SDP) problem which is shown equivalent, via the Charnes-Cooper transformation, to an SDP problem. Then, exploiting a suitable rank-one decomposition, we show that the SDP relaxation is tight and give a procedure to construct (in polynomial time) an optimal solution of the original problem from an optimal solution of the fractional SDP. We also assess the quality of the derived estimator through a comparison between its performance and the constrained Cramer Rao lower Bound (CRB). Finally, we give two applications of the proposed theoretical framework in the context of radar detection. [J1]

"NL-InSAR: Nonlocal Interferogram Estimation"

Interferometric synthetic aperture radar (SAR) data provide reflectivity, interferometric phase, and coherence images, which are paramount to scene interpretation or low-level processing tasks such as segmentation and 3-D reconstruction. These images are estimated in practice from a Hermitian product on local windows. These windows lead to biases and resolution losses due to the local heterogeneity caused by edges and textures. This paper proposes a nonlocal approach for the joint estimation of the reflectivity, the interferometric phase, and the coherence images from an interferometric pair of coregistered single-look complex (SLC) SAR images. Nonlocal techniques are known to efficiently reduce noise while preserving structures by performing the weighted averaging of similar pixels. Two pixels are considered similar if the surrounding image patches are "resembling." Patch similarity is usually defined as the Euclidean distance between the vectors of graylevels. In this paper, a statistically grounded patch-similarity criterion suitable to SLC images is derived. A weighted maximum likelihood estimation of the SAR interferogram is then computed with weights derived in a data-driven way. Weights are defined from the intensity and interferometric phase and are iteratively refined based both on the similarity between noisy patches and on the similarity of patches from the previous estimate. The efficiency of this new interferogram construction technique is illustrated both qualitatively and quantitatively on synthetic and true data. [J2]

"Ship Surveillance With TerraSAR-X"

Ship detection is an important application of global monitoring of environment and security. In order to overcome the limitations by other systems, surveillance with satellite synthetic aperture radar (SAR) is used because of its possibility to provide ship detection at high resolution over wide swaths and in all weather conditions. A new X-band radar onboard the TerraSAR-X (TS-X) satellite gives access to spatial resolution as fine as 1 m. In this paper, first results on the combined use of TS-X ship detection, automatic identification system (AIS), and satellite AIS (SatAIS) is presented. The AIS system is an effective terrestrial method for tracking vessels in real time typically up to 40 km off the coast. SatAIS, as a space-based system, allows almost global coverage for monitoring of ships since not all ships operate their AIS and smaller ships are not equipped with AIS. The system is considered to be of cooperative nature. In this paper, the quality of TS-X images with respect to ship detection is evaluated, and a first assessment of its performance for ship detection is given. The velocity of a moving ship is estimated using complex TS-X data. As test cases, images were acquired over the North Sea, Baltic Sea, Atlantic Ocean, and Pacific Ocean in Stripmap mode with a resolution of 3 m at a coverage of 30 km 100 km. Simultaneous information on ship positions was available from TS-X and terrestrial as well as SatAIS. First results on the simultaneous superposition of SatAIS and high-resolution radar images are presented. [J3]

"Combination of Advanced Inversion Techniques for an Accurate Target Localization via GPR for

Demining Applications"

We used advanced ground-penetrating radar (GPR) inversion techniques for detecting landmines in laboratory conditions. The radar data were acquired with a calibrated vector network analyzer combined with an off-ground monostatic horn antenna, thereby setting up a stepped-frequency continuous-wave radar. Major antenna effects and interactions with the soil and targets were filtered out using frequency-dependent complex antenna transfer functions. The proposed strategy first exploits inversion approaches that are able to give an accurate characterization of the antenna-soil interaction and a reliable estimate of the soil permittivity. The outcomes of this first phase are at the basis of the application of a microwave tomographic approach based on the Born approximation to achieve the imaging of the subsurface. The algorithms were applied for imaging three landmines of different sizes and buried at different depths in sand. Although the radar system was off the ground, the results showed that it was possible to reconstruct all mines, including a shallow plastic mine as small as 5.6 cm in diameter. This last mine was invisible in the raw radar data, and the use of common GPR imaging techniques did not lead to satisfactory results. The proposed integrated method shows great promise for shallow subsurface imaging in a demining context, particularly because it automatically provides accurate information on the shallow soil dielectric permittivity. [J4]

"Multiregion Image Segmentation by Parametric Kernel Graph Cuts"

The purpose of this study is to investigate multiregion graph cut image partitioning via kernel mapping of the image data. The image data is transformed implicitly by a kernel function so that the piecewise constant model of the graph cut formulation becomes applicable. The objective function contains an original data term to evaluate the deviation of the transformed data, within each segmentation region, from the piecewise constant model, and a smoothness, boundary preserving regularization term. The method affords an effective alternative to complex modeling of the original image data while taking advantage of the computational benefits of graph cuts. Using a common kernel function, energy minimization typically consists of iterating image partitioning by graph cut iterations and evaluations of region parameters via fixed point computation. A quantitative and comparative performance assessment is carried out over a large number of experiments using synthetic grey level data as well as natural images from the Berkeley database. The effectiveness of the method is also demonstrated through a set of experiments with real images of a variety of types such as medical, synthetic aperture radar, and motion maps. [J5]

"Sparse representation-based synthetic aperture radar imaging"

There is increasing interest in using synthetic aperture radar (SAR) images in automated target recognition and decision-making tasks. The success of such tasks depends on how well the reconstructed SAR images exhibit certain features of the underlying scene. Based on the observation that typical underlying scenes usually exhibit sparsity in terms of such features, this paper presents an image formation method that formulates the SAR imaging problem as a sparse signal representation problem. For problems of complex-valued nature, such as SAR, a key challenge is how to choose the dictionary and the representation scheme for effective sparse representation. Since features of the SAR reflectivity magnitude are usually of interest, the approach is designed to sparsely represent the magnitude of the complex-valued scattered field. This turns the image reconstruction problem into a joint optimisation problem over the representation of magnitude and phase of the underlying field reflectivities. The authors develop the mathematical framework for this method and propose an iterative solution for the corresponding joint optimisation problem. The experimental results demonstrate the superiority of this method over previous approaches in terms of both producing high-quality SAR images and exhibiting robustness to uncertain or limited data. [J6]

"Estimating the parameters of sinusoids and decaying sinusoids in noise"

Picture a low earth orbit satellite hurtling around the earth in an 800 km orbit. At this altitude, the satellite travels about 7.5 km every second, and any signals between it and an earth terminal experience significant Doppler shifts. These frequency offsets must be estimated and removed at the earth terminal to enable successful communications with the satellite. As in this example, the estimation of the parameters of a sinusoid plays a fundamental role in a variety of applications ranging from seismology to radar and biological signals. Therefore, this problem has received, and continues to receive, significant attention in the literature. In power delivery systems, the estimation of the supply frequency is required for the monitoring of the system quality and the detection of faults [1], [2]. In nuclear magnetic resonance spectroscopy (NMRS), on the other hand, the signal is modelled as a sum of decaying complex exponentials whose frequencies and decay factors must be estimated [3]. [J7]

"Target localisation for distributed multiple-input multiple-output radar and its performance analysis"

This study considers the problem of target localisation with a coherent processing technique for distributed multiple-input multiple-output radar systems. To enable the coherent processing technique, dual-frequency transmitters are employed to eliminate the stochastic phases of complex fading coefficients, which are caused by target angular fluctuations. And then a two-step procedure is introduced to accomplish the target localisation. In the first step, the amplitudes of the complex fading coefficients are estimated. In the second step, the target position is obtained using the MUSIC algorithm with modified target steering vector. With the amplitudes estimated, the target localisation performance is improved. The Cramer-Rao bound (CRB) for target localisation accuracy is derived with precise knowledge of radar positions. The CRB is shown to be inversely proportional to the frequency difference between the transmitted signals. With the radar positions uncertainty, the average asymptotic performance of the proposed method is given. Finally, numerical examples are given to validate the proposed method and the theoretical analyses. [J8]

"Using EMD-FrFT Filtering to Mitigate Very High Power Interference in Chirp Tracking Radars"

This letter presents a new signal processing subsystem for conventional monopulse tracking radars that offers an improved solution to the problem of dealing with manmade high power interference (jamming). It is based on the hybrid use of empirical mode decomposition (EMD) and fractional Fourier transform (FrFT). EMD-FrFT filtering is carried out for complex noisy radar chirp signals to decrease the signal's noisy components. An improvement in the signal-to-noise ratio (SNR) of up to 18 dB for different target SNRs is achieved using the proposed EMD-FrFT algorithm. [J9]

"Accurate UWB Radar Three-Dimensional Imaging Algorithm for a Complex Boundary Without Range Point Connections"

Ultrawide-band pulse radars have immeasurable potential for a high-range-resolution imaging in the near field and can be used for noncontact measurement of industrial products with specular or precision surfaces, such as reflector antenna or aircraft fuselage, or identifying and locating the human body in security systems. In our previous work, we developed a stable and high-speed 3-D imaging algorithm, Envelope, which is based on the principle that a target boundary can be expressed as inner or outer envelopes of spheres, which are determined using antenna location and observed ranges. Although Envelope produces a high-resolution image for a simple shape target that may include edges, it requires an exact connection for observed ranges to maintain the imaging quality. For complex shapes or multiple targets, this connection becomes a difficult task because each antenna receives multiple echoes from many scattering points on the target surface. This paper proposes a novel imaging algorithm without range point connection to accomplish high-quality and flexible 3-D imaging for various target shapes. The algorithm uses an accurate estimation for the direction of arrival using signal amplitudes and realizes direct mapping from observed ranges to target points. Several comparative studies of conventional algorithms clarify that our proposed method accomplishes accurate and reliable 3-D imaging even for complex or multiple boundaries. [J10]

"Multiple-Input Multiple-Output Radar for Lesion Classification in Ultrawideband Breast Imaging"

This paper studies the problem of applying multiple-input multiple-output (MIMO) radar techniques for lesion classification in ultrawideband (UWB) breast imaging. Ongoing work on this topic has suggested that benign and malignant masses, which usually possess remarkable architectural differences, could be distinguished by exploiting their morphology-dependent UWB microwave backscatter. We have previously approached this problem by deriving the complex natural resonances of the late-time target response, where the damping factors vary with the border profiles of anomalies. In this paper, we investigate the potential advantage of MIMO radar to enhance the resonance scattering phenomenon in breast tissue discrimination. MIMO radar can choose freely the probing signals transmitted via its antennas to exploit the independence between signals at the array elements, thereby enhancing the performance of target classification. Based on the observed damping factors and the receiver operating characteristics at different classifiers, which correspond to various diversity paths in the MIMO radar system, two data-fusion rules are proposed for robust lesion differentiation. Finally, numerical examples are provided to demonstrate the efficacy of the proposed imaging technique. [J11]

"Two-Dimensional Imaging via a Narrowband MIMO Radar System With Two Perpendicular Linear Arrays"

This paper presents a system model and method for the 2-D imaging application via a narrowband multiple-input multiple-output (MIMO) radar system with two perpendicular linear arrays. Furthermore, the imaging formulation for our method is developed through a Fourier integral processing, and the parameters of antenna array including the cross-range resolution, required size, and sampling interval are also examined. Different from the spatial sequential procedure sampling the scattered echoes during multiple snapshot illuminations in inverse

synthetic aperture radar (ISAR) imaging, the proposed method utilizes a spatial parallel procedure to sample the scattered echoes during a single snapshot illumination. Consequently, the complex motion compensation in ISAR imaging can be avoided. Moreover, in our array configuration, multiple narrowband spectrum-shared waveforms coded with orthogonal polyphase sequences are employed. The mainlobes of the compressed echoes from the different filter band could be located in the same range bin, and thus, the range alignment in classical ISAR imaging is not necessary. Numerical simulations based on synthetic data are provided for testing our proposed method. [J12]

"Influence of Atmospheric Path Delay on the Absolute Geolocation Accuracy of TerraSAR-X High-Resolution Products"

Two coupled investigations of TerraSAR-X (TSX) high-resolution data are described in this paper: geometric validation, and estimation of the tropospheric path delay using measurements of corner reflectors (CRs) placed at different altitudes but nearly identical ranges. The CRs were placed within Alpine and valley sites in Switzerland, where terrain diversity provides ideal territory for geometric validation studies. Geometric validation was conducted using slant-range complex products from the spotlight and stripmap (SM) modes in ascending and descending configurations. Based on the delivered product annotations, the CR image positions were predicted, and these predictions were compared to their measuredimage positions. To isolate path delays caused by the atmosphere, six TSX SM scenes (~ 35 x 50 km) were examined containing four identical CRs with the same ranges and an altitude difference of ~ 3000 m. The CR arrangement made it possible to verify the annotated TSX atmospheric path delay by comparing the predicted slant range with the slant range obtained by measuring the reflector image coordinates. Range differences between the high- and low-altitude reflectors helped to quantify small variations in the path delay. Both SM and spotlight TSX products were verified to meet the specified accuracy requirements, even for scenes with extreme terrain variations, in spite of the simplicity of the atmospheric model currently integrated into the processor. Small potential improvements of the geolocation accuracy through the implementation of more comprehensive atmospheric modeling were demonstrated. [J13]

"Signals and Systems II Part I: Signals and their representations"

The goal of this series is a principles-based capability to design signal-processing architectures to convert signals between various forms. Signals are continuous-time or discrete-time, real or complex, and baseband or passband. Operations used on those signals include analog filtering, digital filtering, interpolation, decimation, and frequency shifts. The approach is rigorous but largely graphical with little explicit mathematics. [J14]

"High-Resolution Imaging Using a Wideband MIMO Radar System With Two Distributed Arrays"

Imaging a fast maneuvering target has been an active research area in past decades. Usually, an array antenna with multiple elements is implemented to avoid the motion compensations involved in the inverse synthetic aperture radar (ISAR) imaging. Nevertheless, there is a price dilemma due to the high level of hardware complexity compared to complex algorithm implemented in the ISAR imaging system with only one antenna. In this paper, a wideband multiple-input multiple-output (MIMO) radar system with two distributed arrays is proposed to reduce the hardware complexity of the system. Furthermore, the system model, the equivalent array production method and the imaging procedure are presented. As compared with the classical real aperture radar (RAR) imaging system, there is a very important contribution in our method that the lower hardware complexity can be involved in the imaging system since many additive virtual array elements can be obtained. Numerical simulations are provided for testing our system and imaging method. [J15]

"MST Radar Signal Processing Using Cepstral Thresholding"

The cepstrum thresholding approach for variance reduction is applied to estimate the spectrum of mesosphere-stratosphere-troposphere radar data, which are complex. Unlike in a real data case, where the cepstral values are real, for complex signals, cepstral values will be complex. We propose two different thresholding approaches: 1) applying a threshold independently for real and imaginary values of cepstral estimates and 2) threshold application to the modulus of cepstral estimates. Reductions of the total variance of the estimated spectra using the aforementioned two threshold approaches have been tested with simulated data. Finally, the algorithm has been applied to the practical atmospheric radar data to estimate the wind parameters through the computation of Doppler shift. Results have been validated using simultaneous Global Positioning System sonde data. [J16]

"Noncoherent MIMO Radar for Location and Velocity Estimation: More Antennas Means Better Performance"

This paper presents an analysis of the joint estimation of target location and velocity using a multiple-input

multiple-output (MIMO) radar employing noncoherent processing for a complex Gaussian extended target. A MIMO radar with Mtransmit and Nreceive antennas is considered. To provide insight, we focus on a simplified case first, assuming orthogonal waveforms, temporally and spatially white noise-plus-clutter, and independent reflection coefficients. Under these simplifying assumptions, the maximum-likelihood (ML) estimate is analyzed, and a theorem demonstrating the asymptotic consistency, large MN, of the ML estimate is provided. Numerical investigations, given later, indicate similar behavior for some reasonable cases violating the simplifying assumptions. In these initial investigations, we study unconstrained systems, in terms of complexity and energy, where each added transmit antenna employs a fixed energy so that the total transmitted energy is allowed to increase as we increase the number of transmit antennas. Following this, we also look at constrained systems, where the total system energy and complexity are fixed. To approximate systems of fixed complexity in an abstract way, we restrict the total number of antennas employed to be fixed. Here, we show numerical examples which indicate a preference for receive antennas, similar to MIMO communications, but where systems with multiple transmit antennas yield the smallest possible mean-square error (MSE). The joint Cramer-Rao bound (CRB) is calculated and the MSE of the ML estimate is analyzed. It is shown for some specific numerical examples that the signal-to-clutter-plus-noise ratio (SCNR) threshold, indicating the SCNRs above which the MSE of the ML estimate is reasonably close to the CRB, can be lowered by increasing MN. The noncoherent MIMO radar ambiguity function (AF) is developed in two different ways and illustrated by examples. It is shown for some specif--ic examples that the size of the product MNcontrols the levels of the sidelobes of the AF. [J17]

"Dual-Tree Complex Wavelet Transform Based SAR Despeckling Using Interscale Dependence"

In this paper, a dual-tree complex wavelet transform (DTCWT) based despeckling algorithm is proposed for synthetic aperture radar (SAR) images, considering the significant dependences of the wavelet coefficients across different scales. The DTCWT has the advantage of improved directional selectivity, approximate shift invariance, and perfect reconstruction over the discrete wavelet transform. The wavelet coefficients in each subband are modeled with a bivariate Cauchy probability density function (PDF) which takes into account the statistical dependence among the wavelet coefficients. Mellin transform of two dependent random variables is utilized to estimate the dispersion parameter of the bivariate Cauchy PDF from the noisy observations. This method is faster and effective when compared to that of the earlier techniques on numerical integration. Within this framework, we propose a new method for despeckling SAR images employing a maximum a posteriori estimator. Experimental results show that the proposed method based on bivariate Cauchy prior achieves better performance in terms of equivalent number of looks, peak signal-to-noise ratio, and Pratt's figure of merit. [J18]

"Temperature-Dependable Microwave Dielectric Model for an Arctic Soil"

Dielectric measurements of an organic-rich permafrost soil over the range from 1.0 to 16 GHz and from -30??C to +25??C are presented. The measured shrub soil contains up to 90% organic matter and is the first soil of this composition for which the soil dielectric has been characterized. The measurements were fitted to the generalized refractive mixing dielectric model (GRMDM) recently proposed by Mironov et al., which combines the complex refractive indexes for the major components of the soil. These components were found to be the solid content, bound water, transient bound water, liquid capillary water, and moistened ice water. The dielectric properties of the frequency-dispersive components are each described by their own Debye relaxation spectrum. The GRMDM has been modified to incorporate the temperature dependence of the Debye parameters. The phase transformation of the soil water components at the freezing temperature is taken into account. As a result, a temperature-dependable GRMDM (TD GRMDM) has been developed, including model parameters which have a physical interpretation. This TD GRMDM predicts the dielectric for this soil in the whole range of moistures, frequencies, and temperatures measured. The model prediction errors are on the same order as that of dielectric measurements. The model proposed is the first of its kind to provide a physical basis for radar and radiothermal remote sensing algorithms that retrieve the freeze/thaw state and the volumetric moisture in the upper layer of an Arctic soil. [J19]

"HF Radio-Frequency Interference Mitigation"

The dense radio-frequency interference (RFI) distributed on the spectrum in the high-frequency band greatly degrades the performance of radio systems and makes it urgent to find an effective and speedy method to eliminate the interferences. The interference mitigation method introduced in this letter is implemented before any further signal processing. It reconstructs the interference by the exactly estimated frequency, amplitude, and phase parameters in the signal spectrum and then subtracts the artificial interference from the input time-domain complex signal. The procedure steps of the method are illustrated in detail. The data stream of continuous oblique-incident ionospheric detection has been processed effectively and rapidly in real time. Several delay-Doppler ionograms severely contaminated by RFI are selected and presented. Comparisons of the original and mitigated ionograms and the signal-to-noise ratio (SNR) data show that the RFIs are eliminated perfectly and

that the SNR is greatly improved. [J20]

"Modeling Envisat RA-2 Waveforms in the Coastal Zone: Case Study of Calm Water Contamination"

Radar altimeters have so far had limited use in the coastal zone, the area with most societal impact. This is due to both lack of, or insufficient accuracy in the necessary corrections, and more complicated altimeter signals. This letter examines waveform data from the Envisat RA-2 as it passes regularly over Pianosa (a 10-km2island in the northwestern Mediterranean). Forty-six repeat passes were analyzed, with most showing a reduction in signal upon passing over the island, with weak early returns corresponding to the reflections from land. Intriguingly, one third of cases showed an anomalously bright hyperbolic feature. This feature may be due to extremely calm waters in the Golfo della Botte (northern side of the island), but the cause of its intermittency is not clear. The modeling of waveforms in such a complex land/sea environment demonstrates the potential for sea surface height retrievals much closer to the coast than is achieved by routine processing. The long-term development of altimetric records in the coastal zone will not only improve the calibration of altimetric data with coastal tide gauges but also greatly enhance the study of storm surges and other coastal phenomena. [J21]

"The Importance of Soil Moisture and Soil Structure for InSAR Phase and Backscatter, as Determined by FDTD Modeling"

In this paper, we introduce a finite-difference time-domain simulator that accurately models the interaction of microwaves with realistic soils, specifically from spaceborne interferometric synthetic aperture radar (InSAR). The modeled soils are characterized by surface roughness, correlation length, bulk moisture content, vertical moisture gradient, and small air-filled-void content. Simulation results include both backscatter and interferometric phase, and we are particularly interested in assessing the potential of the latter as a proxy for soil moisture. We find that differences in homogeneous bulk moisture result in only small phase differences (< 5?). In contrast, combinations of vertical moisture gradients and small air-filled voids, which may typically exist in more realistic soils, can produce phase changes > 30? for HH and > 50? for VV when the soil moisture is varied from 3% to 30% in the uppermost 2 cm of the soil. Phase changes of this magnitude are easily detectable by spaceborne InSAR techniques. While a strong phase response to a change in mean bulk moisture is common to vertical moisture gradient and small air-filled-void cases, their corresponding backscatter responses are very different. A vertical moisture gradient makes the backscatter response dramatically flatter compared with the case of uniform moisture; in contrast, the introduction of air-filled voids barely alters the backscatter. Thus, it may be possible to infer near-surface soil-structure parameters such as vertical gradients or fractions of voids and inhomogeneities from combined SAR phase and backscatter data. Future SAR sensors could be optimized for this purpose. Prior theoretical work based on the assumption of vertically uniform soil-moisture distributions may need to be adjusted, and the lack of a theory that accommodates more complex soil structures may explain why backscatter inversions have yet to result in a viable operational system. [J22]

"Ray-Tracing Simulation Techniques for Understanding High-Resolution SAR Images"

In this paper, a simulation concept is presented for creating synthetic aperture radar (SAR) reflectivity maps based on ray tracing. Three-dimensional models of man-made objects are illuminated by a virtual SAR sensor whose signal is approximated by rays sent through the model space. To this end, open-source software tools are adapted and extended to derive output data in SAR geometry followed by creating the reflectivity map. Rays can be followed for multiple reflections within the object scene. Signals having different multiple reflection levels are stored in separate image layers. For evaluating the potentials and limits of the simulation approach, simulated reflectivity maps and distribution maps are compared with real TerraSAR-X images for various complex man-made objects like a skyscraper in Tokyo, the Wynn Hotel in Las Vegas, and the Eiffel Tower in Paris. The results show that the simulation can provide very valuable information to interpret complex SAR images or to predict the reflectivity of planned SAR image acquisitions. [J23]

"A Physically Based Screen for Precipitation Over Complex Surfaces Using Passive Microwave Observations"

Physically based passive microwave precipitation retrievals are difficult to develop over land because high nonuniform land emissivity values are difficult to distinguish from those of clouds. This paper uses an empirical approach to determine the covariance of emissivity at different microwave window channels and relies on this covariance to estimate the portion of the observed brightness temperatures that may be attributable to rainfall. One year (2006) of global cloud-free surface emissivity values were retrieved using data sets from multiple instruments on NASA's Aqua satellite. Correlations between the emissivities at different channels were developed for use in an empirical model within an optimal estimation retrieval. The optimal estimation retrieves

surface temperature, total column water vapor, cloud water, and the emissivity at the 10.7-GHz horizontally polarized channel. From this retrieval and the covariance of emissivities, the 89.0-GHz brightness temperature at both polarizations can be estimated. Significant differences between the observed and retrieved high-resolution brightness temperatures are used to screen for precipitation, and results are compared to ground-based radar data for several study regions representing a variety of land surface types in the U.S. The Heidke Skill Score is used to determine the robustness of this methodology and, in all cases, demonstrates at least some increase in skill relative to random chance. [J24]

"Unifying Experiment Design and Convex Regularization Techniques for Enhanced Imaging With Uncertain Remote Sensing Data-Part II: Adaptive Implementation and Performance Issues"

The unified descriptive experiment design regularization (DEDR) method from a companion paper provides a rigorous theoretical formalism for robust estimation of the power spatial spectrum pattern of the wavefield scattered from an extended scene observed in the uncertain remote sensing (RS) environment. For the considered here imaging synthetic aperture radar (SAR) application, the proposed DEDR approach is aimed at performing, in a single optimized processing, SAR focusing, speckle reduction, and RS scene image enhancement and accounts for the possible presence of uncertain trajectory deviations. Being nonlinear and solution dependent, the optimal DEDR estimator requires rather complex signal processing operations ruled by the fixed-point iterative implementation process. To simplify further the processing, in this paper, we propose to incorporate the descriptive regularization via constructing the projections onto convex sets that enable us to factorize and parallelize the reconstructive image processing over the range and azimuth coordinates, design a family of such regularized easy-to-implement iterative algorithms, and provide the relevant computational recipes for their application to fractional imaging SAR. We also comment on the adaptive adjustment of the DEDR operational parameters directly from the actual speckle-corrupted scene images and demonstrate the effectiveness of the proposed adaptive DEDR techniques. [J25]

"Huber-Markov Model for Complex SAR Image Restoration"

This letter presents the despeckling of single-look complex (SLC) synthetic aperture radar (SAR) images using nonquadratic regularization. The objective function consists of an image model, a gradient, and a prior model. The Huber-Markov random field (HMRF) models the prior. A numerical solution is achieved through extensions of half-quadratic regularization methods using complex-valued SAR data. The proposed method using the HMRF prior together with nonquadratic regularization shows the superior results on SLC synthetic and actual SAR images. [J26]

"Road Network Extraction in VHR SAR Images of Urban and Suburban Areas by Means of Class-Aided Feature-Level Fusion"

In this paper, we propose to combine two road extractors from very high resolution synthetic aperture radar scenes: one more successful in rural areas and one explicitly designed for urban areas. In order to get the best combination of both, a rapid mapping filter for discriminating rural and urban scenes is utilized. Finally, the results are fused on a feature level and connected by means of a network optimization. The approach is tested and evaluated on TerraSAR-X data containing complex urban areas and urban-rural fringe scenes. [J27]

"A Novel Autofocusing Approach for Real-Time Through-Wall Imaging Under Unknown Wall Characteristics"

A novel real-time through-wall imaging (TWI) algorithm with autofocusing ability in the presence of wall ambiguities is proposed in this paper. The spectrum Green's function is employed to formulate the TWI algorithm, where the fast Fourier transform can be used to reconstruct the image in a very short computation time. The complex scattering process due to the presence of the wall is automatically included in the imaging formulation through the multilayer Green's function. The autofocusing is achieved by introducing a time factor in the TWI formulation to get a dynamic image at different focusing time. The image at the time instant when the defined entropy is minimized is stored as the output of the TWI result. Simulation results show that the proposed method can provide high-quality focused image in a short computation time regardless of the estimated value of the wall parameters. [J28]

"Field Investigations of Ku-Band Radar Penetration Into Snow Cover on Antarctic Sea Ice"

Monitoring long-term, large-scale changes in the Antarctic sea ice thickness is not currently possible due to the sampling constraints of the ship-based and airborne observations which comprise most of the available thickness data. Satellite radar altimetry has been used to measure sea ice thickness variability in the Arctic where it is

assumed that the highest amplitude radar return originates from the snow/ice interface as the Arctic snow is cold and dry; however, this may not be the case in the Antarctic due to more complex snow stratigraphy caused by warmer winter temperatures and frequent snow flooding. We present the first measurements of radar penetration into snow cover on Antarctic sea ice in the Ku-band at which satellite radar altimeters operate. Data were taken using a sled-borne radar on sea ice off East Antarctica during September and October 2007. Radar data and field measurements of snow density, thickness, wetness, and layers were taken over a range of locations including snow packs with flooding, hard crusts, and icy layers. Detailed snow pit studies showed that the snow/ice interface was the dominant scattering surface only for snow without morphological features or flooding. Analysis of transect data showed that the mean depth of the dominant scattering surface of the radar was only around 50% of the mean measured snow depth, indicating that the dominant scattering surface was not always the snow/ice interface for the Antarctic sea ice surveyed. [J29]

"Covariance Estimation for dInSAR Surface Deformation Measurements in the Presence of Anisotropic Atmospheric Noise"

We study anisotropic spatial autocorrelation in differential synthetic aperture radar interferometric (dInSAR) measurements and its impact on geophysical parameter estimations. The dInSAR phase acquired by the satellite sensor is a superposition of different contributions, and when studying geophysical processes, we are usually only interested in the surface deformation part of the signal. Therefore, to obtain high-quality results, we would like to characterize and/or remove other phase components. A stochastic model has been found to be appropriate to describe atmospheric phase delay in dInSAR images. However, these phase delays are usually modeled as being isotropic, which is a simplification, because InSAR images often show directional atmospheric anomalies. Here, we analyze anisotropic structures and show validation results using both real and simulated data. We calculate experimental semivariograms of the dInSAR phase in several European Remote Sensing satellite-1/2 tandem interferograms. Based on the theory of random functions (RFs), we then fit anisotropic variogram models in the spatial domain, employing Mate??rn- and Bessel-family correlation functions in nested models to represent complex dInSAR covariance structures. The presented covariance function types, in the statistical framework of stationary RFs, are consistent with tropospheric delay models. We find that by using anisotropic data covariance information to weight dInSAR measurements, we can significantly improve both the precision and accuracy of geophysical parameter estimations. Furthermore, the improvement is dependent on how similar the deformation pattern is to the dominant structure of the anisotropic atmospheric signals. [J30]

"SAR Calibration Aided by Permanent Scatterers"

We propose a calibration method suitable for a set of repeated synthetic aperture radar (SAR) acquisitions that uses both absolute calibrated devices (such as corner reflectors) and stable targets identified in the scene [the permanent scatterers (PSs)]. Precisely, the role of the PS is to extend the initial calibration sequence by monitoring the radiometric stability of the system throughout the whole mission life span. At a first step, this paper approaches the problem of PS-based normalization by an iterative maximum-likelihood method that exploits the stack of complex interferometric SAR images. Two solutions are given based on different assumptions on the PS phases. As a second step, the merging of these estimates with the available calibration information is discussed. Results achieved by experimental acquisitions are shown in two different SAR systems: 1) a C-band spaceborne SAR and 2) a Ku-band ground-based SAR. [J31]

"Closed-Form Evaluation of the Second-Order Statistical Distribution of the Interferometric Phases in Dual-Baseline SAR Systems"

Multichannel inteferometric synthetic aperture radar (InSAR) systems allow to improve the accuracy of the estimation of the height profiles of the observed scenes. Multichannel images can be acquired by using different sensors operating at different frequencies (multifrequency InSAR) or acquiring multiple images with slightly different view angles (multibaseline InSAR). The enhanced accuracy height estimation is obtained exploiting the multichannel interferometric phases and an a prioriinaccurate ground profile and requires the knowledge of the joint probability distribution of the multichannel interferometric phases, whose evaluation in a closed form is very complicated and is not found in literature. In this paper, we evaluate the analytical form of the second-order probability density function (pdf) of dual-baseline InSAR phase interferograms, obtained from three mutually correlated interferometric images. The evaluation exploits the Gaussian model for the complex SAR images, takes into account the mutual correlation of all the images, and does not use any approximation. The closed form of the second-order joint pdf can be usefully adopted in statistical digital elevation model (DEM) estimation methods using dual-baseline SAR systems, which commonly use an approximate expression of the joint pdf of measured interferometric phases, given by the product of the marginal pdfs of each phase interferogram, obtained in the assumption of independent interferograms. The effect of this approximation is evaluated by computing the Cramer-Rao lower bounds and the mean square estimation errors obtained using the exact and

the approximate model. Presented results represent the basis for the generalization to the case of more than two interferograms. [J32]

"ISAR Imaging of Maneuvering Target Based on the L-Class of Fourth-Order Complex-Lag PWVD"

In inverse synthetic aperture radar (ISAR) imaging of a maneuvering target, the received signal in a range bin can be characterized as a multicomponent polynomial phase signal (PPS) after motion compensation. The traditional discrete Fourier transform algorithm is not appropriate in analyzing the PPS. In this paper, the L-class of a fourth-order complex-lag polynomial Wigner-Ville distribution (PWVD) is presented to generate a high-resolution time-frequency distribution (TFD) for the multicomponent PPS. For a signal with polynomial phase up to order four (this is accurate enough in ISAR imaging), the cross-terms between different components can be reduced by the convolution in the frequency domain of the L-class of the fourth-order complex-lag PWVD. The new TFD is used in the ISAR imaging of the maneuvering target, and high-quality instantaneous ISAR images are obtained. Results of simulated and real data demonstrate the effectiveness of the method above. [J33]

"A Complex Generalized Gaussian Distribution- Characterization, Generation, and Estimation"

The generalized Gaussian distribution (GGD) provides a flexible and suitable tool for data modeling and simulation, however the characterization of the complex-valued GGD, in particular generation of samples from a complex GGD have not been well defined in the literature. In this correspondence, we provide a thorough presentation of the complex-valued GGD by: (i) constructing the probability density function (pdf); (ii) defining a procedure for generating random numbers from the complex-valued GGD; and (iii) implementing a maximum likelihood estimation (MLE) procedure for the shape and covariance parameters in the complex domain. We quantify the performance of the MLE with simulations and actual radar data. [J34]

"TerraSAR-X Mission Planning System: Automated Command Generation for Spacecraft Operations"

On June 15, 2007, TerraSAR-X was successfully launched from Baikonur, Kazakhstan. On board TerraSAR-X, a high-resolution X-band synthetic aperture radar (SAR) instrument is being operated as the primary payload. The user community requesting SAR products is composed of commercial and scientific partners as documented in a public-private-partnership agreement. The operations of the TerraSAR-X bus as well as payload operations are performed by the Mission Operations Segment (MOS). The Mission Planning System (MPS), which is a part of the MOS, has been designed to handle complex payload and standard bus operations in an automated manner. The purpose of this paper is to describe the concepts and the TerraSAR-X realization of the MPS. [J35]

"Automatic target detection in simulated ground clutter (Weibull distributed) by multilayer perceptrons in a low-resolution coherent radar"

This study presents the problem of detecting known targets (Swerling 0 model) in simulated ground clutter (land cultivated). As a modelled low-resolution coherent radar system is used, the clutter is modelled by a complex-valued time-correlated Weibull distribution. The research exposed in this study looks for two objectives. First, finding a detection scheme that permits the final user (radar operator) determine if a target is present or not, and its position, size and shape. And second, designing a detection scheme as robust as possible against clutter and target condition changes and approximating the specification and measurement of the radar performance by using clutter models. However, these tasks are really complicated, because high-level clutter echoes are received. A detection scheme based on neural networks is proposed, where feedforward multilayer perceptrons are used. The performance obtained with this detection scheme is discussed from subjective (visual analysis of the achieved detection scans) and objective (receiver operating characteristics) points of view. Finally, this scheme is compared with a coherent detector commonly used when Weibull-distributed clutter is present, the target sequence known a priori detector. This comparison empirically demonstrates the performance improvement achieved by the proposed detector comparing with the commonly used. [J36]

"Adaptive detection of a signal with angle uncertainty"

This study deals with adaptive detection of a signal with unknown complex amplitude and whose steering vector presents angle uncertainties. The background environment is assumed homogeneous and Gaussian with unknown covariance matrix. At the design stage, the authors devise a class of robust receivers accounting for the aforementioned uncertainty. To this end, the authors prove that the maximisation of the concentrated likelihood function over the phase parameter shares a hidden convexity property. Specifically, exploiting some recent results concerning trigonometric polynomials, the authors formulate the apparently non-convex maximisation over the phase as a semidefinite programming (SDP) convex optimisation problem. Then, the

authors show that the receivers of the class (but for one) exhibit a bounded-constant false alarm rate (bounded-CFAR) behaviour and derive lower and upper bounds for both the false alarm and the detection performance. At the analysis stage, the authors assess the performance of the new receivers in comparison with some classic detectors available in open literature. [J37]

"New algorithm for fast direction-of-arrival estimation using the shrinking signal subspace and the noise pseudo-eigenvector"

This study presents a new direction-of-arrival (DOA) estimation technique with application to the uniform linear sensor array for rapidly varying signals in the uncorrelated or coherent case. Unlike the conventional subspace-based algorithms, it need not form the covariance matrix using a block of the array data, a complicated computational burden and a prior knowledge of the number of incoming signals. This approach is based on the technologies of the shrinking signal subspace and the noise pseudo-eigenvector. In contrast with Kim's method, our purposed algorithm can improve its performance of resolution capabilities but requires less computational complexity. Computer simulation results that demonstrate the resolution performance of the proposed algorithm are included. Since the algorithm is simple and can maintain resolution capabilities as compared to Kim's method, it may be used on its own to provide a wider application prospect in real-time DOA estimation or be used as good initialisation for more complex and more high-resolution DOA algorithms. [J38]

"Matching Space Antenna Deformation Electronic Compensation Strategies to Support Structure Architectures"

Radar systems are engineered to achieve a complex, yet functional, balance between diverse subsystems and competing requirements. One important trade for large deployable space radar antennas is between antenna dimensional stability and electronic signal processing for deformation compensation. This trade is first investigated for several different electronic compensation methods, and compensation capabilities are mapped into structural requirements. Second the structural requirements are translated into appropriate structural architectures. The scope of this study is limited to space radar systems, where loads causing antenna deformations differ significantly from terrestrial systems. Compensation strategies that allow structural requirements to be reduced by several orders of magnitude are identified. When considered early in the systems engineering process, the methods presented herein can be used to form a rationale for the selection and the development of a complementary combination of compensation electronics and structural architectures. [J39]

"Low Probability of Intercept Antenna Array Beamforming"

A novel transmit array beamforming approach is introduced that offers low probability of intercept (LPI) for surveillance radar systems employing phased array antennas. Radar systems are often highly visible to intercept receivers due to the inherent two-way versus one-way propagation loss. In this paper, the traditional high-gain antenna beam scanned across a search region is replaced with a series of low-gain, spoiled beams. Keeping the transmit antenna gain low reduces the radar visibility, but the radar's antenna performance remains unchanged as the original high-gain beam can be formed by processing the set of spoiled beams. Large transient power density radiated in a traditional scan is replaced with low power density persistently radiated at the target throughout the scan time. The detection performance of the radar is not affected since the total energy on the target is the same. Derivation of the complex weights to synthesize the high-gain patterns from the low-gain basis patterns is presented for both one-way and two-way beam patterns. [J40]

"Analysis of radar human gait signatures"

The authors develop methods for the time-frequency (TF) analysis of human gait radar signals. In particular the authors demonstrate how knowledge of different motion classes can be obtained via a Markov chain model of state transitions based on the TF envelope structure associated with the motion sequence being analysed. The class-conditional knowledge thus obtained allows us to effectively extract the motion curves associated with different body parts via a non-parametric partial tracking algorithm that is coupled with an optimum Gaussian g-Snake modelling of the TF structure. The optimum segmentation of the TF structure into different half-cycles as well as the determination of the initial Doppler control points (corresponding to each half-cycle) is facilitated by a dynamic programming algorithm wherein the associated cost function involves a mean-square minimisation of the best quadratic fit to each segment together with a sparsity prior that enables us to control the smoothness of the approximation space in which the time series being analysed is effectively projected. Finally, the authors describe some of the limitations of our approach and point out future research directions that can overcome some of the difficulties associated with the complex interaction between the inherently non-linear dynamics of human gait motion and radar systems. [J41]

"Very High Resolution Spaceborne SAR Tomography in Urban Environment"

Synthetic aperture radar tomography (TomoSAR) extends the synthetic aperture principle into the elevation direction for 3-D imaging. It uses stacks of several acquisitions from slightly different viewing angles (the elevation aperture) to reconstruct the reflectivity function along the elevation direction by means of spectral analysis for every azimuth-range pixel. The new class of meter-resolution spaceborne SAR systems (TerraSAR-X and COSMO-Skymed) offers a tremendous improvement in tomographic reconstruction of urban areas and man-made infrastructure. The high resolution fits well to the inherent scale of buildings (floor height, distance of windows, etc.). This paper demonstrates the tomographic potential of these SARs and the achievable quality on the basis of TerraSAR-X spotlight data of urban environment. A new Wiener-type regularization to the singular-value decomposition method-equivalent to a maximum a posteriori estimator-for TomoSAR is introduced and is extended to the differential case (4-D, i.e., space-time). Different model selection schemes for the estimation of the number of scatterers in a resolution cell are compared and proven to be applicable in practice. Two parametric estimation algorithms of the scatterers' elevation and their velocities are evaluated. First 3-D and 4-D reconstructions of an entire building complex (including its radar reflectivity) with very high level of detail from spaceborne SAR data by pixelwise TomoSAR are presented. [J42]

"Detection of handguns by their complex natural resonant frequencies"

The decomposition of the late time, transient response of metallic objects illuminated with broadband microwave energy into damped sinusoidal signals which are characterised by aspect-independent poles, is used extensively as a method of radar identification of aircraft and missiles. This method is utilised here for the detection and discrimination of handguns and non-threatening items, such as mobile phone handsets, cameras, keys and pens. It is of critical importance to explore the limits of this method, if it is to be utilised for the detection of such objects concealed on the human body or in bags carried on or close to the body that the limits of this technique is explored. Here, investigation is made by computer modelling of the complex natural resonances of two different handguns and these are compared with those for two non-threat items: a mobile phone handset and a fountain pen. Dependence of pole positions on small details present on a handgun is also investigated as is the effect of combining threat and non-threat items in close proximity. A way of enhancing the natural resonances by the use of a cross polarised receiver is also investigated. [J43]

"Bias-Free Phase Tracking with Linear and Nonlinear Systems"

The arctan function is a well-known Maximum Likelihood (ML) estimator of the phase angle $\alpha \in [-\pi,\pi)$ of a complex signal in additive white Gaussian noise. In this paper we revisit the arctan-based ML phase estimator and identify the bias problem for phase tracking. We show that the posteriori probability density function of α becomes a bi-modal distribution for small values of signal to noise ratio ρ and larger values of α. In such cases the mean and the mode differ from each other, and as a result when such ML phase estimates are used as an input to a linear system (LS), example for phase tracking, the resulting output (which is essentially the mean value of the phase) differs from its true value which is the mode. In such situations there exist a mean (tracking) error at the output of the LS from its true value α, and in (non-Bayesian) statistical terms there exist a bias in the estimates. In this paper, we provide some statistical analysis to explain the above problem, and also provide solutions for bias correction when a LS is used for tracking phase. Furthermore, we also provide two nonlinear phase tracking systems, 1) a Monte-Carlo based sequential phase tracking technique and 2) a second-order digital-phase locked loop based method, for bias-free phase tracking which eliminate the bias problem that occurs in the case of linear phase tracking with ML estimates. [J44]

"Sense & Avoid capability development challenges"

Unmanned Aircraft Systems will require a Sense & Avoid function to protect against collisions with other aircraft as well as various other hazards. Architectural alternatives in the distributions of functionality between aircraft and a ground control station make the development of requirements and standards more complex. A broad variety of candidate sensor technologies has the potential to fulfill the surveillance portion of the system. This explores the capabilities and limitations of these technologies, and suggests deploying combinations of technologies to capitalize upon their respective strengths. A discussion of algorithmic requirements draws upon the experience of the Traffic Alert and Collision Avoidance System (TCAS) in the airspace. Differences and challenges in implementing an algorithm for a UAS are discussed. The broad range of UAS aerodynamic characteristics complicate the process of standardizing an algorithm for Sense & Avoid. In order to build a safety case supporting the certification of a UAS, its performance must be thoroughly evaluated. In the case of Sense & Avoid, flight testing cannot be sufficiently thorough, and instead, the simulation of the system for large numbers of aircraft encounters is recommended. This discusses the considerations in performing such simulations, and in modeling various components of the system and of the potential encounter geometries. Unlike TCAS, an

encounter model cannot be constructed solely from observed data, as UAS are not yet performing the desired uses. The Sense & Avoid work within the RTCA SC-203 standards committee is described. [J45]

"Doppler ambiguity resolution for multiple PRF radar using iterative adaptive approach"

A new improved complex-valued iterative adaptive approach is proposed to effectively resolve Doppler ambiguity in multiple pulse repetition frequency (PRF) radar. Exact termination criterion for the proposed method is adopted based on the sparsity of Doppler spectrum. Numerical studies demonstrated the effectiveness of the proposed method. [J46]

"Nonlinear Calibration of Polarimetric Radar Cross Section Measurement Systems"

Polarimetric radar cross section measurement systems are characterized by polarimetric system parameters εhand εv. These parameters can be measured by use of rotating dihedrals. The full polarimetric dataset as a function of the angle of rotation can be analyzed with a nonlinear set of calibration equations to yield the system-parameter complex constants and the four polarimetric-calibration amplitudes. These amplitudes appropriately reproduce the system's drift, and very accurately satisfy a drift-free system-configuration criterion. The results indicate that the nonlinear approach is better than the previously studied linear approach, which yielded system parameters that were seriously distorted by system drift. [J47]

"Photonic Probes and Advanced (Also Phaseless) Near-Field Far-Field Techniques"

We present innovative near-field test ranges, named compact-near-field (CNF) and very-near-field (VNF). These use photonic probes, and advanced near-field far-field (NFFF) transformations from amplitude and phase (complex) or phaseless measurements. The photonic probe allows AUT-probe distances of less than one wavelength. This drastically reduces test-range and scanner dimensions, improves the signal-to-clutter ratio and the signal-to-noise ratio, and reduces the scanning area and time. In both the cases of complex and phaseless measurements, the neat-field-to-far-field transformation problem is properly formulated to further improve the rejection of clutter, noise, and truncation error. The advantages of the compact-near-field and very-near-field test ranges are discussed and numerically analyzed. Experimental results are presented for both planar and cylindrical scanning geometries. [J48]

"Multi-Channel SAR-GMTI Method Robust to Coregistration Error of SAR Images"

High accuracy in complex images coregistration is essential in ground moving target indication (GMTI) processing of synthetic aperture radar (SAR) data, normally termed SAR-GMTI. The clutter suppression performance is proportional to the coregistration accuracy. In this correspondence, we propose a new SAR-GMTI approach, which is robust to the SAR images coregistration error. The observed clutter-plus-noise vector is built using the neighboring pixels as the first step, thus the corresponding covariance matrix, termed as joint covariance matrix, can be estimated. The joint noise subspace is obtained by eigen-decomposing of the joint covariance matrix. The clutter is suppressed successfully by a projecting operation, i.e., a projection of the joint observed vector into the resulting joint noise subspace. The information of neighboring pixels is substantially exploited in the clutter suppression, resulting in the robustness, even at the presence of large coregistration error. Both the simulated and real multi-channel airborne data are used to validate the proposed approach. [J49]

"On the Role of Phase Stability in SAR Multibaseline Applications"

This paper is meant to present a statistical analysis of the role of propagation disturbances (PDs), such as those due to atmospheric disturbances or to residual platform motion, in multibaseline synthetic aperture radar (SAR) interferometry (InSAR) and tomography (T-SAR) applications. The analysis will consider both pointlike and distributed targets in such a way as to cover all the cases that are relevant in the applications. In order to provide a tool for the evaluation of the impact of PDs on the analysis of an arbitrary scenario, a definition of signal-to-noise ratio (SNR) will be introduced that accounts for both the presence of PDs and the characteristics of the imaged scene. In the case of pointlike targets, it will be shown that such definition of SNR allows reusing well known results following after the Neyman-Pearson theory, thus providing a straightforward tool to asses phase-stability requirements for the detection and localization of multiple pointlike targets. In the case of distributed targets, instead, it will be provided a detailed analysis of the random fluctuations of the reconstructed scene as a function of the extent of the PDs, of the vertical structure of the imaged scene, and of the number of looks that are employed. Results from Monte Carlo simulations will be presented that fully support the theoretical developments within this paper. The most relevant conclusion of this paper is that the impact of PDs is more severe in the case where the imaged scene is characterized by a complex vertical structure or when multiple pointlike targets are present. As a consequence, it follows that the T-SAR analyses require either a higher phase stability or a more accurate phase calibration with respect to InSAR analyses. Finally, an example of phase-

stability analysis and phase calibration of a real data set will be shown, based on a P-band data set relative to the forest site of Remningstorp, Sweden. [J50]

"A Novel Technique for Acquisition and Presentation of Complex Vibration Waveforms"

Oscilloscopes are traditionally used for the graphical presentation and analysis of electrical waveforms. In many experiments, waveform acquisition and live presentation forms the heart of the problem. In particular, data acquisition and presentation of repeating complex signals like sine sweep in vibration generation and testing and frequency-modulated signals in radar and sonar applications offers the challenge of live waveform presentation and their basic measurements. In this paper, we present a new, robust, fast, and simple technique for waveform period estimation in the time domain and oscilloscope triggering for both complex and simple waveforms. The proposed technique, namely, the normalized degree of difference (DOD), has both these capabilities, and it has been verified by extensive software simulations and implementation on the National Instruments (NI) LabVIEW-PXI platform. Successful real-time results are obtained for the sine sweep vibration waveform. The proposed technique, simulation, and implementation results are presented in this paper. [J51]

"Including Spatial Correlations in the Statistical MIMO Radar Target Model"

Previous studies of statistical MIMO radar detection performance have used a target model that consists of a large number of point scatterers located within a rectangular target area. These point scatterers have scattering amplitudes that are complex random variables and are spatially uncorrelated, so that the target is a white noise process in space. Spatial correlations are introduced into the target model in this paper, and the impact of these correlations on MIMO radar system detection performance is analyzed. [J52]

"An Efficient and Flexible Statistical Model Based on Generalized Gamma Distribution for Amplitude SAR Images"

In the context of synthetic aperture radar (SAR) image processing and applications, the precise modeling of statistical knowledge is a crucial problem. In this paper, an efficient and flexible statistical model, called generalized Gamma Rayleigh (G??R) distribution, for amplitude SAR images is proposed by assuming a two-sided generalized Gamma distribution for the real and imaginary parts of the complex SAR backscattered signal. It is shown that the Rayleigh and recently proposed generalized Gaussian Rayleigh distributions can be regarded as special cases of G??R distribution. Considering that the probability density function estimation problem is formulated as a parameter estimation one for the parametric statistical analysis of SAR images, a two-stage estimator based on second-kind cumulants is derived for the parameters of G??R distribution. Furthermore, experimental results on several actual SAR images are given to demonstrate the validity and flexibility of the proposed model. [J53]

"Modeling of Fluorescence Lidar ROC Curves"

In this paper, an analytical model of a receiver operating characteristic (ROC) curve for digital fluorescence lidar sensing of an aerosol biowarfare agent (BWA) simulant in the presence of a single aerosol interferent is presented. The BWA simulant and interferent are characterized by their concentrations, particle size distributions, fluorescence cross sections, and complex refractive indexes. The ROC curve calculation is performed for simulant and interferent lidar signals that are plotted in a biodiscrimination plane defined by normalized particle size ratio Xand particle fluorescence ratio Y. Probability density functions (PDFs) of BWA simulant and interferent in the biodiscrimination plane are due to finite signal-to-noise lidar measurements. These functions are modeled with a joint distribution density function of Xand Yas correlated variables. The Xand Yvariables are calculated from the corresponding lidar equations that compute signal and noise from elastic backscatter and fluorescence cross sections, the concentration of aerosol particles, and lidar optical system parameters. Elastic backscatter is calculated from Mie scattering theory using a particle size distribution approximated by a log-normal distribution. Fluorescence cross sections of BWA simulant or interferent aerosols given in the literature are approximated as being independent/dependent from particle size distribution in the model. Each point of the ROC curve of BWA simulant in the presence of an interferent is defined as the integral of the interferent PDF over the elliptical contour projection of BWA simulant PDF in the biodiscrimination plane for a fixed threshold of aerosol cloud detection, and thus, a fixed probability of aerosol cloud detection. Presented ROC curve method can be generalized to the case of the simultaneous presence of several interferents to the discrimination of one BWA simulant. Calculated elliptical contour projections of- the bioaerosol PDF in the biodiscrimination plane, and corresponding ROC curves are computed and presented for the parameters of an experimental lidar that was tested during BWA simulant and interferent aerosol cloud releases, where aerosol cloud particle concentrations and size distributions were also measured. When the number and identity of interferents and their corresponding concentrations are unknown, the ROC curve can be estimated by assuming a constant bioaerosol PDF in the

biodiscrimination plane. [J54]

"High-Sensitivity Software-Configurable 5.8-GHz Radar Sensor Receiver Chip in 0.13- m CMOS for Noncontact Vital Sign Detection"

In this paper, analyses on sensitivity and link budget have been presented to guide the design of high-sensitivity noncontact vital sign detector. Important design issues such as flicker noise, baseband bandwidth, and gain budget have been discussed with practical considerations of analog-to-digital interface and signal processing methods in noncontact vital sign detection. Based on the analyses, a direct-conversion 5.8-GHz radar sensor chip with 1-GHz bandwidth was designed and fabricated. This radar sensor chip is software configurable to set the operation point and detection range for optimal performance. It integrates all the analog functions on-chip so that the output can be directly sampled for digital signal processing. Measurement results show that the fabricated chip has a sensitivity of better than -101 dBm for ideal detection in the absence of random body movement. Experiments have been performed successfully in laboratory environment to detect the vital signs of human subjects. [J55]

"Coherence improving algorithm for airborne multichannel SAR-GMTI"

The study develops an algorithm to improve coherence for the multichannel airborne along-track synthetic aperture radar (SAR), which can be used for ground moving target indication (GMTI) by comparing two SAR images obtained from different channels. The turbulent aircraft motion, beam pattern difference and frequency response difference that may degrade the coherence are discussed in detail. The aircraft motion error is firstly estimated and corrected based on the range compressed data. After focusing on the beam pattern differences and the receive channel imbalance are compensated using the two two-dimensional (2-D) adaptive filters, the first in the range-Doppler domain and the second in the range-frequency azimuth-time domain. It is shown that using the coherence improving algorithm the coherence of SAR complex image pairs can be improved greatly. The effectiveness of the algorithm is demonstrated with real data acquired by a Chinese X-band multichannel airborne SAR-GMTI system. [J56]

"Signal level Simulator for netted text 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 Figure 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 [1] 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. Herein, algorithms for the simulation of raw radar return signals are presented, based on interpolation and modification of the transmitted signal and modeling 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) [2], netted radar and phased array radar. Preliminary results, presented herein, suggest that these algorithms can simulate physical systems with excellent accuracy. [J57]

"Validation of the ASAR Global Monitoring Mode Soil Moisture Product Using the NAFE'05 Data Set"

The Advanced Synthetic Aperture Radar (ASAR) Global Monitoring (GM) mode offers an opportunity for global soil moisture (SM) monitoring at much finer spatial resolution than that provided by the currently operational Advanced Microwave Scanning Radiometer for the Earth Observing System and future planned missions such as Soil Moisture and Ocean Salinity and Soil Moisture Active Passive. Considering the difficulties in modeling the complex soil-vegetation scattering mechanisms and the great need of ancillary data for microwave backscatter SM inversion, algorithms based on temporal change are currently the best method to examine SM variability. This paper evaluates the spatial sensitivity of the ASAR GM surface SM product derived using the temporal change detection methodology developed by the Vienna University of Technology. This evaluation is made for an area in southeastern Australia using data from the National Airborne Field Experiment 2005. The spatial evaluation is made using three different types of SM data (station, field, and airborne) across several different scales (1-25 km). Results confirmed the expected better agreement when using point (Rstation= 0.75) data as compared to spatial (RPLMR, 1 km= 0.4) data. While the aircraft-ASAR GM correlation values at 1-km resolution were low, they significantly improved when averaged to 5 km (RPLMR, 5 km= 0.67) or coarser. Consequently,

this assessment shows the ASAR GM potential for monitoring SM when averaged to a spatial resolution of at least 5 km. [J58]

"Enhancement of Coupled Multichannel Images Using Sparsity Constraints"

We consider the problem of joint enhancement of multichannel images with pixel based constraints on the multichannel data. Previous work by Cetin and Karl introduced nonquadratic regularization methods for SAR image enhancement using sparsity enforcing penalty terms. We formulate an optimization problem that jointly enhances complex-valued multichannel images while preserving the cross-channel information, which we include as constraints tying the multichannel images together. We pose this problem as a joint optimization problem with constraints. We first reformulate it as an equivalent (unconstrained) dual problem and develop a numerically-efficient method for solving it. We develop the Dual Descent method, which has low complexity, for solving the joint optimization problem. The algorithm is applied to both an interferometric synthetic aperture radar (IFSAR) problem, in which the relative phase between two complex-valued images indicate height, and to a synthetic multimodal medical image example. [J59]

"Iterative Method for Nonlinear FM Synthesis of Radar Signals"

The problem of synthesizing a time-domain signal with a given energy spectral density (ESD) often arises in the field of signal processing. Many solutions have been proposed and successfully used over the years. However the problem of synthesizing a time-domain signal with constraints for a given ESD has not been investigated sufficiently. We propose a solution to one such constraint where the amplitude of the complex-valued time-domain signal is required to be unity. This is equivalent to phase modulating a unit amplitude signal, such that its ESD matches a desired energy spectral density. We provide an algorithm for this solution and apply it to a real problem encountered in radars. [J60]

"Tomographic SAR Inversion by -Norm Regularization-The Compressive Sensing Approach"

Synthetic aperture radar (SAR) tomography (TomoSAR) extends the synthetic aperture principle into the elevation direction for 3-D imaging. The resolution in the elevation direction depends on the size of the elevation aperture, i.e., on the spread of orbit tracks. Since the orbits of modern meter-resolution spaceborne SAR systems, like TerraSAR-X, are tightly controlled, the tomographic elevation resolution is at least an order of magnitude lower than in range and azimuth. Hence, super-resolution reconstruction algorithms are desired. The high anisotropy of the 3-D tomographic resolution element renders the signals sparse in the elevation direction; only a few pointlike reflections are expected per azimuth-range cell. This property suggests using compressive sensing (CS) methods for tomographic reconstruction. This paper presents the theory of 4-D (differential, i.e., space-time) CS TomoSAR and compares it with parametric (nonlinear least squares) and nonparametric (singular value decomposition) reconstruction methods. Super-resolution properties and point localization accuracies are demonstrated using simulations and real data. A CS reconstruction of a building complex from TerraSAR-X spotlight data is presented. [J61]

"GLRT Versus MFLRT for Adaptive CFAR Radar Detection With Conic Uncertainty"

In this paper, we consider the problem of detecting an unknown signal, belonging to a conic region, in the presence of complex Gaussian disturbance. We assume that the cone aperture parameter, which ranges in a pre-assigned interval, is unknown. Hence, we devise two decision rules which are respectively based on the Generalized Likelihood Ratio Test (GLRT) and on the Multifamily Likelihood Ratio Test (MFLRT). Both the receivers ensure the Constant False Alarm Rate (CFAR). At the analysis stage, we compare the performance of the two decision strategies in correspondence of different parameters for the useful signal component. [J62]

"Through-the-Wall SAR Attributed Scattering Center Feature Estimation"

We consider characterization of building interior structure from two-pass interferometric circular synthetic aperture radar data. We model returns from complex building structures as the sum of the responses from scattering primitives-plates, dihedrals, and trihedrals-observed through transfer functions that characterize both the transmission through and reflection from dielectric surfaces. Maximum-likelihood estimates for the location of primitive features and wall propagation/reflection parameters are obtained through a two-stage detection-and-estimation algorithm. We employ a sparse reconstruction algorithm to detect primitive signatures in the presence of wall effects and refine our estimates using a nonlinear minimization of local cost functions. We show that using simplified wall and primitive models, we can extract geometrically relevant features which can be combined to reveal 3-D floorplan estimates of buildings. Examples illustrate the effectiveness of the feature extraction approach. [J63]

"Alternatives to Target Entropy and Alpha Angle in SAR Polarimetry"

The purpose of this paper is to discuss two polarimetric parameters which are widely used in synthetic aperture radar (SAR) polarimetry, namely, target entropy and alpha angle. We propose alternative parameters based on our analysis on how they are connected to covariance matrix similarity invariants and how they can be physically interpreted in optical polarimetry. The proposed alternatives can be computed by a fairly simple algorithm and even by the use of software without complex mathematics abilities. As an example, a NASA/Jet Propulsion Laboratory Airborne SAR L-band image of the San Francisco Bay is used to compare the proposed parameter schemes with the original entropy and alpha. A coherent rationale for these alternative parameters is formulated in order to provide insight to polarimetric parameter interpretation. [J64]

"New Sequence Design Criteria for Multipath Channels"

The merit factor (MF) introduced by Golay has long been accepted as the standard criterion to evaluate and designbinary sequences with good anti-multipath property in sonar, radar, and communication systems for its theoretical tightness and practical simplicity. In this paper, we first show that the MF is a biased anti-multipath performance-evaluation metric in theory and, more importantly, that it is nota pertinent sequence design criterion in practice for most binary sequences of practical interest. Then, we propose the weighted MF (WMF) based on a nonuniform weighting of the out-of-phase aperiodic autocorrelation function (ACF) that provides accurate measurement of self-generated interference for the constant-amplitude complex-valued sequences and the nonconstant modulus sequences. Based on the WMF, a list of ldquobadrdquo (of low MFs) binary sequences (lengths 33-95) with better anti-multipath performance than the ldquobestrdquo (known) binary sequences has been designed to verify its greater pertinence over the MF as a sequence design criterion for sonar, radar, and communication systems. Moreover, we extend the weighted correlation model of the WMF to code-division multiple-access (CDMA) systems and propose the weighted cross-correlation factor (WCF) to evaluate the sequence set's multiple-access interference (MAI) rejection property in the context of multipath propagation. Theoretical analysis corroborated by simulations confirms that the WCF provides greater practical pertinence and analytical tractability than the current standard criterion. [J65]

"Electromagnetic Design and Realization of Innovative Fiber-Reinforced Broad-Band Absorbing Screens"

This paper presents the design and the realization process for radar absorbing panels made of composite materials. It is demonstrated that the proper selection of the carbon fiber length and volume fraction allows reducing sensibly the overall thickness of the screen compared to a standard absorber, and obtaining at the same time broad-band absorption response in the X- and Ku-bands. To this end, the carbon fiber composite material realizing the lossy sheet of the absorbing screen is designed by simulation in order to have tailored complex effective permittivity. Two prototypes of absorbing screens are realized and tested experimentally. The first one is a three-layer panel, characterized by reflection coefficient lower than -10 dB in the frequency range from 8 to 14 GHz, and total thickness of 4.5 mm. The second one is a five-layer panel with reflection coefficient less than -20 dB in the range 9-18 GHz, and total thickness of 5.5 mm. [J66]

"Narrow-Band Interference Suppression for SAR Based on Complex Empirical Mode Decomposition"

Narrow-band interference (NBI) is a common interference source in synthetic aperture radar (SAR) imaging. Its existence will degrade the imaging quality greatly. Based on detailed analysis on the characteristics of NBI, this letter proposes a new NBI suppression algorithm using the complex empirical mode decomposition (CEMD) method. In this algorithm, echoes that include NBI are recognized in the time domain first. Then, these echoes are decomposed into a number of intrinsic mode functions (IMFs) via the CEMD. After that, IMFs that correspond to NBI are subtracted from the echoes by thresholding. Finally, well-focused SAR imagery can be obtained from the separated target echoes using traditional SAR imaging algorithms. The effective data loss in this algorithm is smaller than other NBI suppression approaches. In addition, this algorithm is robust to time-varying NBI. Imaging results of measured data have proved the validity of this algorithm. [J67]

"High-Resolution Three-Dimensional Imaging of Spinning Space Debris"

Since space debris could post a significant threat to orbiting objects around the Earth, their reorganization, measurement, and catalogue are of great importance. This paper establishes a 3-D inverse synthetic aperture radar (ISAR) imaging geometry and signal model for space debris. Then, a 3-D imaging algorithm is proposed to realize coherent imaging in the range-slow-time domain. This algorithm is based on the complex-valued back-projection transform according to the spinning nature of space debris. The simulation results for both point

scattering and continuous targets have proved the validity of the proposed algorithm. [J68]

"Detection of Single Scatterers in Multidimensional SAR Imaging"

Multidimensional synthetic aperture radar (SAR) imaging is a technique based on coherent SAR data combination for space (full 3-D) and space deformation-velocity (4-D) analysis. It is an extension of the concepts of SAR interferometry and differential interferometry SAR and offers new options for the analysis and monitoring of ground scenes. In this paper, we consider the problem of detecting single scatterers for localization and monitoring issues. To this end, we resort to a constant false alarm rate (CFAR) detection scheme which can be synthesized according to three different design criteria: generalized likelihood ratio test, Rao test, and Wald test. At the analysis stage, the performance of the aforementioned detector is compared to that of a previously proposed CFAR scheme, based on the multi-interferogram complex coherence and widely used in persistent scatterer interferometry. The analysis is conducted both on simulated and on real SAR data, acquired by ERS-1/2 satellites. Finally, Cramer-Rao lower bounds for the estimation of the scatterer elevation and velocity are provided. [J69]

"Polarization Symmetric Scatterer Metric Space"

The coherent polarization scattering matrix decomposition presented in Cameron et al. brought attention to the importance of Symmetric Scatterer Space, the space of scattering matrices corresponding to symmetric scatterers. Each symmetric scatterer scattering matrix can be associated with a complex number z, the scatterer-type parameter, where |z| les 1. A distance measure, d(z1, z2), was defined on Symmetric Scatterer Space providing a means of comparing scattering matrices. It will be demonstrated that Symmetric Scatterer Space is a metric space with metric d(z1, z2). A new mapping of the Unit Disc representation of Symmetric Scatterer Space to a sphere is also presented along with a metric on the sphere, ds(thetas1, phi1; thetas2, phi2), that is equivalent to the metric d(z1, z2) on the Unit Disc. [J70]

"Surface-Based Polarimetric C-Band Microwave Scatterometer Measurements of Snow During a Chinook Event"

This paper presents a case study of C-band backscatter observations of snow during a Chinook event. A surface-based C-band polarimetric data set collected in February 2006 is used to contrast the polarimetric response to sampled conditions of bare frozen ground, cold snow-covered ground, and snow during a Chinook event. Chinook activity is inherently spatially and temporally variable across the region in winter and produces considerable spatial variability of snow-cover physical properties associated with snow-water-equivalent (SWE) estimates. A temporal analysis of polarimetric backscatter sensed during a Chinook-induced ablation event on February 27, 2006 is used to describe the associated changes in snow conditions and scattering mechanisms. Analysis reveals that the polarimetric surface-based C-band scatterometer data respond to changes in snow parameters associated with the specific ground and snow conditions and to the temporal Chinook ablation event. Use of the copolarizations, cross-polarization, depolarization ratio, copolarization ratio, complex copolarization correlation coefficient, and the copolarized phase difference information show promise in describing changes in snow physical parameters, differing ground and snow conditions, and transitional ablation events, based on differing scattering mechanisms. This paper infers that an increase in volume scattering and fluctuations in surface scattering during the Chinook ablation event may be associated with specific physical changes such as density, crystal structure, and permittivity caused by wind speed. This paper has implications for remotely sensed estimations of snow-covered area (SCA) and SWE. Association of SCA and SWE with backscatter coefficients is not explicit in this paper; however, changes in SWE and snow properties are inferentially linked to changes in backscatter. [J71]

"New ISAR imaging algorithm based on modified Wigner-Ville distribution"

Inverse synthetic aperture radar (ISAR) imaging of air, space or ship targets with complex motion has attracted the attention of many researchers in the past decade. Complex motion of targets induce cross-range scatterer-variant quadratic phase terms, which will degrade the cross-range resolution and affect focusing quality. A new algorithm is proposed for the ISAR imaging of complex moving targets. First, conventional range alignment, phase compensation and range compression are performed over the raw phase history data such that each range bin can be modelled as the sum of several linear frequency modulation or chirp signals. Secondly, a modified-Wigner-Ville distribution (referred to as M-WVD) approach is proposed, which is based on a scale transform in the time-frequency distribution plane and can effectively suppress the troublesome cross-term interference associated with WVD via coherent integration. Finally, the azimuth ISAR image can be obtained via a simple maximisation projection from the two-dimensional accumulated plot to the azimuth dimension. Compared with existing WVD-based ISAR imaging algorithms, the proposed method has the following features:

better cross-term interference reduction achieved at no resolution loss, computationally more efficient with no expensive two-dimensional parameter search, and higher signal processing gain because of coherent integration during the whole imaging time. Both numerical and experimental results are provided to demonstrate the performance of the proposed method. [J72]

"Cassini Radar Data: Estimation of Titan's Lake Features by Means of a Bayesian Inversion Algorithm"

The analysis derived from the Cassini SAR imagery reflects the complex Titan's surface morphology with a wide range of backscattering coefficients and peculiar features such as periodic structures and lakelike features, which were observed on July 22, 2006, when polar areas were first imaged, and are considered good candidates to be filled with liquid hydrocarbons. In this paper, the modeling description of lakes is addressed by means of a double-layer model which considers an upper liquid-hydrocarbon layer and a lower layer compatible with the radar response of the neighboring areas. This model is introduced into a Bayesian framework for the purpose of inferring the likely ranges of some parameters and, in particular, of the optical thickness of the hypothesized liquid-hydrocarbon layer and of the wind speed. The main idea is to use the information contained in the parameter probability density function, which describes how probability is distributed among the different values of parameters according to the various scenarios considered. The analysis carried out on lakes and surrounding areas on flybys T16 and T19 determines optical thickness values from 0.2 to 6. For T25 flyby, the inferred values of optical thickness indicate that a limit value of optical thickness may be 9. Considering that, beyond these values, the signal from the bottom layer is completely attenuated, information on the wind speed on the upper layer can be inferred. The found mean values of wind speed are around 0.2-0.3 m/s according to different hypotheses on the upper layer dielectric constant. [J73]

"A Support-Vector-Machine-Based Approach to RF Sensor Spectral Signature Classifications"

In this paper, a support vector machine (SVM) classifier was designed to identify tornado vortices based on their characteristics that were determined from the Doppler spectra and eigenvalues that were calculated from the data that were collected in the vicinity of these vortices. To collect these data, weather surveillance radar (WSR-88D) was employed, which is locally operated by the National Severe Storms Laboratory (NSSL) on the north campus of the University of Oklahoma, Norman. This particular radar, which is devoted to experimental research rather than operational weather forecasting, has the unique capability of recording massive volumes of in-phase (I) and quadrature (Q) data over many hours. As such, the received radar echo power and Doppler shift information can be determined from these I and Q complex-valued data, which provides a rich environment for evaluating our new postprocessing algorithms. At the current time, most radar systems, including North America's national network of weather radar systems, process these I and Q data in real time to produce environmental measurements known as ldquospectral moments,rdquo which are the first three statistical moments of the data. These three moments (the reflectivity, the radial velocity, and the spectrum width) are then provided to scientists or forecasters, and the abundance of I and Q data is not preserved to save computer resources. One of the aims of this paper is to show how additional information about the atmosphere can be garnered from the I and Q data. To assist this mission, an SVM-based classifier evades the pitfalls of the traditional statistical learning algorithms, such as neural networks, by setting up a convex optimization problem with a single global minimum. In addition, through the use of kernels and a nonlinear mapping to higher dimensional spaces, the SVM classifier is able to effectively handle nonlinear classification problems. The idea behind this transformation is to facilitate the-- separability of classes by taking the input vectors to a higher dimensional space. The SVM classifier has the added advantage of reducing overfitting by constructing a maximum margin to separate hyperplanes in a higher dimensional feature space to ensure a small generalization error bound. Finally, our practical results are in positive agreement with our theoretical predictions. [J74]

"Singular Unit Restoration in Interferograms Based on Complex-Valued Markov Random Field Model for Phase Unwrapping"

In generating a digital elevation map from an interferogram obtained by interferometric synthetic aperture radar, the filtering process is as important as the phase unwrapping process. Before unwrapping, we usually have to restore the data image by reducing so-called singular points (SPs) by filtering process without destroying or smearing delicate fringes. Previously, an effective SP restoration method was proposed based on the complex-valued Markov random field (CMRF) model. However, there is still room for improvement in the definition of SPs and in the formulation of CMRF parameter estimation. In this letter, we propose a novel scheme by introducing a new concept, namely, the ldquosingular unit.rdquo We also estimate CMRF parameters locally as a weighted sum by taking the distance and SP numbers in sample sites into account. By using this restoration method, we demonstrate a high-performance removal of SPs. We also find that delicate landscape features, which are often lost in conventional filtering, are preserved appropriately. We confirm the quality in higher signal-to-noise ratios

obtained against actual height data. [J75]

"Radar image processing with clusters of computers"

Some radar image processing algorithms such as shape-from-shading are particularly compute-intensive and time-consuming. If, in addition, a data set to be processed is large, then it may make sense to perform the processing of images on multiple workstations or parallel processing systems. We have implemented shape-from-shading, stereo matching, resampling, gridding, and visualization of terrain models in such a manner that they execute either on parallel machines or on clusters of workstations. We were motivated by the large image data set from NASA's Magellan mission to planet Venus, but received additional inspiration from the European Union's Center for Earth Observation program (CEO) and Austria's MISSION initiative for distributed processing of remote sensing images on remote workstations, using publicly-accessible algorithms. We developed a multi-processor approach that we denote as CDIP for Concurrent and Distributed Image Processing. The speedup for image processing tasks increases nearly linearly with the number of processors, be they on a parallel machine or arranged in a cluster of distributed workstations. Our approach adds benefits for users of complex image processing algorithms: the efforts for code porting and code maintenance are reduced and the necessity for specialized parallel processing hardware is eliminated. [J76]

"Exploitation of Ship Scattering in Polarimetric SAR for an Improved Classification Under High Clutter Conditions"

This paper evaluates the potentialities of polarimetric ship scattering for basing classification methods that provide reasonable performance within cluttered scenes. Both simulated and airborne polarimetric synthetic aperture radar (SAR) images have been used to validate the conclusions of a previous phenomenological study. Numerical simulations have been carried out with GRECOSAR, a polarimetric interferometric SAR simulation tool that is able to process highly complex targets with a fast and accurate radar-cross-section prediction module. A representative set of scenarios has been defined, which includes various realistic ship models, sea states, and imaging geometries. In all of them, a two-scale sea surface model precisely accounting for sea-ship interaction and sea clutter has been added. The analysis of different images has shown that, with an adequate spatial resolution, ships may be characterized by a particular spatial arrangement and polarization state distribution of dominant scattering centers. This feature has allowed one to propose a new classification algorithm, which shows a promising behavior after various preliminary tests. In this paper, the performance of this technique is further evaluated with realistic clutter. The results show that robust classification is possible even in highly cluttered scenes if quad-pol imagery is available. On the contrary, in low clutter conditions, the usage of less restrictive solutions, like circular dual-pol schemes, is feasible and may still get an acceptable performance. [J77]

"Monitoring of the Rice Cropping System in the Mekong Delta Using ENVISAT/ASAR Dual Polarization Data"

The rice cropping system in Asia is undergoing major changes to cope with increasing demography and changing climate, making rice monitoring a critical issue. Past studies have demonstrated the use of C-band synthetic aperture radar (SAR) data to map rice areas. The methods were based on the temporal change of intensity backscattering coefficient of vertically or horizontally co-polarized data (VV or HH). In this paper, we assess the use of the HH/VV polarization ratio derived from Advanced SAR (ASAR) data from ENVISAT data for the production of rice paddy maps. The approach is based on past knowledge on the polarization behavior of rice canopy, i.e., VV backscattering is much lower than HH during a large part of the rice season, due to the attenuation of the wave by the vertical structure of the plants. The methodology is developed for the Mekong Delta, Vietnam, where a complex cropping pattern is found (one to three crops of rice per year). The approach includes a statistical analysis of the HH/VV distributions of rice and non-rice classes at different dates. The analysis results confirm that HH/VV can be used as classifier and point out the need for relevant speckle filtering prior to classification. A classification method is developed and applied to single- and multidate data sets. The methods are tested at one district of the province of An Giang and extended to the whole province. Comparisons of the mapping results to geographic-information-system land-use data and official agricultural statistics show very good agreement. The method will be further applied to the entire Mekong Delta. [J78]

"Data Flow and Workflow Organization-The Data Management for the TerraSAR-X Payload Ground Segment"

The payload ground segment (PGS) for the recently launched German radar satellite, TerraSAR-X, performs the operational data management of the acquired satellite data. This comprises well-known functions such as reception, systematic and on-demand processing, archiving and cataloguing, ordering, and dissemination of digital Earth-observation products. In addition, it comprises new functions like large-scale multimode acquisition

ordering by users, integration with a commercial service segment, and new interfaces and workflows within the complete ground segment. The TerraSAR-X PGS is based on the Data Information and Management System (DIMS), the multimission data-handling infrastructure of the German Remote Sensing Data Center (DFD) at the German Aerospace Center. The development and integration of the new functions and complex workflows for TerraSAR-X were achieved and successfully tested on time. After the support of commissioning phase for five months, the system is now operational. As an intended side effect, the PGS for TerraSAR-X is, in several aspects, a pattern being reused for upcoming future missions, thus substantially reducing overall developmental costs. This paper investigates features of the TerraSAR-X PGS that enable the reuse in a multimission environment. It summarizes the achieved enhancements and extensions of DIMS to support the TerraSAR-X mission. Special emphasis is placed on the implementation of the request workflow initiated by user orders and the corresponding data flow within the distributed DFD multimission facility. [J79]

"Glacier Velocity Monitoring by Maximum Likelihood Texture Tracking"

The performance of a tracking algorithm considering remotely sensed data strongly depends on a correct statistical description of the data, i.e., its noise model. The objective of this paper is to introduce a new intensity tracking algorithm for synthetic aperture radar (SAR) data, considering its multiplicative speckle/noise model. The proposed tracking algorithm is discussed regarding the measurement of glacier velocities. Glacier monitoring exhibits complex spatial and temporal dynamics including snowfall, melting, and ice flows at a variety of spatial and temporal scales. Due to these complex characteristics, most traditional methods based on SAR suffer from speckle decorrelation that results in a low signal-to-noise ratio. The proposed tracking technique improves the accuracy of the classical intensity tracking technique by making use of the temporal speckle structure. Even though a new intensity-based matching algorithm is proposed, particularly for incoherent data sets, the analysis of the proposed technique was also performed for correlated data sets. As it is demonstrated, the velocity monitoring can be continuously performed by using the maximum likelihood (ML) texture tracking without any assumption concerning the correlation of the data set. The ML texture tracking approach was tested on ENVISAT-ASAR data acquired during summer 2004 over the Inyltshik glacier in Kyrgyzstan, representing one of the largest alpine glacier systems of the world. It will be demonstrated that the proposed technique is capable of robustly and precisely detecting the surface velocity field and velocity changes in time. [J80]

"Terrain: Slope Influence on QuikSCAT Backscatter"

Soil moisture (SM) is an important variable in determining streamflow, agricultural productivity, weather, and climate. An effective way to map SM over large areas on a regular basis is by using active microwave observations. This paper examines the influence of topography on radar backscatter measurements for a range of vegetation conditions and on the development of a normalization technique for the correction of topography-induced variability. Radar backscatter observations derived from the QuikSCAT sensor were analyzed to investigate the effect of sloping terrain over the North American Monsoon Experiment region that is characterized by heterogeneous surface conditions and complex topographic terrain. A digital elevation model, along with local incidence angle and slope, was used to investigate the backscatter dependence on topography variation for eight main vegetation classes. Pearson product-moment correlation (R) analysis showed strong backscatter dependence on the local incidence angle caused by changes in slope. The overall average reduction in variances after correction for August 2004 depended on vegetation type and ranged between -16% to -42% and -18% to -37% for horizontal and vertical polarizations, respectively. The corrected sigma-0 was also evaluated using insituSM observations obtained during the Soil Moisture Experiment 2004 field campaign. The computed percent change in Rbetween sigma-0 and SM demonstrated significant improvement after correction when using vertically observed sigma-0. The standard errors of estimate for these two vegetation classes were lowered by about 12% and 5%, respectively, after applying the proposed topographic normalization technique to the QuikSCAT observations. [J81]

"Bistatic clutter analysis and range ambiguity resolving for space time adaptive processing"

The clutter characteristics of bistatic airborne radar are more complex than those of monostatic airborne radar. The clutter spectra not only vary severely with range, but also vary with bistatic configuration. The problem of range dependence is more serious in monostatic airborne radar. In this paper, the geometry of arbitrary bistatic airborne radar configuration is firstly analysed, and a formula for Doppler frequency calculation with the variables of azimuth angle and bistatic range is deduced, which is an efficient tool for bistatic clutter analysis. Because of the severe clutter range dependence, the processing of compensation is indispensable in space time adaptive processing (STAP). However, when range ambiguity occurs, the compensation is difficult to be applied to each clutter range cell. To solve this problem, a range ambiguity resolving approach is further proposed by utilising azimuth elements in phased array. Because this approach will result in spatial degrees of freedom (DOF) loss, the overlapped subarray processing is introduced in order obtain enough spatial DOF for STAP. By doing so, the

compensation for mitigating range dependence can be applied effectively to bistatic clutter. [J82]

"Pitch estimation for non-cooperative maritime targets in ISAR scenarios"

Maritime targets are usually involved in complex motions that complicate the generation of focused inverse synthetic aperture radar (ISAR) images and their scaling in cross-range. By assuming some hypotheses that translate to some restrictions in the maritime surveillance scenario, a signal model for the phase history is derived. This function is calculated here using phase gradient autofocus and can be related to the pitch motion of the ship, which may consequently be estimated. The amplitude and the period of this pitch estimate allow us to select imaging times at which the ISAR images are descriptive for classification purposes. The cross-range scaling of these images is also achieved. Simulated data are used to validate the technique and to evaluate its performance when deviations from the nominal scenario are present. Results obtained with live data acquired by a high-resolution radar confirm the effectiveness of the approach. [J83]

"The Application of the Principle of Chirp Scaling in Processing Stepped Chirps in Spotlight SAR"

A new approach to process stepped chirps in spotlight synthetic aperture radar is presented in this letter, which is based on exploiting the principle of chirp scaling (PCS). In particular, PCS is integrated into the polar format algorithm (PFA), obtaining a more efficient solution compared with the existing polar interpolation technique. The main contribution of this letter is the implementation of azimuth scaling, in which the bandwidth synthesis is embedded. The algorithm is developed dedicatedly for dealing with stepped chirps. The signal processing flow is investigated in detail, in which no interpolations but only fast Fourier transform and complex multiplications are involved. Point-target simulation has validated the new approach and indicated that it is more efficient than the classic interpolation-based one. The achieved computational gain measured in execution time is around 25%-30%. [J84]

"A Generalized Approach to Multiresolution Complex SAR Signal Processing"

Multiresolution synthetic aperture radar (SAR) image formation has been proven to be beneficial in a variety of applications such as improved imaging and target detection as well as speckle reduction. SAR signal processing traditionally carried out in the Fourier domain has inherent limitations in the context of image formation at hierarchical scales. We present a generalized approach to the formation of multiresolution SAR images using biorthogonal shift-invariant discrete wavelet transform (SIDWT) in both range and azimuth directions. Particularly in azimuth, the inherent subband decomposition property of wavelet packet transform is introduced to produce multiscale complex matched filtering without involving any approximations. This generalized approach also includes the formulation of multilook processing within the discrete wavelet transform (DWT) paradigm. The efficiency of the algorithm in parallel form of execution to generate hierarchical scale SAR images is shown. Analytical results and sample imagery of diffuse backscatter are presented to validate the method. [J85]

"Dual-band fractal shape antenna design for RFID applications"

A compact printed dipole antenna is proposed for radio frequency identification (RFID) applications. It consists of a combination of two kinds of fractal shapes with the aim of reducing antenna size. To ensure conjugate matching with the essentially complex impedance of the electronic chip directly embedded into the radiator, a double T-match structure is used. The antenna has been designed and optimised to cover the bi-band for the passive RFID tag at 915 MHz and 2.4 GHz. Details of the proposed antenna design and measured results are presented and discussed. [J86]

"Spectral Difference Between Microwave Radar and Microwave-Induced Thermoacoustic Signals"

This letter presents a spectral content comparison of the signals generated in the microwave radar (MR) and microwave-induced thermoacoustic (MIT) imaging systems. Two physical processes occur when microwave interacts with a lossy dielectric object. First, due to the contrast in the complex permittivity between the embedded object and background medium, reflection of microwave energy occurs at the interface. Second, due to the contrast in the absorption coefficient between the object and background medium and the consequent thermal expansion, microwave induces an acoustic wave. As a method of comparison between the inputs and outputs of the MR and MIT processes, we define the MR and MIT channels. We use a two-dimensional (2-D) example to demonstrate that the MR channel over the ultrawideband (UWB) spectrum from 3.1 to 10.6 GHz manifests different fading from the MIT channel over the ultrasonic spectrum from 0.32 to 1.10 MHz. The two output signals are distinctive, but they are co-registered to the same object. Hence, using the information provided by both could enhance the imaging modality. We apply this dual-physics scheme in the context of breast tumor detection. [J87]

"Parallel MoM Using Higher-Order Basis Functions and PLAPACK In-Core and Out-of-Core Solvers for Challenging EM Simulations"

Typically, the problem size that can be solved by the Method of Moments (MoM) is limited by the amount of RAM installed in the computer. To reduce the number of unknowns for MoM, higher-order polynomial functions have been introduced as the basis functions. To extend the capability of the MoM code, this paper presents a new development: the use of a new parallel out-of-core solver called PLAPACK. The PLAPACK library package offers benefits that are not available in the more commonly used ScaLAPACK libraries. Numerical results on a typical computer platform for two different challenging electromagnetic problems show that the PLAPACK out-of-core solver introduced here is a very efficient way to deal with large matrix equations. The implementation of these advancements creates a powerful tool for the efficient computational electromagnetic solution of large and complex real-world problems. [J88]

"Computation of RCS of targets modelled with trimmed NURBS surfaces"

A novel technique for the monostatic radar cross-section (RCS) computation of complex targets modelled with trimmed nonuniform rational B-spline (NURBS) surfaces is proposed using physical optics (PO). The stationary phase method (SPM) is demonstrated to be invalid in evaluation of the PO integral over trimmed surfaces. Thus a new method, which combines SPM with the Gordon method (namely SPM-Gordon) is presented as a substitute and good candidate. Examples show that excellent accuracy is obtained. [J89]

"Radar target classification method with reduced aspect dependency and improved noise performance using multiple signal classification algorithm"

This study introduces a novel aspect and polarisation invariant radar target classification method based on the use of multiple signal classification (MUSIC) algorithm for feature extraction. In the suggested method, for each candidate target at each designated reference aspect, feature matrices called `MUSIC spectrum matrices (MSMs)` are constructed using the target`s scattered data at different late-time intervals. An individual MSM corresponds to a map of a target`s natural resonance-related power distribution over the complex frequency plane under the chosen aspect angle`late-time interval conditions. The collection of these feature matrices is used first to determine the best late-time interval for optimal feature extraction. Then, the MSM of a target, which are computed over the optimal time interval at all reference aspects, are superposed to obtain the `fused MUSIC spectrum matrix (FMSM)`. The FMSM of a target is its main classifier feature in the proposed method as the aspect dependency of an FMSM is highly reduced because of its multi-aspect construction process. The suggested method is demonstrated for both simple and complex target geometries such as conducting spheres, dielectric spheres and small-scale aircraft targets with high accuracy rates even for low SNR values using feature fusion at only a few different reference aspects. [J90]

"A Lossy Dielectric-Ring Loaded Waveguide With Suppressed Periodicity for Gyro-TWTs Applications"

A dielectric-loaded (DL) waveguide is an attractive possibility for interaction circuits with high-power sources in the millimeter-wave regime down to tenths of millimeters, particularly for gyrotron-traveling-wave-tube amplifiers (gyro-TWTs). We present results on a systematic investigation of the influence of the periodically loaded lossy dielectric on the propagation characteristics of the operating modes, which reveals that a complex mode in the periodic system can be mapped to a corresponding mode in an empty waveguide or a uniform DL waveguide. Dielectric losses not only induce modal transitions between different modes with similar field structures and close phase velocities in the uniform system but also unify the discrete mode spectrum into a continuous spectrum in the periodic system. Since the lossy dielectric functions as a power sink, the higher order Bloch harmonic components arising from the structural periodicity are suppressed, and the mode spectrum of the lossy periodic system degenerates into that of an empty waveguide. This alleviates the potential danger of spurious oscillations induced by the higher order harmonic components, making the periodic lossy DL waveguide promising in a high-power millimeter-wave gyro-TWT. [J91]

"Estimation of the Equivalent Number of Looks in Polarimetric Synthetic Aperture Radar Imagery"

This paper addresses estimation of the equivalent number of looks (ENL), an important parameter in statistical modeling of multilook synthetic aperture radar (SAR) images. Two new ENL estimators are discovered by looking at certain moments of the multilook polarimetric covariance matrix, which is commonly used to represent multilook polarimetric SAR (PolSAR) data, and assuming that the covariance matrix is complex Wishart distributed. First, a second-order trace moment provides a polarimetric extension of the ENL definition and also a matrix-variate version of the conventional ENL estimator. The second estimator is obtained from the log-

determinant matrix moment and is also shown to be the maximum likelihood estimator under the Wishart model. It proves to have much lower variance than any other known ENL estimator, whether applied to single-polarization or PolSAR data. Moreover, this estimator is less affected by texture and thus provides more accurate results than other estimators should the assumption of Gaussian statistics for the complex scattering coefficients be violated. These are the first known estimators to use the full covariance matrix as input, rather than individual intensity channels, and therefore to utilize all the statistical information available. We finally demonstrate how an ENL estimate can be computed automatically from the empirical density of small sample estimates calculated over a whole scene. We show that this method is more robust than procedures where the estimate is calculated in a manually selected region of interest. [J92]

"Extraction of mixed-order multicomponent ship target signals from broadened sea clutter in bistatic shipborne surface wave radar"

A dynamic geometry model was built to describe the Doppler-broadening characteristics of the first-order Bragg lines for bistatic shipborne surface wave radar. They are time-varying because the Doppler frequency shifts of sea echoes are simultaneously modulated by the velocity components projected from the unavoidably different motions of both platforms, which is more complex than its counterpart in the monostatic mode. The geometrical relation is used to obtain the received signal model: strong first-order sea clutter interferences and submerged ship targets with constant and non-constant speeds are considered as mixed-order multicomponent polynomial-phase signals (mc-PPSs) and both second-order sea clutter continuum and atmospheric noise as additive noise. Then, a scheme based on the product high-order ambiguity function is proposed to extract the targets; it is a recursive procedure in which the first-order sea clutter is removed by an existing time-space cascaded filtering method. Monte Carlo simulations show the validity and efficiency of the proposed scheme. [J93]

"Phase of Target Scattering for Wetland Characterization Using Polarimetric C-Band SAR"

Wetlands continue to be under threat, and there is a major need for mapping and monitoring wetlands for better management and protection of these sensitive areas. Only a few studies have been published on wetland characterization using polarimetric synthetic aperture radars (SARs). The most successful results have been obtained using the phase difference between HH and VV polarizations, phiHH- phiVV, which has shown promise for separating flooded wetland classes. Recently, we have introduced a new decomposition, the Touzi decomposition, which describes target scattering type in terms of a complex entity, the symmetric scattering type. Huynen's target helicity is used to assess the symmetric nature of target scattering. In this paper, the new complex-scattering-type parameters, the magnitude alphasand phase Phialphas, are investigated for wetland characterization. The use of the dominant-scattering-type phase Phialphasmakes it possible to discriminate shrub bogs from poor (sedge or shrub) fens. These two classes cannot be separated using phiHH- phiVV, or the radiometric scattering information provided by alphas, the Cloude alpha, the entropy H, and the multipolarization HH-HV-VV channels. phialphas, which cannot detect deep (45 cm below the peat surface) water flow in a bog, is more sensitive to the shallower (10-20-cm) fen beneath water, and this makes possible the separation of poor fens from shrub bogs. Phialphasalso permits the discrimination of conifer-dominated treed bog from upland deciduous forest under leafy conditions. Target helicity information is exploited to introduce a new parameter, the target asymmetry. The latter is shown very promising for detection of forest changes between leafy and no-leaf conditions. The analysis of low-entropy marsh scattering showed that both the scattering-type magnitude and phas--e alphasand Phialphas, respectively, as well as the maximum polarization intensity of the dominant scattering m, are needed for a better understanding of marsh complex scattering mechanisms. The unique information provided by the new roll-invariant decomposition parameters are demonstrated using repeat-pass Convair-580 polarimetric C-band SAR data collected in June and October 1995 over the RAMSAR Mer Bleue wetland site near Ottawa (Canada). [J94]

"Coherence-Improving Algorithm for Image Pairs of Bistatic SARs With Nonparallel Trajectories"

Ground moving target indication (GMTI) is one of the most important applications in a general bistatic synthetic aperture radar (SAR) system, where the transmitter and receiver move along nonparallel trajectories with different velocities. In order to improve the capability of clutter cancellation in bistatic SAR/GMTI processing, the coherence between two echoes collected by two receivers is investigated, and the full-coherence conditions are derived. A new coherence-improving algorithm for general bistatic SAR complex image pairs is proposed, which can be realized in the following steps: 2-D range azimuth prefiltering processing, relative geometric deformation correction, and image registration. An approximate implementation of 2-D prefiltering and the corresponding prefilter parameter analysis are also given. Last, two numerical experiment results are given to demonstrate the effectiveness of the proposed algorithm. [J95]

"Power converters and amplifiers (review of "RF Power Amplifiers" by Kazimierczuk, M.K.; 2008)

[JBook News]"

This is a comprehensive textbook covering the fundamentals of RF power amplifiers and their range of applications in radio and TV broadcasting, wireless communications, and radars. It presents accessible coverage of the complex principles of operation of RF power amplifiers and radio power systems. It introduces the fundamental design techniques and procedures for practitioners for RF power amplifiers. All the chapters contain examples and design procedures throughout, with review questions, problems, and references at the end of each chapter. A solutions manual is available for instructors. This textbook is helpful for students as well as for practicing engineers working with RF power amplifiers in such application areas as computers, telecommunications, industrial electronic systems, automotive electronics, radars, medical equipment, and aerospace power technology. [J96]

"MEMS tomographic imaging system simulation"

This describes a simulation architecture used to simulate an ultra-narrowband radar tomographic imaging (UNBRaTI) system. The work is being performed at Rochester Institute of Technology. This 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. [J97]

"Circularity and Gaussianity Detection Using the Complex Generalized Gaussian Distribution"

Knowing the statistical properties of a complex-valued signal is important in many signal processing applications by providing the necessary information for choosing the appropriate algorithm. In this paper, we provide generalized likelihood ratio tests (GLRT), based on the complex generalized Gaussian distribution (CGGD), for detecting two important signal properties: 1) the circularity of a complex random variable, not constrained to the Gaussian case and 2) whether a complex random variable is complex Gaussian. These tests can be combined to statistically determine if a complex random variable is, the often assumed, circular Gaussian. Simulations are used to quantify the performance of the detectors followed by application to communication signals and actual radar data. [J98]

"Adaptive Radar Detection in Doubly Nonstationary Autoregressive Doppler Spread Clutter"

The problem of adaptive radar detection in clutter which is nonstationary both in slow and fast time is addressed. Nonstationarity within a coherent processing interval (CPI) often precludes target detection because of the masking induced by Doppler spreading of the clutter. Across range bins (i.e., fast time), nonstationarity severely limits the amount of training data available to estimate the noise covariance matrix required for adaptive detection. Such difficult clutter conditions are not uncommon in complex multipath propagation conditions where path lengths can change abruptly in dynamic scenarios. To mitigate nonstationary Doppler spread clutter, an approximation to the generalized likelihood ratio test (GLRT) detector is presented wherein the CPI from the hypothesized target range is used for both clutter estimation and target detection. To overcome the lack of training data, a modified time-varying autoregressive (TVAR) model is assumed for the clutter return. In particular, maximum likelihood (ML) estimates of the TVAR parameters, computed from a single snapshot of data, are used in a GLRT for detecting stationary targets in possibly abruptly nonstationary clutter. The GLRT is compared with three alternative methods including a conceptually simpler ad hoc approach based on extrapolation of quasi-stationary data segments. Detection performance is assessed using simulated targets in both synthetically-generated and real radar clutter. Results suggest the proposed GLRT with TVAR clutter modeling can provide between 5-8 dB improvement in signal-to-clutter plus noise ratio (SCNR) when compared with the conventional methods. [J99]

"Hybrid GPU-Based Single- and Double-Bounce SAR Simulation"

In this paper, a new hybrid graphics-processing-unit (GPU)-based real-time synthetic aperture radar (SAR) simulation system is presented. Previous real-time SAR simulators only supported single-bounce simulation in real time. The new hybrid system uses the rasterization approach for real-time single-bounce simulation and a new image-based GPU ray-tracing approach for monostatic SAR double-bounce simulation. This approach provides fast simulation results even while simulating complex and extended scenes. The simulation results are compared to a high-resolution airborne SAR image, and the limitations of the approach are discussed. [J100]

"Phase-Based Clutter Identification in Spectra of Weather Radar Signals"

A novel method for suppression of ground clutter (GC) in weather radar is presented. The novel identification scheme is entirely phase based, unlike power-based schemes that are generally used. GC contributions to the Doppler spectrum are identified from the differential phase between complex spectral coefficients of two spectra estimated for odd- and even-indexed half-sequences of the original time series. Phase values near zero are used as indicators of clutter contributions for Doppler bins close to zero velocity. Indicated Doppler bins are notched from the original spectrum, and the moments are then obtained. The identification scheme is motivated by spectra of an electronically steered phased array of the National Weather Radar Testbed (NWRT) and requires a sufficient number of pulses/samples for spectral analyses. However, the method can be used with a mechanically steered antenna with an appropriate adjustment compensating smearing due to antenna rotation. The method was tested on several NWRT data sets obtained in clear air and in precipitation. One example of clutter-filtered power in precipitation is shown here. There is no baseline for comparison, as the NWRT does not have clutter filtering at the present time. Nonetheless, for a comparison of power- and phase-based identification schemes, a power-based clutter filter similar to the one used by the National Weather Service on the network of mechanically steerable Weather Surveillance Doppler radars WSR-88Ds is implemented on NWRT and used as a preliminary baseline for comparison. [J101]

"Distributed sensing based on intelligent sensor networks"

Network centric approach to complex systems has been attracting a lot of attention in the recent past. With specific applications in space, military and other information enterprises, such an approach is capable of yielding autonomy at the system level. This article describes a distributed approach to information processing in sensor networks. The network architecture entails a hierarchy of capabilities, information and control, where nodes in the network are thoroughly or partially autonomous. The network also consists of slave nodes dedicated to sensing and gathering information. Individual nodes are expected to possess resources for networking and computing and presume autonomy through multi functional modules for sensory processing and situation assessment. Data association, registration and fusion are formulated into a joint process, and an expectation maximization (EM) approach is developed to solve the three problems simultaneously. A fuzzy cognitive map (FCM) is proposed to perform situation assessment, while a genetic algorithm (GA) is applied for learning, to identify an optimal structure. The distributed architecture is applied to coastal surveillance with simulations on the west coast of Canada. [J102]

"UWB radar for human being detection [Jsame as "UWB radar for human being detection", ibid., vol. 21, n. 11, 06]"

UWB radar for detection and positioning of human beings in a complex environment has been developed and manufactured. The novelty of the radar lies in its large operational bandwidth (11.7 GHz at -10 dB level) combined with high time stability. Detection of respiratory movement of a person in laboratory conditions has been demonstrated. Based on experimental results, human being radar return has been analysed in the frequency band from 1 GHz to 12 GHz. The novel principle of human being detection is considered and verified experimentally. [J103]

"Effect of Salinity on the Dielectric Properties of Geological Materials: Implication for Soil Moisture Detection by Means of Radar Remote Sensing"

We consider the exploitation of dielectric properties of saline deposits for the detection and mapping of moisture in arid regions on both Earth and Mars. We present simulated and experimental study in order to assess the effect of salinity on the complex permittivity of geological materials and, therefore, on the radar backscattering coefficient in the [1-7 GHz] frequency range. Laboratory measurements are performed on sand/sodium chloride aqueous mixtures using a vectorial network analyzer coupled to an open-ended coaxial dielectric probe. We aim at calibrating and validating semiempirical dielectric mixing models. In particular, we evaluated the dependence of the real and imaginary parts of complex permittivity on the microwave frequency, water content, and salinity. Our results confirm that if the real part is mainly affected by the moisture content, the imaginary part is more sensitive to salinity. In addition to the classic formulas of mixing models, the ionic-conductivity losses, which are due to mobile ions in the saline solution, are taken into account in order to better assess the effect of salinity on the dielectric properties of mixtures. Dielectric mixing models are then used as input parameters for the simulation of the radar backscattering coefficients by means of an analytical model: the integral equation model. Simulation results show that salinity should have a significant impact on the radar backscattering recorded in synthetic aperture radar data in terms of the magnitude of the backscattering coefficient. Moreover, our results suggest that VV polarization provides a greater sensitivity to salinity than HH polarization. [J104]

"GLRT subspace detection for range and Doppler distributed targets"

A generalized likelihood ratio test (GLRT) is derived for adaptive detection of range and Doppler-distributed targets. The clutter is modeled as a spherically invariant random process (SIRP) and its texture component is range dependent (heterogeneous clutter). We suppose here that the speckle component covariance matrix is known or estimated thanks to a secondary data set. Thus, unknown parameters to be estimated are local texture values, the complex amplitudes and Doppler frequencies of all scattering centers. To do so, we use superresolution methods. The proposed detector assumes a priori knowledge on the spatial distribution of the target and has the precious property of having a constant false alarm rate (CFAR) with the assumption of a known speckle covariance matrix or by the use of frequency agility. [J105]

"Radar Cross Section (RCS) Modeling and Simulation, Part 2: A Novel FDTD-Based RCS Prediction Virtual Tool for the Resonance Regime"

A novel FDTD-based virtual radar cross section (RCS) prediction tool is introduced. Characteristic examples using simple three-dimensional structures, as well as more-realistic complex air and surface targets, are presented. The virtual tool automatically constructs a wire-grid model of the structure under investigation. It is therefore also possible to compare FDTD results against MoM-based NEC (Numerical Electromagnetics Code) data. It is shown that this virtual tool can be used for both educational and research purposes. [J106]

"CramЙr-Rao Bounds for Multiple Poles and Coefficients of Quasi-Polynomials in Colored Noise"

In this paper, we provide analytical expressions of the Cramer-Rao bounds for the frequencies, damping factors, amplitudes, and phases of complex exponentials in colored noise. These expressions show the explicit dependence of the bounds of each distinct parameter with respect to the amplitudes and phases, leading to readily interpretable formulae, which are then simplified in an asymptotic context. The results are presented in the general framework of the polynomial amplitude complex exponentials (PACE) model, also referred to as the quasi-polynomial model in the literature, which accounts for systems involving multiple poles and represents a signal as a mixture of complex exponentials modulated by polynomials. This work looks further and generalizes the studies previously undertaken on the exponential and the quasi-polynomial models. [J107]

"Optimal Particle Filters for Tracking a Time-Varying Harmonic or Chirp Signal"

We consider the problem of tracking the time-varying (TV) parameters of a harmonic or chirp signal using particle filtering (PF) tools. Similar to previous PF approaches to TV spectral analysis, we assume that the model parameters (complex amplitude, frequency, and frequency rate in the chirp case) evolve according to a Gaussian AR(1) model; but we concentrate on the important special case of a single TV harmonic or chirp. We show that the optimal importance function that minimizes the variance of the particle weights can be computed in closed form, and develop procedures to draw samples from it. We further employ Rao-Blackwellization to come up with reduced-complexity versions of the optimal filters. The end result is custom PF solutions that are considerably more efficient than generic ones, and can be used in a broad range of important applications that involve a single TV harmonic or chirp signal, e.g., TV Doppler estimation in communications, and radar. [J108]

"Fisher Distribution for Texture Modeling of Polarimetric SAR Data"

The multilook polarimetric synthetic aperture radar (PolSAR) covariance matrix is generally modeled by a complex Wishart distribution. For textured areas, the product model is used, and the texture component is modeled by a Gamma distribution. In many cases, the assumption of Gamma-distributed texture is not appropriate. The Fisher distribution does not have this limitation and can represent a large set of texture distributions. As an example, we examine its advantage for an urban area. From a Fisher-distributed texture component, we derive the distribution of the complex covariance matrix for multilook PolSAR data. The obtained distribution is expressed in terms of the KummerU confluent hypergeometric function of the second kind. Those distributions are related to the Mellin transform and second-kind statistics (Log-statistics). The new KummerU-based distribution should provide in many cases a better representation of textured areas than the classic Kdistribution. Finally, we show that the new model can discriminate regions with different texture distribution in a segmentation experiment with synthetic textured PolSAR images. [J109]

"SAR for disaster management"

In the last couple of years, an indigenous airborne synthetic aperture radar for disaster management (DMSAR) has been under development at SAC / ISRO, as a capacity building measure for evolving an effective disaster management support (DMS) system in India. Synthetic aperture radar (SAR) has an unique role to play in the mapping and monitoring of large areas affected by natural disasters, especially floods, owing to its unique

capability to see through clouds as well as all-weather imaging capability. DMSAR is presently mounted on-board Beechcraft B-200 aircraft and will he subsequently carried on a jet class aircraft and utilized for estimating the extent of damage over large areas (~50-75 Km) and also assess the effectiveness of the relief measures undertaken during disasters like floods. Considering the unique application requirements of disaster management, one of the major essential and critical requirements is the generation and availability of DMSAR images in real- or near-real-time with very fast turn-around times. DMSAR image generation involves complex signal processing of the acquired raw data, involving data decompression, two-dimensional SAR processing, motion sensing and compensation tasks, and image mosaicing on display as well as storage of processed SAR images on suitable recording media. [J110]

"Noise Reduction in Interferograms Using the Wavelet Packet Transform and Wiener Filtering"

A novel noise reduction scheme for synthetic aperture radar (SAR) interferograms based on the wavelet packet transform (WPT) and the Wiener filter is introduced in this letter. First, by employing the WPT in the spatial frequency domain, the real and imaginary parts of the complex noisy interferogram are decomposed, respectively, and the wavelet coefficients are obtained. Then, for these coefficients, Wiener filtering is adopted to remove noise. This scheme can filter noise adaptively according to the local noise level, without requiring any a priori information. By using a simulated noisy interferogram and two ENVISAT advanced synthetic aperture radar C-band interferograms, the performance of this scheme, in terms of noise reduction and fringes preservation, is reported and compared with other filter algorithms. The experimental results demonstrate the effectiveness of the proposed scheme. [J111]

"Signal Interpretation of Multifunction Radars: Modeling and Statistical Signal Processing With Stochastic Context Free Grammar"

Multifunction radars (MFRs) are sophisticated sensors with complex dynamical modes that are widely used in surveillance and tracking. Because of their agility, a new solution to the interpretation of radar signal is critical to aircraft survivability and successful mission completion. The MFRs' three main characteristics that make their signal interpretation challenging are: i) MFRs' behavior is mission dependent, that is, selection of different radar tasks in similar tactic environment given different policies of operation; ii) MFRs' control mechanism is hierarchical and their top level commands often require symbolic representation; and iii) MFRs are event driven and difference and differential equations are often not adequate. Our approach to overcome these challenges is to employ knowledge-based statistical signal processing with syntactic domain knowledge representation: a signal-to-symbol transformer maps raw radar pulses into abstract symbols, and a symbolic inference engine interprets the syntactic structure of the symbols and estimates the state of the MFR. In particular, we model MFRs as systems that "speak" a language that can be characterized by a Markov modulated stochastic context free grammar (SCFG). We demonstrate that SCFG, modulated by a Markov chain, serves as an adequate knowledge representation of MFRs' dynamics. We then deal with the statistical signal interpretation, the threat evaluation, of the MFR signal. Two statistical estimation algorithms for MFR signal are derived-a maximum likelihood sequence estimator to estimate the system state, and a maximum likelihood parameter estimator to infer the system parameter values. Based on the interpreted radar signal, the interaction dynamics between the MFR and the target is studied and the control of the aircraft's maneuvering models is implemented. [J112]

"The Adaptive Coherence Estimator is the Generalized Likelihood Ratio Test for a Class of Heterogeneous Environments"

The adaptive coherence estimator (ACE) is known to be the generalized likelihood ratio test (GLRT) in partially homogeneous environments, i.e., when the covariance matrix Msof the secondary data is proportional to the covariance matrix Mpof the vector under test (or Ms= gamma/Mp). In this letter, we show that ACE is indeed the GLRT for a broader class of nonhomogeneous environments, more precisely when Msis a random matrix, with inverse complex Wishart prior distribution whose mean only is proportional to Mp. Furthermore, we prove that, for this class of heterogeneous environments, the ACE detector satisfies the constant false alarm rate (CFAR) property with respect to gamma and Mp. [J113]

"Processing of Azimuth-Invariant Bistatic SAR Data Using the Range Doppler Algorithm"

This paper discusses bistatic synthetic aperture radar processing (complex image formation) using the Range Doppler Algorithm. The key step is to use an analytical form of the signal spectrum derived by the method of series reversion. The spectrum is used for secondary range compression (SRC), range cell migration correction, and azimuth compression. The algorithm is able to focus the azimuth-invariant bistatic configuration where the transmitter and receiver platforms are moving in parallel tracks with identical velocities. Moreover, the algorithm is able to handle reasonably high squints and wide apertures because SRC can be performed in the 2-D

frequency domain. [J114]

"Improving Coherence of Complex Image Pairs Obtained by Along-Track Bistatic SARs Using Range-Azimuth Prefiltering"

An along-track interferometric synthetic aperture radar (SAR) can be used for ground moving target indication (GMTI) by comparing two SAR images obtained at different observation times. Different geometries of the two observations bring the decorrelation noise, which will degrade the detection performance. For bistatic SARs, the decorrelation theory is quite different from that for monostatic ones. This paper deals with the coherence between two complex SAR images formed by two along-track bistatic SARs with different baseline lengths. Using the single scattering model, the coherence between the two echoes collected by the two receivers is investigated, and the full-coherence conditions are derived. Then, a new method based on range-azimuth prefiltering is proposed to improve the coherence of complex image pairs. As the precise prefiltering is complicated, its three approximate implementations are given. The effects of prefiltering on SAR images are also analyzed. Finally, simulation results validate the effectiveness of the proposed method. [J115]

"Phase Unwrapping for SAR Interferometry-A Data Fusion Approach by Kalman Filtering"

This paper considers the problem of unwrapping the phase image obtained from a noisy interferometric synthetic aperture radar (InSAR) image. The implicit nonlinearity of the problem is reflected, as well as the drawbacks of this nonlinearity on the performance of phase unwrapping approaches. Some general concepts concerning basic estimation techniques are shortly reviewed. On this background, a Kalman filter-based data fusion approach to unwrap and simultaneously filter the phases of InSAR images is developed. The data fusion concept exploits phase information extracted from the complex interferogram rather than from the phase image and fuses that information with phase slope information extracted from the power spectral density of the interferogram. [J116]

"A Stationary Wavelet-Domain Wiener Filter for Correlated Speckle"

In this paper, we develop a Wiener-type speckle filter that operates in the stationary wavelet domain. We denote it as the stationarywavelet-domainWiener(SWW) speckle filter. We assume that both the speckle-free image and the speckle contribution have spatial correlations and utilize well-established models for the power density spectrum of the radar cross section to estimate the autospectra that define the filter. It turns out that the filter is independent of the wavelet-domain scale level, i.e., the filter is the same at all scale levels. The SWW filter works on nonoverlapping blocks in the wavelet domain, which are obtained by a quadtree algorithm. Due to the dyadic support of the wavelet coefficients, a natural smoothing is carried out on the boundaries between neighboring blocks, and no visual boundary effects can be observed. The SWW filter is unbiased and shows good performance in despeckling synthetic aperture radar (SAR) images. It smooths homogeneous areas while preserving textured areas and point scatterers. In contrast to most other speckle filters, the SWW filter requires the SAR data to be given in single-look complex form. [J117]

"Fast Algorithms for Polynomial Time-Frequency Transforms of Real-Valued Sequences"

This paper presents fast algorithms for computing the polynomial time-frequency transform that deals with a real-valued sequence of length-apb, where a, b and p are positive integers. In particular, it shows that the polynomial time-frequency transform has a conjugate symmetric property, similar to that of the discrete Fourier transform, if the input sequence is real-valued. The computational complexities needed by these proposed algorithms are analyzed in terms of the numbers of real additions and real multiplications. When a=3,4, and 8, comparisons show that the computational complexities required by the proposed algorithms are less than 60% of those needed by the fast algorithms for complex-valued sequences. [J118]

"Fiber lasers: A future technology for lasers in space"

The constraints of operation in space have largely precluded the use of conventional solid-state laser systems for applications including remote sensing, communication relays, and active laser radars. A new technology, fiber lasers, may offer all of the needed features at an affordable price. An appealing aspect of the fiber laser is that it does not need a rigid optical bench. Only the output end of the fiber need be held in rigid reference to the optical tracking system. Design, fabrication, and testing of the laser resonator is generally the most expensive and longest lead part of the effort for conventional solid-state lasers. Advances in fiber optic technology and devices mean that the "fiber laser" need not be a simple device but may be a complex system employing sophisticated technology, such as wavelength selective Bragg reflectors and nonlinear optical frequency shifters. Three companies have obtained single-mode outputs of 35-40 watts single mode at 1.03-1.1 mu. [J119]

"Fusion of Hyperspectral and LIDAR Remote Sensing Data for Classification of Complex Forest Areas"

In this paper, we propose an analysis on the joint effect of hyperspectral and light detection and ranging (LIDAR) data for the classification of complex forest areas. In greater detail, we present: 1) an advanced system for the joint use of hyperspectral and LIDAR data in complex classification problems; 2) an investigation on the effectiveness of the very promising support vector machines (SVMs) and Gaussian maximum likelihood with leave-one-out-covariance algorithm classifiers for the analysis of complex forest scenarios characterized from a high number of species in a multisource framework; and 3) an analysis on the effectiveness of different LIDAR returns and channels (elevation and intensity) for increasing the classification accuracy obtained with hyperspectral images, particularly in relation to the discrimination of very similar classes. Several experiments carried out on a complex forest area in Italy provide interesting conclusions on the effectiveness and potentialities of the joint use of hyperspectral and LIDAR data and on the accuracy of the different classification techniques analyzed in the proposed system. In particular, the elevation channel of the first LIDAR return was very effective for the separation of species with similar spectral signatures but different mean heights, and the SVM classifier proved to be very robust and accurate in the exploitation of the considered multisource data. [J120]

"Radar Detection and Classification of Jamming Signals Belonging to a Cone Class"

This paper considers the problem of detecting and classifying a radar target signal and a jamming signal produced by a deception electronic counter measure (ECM) system based on a digital radio frequency memory (DRFM) device. The disturbance is modeled as a complex correlated Gaussian process. The jamming is modeled as a signal belonging to a cone whose axis is the true target signal. Two different approaches are analyzed, based on the adaptive coherent estimator (ACE) and on the generalized likelihood ratio test (GLRT), yielding both to a two-block device. The performance of the two detection/classification algorithms are evaluated, analytically, when possible, and by Monte Carlo simulation. [J121]

"Update: Magnetic Field Sensors Could Help Halt Runway Crashes"

Air-traffic control is a complex and high-stress business. Mistakes are not allowed. And it's not limited to directing planes for takeoff and landing-a job that's been memorably described as three-dimensional chess. It also includes keeping track of where planes are on the ground. According to safety watchdog Eurocontrol, in 2005 alone there were 600 occasions when people, cars, or planes crossed Europe's airport taxiways when they shouldn't have. In fact, the most deadly airline accident ever happened on the ground: in 1977, two 747 jumbo jets collided in the Canary Islands, killing 583 people. Most big airports have expensive ground-radar systems to keep track of where the hundreds of moving planes are on the sprawling tarmacs. But ground radar sometimes reflects off buildings and terminals, leaving small gaps in coverage. Smaller airports like the one in Thessaloniki, Greece, can't afford ground radar. Such blind spots on the ground at airports large and small have prompted European researchers to explore the use of fluctuations in the Earth's magnetic field to better pinpoint where planes are on busy taxiways. The results, researchers say, show that using US $150 sensors can fill in the blind spots. [J122]

"Computing and bounding the first-order Marcum Q-function: a geometric approach"

A geometric interpretation of the first-order Marcum Q-function, Q(a,b), is introduced as the probability that a complex, Gaussian random variable with real mean a, takes on values outside of a disk CO,bof radius b centered at the origin O. This interpretation engenders a fruitful approach for deriving new representations and tight, upper and lower bounds on Q(a,b). The new representations obtained involve finite-range integrals with pure exponential integrands. They are shown to be simpler and more robust than their counterparts in the literature. The new bounds obtained include the generic exponential bounds which involve an arbitrarily large number of exponential functions, and the simple erfc bounds which involve just a few erfc functions, together with exponential functions in some cases. The new generic exponential bounds approach the exact value of Q(a,b) as the number of exponential terms involved increases. These generic exponential bounds evaluated with only two terms and the new simple erfc bounds are much tighter than the existing exponential bounds in most cases, especially when the arguments a and b are large. Thus, in many applications requiring further analytical manipulations of Q(a,b), these new bounds can lead to some closed-form results which are better than the results available so far. [J123]

"Joint detection and tracking of unresolved targets with monopulse radar"

Detection and estimation of multiple unresolved targets with a monopulse radar is a challenging problem. For ideal single bin processing, it was shown in the literature that at most two unresolved targets can be extracted

from the complex matched filter output signal. A new algorithm is developed to jointly detect and track more than two unresolved targets from a single detection with the help of tracking information. That is, the method involves the use of tracking information in the detection process. For this purpose, target states are transformed into detection parameter space, which involves high nonlinearities. In order to handle the nonlinearities, the particle filter, which has proven to be effective in nonlinear non-Gaussian estimation problems, is used as the basis of the closed loop system for tracking multiple unresolved targets. In addition to the standard particle filtering steps, the detection parameters corresponding to the predicted particles are evaluated using the nonlinear monopulse radar beam model. This in turn enables the evaluation of the likelihood of the monopulse signal given tracking data. Bayesian model selection is then used to find the correct detection event. The corresponding particle set is taken as the correct representation of the target posterior. A simulated amplitude comparison monopulse radar is used to generate the data and validate the joint detection and tracking of more than two unresolved targets. [J124]

"Polar format agorithm using chirp scaling for spotlight SAR image formation"

A novel implementation of the polar format algorithm (PFA) using the principle of chirp scaling (PCS) for spotlight synthetic aperture radar (SAR) image formation is addressed. A PFA completely free of interpolation has been achieved in moderate squinted imaging geometry. The presented approach consists of the range and azimuth scaling of the polar samples, in which only fast Fourier transforms (FFTs) and complex vector multiplications are involved. Following different processing chains, the dechirped and the chirped SAR signals are treated separately in this paper. Relative to the classic polyphase filter that uses the long sinc kernel, the new solution is able to attain a comparable result, but is much quicker by exploiting inherent properties of the linear frequency modulated (LFM) signal. Point target simulation has validated the presented methodology. [J125]

"On-board axial detection of wake vortices using a 2-m m LiDAR"

This paper describes the first successful attempt to detect wake vortices axially using an on-board infrared pulsed Doppler LiDAR (light detection and ranging) is described. On-board axial detection is more complex than the classic ground-based tangential approach, because the axial air speed in vortices is low and the atmospheric particle density is reduced, yielding a poorer SNR. To provide meaningful results in such unfavorable conditions we have developed a new flexible signal processing method based on a two-primitive model fitting the spectrum of the Doppler return. This new spectral estimation successfully detects wake vortices with an admissible SNR that is lower than other on-board state-of-the-art approaches. It was validated through flight tests. [J126]

"A Physical Full-Resolution SAR Ship Detection Filter"

Synthetic aperture radar (SAR) ship detection is an important application in the context of environment and security monitoring. It allows monitoring traffic, fisheries, and associating ships with oil discharge over wide areas with high spatial resolution almost independently from weather conditions and both day and night time. Since full-resolution SAR images are heavily affected by the presence of speckle, ship detection algorithms generally employ speckle reduced SAR images at the expense of a degradation of the spatial resolution. A new physical approach, which considers ships as dominant scatterers and, therefore, responsible for a strong and coherent backscattered signal, is here proposed. Based on this rationale, a new simple and very effective filtering technique, which is able to process full-resolution SAR images, has been conceived and implemented. Experiments, accomplished over C-band European Remote Sensing satellite (ERS) 1/2 single-look complex SAR images, show the effectiveness of the proposed approach. [J127]

"Multiple-Mode Selection of Walled-LTSA Array Elements for High-Resolution Imaging to Visualize Antipersonnel Plastic Landmines"

We propose a resolution improvement technique for a high-density array of walled linearly tapered slot antennas (LTSAs) in ground-penetrating radar imaging. In the system, we use the walled-LTSA array in a near-field measurement configuration and select various pairs of transmitter and receiver antennas out of the array elements. We prepare four selection modes so that we can practically enhance the imaging resolution. We remove the direct-coupling effect and compensate the path-length fluctuation caused by element individuality and element selection. Experiments demonstrate that the technique realizes higher resolution image acquisition to yield a clearer segmentation of antipersonnel plastic landmines in combination with adaptive image processing, based on complex-amplitude texture, even on a wet laterite soil condition. [J128]

"Dispersion Characteristics of a Rectangular Helix Slow-Wave Structure"

A special type of helical slow-wave structure encompassing a rectangular geometry is investigated in this paper,

and the slow-wave characteristics are studied taking into account the anisotropically conducting helix. By using the electromagnetic integral equations at the boundaries, the dispersion equation and the interaction impedance of transverse antisymmetric modes in this structure are derived. Moreover, the obtained complex dispersion equation is numerically calculated. The calculation results by our theory agree well with the results obtained by the 3-D EM simulation software HFSS. The numerical results reveal that the phase velocity decreases and interaction impedance increases at higher frequencies by flattening (increasing the aspect ratio of) the rectangular helix structure. In addition, a comparison of slow-wave characteristics of this structure with a conventional round helix is made. [J129]

"Model-Based Polarimetric SAR Speckle Filter"

In this paper, a new framework to filter speckle noise in polarimetric synthetic aperture radar (PolSAR) data is presented. The proposed filter, named the model-based PolSAR (MBPolSAR) filter, is based on exploiting the multiplicative-additive speckle noise model for multidimensional SAR data. The entries of the sample covariance matrix are processed according to this multiplicative-additive speckle noise model as a function of the complex correlation coefficient. Hence, the covariance matrix elements are processed differently. This filtering scheme improves the reduction of speckle noise and ameliorates the estimation of the polarimetric information. The filtering performances of the MBPolSAR approach are first tested quantitatively by means of simulated PolSAR data. In a second stage, they are evaluated by means of experimental SAR data acquired by the Deutsches Zentrum fu umlr Luft-und Raumfahrt. [J130]

"Mechanical engineering's role in multi-disciplinary radar design"

Successful execution of a program and full satisfaction of the customer's requirements is a challenge for any contractor. Raytheon Company responds to this challenge by following a proven program execution methodology. The methodology includes all program aspects from financial planning to engineering to validation and test. This discusses the engineering team and the role of the mechanical engineer. A radar system is ultimately an assembly of advanced electronics and software. However, the design, fabrication, assembly, integration, and test Of this complex system requires a coherent multi-disciplinary approach. Raytheon, like many contractors, chooses to assemble an integrated product team (IPT) including all engineering disciplines. Mechanical engineering is integral to satisfying performance requirements, performing preliminary and detailed design, transition of the design to manufacturing, and implementation of the hardware in the field. During definition, mechanical engineering assists fundamental architecture development, conceptual design, and requirements development which precludes issues that are sometimes ignored to the detriment of many programs. These design issues include environmental protection, structural stiffness to meet deflection requirements, cooling system capacity to properly remove dissipated heat, manufacturability to control cost, maintainability to enable repair in the field, and transportability. Recognizing and trading off these issues early greatly increases the Probability Of satisfying customer objectives. This discusses the approach Raytheon is taking to ensure an overall multi-disciplinary solution to our design challenges from the perspective of the mechanical engineer. [J131]

"Imaging of Micromotion Targets With Rotating Parts Based on Empirical-Mode Decomposition"

For micromotion targets with rotating parts, the inverse synthetic-aperture-radar image of the main body may be shadowed by the micro-Doppler. To solve this problem, this paper proposes an imaging algorithm based on the complex-valued empirical-mode decomposition. First, the radar echoes are decomposed into a series of complex-valued intrinsic-mode functions (IMFs). Then, the IMFs from the rotating parts and those from the main body are separated according to the characteristics of their zero-crossings. Finally, the well-focused imaging of the main body via traditional imaging algorithm and the accurate parameter estimation of the rotating part can be obtained. Both the imaging results for the simulated and measured data are given to verify the validity of the proposed algorithm. [J132]

"Parallel in-core and out-of-core solution of electrically large problems using the RWG basis functions"

Currently, the problem size that can be solved in reasonable time using the Method of Moments is limited by the amount of memory installed in the computer. This paper offers a new development that not only breaks this memory constraint, but also maintains the efficiency of running the problem in-core. In this paper, highly efficient parallel matrix-filling schemes are presented for parallel in-core and parallel out-of-core integral-equation solvers with subdomain RWG basis functions. The parallel methodology for matrix filling is quite different when using a subdomain basis as opposed to using a higher-order basis. The parallel in-core solver uses memory, which is often expensive and limited in size. The parallel out-of-core solver is introduced to extend the capability of MoM

to solve larger problems that can be as large as the amount of storage on the hard disk. Numerical results on several typical computer platforms show that the parallel matrix-filling schemes and matrix-equation solvers introduced here are highly efficient and achieve theoretical predictions. The implementation of these advancements with the widely used RWG basis functions creates a powerful tool for efficient computational electromagnetics solution of complex real-world problems. [J133]

"Random Body Movement Cancellation in Doppler Radar Vital Sign Detection"

The complex signal demodulation and the arctangent demodulation are studied for random body movement cancellation in quadrature Doppler radar noncontact vital sign detection. This technique can be used in sleep apnea monitor, lie detector, and baby monitor to eliminate the false alarm caused by random body movement. It is shown that if the dc offset of the baseband signal is accurately calibrated, both demodulation techniques can be used for random body movement cancellation. While the complex signal demodulation is less likely to be affected by a dc offset, the arctangent demodulation has the advantage of eliminating harmonic and intermodulation interference at high carrier frequencies. When the dc offset cannot be accurately calibrated, the complex signal demodulation is more favorable. Ray-tracing model is used to show the effects of constellation deformation and optimum/null detection ambiguity caused by the phase offset due to finite antenna directivity. Experiments have been performed using 4-7 GHz radar to verify the theory. [J134]

"Beam Sharpening of Delay/Doppler Altimeter Data Through Chirp Zeta Transform"

The main goal of a satellite radar altimeter is to measure the height of the reflecting surface scanned by the passage of the instrument overhead. A delay/Doppler altimeter reduces the along-track footprint size by exploiting the coherence of the emitted pulses to synthetize a narrower antenna. Doppler beam formation is then a straightforward procedure that implies application of the discrete Fourier transform to time-domain bursts. Speckle and thermal noise on Doppler echoes are usually reduced using multilooking, i.e., summing incoherent contributions coming from different bursts. The summation of Doppler beams requires precise pointing toward output sample locations, particularly when highly variable topography is effective. However, the procedure of steering after beam sharpening needs a step of interpolation. In this paper, a Doppler beam sharpening and direction toward the sample position are presented which make use of the Chirp Zeta Transform to join the two operations together. This method must be compared with the existing ones to show that a little can be sacrificed to precision for computational gain. To support the discussion, experimental results will be compared with a precise-and so of reference-direct 2-D correlation algorithm over puntiform targets and more complex scenarios. [J135]

"Adaptive chaotic maps for identification of complex targets"

Identification of complex targets in radar or sonar is a difficult problem. The author shows how the parameters of a simple chaotic map may be optimised to increase the cross correlation of a transmitted signal with the reflection from one target while decreasing the cross correlation with another target. The targets consist of simple arrays of point scatterers. The author shows that the optimisation process produces a chaotic signal with a power spectrum that maximises the ratio of the cross correlation with one target to the cross correlation with a different target, however the author also shows that the specific time ordering of the chaotic signal is also important in determining the cross correlation. The performance of the chaotic signal is better than a random signal with the same power spectrum. The author also shows an example of applying these methods to targets that are more complex. [J136]

"Information Theory-Based Approach for Contrast Analysis in Polarimetric and/or Interferometric SAR Images"

We propose a new approach for evaluating the contribution of the different channels of polarimetric and interferometric synthetic aperture radar (PolInSAR) images. For that purpose, we demonstrate that the Bhattacharyya distance between the probability density functions of neighboring regions in the image provides an efficient scalar contrast measure. We show that the analysis of this contrast measure allows one to precisely characterize the contribution of each channel for different system configurations, including intensity, polarimetric, and interferometric images. We illustrate this approach using a real synthetic aperture radar image to compare several polarimetric system architectures. Since PolInSAR imaging configurations can correspond to complex and expensive systems, the proposed method can be helpful in system imaging optimization. [J137]

"Imaging Simulation of Bistatic Synthetic Aperture Radar and Its Polarimetric Analysis"

Employing the 3-D mapping and projection algorithm (MPA), an imaging simulation of bistatic synthetic aperture radar (BISAR) observation over a complex scenario is developed. Based on the explicit expression of the point

target response of stripmap BISAR imaging, raw data are efficiently generated from the scattering map precalculated by MPA. Some examples of BISAR image simulation are studied. The polarimetric characteristics of a BISAR image are then discussed. It is found that some typical polarimetric parameters such as Cloude's alpha, beta and gamma and might become unable to describe the scattering mechanism under bistatic observation. A transform of unified bistatic polar bases for a BISAR image is proposed. The parameters alpha, beta and gamma and are modified to retain the property of orientation independence in the bistatic circumstance. Analysis of simulated images shows that the redefined alpha, beta and gamma and after the unified bistatic polar bases transform well describe different scattering mechanisms in BISAR imaging. It provides a primary tool for BISAR image interpretation and terrain classification. [J138]

"A Refined GTD Ray System for an Embedded Object and Its Polarimetric Behavior"

A refined ray system based on the geometrical theory of diffraction (GTD) for an object embedded in soil for a monostatic transmitter-receiver alignment is presented. Apart from the investigation of the ldquoclassicalrdquo reflections from the target, creeping waves are also taken into account, and their formalism is presented. The objective of such a ray set is to better understand the different scattering mechanisms, which are presented in the complex scattering framework. In electromagnetic modeling based on GTD, the complex shape of a target is replaced by simpler canonical objects, e.g., facets, cones, wedges, spheres, or cylinders. Here, a cylinder is located in parallel and closely to the plane interface of two dielectric half-spaces. The example of air-soil is taken into account. The numerical results obtained for various directions of incidence are employed to describe the polarimetric characteristics of the diffracted field from grazing to perpendicular incidence to the surface. By representing the diffracted GTD field on the Poincare sphere, the location on the sphere has a one-to-one relationship to the dielectric properties of the soil. The relation can be employed to extract information as the soil moisture. [J139]

"Fiber lasers: A future space technology [Jsame article as "Fiber lasers: A future technology for lasers in space", ibid, vol. 23, n. 4, pp. 25-30, 08]"

The constraints of operation in space have largely precluded the use of conventional solid-state laser systems for applications including remote sensing, communication relays, and active laser radars. A new technology, fiber lasers, may offer all of the needed features at an affordable price. An appealing aspect of the fiber laser is that it does not need a rigid optical bench. Only the output end of the fiber need be held in rigid reference to the optical tracking system. Design, fabrication, and testing of the laser resonator is generally the most expensive and longest lead part of the effort for conventional solid-state lasers. Advances in Fiber Optic technology and devices mean that the "fiber laser" need not be a simple device but may be a complex system employing sophisticated technology such as wavelength selective Bragg reflectors and nonlinear optical frequency shifters. Three companies have recently obtained single-mode outputs of 3540 watts single mode at 1.03-1.1 microns. [J140]

"Model-Based Interpretation of High-Resolution SAR Images of Buildings"

High-resolution (HR) synthetic aperture radar (SAR) images of urban areas reveal a large variety of details that, although potentially bringing a lot of information, are often very difficult to interpret. Until now, most of the research activity in this field has been devoted to the attempt to retrieve geometric information on buildings in terms of their positions and sizes, by using simplified geometrical models. However, this approach does not allow us to fully exploit the large amount of information present in HR SAR images. In order to improve information retrieval from such images, and, hence, their interpretation, in this paper, we propose to employ a more refined model that accounts for both geometrical (including fine details) and electromagnetic properties of the building. A meaningful case study is presented to show that the main features appearing on the SAR image of a building can be interpreted by using our geometric and electromagnetic model. In addition, a first example of retrieval of the complex dielectric constant of building materials from a SAR image is presented. [J141]

"Solving large complex problems using a higher-order basis: parallel in-core and out-of-core integral-equation solvers"

The future of computational electromagnetics is changing drastically with the new generation of computer chips, which are multi-cored instead of single-cored. Previously, advancements in chip technology meant an increase in clock speed, which was typically a benefit that computational code users could enjoy. This is no longer the case. In the new roadmaps for chip manufacturers, speed has been sacrificed for improved power consumption, and the direction is multi-core processors. The burden now falls on the software programmer to revamp existing codes and add new functionality to enable computational codes to run efficiently on this new generation of multi-core processors. In this paper, a new roadmap for computational code designers is provided, demonstrating how

to navigate along with the chip designers through the multi-core advancements in chip design. A new parallel code, using the method of moments (MoM) and higher-order functions for expansion and testing, and executed on a range of computer platforms, will illustrate this roadmap. The advantage of a higher-order basis over a subdomain basis is a reduction in the number of unknowns. This means that with the same computer resources, a larger problem can be solved using higher-order basis than using a subdomain basis. The matrix filling for MoM with subdomain basis must be programmed with multiple loops over the edges of the patches to account for the interactions. However, higher- order basis functions, such as polynomials, can be calculated more efficiently with fewer integrations, at least for the serial code. In terms of parallel integral-equation solvers, the differences between these categories of basis functions must be understood and accommodated. [J142]

"Electromagnetic simulation of complex and electrically large structures in WIPL-D Pro [JApplication Notes]"

This article has demonstrated the application of higher order basis functions, smart reduction of expansion orders, and multilevel fast multipole method in efficient 3-D EM simulation of complex and electrically large structures (from compact multiband antenna for wireless applications to 160 lambda long aircraft scatterer) at a desktop computer. [J143]

"Fast acquisition implementation for high sensitivity global positioning systems receivers based on joint and reduced space search"

In Global Positioning Systems (GPS), unique pseudorandom codes allow different satellites to share available frequency spectra without interference. In receivers, the locally generated codes (replicas) are correlated with received signals to extract a particular satellite's signal and wipe-off its pseudorandom code. The signals received are generally misaligned with replicas. As a result, receivers search for signals using different codes, code phases, and additional residual sinusoidal demodulations at several possible frequencies. This search is called acquisition and it is computationally challenging for receivers operating under weak signal conditions. Software GPS receivers have been developed over the past several years and continue to be an area of extensive research. Faster, less complex, and more efficient algorithms are required for software GPS receivers. We present a fast algorithm for accelerating acquisition. Several frequency domain approaches proposed by authors earlier are combined to reduce computational complexity. These are (i) joint code, code delay and frequency search; (ii) limited code-phase search; and (iii) a shifting replica approach. Significant gains in arithmetic complexity are achieved. A novel method for restoring correlation degradation introduced by limited code phase search is also presented in this paper. Overall performance of the acquisition is illustrated on different platforms. [J144]

"Inverse synthetic aperture radar imaging of ship target with complex motion"

High-resolution inverse synthetic aperture radar (ISAR) imaging and recognition of ship target is very important for many applications. Although the principle of ISAR imaging of ship target on the sea is the same as that of flying target in the sky, the former usually has more complex motion (fluctuation with the oceanic waves) than the latter, which makes the motion compensation very difficult. However, the change in phase chirp rate caused by the complex motion of ships will deteriorate the azimuth focusing quality. In this paper, we first model the complex motion of ship target with cubic phase terms (parameterised on chirp rate and its change rate), then a new ISAR imaging method, referred to as TC-DechirpClean, is proposed, which estimates the chirp rate and the change rate of chirp rate of all scatters in the time-chirp distribution plane. Both numerical and experimental results are provided to demonstrate the performance of the proposed method. [J145]

"Call Completion in Wireless Networks Over Lossy Link"

The call completion characteristics in wireless networks with the presence of an inherently lossy wireless link are presented in this paper. The closed-form formula for the significant performance metric in terms of the call completion probability is developed under the generalized wireless channel model and the general call holding time distribution based on the complex theory and transform techniques (Laplace-Stieltjes transform and z transform). The particular results under the typical wireless channel model and the commonly used call holding time are presented. In order to reflect the unique characteristics of the wireless channel erroneous state, we further introduce the resource occupancy time per call and the completed call holding time per call and present their properties in terms of probability density function and statistical moments. The comparison indicates that different call holding time distributions may lead to a substantial discrepancy. The effects of the first-order as well as second-order statistical moments of the call holding time and the wireless channel state duration upon the performance metrics are discussed [J146]

"Observations of Snow Water Equivalent Change on Landfast First-Year Sea Ice in Winter Using Synthetic Aperture Radar Data"

In this paper, we examine the utility of synthetic aperture radar (SAR) backscatter data to detect a change in snow water equivalent (SWE) over landfast first-year sea ice during winter at relatively cold temperatures. We begin by reviewing the theoretical framework for linking microwave scattering from SAR to the thermodynamic and electrical properties of first-year sea ice. Previous research has demonstrated that for a given ice thickness and air-temperature change, a thick snow cover will result in a smaller change in the snow-ice interface temperature than will a thin snow cover. This small change in the interface temperature will result in a relatively small change in the brine volume at the interface and the resulting complex permittivity, thereby producing a relatively small change in scattering. A thin snow cover produces the opposite effect-a greater change in interface temperature, brine volume, permittivity, and scattering. This work is extended here to illustrate a variation of this effect over landfast first-year sea ice using in situ measurements of physical snow properties and RADARSAT-1 SAR imagery acquired during the winter of 1999 in the central Canadian Archipelago at cold (~-26degC) and moderately cold (~-14degC) snow-sea-ice interface temperatures. We utilize in situ data from five validation sites to demonstrate how the change in microwave scattering covaries and is inversely proportional with the change in the magnitude of SWE. These changes are shown to be detectable over both short (2 days) and longer (45 days) time durations [J147]

"Combining Airborne Photographs and Spaceborne SAR Data to Monitor Temperate Glaciers: Potentials and Limits"

Monitoring temperate glacier activity has become more and more necessary for economical and security reasons and as an indicator of the local effects of global climate change. Remote sensing data provide useful information on such complex geophysical objects, but they require specific processing techniques to cope with the difficult context of moving and changing features in high-relief areas. This paper presents the first results of a project involving four laboratories developing and combining specific methods to extract information from optical and synthetic aperture radar (SAR) data. Two different information sources are processed, namely: 1) airborne photography and 2) spaceborne C-band SAR interferometry. The difficulties and limitations of their processing in the context of Alpine glaciers are discussed and illustrated on two glaciers located in the Mont-Blanc area. The results obtained by aerial triangulation techniques provide digital terrain models with an accuracy that is better than 30 cm, which is compatible with the computation of volume balance and useful for precise georeferencing and slope measurement updating. The results obtained by SAR differential interferometry using European Remote Sensing Satellite images show that it is possible to measure temperate glacier surface velocity fields from October to April in one-day interferograms with approximately 20-m ground sampling. This allows to derive ice surface strain rate fields required to model the glacier flow. These different measurements are complementary to results obtained during the summer from satellite optical data and ground measurements that are available only in few accessible points [J148]

"Adaptive Radar Detection of Distributed Targets in Homogeneous and Partially Homogeneous Noise Plus Subspace Interference"

This paper addresses adaptive radar detection of distributed targets in noise plus interference assumed to belong to a known or unknown subspace of the observables. At the design stage we resort to either the GLRT or the so-called two-step GLRT-based design procedure and assume that a set of noise-only data is available (the so-called secondary data). Detection algorithms have been derived modeling noise vectors, corresponding to different range cells, as independent, zero-mean, complex normal ones, sharing either the same covariance matrix (homogeneous environment) or the same covariance matrix up to possibly different (mean) power levels between primary data, i.e., range cells under test, and secondary ones (partially homogeneous environment). The performance assessment has been conducted by Monte Carlo simulation, also in comparison to previously proposed detection algorithms, and confirms the effectiveness of the newly proposed ones [J149]

"A Multiscale Curvature Algorithm for Classifying Discrete Return LiDAR in Forested Environments"

One prerequisite to the use of light detection and ranging (LiDAR) across disciplines is differentiating ground from nonground returns. The objective was to automatically and objectively classify points within unclassified LiDAR point clouds, with few model parameters and minimal postprocessing. Presented is an automated method for classifying LiDAR returns as ground or nonground in forested environments occurring in complex terrains. Multiscale curvature classification (MCC) is an iterative multiscale algorithm for classifying LiDAR returns that exceed positive surface curvature thresholds, resulting in all the LiDAR measurements being classified as ground or nonground. The MCC algorithm yields a solution of classified returns that support bare-earth surface interpolation at a resolution commensurate with the sampling frequency of the LiDAR survey. Errors in classified

ground returns were assessed using 204 independent validation points consisting of 165 field plot global positioning system locations and 39 National Oceanic and Atmospheric Administration-National Geodetic Survey monuments. Jackknife validation and Monte Carlo simulation were used to assess the quality and error of a bare-earth digital elevation model interpolated from the classified returns. A local indicator of spatial association statistic was used to test for commission errors in the classified ground returns. Results demonstrate that the MCC model minimizes commission errors while retaining a high proportion of ground returns and provides high confidence in the derived ground surface [J150]

"GLRT-Based Direction Detectors in Homogeneous Noise and Subspace Interference"

In this paper, we derive and assess decision schemes to discriminate, resorting to an array of sensors, between the H0hypothesis that data under test contain disturbance only (i.e., noise plus interference) and the H1hypothesis that they also contain signal components along a direction which is a priori unknown but constrained to belong to a given subspace of the observables. The disturbance is modeled in terms of complex normal random vectors plus deterministic interference assumed to belong to a known subspace. We assume that a set of noise-only (secondary) data is available, which possess the same statistical characterization of noise in the cells under test. At the design stage, we resort to either the plain generalized-likelihood ratio test (GLRT) or the two-step GLRT-based design procedure. The performance analysis, conducted resorting to simulated data, shows that the one-step GLRT performs better than the detector relying on the two-step design procedure when the number of secondary data is comparable to the number of sensors; moreover, it outperforms a one-step GLRT-based subspace detector when the dimension of the signal subspace is sufficiently high [J151]

"High-Resolution 3-D Flood Information From Radar Imagery for Flood Hazard Management"

This paper presents a remote-sensing-based steady-state flood inundation model to improve preventive flood-management strategies and flood disaster management. The Regression and Elevation-based Flood Information eXtraction (REFIX) model is based on regression analysis and uses a remotely sensed flood extent and a high-resolution floodplain digital elevation model to compute flood depths for a given flood event. The root mean squared error of the REFIX, compared to ground-surveyed high water marks, is 18 cm for the January 2003 flood event on the River Alzette floodplain (G.D. of Luxembourg), on which the model is developed. Applying the same methodology on a reach of the River Mosel, France, shows that for some more complex river configurations (in this case, a meandering river reach that contains a number of hydraulic structures), piecewise regression is required to yield more accurate flood water-line estimations. A comparison with a simulation from the Hydrologic Engineering Centers River Analysis System hydraulic flood model, calibrated on the same events, shows that, for both events, the REFIX model approximates the water line reliably [J152]

"Reflection of radar signals from multiple phase-modulated surfaces"

A phase-modulated surface (PMS) has been shown to provide an effective method of dynamically controlling the scattering from simple planar or cylindrical targets. Real radar targets however have complex geometry comprised of many scattering centres, and multiple interactions may occur between these. Therefore, the authors explore whether the PMS technique is still effective when applied to more realistic target geometries [J153]

"Onboard trajectory equipment measurements"

In past years, the onboard trajectory measurements complex (OTMC) was found in flight tests of flight vehicles (FV). The quick-release small-sized complex makes registration of the information of onboard systems, definition of trajectory parameters of FV, the information synchronization of onboard systems, and trajectory parameters. OTMC is used for the solution of the whole set of different tasks on estimation of the characteristics of FV and its onboard equipment. With the help OTMC in flight tests there solved the tasks of estimation: operation and accuracy characteristics of air navigation computing systems, inertial navigational systems, integrated navigational systems; SNS receivers, landing radio engineering systems, accuracy of flights under the standard takeoff patterns and landing, take-off and landing characteristics, accuracy characteristics of radars, corrections of high-altitude, fast-track parameters, systems of early warning of ground proximity etc [J154]

"Coregistration Based on Three Parts of Two Complex Images and Contoured Windows for Synthetic Aperture Radar Interferometry"

The coregistration of complex image pairs is a very important step in synthetic aperture radar interferometry (InSAR) data processing. This letter proposes a novel coregistration method that only needs three arbitrary parts of the two complex images instead of four parts in the existing coregistration methods. This method constitutes an integrated three-part method for InSAR data processing with our contoured-correlation-interferometry method for phase-image generation. Saving one part transmission makes a significant advantage when processing SAR

images on satellites. Furthermore, we demonstrate that, by means of using fringe contoured windows instead of squared windows, the accuracy of the coregistration for both the three-part coregistration method and the existing methods can be improved considerably [J155]

"A Keystone Transform Without Interpolation for SAR Ground Moving-Target Imaging"

Synthetic aperture radar (SAR) image formation for a ground moving target necessitates the compensation of the unknown target trajectory. The keystone transform has been employed to remove the linear component of the range migration for the moving target, where interpolation is required. In this letter, a realization of the keystone transform avoiding interpolation is presented. The kernel of this transform, i.e., the range-frequency-dependent azimuth time rescaling, is implemented using only complex multiplications and fast Fourier transforms based on the scaling principle, which has been successfully applied in the equalization of the space-variant range cell migration in SAR processing. In addition, the moving target is coarsely focused according to the SAR geometry and the platform velocity while exploiting the scaling principle. This preliminary focusing is helpful in the isolation of the moving target from ground clutter, so as to facilitate a more refined processing with respect to each mover. SAR raw data combined with simulated echoes of moving targets are utilized to validate the presented approach [J156]

"Complex Empirical Mode Decomposition"

A method for the empirical mode decomposition (EMD) of complex-valued data is proposed. This is achieved based on the filter bank interpretation of the EMD mapping and by making use of the relationship between the positive and negative frequency component of the Fourier spectrum. The so-generated intrinsic mode functions (IMFs) are complex-valued, which facilitates the extension of the standard EMD to the complex domain. The analysis is supported by simulations on both synthetic and real-world complex-valued signals [J157]

"Grid Computing Yields Earthquake Forecast"

The physical forces that govern seismic events are so complex that scientists have struggled to assemble forecasts on the scale of decades. Now a new statistical technique has enabled John Rundle and his team at the University of California to narrow the forecast window to less than three years. The calculations require a day of supercomputing time, but he and his partners plan to automate research-quality forecasts and make them available online. You can only do this with grid computing. The idea of linking supercomputers into a computational grid to confront big problems isn't a new one, but Rundle and others in Earth science are doing something different. They're linking grids together-effectively, using grids of grids-thanks to a software movement that takes its name from the musical phenomenon known as the mashup [J158]

"Detection of Antipersonnel Mines by Using the Factorization Method on Multistatic Ground-Penetrating Radar Measurements"

The factorization method (FM) has been applied to measurement data from a multistatic ground-penetrating radar operating in close proximity to the ground, which was used in a measurement campaign on the Joint Research Centre mine test lane in Ispra, Italy. This paper is targeted toward a future hand-held demining system. The according space limits restrict an independent positioning of transmit and receive antennas. Hence, very small multistatic datasets are obtained, representing a difficult case for the reconstruction with the FM [J159]

"A GPS-Reflections Receiver That Computes Doppler/Delay Maps in Real Time"

This paper describes a new instrument that was specially designed and developed to gather Global Positioning System (GPS) signals after they have been reflected from suitable surfaces (sea, ice, and ground), for Earth remote sensing. The device has been called the GPS open-loop differential real-time receiver (GOLD-RTR). Its main and most innovative feature is its computation and storage, in real time, of complex-valued (I and Q) cross correlations (waveforms) between GPS L1-C/A signals-received directly and after reflection-and the corresponding models of these signals. Particularly, the GOLD-RTR schedules consecutive coherent integration time slots of 1 ms over which ten parallel correlation channels, with 64 lags each, work simultaneously and continuously with the input raw data sampled at 40 MHz. The total throughput is 10 000 waveforms per second, each waveform being 64 lags long. These real-time correlation resources can be flexibly distributed in several configurations according to the observational requirements, for instance: Doppler/delay maps or up to ten simultaneous reflected waveforms for ten different GPS satellites are examples of what can be done. The further processing of the real-time computed 1-ms waveforms in a flight campaign over the ocean, ice, or ground can be used to obtain geophysical parameters such as sea level and tides, sea surface mean-square slopes, ice

roughness and thickness, soil moisture and biomass, or future applications. This paper covers the GOLD-RTR architecture and hardware, signal processing and data storage issues, machine-user interface, laboratory readiness tests, and waveform data samples from the first two jet aircraft campaigns at 9300 m over the sea [J160]

"Shift–Scale Complex Correlation for Wide-Angle Coherent Cross-Track SAR Stereo Processing"

Automated synthetic aperture radar (SAR) stereo correspondence becomes increasingly difficult when imaging high-relief terrain utilizing large stereo crossing-angle geometries because high-relief SAR image features can undergo significant spatial distortions, causing a failure of traditional correlation matching. This paper presents eight coherent spotlight-mode cross-track stereo pairs with stereo crossing angles averaging 93.7deg collected over a terrain with slopes greater than 20deg. These stereo pairs suffer from terrain-induced distortions, resulting in a decrease in complex correlation (coherence) when utilizing scanning-window correlation calculations. The search to maximize complex correlation is changed from a shift-only (disparity) search to a shift-and-scale search using the downhill simplex method. This approach is tested against complex imagery with simulated distortions and then employed on the eight wide-angle stereo collects. The resulting digital terrain maps (DTMs) are compared to ground truth. Using a shift-and-scale correlation approach to estimate disparity, the relative height errors decrease, and the number of reliable DTM posts increase [J161]

"Radar automatic target recognition using complex high-resolution range profiles"

Radar high-resolution range profile (HRRP) has received intensive attention from the radar automatic target recognition (RATR) community. Usually, since the initial phase of a complex HRRP is strongly sensitive to target position variation, only the amplitude information in complex HRRPs is used for RATR, whereas the phase information is discarded. However, the remaining phase information except for initial phases in complex HRRPs may also contain valuable target discriminant information. RATR using complex HRRPs is discussed. The complex HRRPs' feature subspace within each target-aspect sector is extracted via principal component analysis as the corresponding template during the training phase; while in the test phase we decide that a test sample belongs to the feature subspace which has the test sample's minimum reconstruction error approximation. It is shown that the whole process is independent of the initial phases, but exploits the remaining phase information in complex HRRPs. Furthermore, to make the proposed recognition method more practical, a fast time-shift compensation algorithm is proposed. In the recognition experiments based on measured data, the proposed recognition method using complex HRRPs achieves better recognition results than that using only the amplitude vectors of the complex HRRPs [J162]

"A Variance Equality Test for Two Correlated Complex Gaussian Variables With Application to Spectral Power Comparison"

Complex-valued Gaussian distributions occur frequently in signal processing. We derive a simple statistic, independent of any complex-valued correlation, for testing for the equality of variances using a sample drawn from such a bivariate distribution. The percentage points of the distribution are easy to compute. The power of the test is determined and shown to be high even for very small sample sizes when the variables are highly correlated. The new test is used to determine whether the spectral power associated with an ultralow-frequency wave in the solar magnetic field is equal at two different observing spacecraft [J163]

"Systems Engineering Analysis of a TRMM PR-Like Rainfall Retrieval Algorithm"

Systems engineering constitutes a group of processes and methods to design and implement a system for optimal performance given limited time, technology, or resources. As with any system, it is important to understand which subcomponents are most important and which are less important so that appropriate resource allocations may be made. An example of a complex system is the Tropical Rainfall Measuring Mission (TRMM). Its subsystems include the satellite vehicle, the precipitation radar (PR), the ground validation system, and the retrieval algorithms. Each of these subsystems contributes to the overall success of the mission. Sensitivity analysis (SA) is a method whereby the output response from a model can be linked back to the variability in the input parameters. This paper describes a method of performing SA on a TRMM PR-like (TL) rainfall retrieval algorithm (based on the TRMM 2A25 algorithm) to better describe how the uncertainty in the model output can be apportioned to the uncertainty in the input factors and gain greater understanding as to the relative importance of each factor. For example, assuming a model with several input factors, if one factor is found to be the dominating cause of model error, and the others contribute relatively little, then resources can be devoted to improving the accuracy of one factor, thereby improving the overall model accuracy. This paper is based on global SA using a variance decomposition technique. Analyses are done and results are presented for factor importance for cases over both ocean and land. Results for the simple TL algorithm considered in this paper

show that at low rain rate, the a and b coefficients in the R=aZebrelationship contribute the greatest amount to the output variance. At higher rain rates, above about 8 mm/h, the error from Deltasigmadeg is the greatest contributor to error in algorithm output [J164]

"Improved Multiple Target Tracking via Global Motion Compensation and Optoelectronic Correlation"

Camera motion estimation in image sequences generally focuses on the recovery of the frames when the camera is mounted on a moving platform. Global motion in video sequences is more complex and involves camera operation, camera motion, and other nontarget motions. Global motion compensation is usually handled by compensating the dominant motion using estimation and segmentation techniques. To enhance tracker performance and accuracy, frame recovery operation plays a crucial role by estimating undesired motion. In this paper, a normalized correlation-based regional template-matching (TM) algorithm has been developed to accurately recover frames before the application of the tracking algorithm. Then, a robust multiple-target-tracking system has been developed using a combination of fringe-adjusted joint transform correlator and TM techniques. Joint transform correlation detects a target optoelectronically, while TM technique is performed digitally. To increase the tracking system speed and decrease the effects of clutter, a subframe segmentation and local deviation-based image-preprocessing algorithm has been proposed. The improved performance of multiple-target-tracking system is tested using real-life forward-looking infrared (IR) imagery video sequences obtained from IR sensors mounted on an airborne platform [J165]

"Conceptual Case for Assimilating Interferometric Synthetic Aperture Radar Data Into the HAZUS-MH Earthquake Module"

The study of the Earth as a system is being adopted widely by geoscientists. Numerical models and simulations are providing the capability to rapidly test hypotheses and make forecasts of complex geophysical behavior. International efforts are seeking to integrate existing and emerging Earth observation systems into a global network, with enhanced data distribution, models, and decision support tools. Remote sensing is poised to fulfil the increasing need for a synoptic framework. However, the desire to improve the connection between scientific research and societal benefits has not been matched with resources and tools required to bridge the gap between research and applications. Natural hazards research and disaster management are a prime example. Here, we present a conceptual case for how interferometric synthetic aperture radar (InSAR) data could make a definitive contribution to understanding earthquake processes while simultaneously supporting policy- and decision-making. InSAR measurements derived from time series of radar observations from Earth orbit uniquely can provide geographically comprehensive maps of surface deformation. Observing system simulations are suggested to evaluate the potential contributions of a future system. Simulations would adopt an open seismic hazard analysis (SHA) framework, OpenSHA, recognizing the need for more physics-based modeling and computational infrastructure. SHA is employed by the HAZUS-MH earthquake module to estimate losses. InSAR measurements of strain accumulation would provide event magnitude recurrence bounds for probabilistic SHA, while coseismic InSAR measurements would add constraints on fault rupture models for deterministic approaches. Moreover, interferograms would be incorporated graphically as proxy seismic risk maps for planning and mitigation [J166]

"Multidimensional Frequency Estimation With Finite Snapshots in the Presence of Identical Frequencies"

Recently, an eigenvector-based algorithm has been developed for multidimensional frequency estimation with a single snapshot of data mixture. Unlike most existing algebraic approaches that estimate frequencies from eigenvalues, the eigenvector-based algorithm achieves automatic frequency pairing without joint diagonalization of multiple matrices, but it fails when there exist identical frequencies in certain dimensions because eigenvectors are not linearly independent anymore. In this paper, we develop an eigenvector-based algorithm for multidimensional frequency estimation with finite data snapshots. We also analyze the identifiability (ID) and performance of the proposed algorithm. It is shown that our algorithm offers the most relaxed statistical ID condition for multidimensional frequency estimation from finite snapshots. More important, we introduce complex weighting factors so that the algorithm is still operational when there exist identical frequencies in one or more dimensions. Furthermore, the weighting factors are optimized to minimize the mean square errors of the frequency estimates. Simulation results show that the proposed algorithm offers competitive performance when compared to existing algebraic approaches but at lower complexity. [J167]

"Model Limitations and Parameter-Estimation Methods for Agricultural Applications of Polarimetric SAR Interferometry"

Application of polarimetric synthetic aperture radar interferometry to the retrieval of geophysical parameters from vegetated scenes is based on simple direct models of such scenes. The first part of this paper presents an analysis of the correspondence between these simple models, namely, the random volume over ground and the oriented volume over ground (OVoG), and experimental data from samples of two agricultural crops (maize and rice) acquired in controlled conditions. Although an overall agreement between model and data is clear, some discrepancies have been found as a consequence of two assumptions in the model formulation: vertical homogeneity of the vegetation volume and absence of multiple scattering effects inside the volume. This paper presents the shape and location of the visible region of the experimental coherences on the complex plane and compares it with the feasible region predicted by the model. This comparison has also pointed out the low sensitivity of the direct model to extinction coefficients. In the second part, two different strategies for a complete inversion (i.e., estimation of all model parameters) of the OVoG model are proposed and compared, using the same data set. The first one is based on a combination of geometrical and numerical approaches (genetic algorithms) and the second one on a dual-baseline configuration. In all cases, ground topography is accurately estimated, with a maximum error of 10 cm. Vegetation height estimates are accurate up to 30 cm, with some bands and baseline configurations providing errors below 15 cm. However, results obtained for the extinction coefficients are not stable with frequency and exhibit high variability. [J168]

"A Multiple-Hypothesis Approach for Multiobject Visual Tracking"

In multiple-object tracking applications, it is essential to address the problem of associating targets and observation data. For visual tracking of multiple targets which involves objects that split and merge, a target may be associated with multiple measurements and many targets may be associated with a single measurement. The space of such data association is exponential in the number of targets and exhaustive enumeration is impractical. We pose the association problem as a bipartite graph edge covering problem given the targets and the object detection information. We propose an efficient method of maintaining multiple association hypotheses with the highest probabilities over all possible histories of associations. Our approach handles objects entering and exiting the field of view, merging and splitting objects, as well as objects that are detected as fragmented parts. Experimental results are given for tracking multiple players in a soccer game and for tracking people with complex interaction in a surveillance setting. It is shown through quantitative evaluation that our method tracks through varying degrees of interactions among the targets with high success rate. [J169]

"Signal Representation and the Nonlinear Property of Phase Images"

This letter proposes a representation of pixel value in a phase image as a complex number, which implies that the phase image is a nonlinear field. Consequently, conventional linear filtering will not properly work. Local statistics filters (LSFs) are chosen as a special case of the signal-processing algorithm to show the significance of signal representation to filtering performance. First, relationships among various LSFs, namely, ordinary LSF, speckle LSF, and phasor LSF, are discussed. We found that they are related to each other, whose general form is a complex-valued LSF (CV-LSF). It is also realized that directional windowing for the CV-LSF is actually not required, which indicates that the complex-valued formulation (representation and algorithm) is the most suitable one for phase image filtering. We demonstrate that the linear filtering to a simulated complex-valued image and an actual interferometric synthetic aperture radar image will start to fail when the window size is subsequently enlarged due to the nonlinear nature of the phase image. [J170]

"Visual Learning by Evolutionary and Coevolutionary Feature Synthesis"

In this paper, we present a novel method for learning complex concepts/hypotheses directly from raw training data. The task addressed here concerns data-driven synthesis of recognition procedures for real-world object recognition. The method uses linear genetic programming to encode potential solutions expressed in terms of elementary operations, and handles the complexity of the learning task by applying cooperative coevolution to decompose the problem automatically at the genotype level. The training coevolves feature extraction procedures, each being a sequence of elementary image processing and computer vision operations applied to input images. Extensive experimental results show that the approach attains competitive performance for three-dimensional object recognition in real synthetic aperture radar imagery. [J171]

"A Self-Initializing PolInSAR Classifier Using Interferometric Phase Differences"

This paper describes an unsupervised classifier for polarimetric interferometric synthetic aperture radar (PolInSAR) data. Expectation maximization is used to estimate class parameters that maximize the likelihood of observations in an input data set for a given number of classes. Polarimetric information, in the form of coherency matrices, and interferometric information, in the form of complex coherences, are taken into account. Differences in interferometric phase across different polarization states are explicitly modeled to make the

classifier sensitive to the vertical structure of the scene under observation, and the distribution over such phase differences is introduced. The classifier is self-initializing, in that it does not rely on decompositions or thresholds. Classification results obtained for real polarimetric interferometric data are presented and discussed. [J172]

"An Unsupervised Segmentation With an Adaptive Number of Clusters Using the SPAN/H/α/A Space and the Complex Wishart Clustering for Fully Polarimetric SAR Data Analysis"

In this paper, an unsupervised segmentation is proposed for fully polarimetric synthetic aperture radar (SAR) data analysis. The backscattering power SPANcombined with H/alpha/Ais used to obtain the initial cluster centers. We use the Wishart test statistic to perform an agglomerative hierarchical clustering to obtain the segmentation results with different numbers of clusters. The appropriate number of clusters is automatically estimated using the data log-likelihood (Lm), and the resulting images with the estimated number of clusters are the final segmentation results. The experiments show that the SPANhas additional information that is not contained in H/alpha/A, and this information could be useful for the initialization. The number of clusters seems to be a crucial point for the segmentation, which will affect the segmentation performance. It is also shown that the data log-likelihood has the potential ability to reveal the inner structure of fully polarimetric SAR data. [J173]

"A Multiple Conditional Random Fields Ensemble Model for Urban Area Detection in Remote Sensing Optical Images"

With complex building composition and imaging condition, urban areas show versatile characteristics in remote sensing optical images. It demonstrates that multiple features should be utilized to characterize urban areas. On the other hand, since levels of development in neighboring areas are not statistically independent, the features of each urban area site depend on those of neighboring sites. In this paper, we present a multiple conditional random fields (CRFs) ensemble model to incorporate multiple features and learn their contextual information. This model involves two aspects: one is to use a CRF as the base classifier to automatically generate a set of CRFs by changing input features, and the other is to integrate the set of CRFs by defining a conditional distribution. The model has some distinct merits: each CRF component models a kind of feature, so that the ensemble model can learn different aspects of training data. Moreover, it lets the ensemble model search in a wide solution space. The ensemble model can also avoid the well-known overfitting problem of a single CRF, i.e., the many features may cause the redundancy of irrelevant information and result in counter-effect. Experiments on a wide range of images show that our ensemble model produces higher detection accuracy than single CRF and is also competitive with recent results in urban area detection. [J174]

"Effect of Apodization on SAR Image Understanding"

This paper investigates the effect of apodization on the statistical properties of synthetic aperture radar (SAR) images and its impact on the capability of extracting information from homogeneous regions of apodized SAR images. The statistical model for the pixel complex amplitude of the apodized image is derived in terms of both probability density function and statistical moments. Knowledge of the statistical properties is then used to develop appropriate schemes for parameter estimation and supervised classification of homogeneous regions with different radar cross sections in apodized SAR images. The performance analysis shows that the new techniques (properly derived for the apodized case) provide information extraction capabilities only slightly worse than those provided by the conventional techniques applied to the nonapodized case. This allows us to conclude that the use of nonlinear apodization yields sidelobe level reduction and main lobe resolution preservation that can be traded with the small losses above. A full characterization of the estimation and classification performance of these new techniques shows that nonlinear apodization globally introduces a performance degradation comparable to a reduction of the number of looks of a factor of 1.455 for a homogeneous region. [J175]

"Focused 70-cm Wavelength Radar Mapping of the Moon"

We describe new 70-cm wavelength radar images of the lunar near-side and limb regions obtained via a synthetic-aperture-radar patch-focusing reduction technique. The data are obtained by transmitting a circularly polarized pulsed waveform from the Arecibo telescope in Puerto Rico and receiving the echo in both senses of circular polarization with the Robert C. Byrd Green Bank Telescope in West Virginia. The resultant images in both polarizations have a spatial resolution as fine as 320 m 450 m near the lunar limb. The patch-focusing technique is a computationally efficient method for compensating for range migration and Doppler (azimuth) smearing over long coherence times, i.e., 983 s, which is needed to achieve the required Doppler resolution. Three to nine looks are averaged for speckle reduction and to improve the signal-to-noise ratio. At this long wavelength, the radar signal penetrates up to several tens of meters into the dry lunar surface materials, thus revealing details of the bulk loss properties and decimeter-scale rock abundance not evident in multispectral and

other remote-sensing data. Application of the new radar images to the analysis of basalt flow complexes in Mare Serenitatis shows that the long-wavelength radar data are sensitive to differences in both flow age and composition, and may be particularly useful for studies of smaller deposits that do not have robust crater statistics. The new 70-cm lunar radar data are archived at the National Aeronautics and Space Administration Planetary Data System. [J176]

"A Discrete Wavelet Transform Approach to Multiresolution Complex SAR Image Generation"

We present a signal processing approach using discrete wavelet transform (DWT) for the generation of complex synthetic aperture radar (SAR) images at an arbitrary number of dyadic scales of resolution. The method is computationally efficient and is free from significant system-imposed limitations present in traditional subaperture-based multiresolution image formation. Problems due to aliasing associated with biorthogonal decomposition of the complex signals are addressed. The lifting scheme of DWT is adapted to handle complex signal approximations and employed to further enhance the computational efficiency. Multiresolution SAR images formed by the proposed method are presented. [J177]

"Walled LTSA Array for Rapid, High Spatial Resolution, and Phase-Sensitive Imaging to Visualize Plastic Landmines"

We propose a walled linearly tapered slot antenna (LTSA) array to visualize plastic landmines. Previously, we reported an adaptive nonlinear visualization system based on a complex-valued self-organizing map (CSOM) that deals with complex amplitude texture in reflection images at multiple frequencies. The system distinguishes landmines from clutter by paying attention to textural features obtained by high spatial resolution and wideband reflection measurement. Because the system employed a mechanical scan of a pair of horn antennas, the measurement required a long time. An array antenna can reduce the time. The antenna element to be used there should therefore be compact and wideband. This paper reports the design and fabrication of a walled LTSA array visualization system. The antenna element has a 14 times 28 mm aperture size, and works at the 8-12 GHz frequency band. Because the structure is a simple combination of glass epoxy substrates and metal plates, we can easily fabricate low-cost and lightweight arrays. Electrical switches realize a high-speed scanning of 12 times 12 = 144 elements in total. We also report the results of a visualization experiment, in which plastic landmines are clearly visualized with the array in combination with the adaptive CSOM processing. Detection of landmines at frequencies of 10 GHz is only likely to be possible for targets buried a few centimeter deep or where the soil attenuation is very low. This might be a severe limitation of applicability of the method, as in field conditions soil attenuations of 10 dB or considerably more are commonly encountered, requiring the radar to operate at frequencies below 2-3 GHz. The best solution may be a multisensor system comprising these complementary high- and low-frequency radars. [J178]

"Parameters localisation of coherently distributed sources based on sparse signal representation"

A robust and low-complexity parameters estimation method, which combines TLS-ESPRIT and sparse signal representation (SSR) to estimate the parameter of coherently distributed sources is presented. The central direction-of-arrivals are estimated by TLS-ESPRIT based on approximate rotational relationship between two identical uniform linear arrays (ULAs), and angular spreads are given by basis selection method using SSR. Hence the method is a low-complex estimator that does not need a search in one or two-dimensional parameter space. And it owns more robustness in estimating angular spread than one-dimensional distributed source parameter estimator (DSPE). In addition, our method can estimate parameters of the sources with different angular signal distribution functions, which DSPE cannot work. The simulation results prove the effectiveness of our method. [J179]

"Algebraic Algorithms to Separate Overlapping Secondary Surveillance Radar Replies"

The secondary surveillance radar (SSR) is a transponder system used in air-traffic control (ATC). Due to growing traffic densities, it is increasingly likely that a ground station receives a mixture of responses of various aircraft, partly overlapping in frequency and time. Currently such "collisions" are disregarded, at a loss of system performance and reliability. In this paper, we propose to equip the ground station with an antenna array, and investigate techniques to blindly separate such a mixture based on source waveform properties. At baseband, a received SSR signal consists of a binary sequence with alphabet {0,1}, modulated by a complex exponential due to the residual carrier frequency. We present three algebraic algorithms to compute the separating beamformers by taking into account the particular modulation format of the received signal. The Cramer-Rao bound (CRB) is derived, extensive simulations are presented, and an experimental platform has been built to collect measurement data and demonstrate the algorithms. [J180]

"Syntactic Modeling and Signal Processing of Multifunction Radars: A Stochastic Context-Free Grammar Approach"

Multifunction radars (MFRs) are sophisticated sensors with complex dynamical modes that are widely used in surveillance and tracking. This paper demonstrates that stochastic context-free grammars (SCFGs) are adequate models for capturing the essential features of the MFR dynamics. Specifically, MFRs are modeled as systems that ldquospeakrdquo a language that is characterized by an SCFG. The paper shows that such a grammar is modulated by a Markov chain representing radar's policy of operation. The paper also demonstrates how some well-known statistical signal processing techniques can be applied to MFR signal processing using these stochstic syntactic models. We derive two statistical estimation approaches for MFR signal processing-a maximum likelihood sequence estimator to estimate radar's policies of operation, and a maximum likelihood parameter estimator to infer the radar parameter values. Two layers of signal processing are introduced in this paper. The first layer is concerned with the estimation of MFR's policies of operation. It involves signal processing in the CFG domain. The second layer is concerned with identification of tasks the radar is engaged in. It involves signal processing in the finite-state domain. Both of these signal processing techniques are important elements of a bigger radar signal processing problem that is often encountered in electronic warfare applications-the problem of the estimation of the level of threat that a radar poses to each individual target at any point in time. [J181]

"Full-Waveform Inversion of Crosshole Radar Data Based on 2-D Finite-Difference Time-Domain Solutions of Maxwell's Equations"

Crosshole radar techniques are important tools for a wide range of geoscientific and engineering investigations. Unfortunately, the resolution of crosshole radar images may be limited by inadequacies of the ray tomographic methods that are commonly used in inverting the data. Since ray methods are based on high-frequency approximations and only account for a small fraction of the information contained in the radar traces, they are restricted to resolving relatively large-scale features. As a consequence, the true potential of crosshole radar techniques has yet to be realized. To address this issue, we introduce a full-waveform inversion scheme that is based on a finite-difference time-domain solution of Maxwell's equations. We benchmark our new scheme on synthetic crosshole data generated from suites of increasingly complex models. The full-waveform tomographic images accurately reconstruct the following: (1) the locations, sizes, and electrical properties of isolated subwavelength objects embedded in homogeneous media; (2) the locations and sizes of adjacent subwavelength objects embedded in homogeneous media; (3) abrupt media boundaries and average and stochastic electrical property variations of heterogeneous layered models; and (4) the locations, sizes, and electrical conductivities of water-filled tunnels and closely spaced subwavelength pipes embedded in heterogeneous layered models. The new scheme is shown to be remarkably robust to the presence of uncorrelated noise in the radar data. Several limitations of the full-waveform tomographic inversion are also identified. For typical crosshole acquisition geometries and parameters, small resistive bodies and small closely spaced dielectric objects may be difficult to resolve. Furthermore, electrical property contrasts may be underestimated. Nevertheless, the full-waveform inversions usually provide substantially better results than those supplied by traditional ray methods. [J182]

"Polarimetric Analysis of Bistatic SAR Images From Polar Decomposition: A Quaternion Approach"

This paper focuses on polar decomposition, which is based on the quaternion formalism, in single-look and multilook synthetic aperture radar polarimetry. Polar decomposition is used to decompose a bistatic or monostatic polarimetric scattering matrix into a product of a Hermitian matrix (boost) and a unitary matrix (rotation). After an overview of polar decomposition principle and quaternion properties, coherent (single-look complex) and incoherent (multilook) polar decompositions are discussed. In single-look polar decomposition, we introduce the boost parameter and the rotation parameter with the purpose of classifying scattering mechanisms of different natures. New relationships between these geometrical parameters and the scattering matrix elements are obtained. We also briefly reexamine the standard coherent polarimetric target decomposition algorithms in the light of quaternions. Next, an original use of polar decomposition for incoherent polarimetric imaging is proposed, which leads to the definition of the multilook boost parameter and of the degree of polarization dispersion. Subsequently, a new approach is presented, which consists in decomposing the scattering matrix into boost and rotation components before vectorization, then in averaging to generate boost and rotation coherency matrices separately. This leads to new inferred parameters: the boost and rotation entropies, and the concurrent dominant scattering mechanisms. The link between these new parameters and standard polarimetric invariants from the Cloude and Pottier decomposition is discussed. Eventually, the multilook extension of polar decomposition may allow this to be applied to the classification of remote sensing data. In this framework, a set of five parameters reducing to four in the monostatic case can be considered. [J183]

"Derivation of the Norton Surface Wave Using the Compensation Theorem"

This paper presents a tutorial exposition of the derivation of the Norton surface wave using the compensation theorem. Only the case of a vertical electric dipole above an infinite ground plane satisfying an impedance boundary condition is treated. This is the most interesting case in practice, and the one on which applications such as MF AM broadcasting and HF surface-wave radar rely. It is attractive to use the compensation theorem to treat this relatively complex problem. This theorem, itself simply derived starting from Lorentz reciprocity, is easily understood, and the development that follows draws only on ideas already familiar in at least some context to almost all electrical engineers. This makes it for the most part easier to follow than equivalent alternative presentations. While not the first such derivation to have appeared in the literature, and to some extent paralleling these earlier developments to allow direct comparison, the present paper aims to differentiate itself both by being easier to follow and in removing some errors. [J184]

"Autonomous Navigation: Achievements in Complex Environments"

During the past decade, an explosion of interest in the estimation of an autonomous robot's location state and that of its surroundings, known as simultaneous localization and map building (SLAM), is evident. The goal of an autonomous vehicle performing SLAM is to build a map incrementally by using the uncertain information extracted from its sensors, while simultaneously using that map to localize itself with respect to a reference coordinate frame. To demonstrate the state of the art in autonomous navigation, this article focuses on outdoor research work within complex, semi-structured environments with an array of vehicles, using RADAR and laser range finders. Two classes of sensors that we use to get information are proprioceptive sensors and exteroceptive sensors. This paper focuses on sensor data interpretation, information extraction, and data association. [J185]

"A Novel Direction-Finding Algorithm for Directional Borehole Radar"

A directional borehole radar system has been developed for the purpose of 3-D imaging of subsurface targets in a single-hole measurement. The radar system is equipped with a uniform circular array consisting of four dipole antennas as a receiver in order to realize azimuth bearing sensitivity. We propose a new direction-finding (DF) algorithm that is suitable for directional borehole radar measurement, and we apply this algorithm to actual field measurement data. This algorithm is based on the Adcock DF antenna principle where the complex time series (analytic signal) expression, the optimization, and the filtering procedure are incorporated to provide more accurate estimation. The algorithm was first verified in a transmission measurement in boreholes with a cross-hole configuration (15 m apart from each other) by estimating a direction of the incident wave from a transmitter to the receiver. Finally, the algorithm was applied to single-hole measurement data to demonstrate the ability to detect the 3-D location of a subsurface tunnel which was located 5.5 m from the borehole. The result showed fairly good agreement with the actual location of the tunnel, i.e., to an azimuth estimation error of within 10deg. [J186]

"Minimum norm property for the sum of the adaptive weights for a direct data domain least squares algorithm"

In most adaptive algorithms, it is generally assumed that one knows the direction of arrival (DOA) of the signal of interest (SOI) through the steering vector of the array and the goal is to estimate its complex amplitude in the presence of jammer, clutter and noise. In space-time adaptive processing (STAP) the goal is to seek for a target located along a certain look direction and at a particular Doppler frequency through a given steering vector. Therefore, the accuracy of the computed results in either case is based on the reliability of this a priori assumption of the steering vector. It is possible that due to mechanical vibrations, calibration errors or atmospheric refractions of the incident electromagnetic waves, the assumed DOA may not be very accurate or that the assumed value of the Doppler frequency is not appropriate. In either of these cases, the adaptive algorithm treats the SOI as an interferer and nulls it out. This perennial problem of signal cancellation is an open problem for adaptive algorithms. In this paper It is shown that the proper steering vector occurs at the minimum of the sum of the norm of the adaptive weights and can be used as an indicator to refine the estimate of the DOA of the SOI in adaptive algorithms or both the DOA or/and the Doppler frequency in STAP. Examples are presented to illustrate that the secondary processing outlined in this paper, may provide a refined estimate for the true DOA or/and Doppler frequency for the SOI in the presence of interference, clutter and noise [J187]

"Knowledge-aided adaptive radar at DARPA: an overview"

For the past several years, the Defense Advanced Research Projects Agency (DARPA) has been pioneering the development of the first ever real-time knowledge-aided (KA) adaptive radar architecture. The impetus for this program is the ever increasingly complex missions and operational environments encountered by modern radars

and the inability of traditional adaptation methods to address rapidly varying interference environments. The DARPA KA sensor signal processing and expert reasoning (KASSPER) program has as its goal the demonstration of a high performance embedded computing (HPEC) architecture capable of integrating high-fidelity environmental knowledge (i.e., priors) into the most computationally demanding subsystem of a modern radar: the adaptive space-time beamformer. This is no mean feat as environmental knowledge is a memory quantity that is inherently difficult (if not impossible) to access at the rates required to meet radar front-end throughput requirements. In this article, we will provide an overview of the KASSPER program highlighting both the benefits of KA adaptive radar, key algorithmic concepts, and the breakthrough look-ahead radar scheduling approach that is the keystone to the KASSPER HPEC architecture. [J188]

"Distinguished Lecturers Program"

One of the general trends of the MEMS sensors business is the utilization of the technology to satisfy harsh environment requirements (temperature, shock, vibration, environment security). The conjunction of material (standard Silicon, SiC or SOI), with complex micromachining techniques and advanced assembly techniques are the key to provide robust sensors with a miniimum concession on specification. The goal of this paper is to present progress on gun hard (>20,000 g) and wide temperature range MEMS accelerometers (-120Г‚В°C to +180Г‚В°C). Concrete solutions and results (out of more than 500 tested products)) will be presented and discussed in detail. [J189]

"Fast algorithms for single frequency estimation"

In this paper, some new estimators of the frequency of a single complex sinusoid are presented. The rotate-add-decimate (RAD) method of Crozier is first refined to more closely approach the Cramer-Rao Bound (CRB). An additional modification yields an unbiased estimator (ERAD) that essentially achieves the CRB above a signal-to-noise ratio (SNR) threshold comparable to that of RAD. In addition, this estimator is proven to achieve the CRB for high SNR. The ERAD method requires approximately 2N complex multiply-adds and log2N arctangents. A modified ERAD (MERAD) is proposed that matches the SNR threshold and computational complexity of the RAD method (approximately 3N complex multiply-adds and log2N arctangents) but achieves the CRB for high SNR. [J190]

"Adaptive Doppler-Kalman filter for radar systems"

Time-dependent Fourier transform plays an important role in radar signal analysis. The Doppler frequency carries information about the relative velocity of a moving target regarding the radar antenna. However, because the target movement may be very complex, with temporary high-intensity manoeuvres, the Doppler frequency must be estimated by using a window function. In order to minimise the estimation error, the window function width must be dependent on the target manoeuvre as well as on the signal-to-noise ratio. Here, a system consisting of a Doppler filter and a second-order Kalman filter, connected in an adaptive structure, has been proposed as an efficient solution to this problem. The proposed approach enables the window width adaptation, based on the estimates of target acceleration and signal-to-noise ratio, generated by an adaptive Kalman filter. Simulation results demonstrate the advantage of this structure compared to the fixed-width, window-based algorithms, giving acceptable results even for very bad signal-to-noise conditions. [J191]

"SAR amplitude probability density function estimation based on a generalized Gaussian model"

In the context of remotely sensed data analysis, an important problem is the development of accurate models for the statistics of the pixel intensities. Focusing on synthetic aperture radar (SAR) data, this modeling process turns out to be a crucial task, for instance, for classification or for denoising purposes. In this paper, an innovative parametric estimation methodology for SAR amplitude data is proposed that adopts a generalized Gaussian (GG) model for the complex SAR backscattered signal. A closed-form expression for the corresponding amplitude probability density function (PDF) is derived and a specific parameter estimation algorithm is developed in order to deal with the proposed model. Specifically, the recently proposed "method-of-log-cumulants" (MoLC) is applied, which stems from the adoption of the Mellin transform (instead of the usual Fourier transform) in the computation of characteristic functions and from the corresponding generalization of the concepts of moment and cumulant. For the developed GG-based amplitude model, the resulting MoLC estimates turn out to be numerically feasible and are also analytically proved to be consistent. The proposed parametric approach was validated by using several real ERS-1, XSAR, E-SAR, and NASA/JPL airborne SAR images, and the experimental results prove that the method models the amplitude PDF better than several previously proposed parametric models for backscattering phenomena. [J192]

"UWB radar for human being detection"

UWB radar for detection and positioning of human beings in complex environment has been developed and manufactured. Novelty of the radar lies in its large operational bandwidth (11.7GHz at -10dB level) combined with high time stability. Detection of respiratory movement of a person in laboratory conditions has been demonstrated. Based on experimental results human being radar return has been analysed in the frequency band from 1 GHz to 12 GHz. Novel principle of human being detection is considered and verified experimentally. [J193]

"A locally adaptive filter of interferometric phase images"

We propose an adaptive filtering approach for interferograms, which is a modification to the Lee adaptive complex filter. Based on local frequency estimates, we compute the normal orientation of local phase fringes. A directionally dependent filtering window is aligned perpendicular to the normal orientation of local phase fringes (i.e., along local phase fringes) by interpolation, making the pixels included in the filtering window have approximately more homogeneous values. Moreover, the computation of the filter parameter does not require local phase unwrapping in the real plane. This filter minimizes the loss of signal and reduces the level of noise. By using two sets of simulated data, its effectiveness can be seen in terms of the fidelity to noise-free phases, fringe preservation, and residue reduction. [J194]

"Inversion of a lidar waveform model for forest biophysical parameter estimation"

Due to its measurement principle, light detection and ranging (lidar) is particularly suited to estimate the horizontal as well as vertical distribution of forest structure. Quantification and characterization of forest structure is important for the understanding of the forest ecosystem functioning and, moreover, will help to assess carbon sequestration within forests. The relationship between the signal recorded by a lidar system and the canopy structure of a forest can be accurately characterized by physically based radiative transfer models (RTMs). A three-dimensional RTM is capable of representing the complex forest canopy structure as well as the involved physical processes of the lidar pulse interactions with the vegetation. Consequently, the inversion of such an RTM presents a novel concept to retrieve biophysical forest parameters that exploits the full lidar signal and underlying physical processes. A synthetic dataset and data acquired in the Swiss National Park (SNP) successfully demonstrated the feasibility and the potential of RTM inversion to retrieve forest structure from large-footprint lidar waveform data. The SNP lidar data consist of waveforms generated from the aggregation of small-footprint lidar returns. Derived forest biophysical parameters, such as fractional cover, leaf area index, maximum tree height, and the vertical crown extension, were able to describe the horizontal and vertical forest canopy structure. [J195]

"Robust DFT with high breakdown point for complex-valued impulse noise environment"

Modification of the robust discrete Fourier transform (DFT) is proposed in order to achieve a high breakdown point for signals corrupted by complex-valued impulse noise with independent real and imaginary parts. Obtained results are compared with existing robust DFT forms. In addition, an adaptive procedure for selection of the modified robust DFT form is developed. [J196]

"The autocorrelation of waveforms generated from ocean-scattered GPS signals"

A "waveform" is generated by cross-correlating local copies of a global positioning system (GPS) signal with an ocean-reflected GPS signal, over a range of carrier frequencies and code delays. The shape of this waveform can be inverted to obtain estimates of the ocean surface roughness. To assess the accuracy of these retrievals, a stochastic model for the waveform time series measurements was developed in a previous publication. In this letter, this model is validated by comparing the predicted autocorrelation function of the waveform against the autocorrelation computed from experimental waveforms collected from an airborne receiver. A 1-ms coherent integration time was used at first. Then, blocks of these measurements were concatenated to produce equivalent integration times of up to 5 ms to compare the dependence of model predictions on integration time. Correlation time was estimated by fitting a model Gaussian function to the magnitude or the real part of the autocorrelation function. The magnitude and phase of the complex autocorrelation function from the model were also studied to show the location of the first, and better explain cases in which the Gaussian function did not fit well. The autocorrelation is found to be weakly dependent upon the surface roughness, over a range of moderate wind speeds. [J197]

"Knowledge-based radar signal and data processing: a tutorial review"

Radar systems are an important component in military operations. In response to increasingly severe threats from military targets with reduced radar cross sections (RCSs), slow-moving and low-flying aircraft hidden in foliage, and in environments with large numbers of targets, knowledge-based (KB) signal and data processing

techniques offer the promise of significantly improved performance of all radar systems. Radars under KB control can be deployed to utilize valuable resources such as airspace or runways more effectively and to aid human operators in carrying out their missions. As battlefield scenarios become more complex with increasing numbers of sensors and weapon systems, the challenge will be to use already available information effectively to enhance radar performance, including positioning, waveform selection, and modes of operation. KB processing fills this need and helps meet the challenge. [J198]

"PolInSAR analysis of X-band data over vegetated and urban areas"

This paper investigates the polarimetric and polarimetric interferometric synthetic aperture radar (PolInSAR) information contained in the high-resolution X-band data acquired by the RAMSES airborne SAR system over an area around Avignon, France containing bare surfaces, vegetation, and urban areas. The interferometric coherences are computed over natural and urban areas for all possible baseline copolar polarizations. In the complex plane, the obtained regions of coherence corresponding to most vegetation areas display small angular extents, meaning that if penetration occurs in the foliage, it is shallower than the system height accuracy. To quantify the PolInSAR information, an analysis of the interferometric height accuracy is first performed, and the results are compared with those associated with a theoretical and an empirical model. Concerning vegetation, a 6-m height difference is measured between the different polarimetric phase centers over a sparse pine forest, probably due to the presence of holes in the canopy. Crop study reveals also that wheat-type fields present oriented media properties at X-band due to their vertical structure. Over urban areas, in most cases, building height can be accurately obtained by using Pauli polarimetric phase center information. [J199]

"Varying complexity in tree-structured image distribution models"

Probabilistic models of image statistics underlie many approaches in image analysis and processing. An important class of such models have variables whose dependency graph is a tree. If the hidden variables take values on a finite set, most computations with the model can be performed exactly, including the likelihood calculation, training with the EM algorithm, etc. Crouse et al. developed one such model, the hidden Markov tree (HMT). They took particular care to limit the complexity of their model. We argue that it is beneficial to allow more complex tree-structured models, describe the use of information theoretic penalties to choose the model complexity, and present experimental results to support these proposals. For these experiments, we use what we call the hierarchical image probability (HIP) model. The differences between the HIP and the HMT models include the use of multivariate Gaussians to model the distributions of local vectors of wavelet coefficients and the use of different numbers of hidden states at each resolution. We demonstrate the broad utility of image distributions by applying the HIP model to classification, synthesis, and compression, across a variety of image types, namely, electrooptical, synthetic aperture radar, and mammograms (digitized X-rays). In all cases, we compare with the HMT. [J200]

"Intensity-driven adaptive-neighborhood technique for polarimetric and interferometric SAR parameters estimation"

In this paper, a new method to filter coherency matrices of polarimetric or interferometric data is presented. For each pixel, an adaptive neighborhood (AN) is determined by a region growing technique driven exclusively by the intensity image information. All the available intensity images of the polarimetric and interferometric terms are fused in the region growing process to ensure the validity of the stationarity assumption. Afterward, all the pixels within the obtained AN are used to yield the filtered values of the polarimetric and interferometric coherency matrices, which can be derived either by direct complex multilooking or from the locally linear minimum mean-squared error (LLMMSE) estimator. The entropy/alpha/anisotropy decomposition is then applied to the estimated polarimetric coherency matrices, and coherence optimization is performed on the estimated polarimetric and interferometric coherency matrices. Using this decomposition, unsupervised classification for land applications by an iterative algorithm based on a complex Wishart density function is also applied. The method has been tested on airborne high-resolution polarimetric interferometric synthetic aperture radar (POL-InSAR) images (Oberpfaffenhofen area-German Space Agency). For comparison purposes, the two estimation techniques (complex multilooking and LLMMSE) were tested using three different spatial supports: a fix-sized symmetric neighborhood (boxcar filter), directional nonsymmetric windows, and the proposed AN. Subjective and objective performance analysis, including coherence edge detection, receiver operating characteristics plots, and bias reduction tables, recommends the proposed algorithm as an effective POL-InSAR postprocessing technique. [J201]

"On the Azimuthally Anisotropy Effects of Polarization for Altimetric Measurements"

We have investigated the effect of the radar-altimeter antenna polarization on European Remote-sensing

Satellite and Envisat observations of the media penetrable by a radar microwave such as ice sheets. This effect is due to the complex interaction between the radar wave, the subsurface backscatter, and the antenna polarization direction. It is modulated by the angle between the antenna polarization and the direction of the anisotropy of the target. Thus, it depends on both the anisotropy direction and the interaction between the radar wave and the reflecting surface. This effect leads to one of the most complex and least understood errors of radar altimetry over ice sheets and can be clearly identified when looking at the crossover differences between ascending and descending satellite tracks. The crossover differences are as large as a few decibels for a backscattering coefficient and a few meters for height, and affect more strongly the Ku-band than the S-band. This causes limitations and difficulties for the processing of altimetric observations, for instance when comparing time series from different satellites whose polarization geometry differs. This will be the case when a new altimeter will fly on a different orbit, as planned for CryoSat. Nevertheless, the ability of both the roughness anisotropy direction and the subsurface modulation to be inverted with satisfactory precision by using simultaneous observations at crossover points between two different satellites is demonstrated here. Thus, it offers a unique way of describing this error accurately to correct for it [J202]

"Application of Iterative Techniques for Electromagnetic Scattering From Dielectric Random and Reentrant Rough Surfaces"

Stationary [e.g., forward-backward method (FBM)] and nonstationary [e.g., conjugate gradient squared, quasi-minimal residual, and biconjugate gradient stabilized (Bi-CGSTAB)] iterative techniques are applied to the solution of electromagnetic wave scattering from dielectric random rough surfaces with arbitrary complex dielectric constants. The convergence issues as well as the efficiency and accuracy of all the approaches considered in this paper are investigated by comparing obtained scattering (in the form of normalized radar cross section) and surface field values with the numerically exact solution, computed by employing the conventional method of moments. It has been observed that similar to perfectly and imperfectly conducting rough surface cases, the stationary iterative FBM converges faster when applied to geometries yielding best conditioned systems but exhibits convergence difficulties for general geometries due to its inherit limitations. However, nonstationary techniques are, in general, more robust when applied to arbitrarily general dielectric random rough surfaces, which yield more ill-conditioned systems. Therefore, they might prove to be more suitable for general scattering problems. Besides, as opposed to the perfectly and imperfectly conducting rough surface cases, the Bi-CGSTAB method and FBM show two interesting behaviors for dielectric rough surface profiles: 1) FBM generally converges for reentrant surfaces when the vertical polarization is considered and 2) the Bi-CGSTAB method has a peculiar convergence problem for horizontal polarization. Unlike the other nonstationary iterative techniques used in this paper, where a Jacobi preconditioner is used, convergent results are obtained by using a block-diagonal preconditioner [J203]

"Ground Target Recognition Using Rectangle Estimation"

We propose a ground target recognition method based on 3-D laser radar data. The method handles general 3-D scattered data. It is based on the fact that man-made objects of complex shape can be decomposed to a set of rectangles. The ground target recognition method consists of four steps; 3-D size and orientation estimation, target segmentation into parts of approximately rectangular shape, identification of segments that represent the target's functional/main parts, and target matching with CAD models. The core in this approach is rectangle estimation. The performance of the rectangle estimation method is evaluated statistically using Monte Carlo simulations. A case study on tank recognition is shown, where 3-D data from four fundamentally different types of laser radar systems are used. Although the approach is tested on rather few examples, we believe that the approach is promising [J204]

"Schedulability Envelope for Real-Time Radar Dwell Scheduling"

This paper proposes novel techniques for scheduling radar dwells in phased array radar systems. In order to handle complex physical characteristics such as dwell interleaving, transmitting duty cycle constraint, and energy constraint, we propose a notion of schedulability envelope. The schedulability envelope designed offline hides the details of complex radar dwell scheduling and provides a simple measure for the schedulability check. Using the schedulability envelope, the proposed technique can efficiently perform the admission control for dynamic target tracking tasks. The simulation results show that the proposed approach can significantly improve the system utilization by taking advantage of dwell interleaving while guaranteeing the schedulability and physical constraints [J205]

"Ordered and chaotic electrical solitons: communication perspectives"

While the use of sinusoidal electromagnetic waves as information carriers is taken as one of the principal axioms

of today's wireless system design, certain nonsinusoidal waves may further enrich the scope and capacity of modern wireless engineering. Two notable nonsinusoid examples are impulses and chaotic signals. The short temporal width of impulses has enabled applications such as ranging radars and ultra wideband (UWB). The complex nature of chaotic signals offers a new means of encrypted communication. Here we review a new circuit paradigm, the electrical soliton oscillator, which can self-generate both impulse and chaotic signals of very large bandwidth by leveraging the singular dynamics of a nonlinear wave known as the electrical soliton. By combining a nonlinear transmission line with a unique amplifier that can "tame" the inherently unruly dynamics of solitons, the oscillator self-generates a stable, periodic train of short impulses. If the taming functions of the amplifier are turned off, the circuit self-generates chaotic signals by positively exploiting solitons' unruly nature. While still in its early stages, this soliton circuit may one day serve as the heartbeat of both impulse and chaotic wireless systems [J206]

"UWB Radar for Human Being Detection"

UWB radar for detection and positioning of human beings in complex environment has been developed and manufactured. Novelty of the radar lies in its large operational bandwidth (11.7 GHz at -10 dB level) combined with high time stability. Detection of respiratory movement of a person in laboratory conditions has been demonstrated. Based on experimental results human being radar return has been analysed in the frequency band from 1 GHz until 12 GHz. Novel principle of human being detection is considered and verified experimentally [J207]

"Imaging of Single and Double Scatterers in Urban Areas via SAR Tomography"

Microwave scattering is a rather complex mechanism, especially in urban areas. Three-dimensional (3-D) synthetic aperture radar (SAR) tomography is a technique that uses multiple views to map the scattering power at different heights, thus extending the capability of SAR sensors to fully image the scene in the 3-D space. This paper presents a first validation of spaceborne long-term SAR tomography by demonstrating the capability to resolve a simple layover case, i.e., to separate single- and double-scattering mechanisms within imaged pixels. Results obtained with real data acquired by the European Remote Sensing 1 and 2 (ERS-1 and ERS-2) satellites over the urban area of Napoli are presented. As an additional contribution, an innovative algorithm estimating residual topography and surface deformation, called the spatial-differencing technique, is also discussed in detail at the data calibration stage [J208]

"On the Usage of GRECOSAR, an Orbital Polarimetric SAR Simulator of Complex Targets, to Vessel Classification Studies"

This paper presents a synthetic aperture radar (SAR) simulator that is able to generate polarimetric SAR (POLSAR) and polarimetric inverse SAR data of complex targets. It solves the electromagnetic problem via high-frequency approximations, such as physical optics and the physical theory of diffraction, with notable computational efficiency. In principle, any orbital monostatic sensor working at any band, resolution, and operating mode can be modeled. To make simulations more realistic, the target's bearing and speed are considered, and for the particular case of vessels, even the translational and rotational movements induced by the sea state. All these capabilities make the simulator a powerful tool for supplying large amounts of data with precise scenario information and for testing future sensor configurations. In this paper, the usefulness of the simulator on vessel classification studies is assessed. Several simulated polarimetric images are presented to analyze the potentialities of coherent target decompositions for classifying complex geometries, thus basing an operational algorithm. The limitations highlighted by the results suggest that other approaches, like POLSAR interferometry, should be explored [J209]

"SAR image filtering based on the heavy-tailed Rayleigh model"

Synthetic aperture radar (SAR) images are inherently affected by a signal dependent noise known as speckle, which is due to the radar wave coherence. In this paper, we propose a novel adaptive despeckling filter and derive a maximum a posteriori (MAP) estimator for the radar cross section (RCS). We first employ a logarithmic transformation to change the multiplicative speckle into additive noise. We model the RCS using the recently introduced heavy-tailed Rayleigh density function, which was derived based on the assumption that the real and imaginary parts of the received complex signal are best described using the alpha-stable family of distribution. We estimate model parameters from noisy observations by means of second-kind statistics theory, which relies on the Mellin transform. Finally, we compare the proposed algorithm with several classical speckle filters applied on actual SAR images. Experimental results show that the homomorphic MAP filter based on the heavy-tailed Rayleigh prior for the RCS is among the best for speckle removal [J210]

"Improvements of Complex-Valued Hopfield Associative Memory by Using Generalized Projection Rules"

In this letter, new design methods for the complex-valued multistate Hopfield associative memories (CVHAMs) are presented. We show that the well-known projection rule proposed by Personnaz can be generalized to complex domain such that the weight matrix of the CVHAM can be designed by using a simple and effective method. The stability of the proposed CVHAM is analyzed by using energy function approach which shows that in synchronous update mode the proposed model is guaranteed to converge to a fixed point from any given initial state. Moreover, the projection geometry of the generalized projection rule (GPR) is discussed. In order to enhance the recall capability, a strategy of eliminating the spurious memories is also reported. The validity and the performance of the proposed methods are investigated by computer simulation [J211]

"Interferometric SAR coherence magnitude estimation using second kind statistics"

Coherence magnitude is a fundamental parameter for the analysis of applications using interferometric synthetic aperture radar (InSAR). The coherence magnitude estimators are biased and need bias removal. The sample coherence magnitude estimation, computed on a window basis, depends on the number of independent samples and theoretical coherence. It has been shown that the sample coherence magnitude estimator is the maximum-likelihood one. It is a biased estimator, especially for low coherence values. In this paper, we present a novel coherence magnitude estimator obtained from the method of moments using "second kind statistics". Classical methods (with regular statistics) for coherence computation are based on a probability density function (pdf) model for estimating regular moments (first kind statistics) defined with the Fourier transform. The proposed approach is based on the same pdf model to compute the second kind statistics defined with the Mellin transform (log-moment). Thus, it is shown that the estimated coherence given by the first log-moment is less biased. Moreover, it is shown that the coherence magnitude estimation from complex coherence maps (interferometric data) using second kind statistics is the optimal estimation procedure of interferometric coherence. It gives the smallest bias near zero comparing with existing estimators. The developed estimation approaches have been applied to obtain coherence measurements from tandem European Remote Sensing 1 and 2 satellite interferometric data, collected over varying terrain with a variety of ground cover types (agriculture field, forest, lake, urban area, sea) in Tunisia, France, and Nepal [J212]

"On the Fourier Transform of Finite Chirps"

In this letter, closed-form expressions for the discrete Fourier transform (DFT) of a finite chirp are derived. It is shown that when the normalized chirp rate is coprime with the chirp length, then the DFT of a finite chirp is again a finite chirp with magnitude, chirp rate, and carrier frequency appropriately scaled. In particular, when the normalized chirp rate is of unit value, then the DFT of a finite chirp is the same chirp, up to a complex scaling factor. Conversely, when the normalized chirp rate has a common factor with the chirp length, then the support of the DFT of a finite chirp is equal to the ratio of chirp length and the common factor. Among other things, results given here complement certain results, obtained by Janssen, on the computation of time-continuous chirps with rational sweep rates [J213]

"Maximum Likelihood Estimation of Compound-Gaussian Clutter and Target Parameters"

Compound-Gaussian models are used in radar signal processing to describe heavy-tailed clutter distributions. The important problems in compound-Gaussian clutter modeling are choosing the texture distribution, and estimating its parameters. Many texture distributions have been studied, and their parameters are typically estimated using statistically suboptimal approaches. We develop maximum likelihood (ML) methods for jointly estimating the target and clutter parameters in compound-Gaussian clutter using radar array measurements. In particular, we estimate i) the complex target amplitudes, ii) a spatial and temporal covariance matrix of the speckle component, and iii) texture distribution parameters. Parameter-expanded expectation-maximization (PX-EM) algorithms are developed to compute the ML estimates of the unknown parameters. We also derived the Cramer-Rao bounds (CRBs) and related bounds for these parameters. We first derive general CRB expressions under an arbitrary texture model then simplify them for specific texture distributions. We consider the widely used gamma texture model, and propose an inverse-gamma texture model, leading to a complex multivariate t clutter distribution and closed-form expressions of the CRB. We study the performance of the proposed methods via numerical simulations [J214]

"The Multidimensional Phase Unwrapping Integral and Applications to Microwave Tomographical Image Reconstruction"

Spatial unwrapping of the phase component of time varying electromagnetic fields has important implications in a

range of disciplines including synthetic aperture radar (SAR) interferometry, MRI, optical confocal microscopy, and microwave tomography. This paper presents a fundamental framework based on the phase unwrapping integral, especially in the complex case where phase singularities are enclosed within the closed path integral. With respect to the phase unwrapping required when utilized in Gauss-Newton iterative microwave image reconstruction, the concept of dynamic phase unwrapping is introduced where the singularity location varies as a function of the iteratively modified property distributions. Strategies for dynamic phase unwrapping in the microwave problem were developed and successfully tested in simulations and clinical experiments utilizing large, high contrast targets to validate the approach [J215]

"A novel approach to complex target recognition using RCS wavelet decomposition"

A novel approach to complex target recognition using wavelet decomposition of the radar cross section is introduced. The analysis technique is presented, and it shown how it can be implemented using MATLAB software. Applications in the radar field are then investigated, both for simple and complex targets. The results obtained show that this technique is very promising and yields recognition levels difficult to achieve with any other available technique. [J216]

"Landmine detection and classification with complex-valued hybrid neural network using scattering parameters dataset"

Neural networks have been applied to landmine detection from data generated by different kinds of sensors. Real-valued neural networks have been used for detecting landmines from scattering parameters measured by ground penetrating radar (GPR) after disregarding phase information. This paper presents results using complex-valued neural networks, capable of phase-sensitive detection followed by classification. A two-layer hybrid neural network structure incorporating both supervised and unsupervised learning is proposed to detect and then classify the types of landmines. Tests are also reported on a benchmark data. [J217]

"Statistical resolution limits and the complexified Cramer'r-Rao bound"

Array resolution limits and accuracy bounds on the multitude of signal parameters (e.g., azimuth, elevation, Doppler, range, cross-range, depth, frequency, chirp, polarization, amplitude, phase, etc.) estimated by array processing algorithms are essential tools in the evaluation of system performance. The case in which the complex amplitudes of the signals are unknown is of particular practical interest. A computationally efficient formulation of these bounds (from the perspective of derivations and analysis) is presented for the case of deterministic and unknown signal amplitudes. A new derivation is given using the unknown complex signal parameters and their complex conjugates. The new formula is readily applicable to obtaining either symbolic or numerical solutions to estimation bounds for a very wide class of problems encountered in adaptive sensor array processing. This formula is shown to yield several of the standard Cramer'r-Rao results for array processing, along with new results of fundamental interest. Specifically, a new closed-form expression for the statistical resolution limit of an aperture for any asymptotically unbiased superresolution algorithm (e.g., MUSIC, ESPRIT) is provided. The statistical resolution limit is defined as the source separation that equals its own Cramer'r-Rao bound, providing an algorithm-independent bound on the resolution of any high-resolution method. It is shown that the statistical resolution limit of an array or coherent integration window is about 1.2·SNR-14/ relative to the Fourier resolution limit of 2pi/N radians (large number N of array elements). That is, the highest achievable resolution is proportional to the reciprocal of the fourth root of the signal-to-noise ratio (SNR), in contrast to the square-root (SNR-12/) dependence of standard accuracy bounds. These theoretical results are consistent with previously published bounds for specific superresolution algorithms derived by other methods. It is also shown that the potential resolution improvement obtained by separating two collinear arrays (synthetic ultra-wideband), each with a fixed aperture B wavelengths by M wavelengths (assumed large), is approximately (M/B)12/, in contrast to the resolution improv- ement of M/B for a full aperture. Exact closed-form results for these problems with their asymptotic approximations are presented. [J218]

"Rank-deficient robust Capon filter bank approach to complex spectral estimation"

We consider nonparametric complex spectral estimation using an adaptive filtering-based approach where the finite-impulse response (FIR) filter bank is obtained via a rank-deficient robust Capon beamformer. We show that, by allowing the sample covariance matrix to be rank deficient, we can achieve much higher resolution than existing approaches, which is useful in many applications, including radar target detection and feature extraction. Numerical examples are provided to demonstrate the performance of the new approach as compared to the existing data-adaptive and data-independent FIR filtering-based spectral estimation methods. [J219]

"Integration of optical and radar classifications for mapping pasture type in Western Australia"

In this study, independent classifications of Landsat Thematic Mapper imagery and Jet Propulsion Laboratory AirSAR were combined to create an integrated classification of pasture and other vegetation types for a study area in the agricultural zone of Western Australia. The resulting classification combines greenness and brightness information from optical data with structure and water content information from synthetic aperture radar (SAR). Field observations of vegetation type, botanical composition, ground cover percentage, wet and dry biomass, canopy height, and soil water content were collected at 34 sites representing a range of pastures, browse shrubs, and crops. An unsupervised version of the Complex Wishart classification procedure, based on preserving scattering characteristics from the Freeman and Durden backscatter decomposition, was applied to the C-, L-, and P-band polarimetric SAR data. The optical classification was carried out using a principle component analysis on the green, red, and near-infrared bands and clustering on the basis of a class centroid distance measure and knowledge of ground targets. These two classification results were then fused together. Assessment of a confusion matrix using the individual sites showed that identification of more uniform, dense, and structurally distinct canopies was better than that of more diverse, sparse, and structurally ambiguous canopies, as the former were better represented by the canopy height attribute used in the SAR classification component. The optical classification enabled correction of SAR misclassification of vegetation due to surface roughness and soil moisture effects, or similar backscatter responses from herbaceous or arboreal canopies. The results show that simplification of vegetation into groups based upon properties with sensitive responses in both the optical and SAR domains, and combination of separate SAR and optical classifications, has potential for improving classification of diverse and heterogeneous herbaceous and browse cover in grazing lands. However, collection of ground calibration data must be at an appropriate spatial scale and include canopy and surface measurements directly related to backscatter mechanisms and spectral sensitivity. [J220]

"Localization via ultra-wideband radios: a look at positioning aspects for future sensor networks"

UWB technology provides an excellent means for wireless positioning due to its high resolution capability in the time domain. Its ability to resolve multipath components makes it possible to obtain accurate location estimates without the need for complex estimation algorithms. In this article, theoretical limits for TOA estimation and TOA-based location estimation for UWB systems have been considered. Due to the complexity of the optimal schemes, suboptimal but practical alternatives have been emphasized. Performance limits for hybrid TOA/SS and TDOA/SS schemes have also been considered. Although the fundamental mechanisms for localization, including AOA-, TOA-, TDOA-, and SS-based methods, apply to all radio air interface, some positioning techniques are favored by UWB-based systems using ultrawide bandwidths. [J221]

"Unsupervised classification of polarimetric synthetic aperture Radar images using fuzzy clustering and EM clustering"

Five clustering techniques are compared by classifying a polarimetric synthetic aperture radar image. The pixels are complex covariance matrices, which are known to have the complex Wishart distribution. Two techniques are fuzzy clustering algorithms based on the standard ℓ1and ℓ2metrics. Two others are new, combining a robust fuzzy C-means clustering technique with a distance measure based on the Wishart distribution. The fifth clustering technique is an application of the expectation-maximization algorithm assuming the data are Wishart. The clustering algorithms that are based on the Wishart are demonstrably more effective than the clustering algorithms that appeal only to the ℓpnorms. The results support the conclusion that the pixel model is more important than the clustering mechanism. [J222]

"Outlier probability of generalized chirpogram-based estimators for multicomponent polynomial-phase signals"

Outliers are often encountered by estimators that have a nonlinear nature. In this paper, the probability of outliers is derived concerning the generalized chirpogram (GC)-based estimators for polynomial-phase signals (PPS). To derive the approximate theoretical expressions, we develop an approach that is based on the extrema theory of complex Gaussian envelope and the asymptotic Poisson model. The semi-aliasing effect of PPS is also considered in order to predict the outliers more accurately. Then expressions of the probability of outliers are presented for several typical cases of PPS, including single-tone and chirp signals and their two-component versions. The GC with the Hamming windowing is also incorporated. Numerical examples of computer simulations are also provided to show the accuracy of the theoretical expressions. [J223]

"Human-centered concepts for exploration and understanding of Earth observation images"

The progress in information retrieval, computer vision, and image analysis makes it possible to establish very complete bases of algorithms and operators. A specialist in remote sensing or image processing now has the tools that allow him, at least in theory, to configure applications solving complex problems of image

understanding. However, in reality, earth observation (EO) data analysis is still performed in a very laborious way at the end of repeated cycles of trial and error. To overcome this, we proposed a novel advanced remote sensing information processing system knowledge-driven information mining (KIM). KIM is based on human-centered concepts (HCCs), which implements new features and functions allowing improved feature extraction, search on a semantic level, the availability of collected knowledge, interactive knowledge discovery, and new visual user interfaces. We assess the HCC methodology for solving several difficult tasks in EO image interpretation, using a broad variety of sensor data, from meter-resolution synthetic aperture radar and optical images to hyperspectral data. [J224]

"Retrieval of biophysical parameters of agricultural crops using polarimetric SAR interferometry"

An existing two-layer model for forest height estimation is adapted for agricultural crops in order to develop a retrieval algorithm based on polarimetric synthetic aperture radar interferometry. This new inversion scheme is specifically tailored for vertically oriented agricultural crops, with extinction coefficients dependent on the wave polarization. Physical parameters of the vegetation scene are estimated from the location of the measured coherences in the complex plane. The proposed inversion scheme is validated experimentally with indoor wide-band polarimetric measurements on samples of corn and rice fields. Results show that the estimates of the thickness of the vegetation layer and the ground topography are reasonably accurate for a wide range of frequencies and baselines. Moreover, some interesting results are also obtained when using only dual-polarized data, which brings up new applications for present and future spaceborne missions. [J225]

"Radar: the evolution since World War II"

Modern radar design has benefited from the evolution of specialized digital processing, allowing high resolution ground mapping, target identification, and target tracking under many conditions. Air-to-air interception makes use of complex decision processes to select from many modes that depend on the clutter backgrounds and flight profiles. Today's multimode radars provide this information for each task while minimizing distractions. Fire control radars support a wide selection of weapons, including cannons and guided missiles. This is possible because of advanced digital processing. In the interval since WW II, radar design evolved from vacuum tubes to semiconductors and then to massively integrated circuits. Computers specialized for fast Fourier transforms (FFTs) have revolutionized radar data processing. System reliability has improved from a few hours to hundreds of hours. Effective built-in test informs ground maintenance personnel of problems for easy maintenance and low failure rates reduce or eliminate field maintenance benches at forward locations. Airborne surveillance radars, such as AW ACS Joint Stars have changed the nature of warfare. Commanders have virtually full view of enemy and friendly forces. Radars, in combination with other remote sensors, provide precise weapon delivery, reducing collateral damage and making all weapons more effective [J226]

"Adaptive removal of azimuth ambiguities in SAR images"

We introduce an innovative algorithm that is capable of suppression of strong azimuth ambiguities in single-look complex (SLC) synthetic aperture radar images, to be used both for detected products and for interferometric surveys. The algorithm exploits a band-pass filter to select that portion of the azimuth spectrum that is less influenced by aliasing, the one that corresponds to the s in the replicated azimuth antenna pattern. The selectivity of this filter adapts locally depending on the estimated ambiguity intensity: the filter is more selective in the presence of strong ambiguities and becomes all-pass in absence of ambiguities. The design of such filter frames in the Wiener approach with two different normalization options, depending on the use of the SLC image, either for getting multilook averaged detected products or for interferometric applications. Preliminary results achieved by processing ENVISAT Advanced Synthetic Aperture Radar sensor data are provided. [J227]

"Four-component scattering model for polarimetric SAR image decomposition"

A four-component scattering model is proposed to decompose polarimetric synthetic aperture radar (SAR) images. The covariance matrix approach is used to deal with the nonreflection symmetric scattering case. This scheme includes and extends the three-component decomposition method introduced by Freeman and Durden dealing with the reflection symmetry condition that the co-pol and the cross-pol correlations are close to zero. Helix scattering power is added as the fourth component to the three-component scattering model which describes surface, double bounce, and volume scattering. This helix scattering term is added to take account of the co-pol and the cross-pol correlations which generally appear in complex urban area scattering and disappear for a natural distributed scatterer. This term is relevant for describing man-made targets in urban area scattering. In addition, asymmetric volume scattering covariance matrices are introduced in dependence of the relative backscattering magnitude between HH and VV. A modification of probability density function for a cloud of dipole scatterers yields asymmetric covariance matrices. An appropriate choice among the symmetric or

asymmetric volume scattering covariance matrices allows us to make a best fit to the measured data. A four-component decomposition algorithm is developed to deal with a general scattering case. The result of this decomposition is demonstrated with L-band Pi-SAR images taken over the city of Niigata, Japan. [J228]

"State-space spectral estimation of characteristic electromagnetic responses in wideband data"

This letter utilizes a robust spectral estimation method, based on state-space control theory, to coherently process wideband frequency domain field data of any object and extract specific modal (or characteristic) responses associated with wave propagation along the object. The estimation problem is formulated in terms of well-known range processing used in radar imaging. Thus, the data is modeled in terms of complex sinusoids, whose amplitude is scaled by the decay constants of the modes and whose phase yields the range associated with scattering centers pertinent to modal propagation. Unlike other approaches that require the system poles to be inside the unit circle, the complex poles yielding the decay constants in the proposed approach can be located anywhere in the z-plane, and can vary with frequency, in order to capture the dynamic wideband behavior of the scattering mechanism. The method is illustrated by application to mode extraction for a cylindrically stratified dielectric scatterer. [J229]

"Robust separation of background and target signals in radar cross section measurements"

Coherent measurements of radar cross-section on a target moving along the system line-of-sight in free space will trace a circle centered on the origin of the complex (I,Q) plane. The presence of additional complex background signals (including stationary clutter, target support, and averaged target-mount interactions), which do not depend on target position, will translate the origin of the circle to some complex point (I0,Q0). The presence of outliers (mostly due to radio-frequency interference) can introduce significant errors in the determination of the radius and center of the I-Q circle. We have implemented a combination of a robust and efficient least median square and an orthogonal-distance regression algorithm to eliminate or to reduce the influence of outliers, and then to separate the target and background signals. Concurrently, the influence of noise is also reduced. Thus, we can obtain both target-independent estimates of the background and a background-free estimates of the radar cross-sections of calibration artifacts. In measurements on low-observable targets, the subtraction of the background signal from the measurement and calibration significantly improves the measurement accuracy. This technique is especially useful for subwavelength translations at very and ultra-high-frequencies, where spectral techniques are not applicable because the available arc of data is limited. [J230]

"Digital channelized receiver based on time-frequency analysis for signal interception"

A digital channelized receiver is presented for the interception of a wide variety of signals of complex structure, including those with low probability of interception. The receiver is designed from the perspective of the time-frequency analysis. It uses an extended time-frequency representation based on the noncoherent integration of the short-time Fourier transform (STFT) on which the detection system and the encoder work. The encoder includes robust frequency estimation, automatic modulation recognition, and clustering, to handle broadband and simultaneous signals and to prevent out-of-channel detections (a typical phenomenon in channelized receivers). The receiver has been evaluated for a wide range of signals and shows a good performance in terms of detection, estimation, and processing of simultaneous signals. Signals collected from real-life systems and synthetic signals have been utilized. [J231]

"A novel CFAR tonal detector using phase compensation"

A novel tonal detector is presented in this paper. The detector uses phase compensation for detecting sinusoidal signal with unknown amplitude, frequency, and phase in complex Gaussian noise with unknown variance. We analyze the statistical properties of the discrete Fourier transform (DFT) of the observations and consider the leakage effect. Then we develop the detector by using generalized likelihood ratio test (GLRT). The new detector fully utilizes the phase information of the signal and achieves constant false alarm rate (CFAR) property. Theoretical analysis and simulation results show its improvement in detection performance [J232]

"Operational oil-slick characterization by SAR imagery and synergistic data"

A methodology is proposed for the semiautomatic detection, characterization, and classification of slicks detected in C-band Synthetic Aperture Radar (SAR). For the first detection step, automatic algorithms were tested on Environmental Research Satellite (ERS) and Environmental Satellite (EnviSat) images acquired during the Prestige tanker accident. These tests reveal that simple filter or segmentation methods efficiently detect slicks with high contrasts and simple shapes, while a new and more complex multiscale method is able to detect a wider range of slicks. The characteristics of automatically detected slicks are then combined with meteooceanic

data in order to eliminate slicks related to wind anomalies and current fronts. The data suggest that slicks in cold upwelling waters are natural, and confirm that slicks are heavy oils when high sea states are present. This detection-classification methodology is validated with aircraft slick-tracking maps. In most cases, joint SAR and environmental data are sufficient to classify the slicks. [J233]

"Analytical study on change of temperature and absorption characteristics of a single-Layer radiowave absorber under irradiation electric power"

Radiowave absorbers are frequently used in high power applications, such as radar sites, and the rise of temperature of the absorber has often become a matter of concern. In this paper, the finite-difference time-domain (FDTD) method combined with the heat transport equation (HTE), also known as the FDTD-HTE method, which has been widely used in the analysis of microwave heating or temperature increase in the human head due to portable phones, is used in the analysis of the wave absorption characteristics of a single-layer wave absorber. The complex permittivity of a sample made of epoxy resin, measured by a cavity-resonator method when the sample is irradiated by a high power field for different irradiation times, is used in the analysis, and the wave absorption characteristics of the absorber under investigation highly depend on the input power and irradiation time of the high power field. [J234]

"Fisher information for a complex Gaussian random variable: beamforming applications for wave propagation in a random medium"

We derive a general expression for the Fisher information for a special class of complex Gaussian random variables, whose mean and covariance may be expressed in terms of a specific parameterized linear transformation. The deterministic unknown parameter case is considered. This class is descriptive of signals that propagate in a homogeneous or inhomogeneous medium and also occurs in numerous beamforming applications. The Fisher information derived here encompasses a wide range of previously derived, well-known results for complex Gaussian signals propagating in a homogeneous medium and is also applicable to more recent models for signals propagating in an inhomogenous medium. The conditions for the estimates of the azimuth and elevation to decouple from the estimates of the nuisance parameters are studied for monochromatic plane-wave and spherical-wave propagation in a random medium. For propagation in an anisotropic medium, it is found that, in general, the Cramer-Rao lower bounds (CRLBs) of the entire unknown parameter set will be coupled. For special cases of propagation in an isotropic medium, it is found that for plane waves, the CRLBs of the angles of arrival will be approximately decoupled from the CRLBs of the other unknowns, and for spherical waves, the CRLBs of the angles of arrival will be always be coupled to the CRLBs of all other unknowns, although the couplings may be minimized under certain conditions. [J235]

"Mm wavelengths complex Doppler analysis using dark field illumination"

Experimental results that indicate that at least two fundamental modes of Doppler generation are present when a rotating steel cylinder is broadside illuminated by radar. Improvised bistatic measurements at 77GHz are discussed and second order Doppler effects studied. Complex Doppler returns, consisting of two or more Doppler contributions, are decomposed and studied using empirical methods. In particular, ground illumination techniques are used to study Doppler in the shadow region of a cylinder of circumference 81 wavelengths. It is concluded that the complex Doppler response from the spinning cylinder consists of both direct (first order) and delayed (second order) Doppler components. Further measurements are proposed to study the delayed Doppler effect further. [J236]

"A Hybrid Phase-Based Single Frequency Estimator"

The topic of low computational complexity frequency estimation of a single complex sinusoid corrupted by additive white Gaussian noise has received significant attention over the last decades due to the wide applicability of such estimators in a variety of fields. In this letter, we propose a computationally fast and statistically improved hybrid phase-based estimator that outperforms other recently proposed approaches, lowering the signal-to-noise ratio at which the CramЙr–Rao lower bound is closely followed. [J237]

"Leaf area index estimation of boreal forest using ENVISAT ASAR"

A method for retrieval of leaf area index (LAI) using ENVISAT Advanced Synthetic Aperture Radar vertical/horizontal (VV/HH) polarization ratio was derived for boreal forests. Five alternating polarization single-look complex images of the test site were acquired in summer 2003. The swath range from IS1-IS6 was studied. The VV/HH polarization ratio correlated quite well with the ground truth LAI values. The mean error of the LAI estimates was 0.27 for the test site with mixed forest when data from all images and stands were used without

separating between species (or swaths). The respective mean LAI estimation error was 0.3 for Norway spruce (Picea abies (L.) Karst.) and 0.07 for Scots pine (Pinus sylvestris L.) dominated stands. [J238]

"Radar backscattering model for multilayer mixed-species forests"

A multilayer canopy scattering model is developed for mixed-species forests. The multilayer model provides a significantly enhanced representation of actual complex forest structures compared to the conventional canopy-trunk layer models. Multilayer Michigan Microwave Canopy Scattering model (Multi-MIMICS) allows overlapping layer configuration and a tapered trunk model applicable to forests of mixed species and/or mixed growth stages. The model is the first-order solution to a set of radiative transfer equations and includes layer interactions between overlapping layers. It simulates SAR backscattering coefficients based on input dimensional, geometrical, and dielectric variables of forest canopies. The Multi-MIMICS is an efficient realization of actual forest structures and can be shaped for specific interest of forest parameters. We present the model's application and validation in the paper. The model is parameterized using data collected from a 220,000-ha area of forests in central Queensland, Australia. Fifteen 50Ч50 m test sites representing the general forest diversity and growth stages are chosen as ground truth. Polarimetric backscattering airborne SAR (AIRSAR) data of the same area are acquired to validate the model simulations. The model predicts SAR backscattering coefficients of the test areas. Simulation results show a good agreement with AIRSAR data at most frequencies and polarizations. The simulated backscattering coefficient from the multilayer model and the standard MIMICS are also compared and significant improvements are observed. [J239]

"A simplistic incidence angle approach to retrieve the soil moisture and surface roughness at X-band"

Nowadays, it is an important point of research to classify the moisture and roughness using microwave data with less complex models. For this purpose, microwave measurements were conducted for observing roughness and soil moisture at X-band (9.5 GHz). These measurements were carried out over a range of incidence angle from 20° to 70° at the step of 5° for both polarizations (i.e., horizontal (H) and vertical (V) polarizations). Surface roughness (i.e., root mean square height) and moisture were varied in controlled conditions. Microwave emissivity has been derived with the measurements of reflectivity from a microwave system. Results show a good angular variation of emissivity with surface roughness and moisture for both polarizations. An algorithm is developed using incidence angle as a modulating factor for retrieving the soil moisture and surface roughness at X-band. A good agreement between observed and retrieved surface roughness (i.e., standard error; SE-0.066 for H-polarization) and soil moisture (SE-0.045 for H-polarization) has been obtained by the proposed model. [J240]

"Modeling SAR images with a generalization of the Rayleigh distribution"

Synthetic aperture radar (SAR) imagery has found important applications due to its clear advantages over optical satellite imagery one of them being able to operate in various weather conditions. However, due to the physics of the radar imaging process, SAR images contain unwanted artifacts in the form of a granular look which is called speckle. The assumptions of the classical SAR image generation model lead to a Rayleigh distribution model for the histogram of the SAR image. However, some experimental data such as images of urban areas show impulsive characteristics that correspond to underlying heavy-tailed distributions, which are clearly non-Rayleigh. Some alternative distributions have been suggested such as the Weibull, log-normal, and the k-distribution which had success in varying degrees depending on the application. Recently, an alternative model namely the α-stable distribution has been suggested for modeling radar clutter. In this paper, we show that the amplitude distribution of the complex wave, the real and the imaginery components of which are assumed to be distributed by the α-stable distribution, is a generalization of the Rayleigh distribution. We demonstrate that the amplitude distribution is a mixture of Rayleighs as is the k-distribution in accordance with earlier work on modeling SAR images which showed that almost all successful SAR image models could be expressed as mixtures of Rayleighs. We also present parameter estimation techniques based on negative order moments for the new model. Finally, we test the performance of the model on urban images and compare with other models such as Rayleigh, Weibull, and the k-distribution. [J241]

"Two-dimensional ESPRIT with tracking for radar imaging and feature extraction"

Estimation of signal parameters via rotational invariance techniques (ESPRIT) appears to be the best of the known spectral-analysis methods. It has the highest resolution, has no spectral splatter and is robust in the presence of noise. It answers immediately and explicitly the question "What frequencies, real or complex, are present and what are their amplitudes?" Fourier methods (and other high-resolution methods), answer the less direct question "What amplitudes, applied to a set of regularly-spaced real frequencies, best represent the data?"

They then present the problem of interpreting the amplitudes. These attributes of ESPRIT, in the two-dimensional (2-D) version described here, make it a natural for radar signal processing, where it answers the need for high-resolution imaging, free of sidelobes in range and range rate, and for high-fidelity feature extraction. The paper starts with the mathematical data model, describes a "resampling" procedure to fit the data better to the model, summarizes the 2-D ESPRIT algorithm itself, and presents examples of its performance. The paper covers the details of this least-squares version of ESPRIT, including an enhancement that allows the scatterers to be tracked individually. The algorithm properly distinguishes between scatterers having one coordinate in common, and it automatically pairs correctly the range and range-rate of each scatterer. [J242]

"Unsupervised terrain classification preserving polarimetric scattering characteristics"

In this paper, we proposed an unsupervised terrain and land-use classification algorithm using polarimetric synthetic aperture radar data. Unlike other algorithms that classify pixels statistically and ignore their scattering characteristics, this algorithm not only uses a statistical classifier, but also preserves the purity of dominant polarimetric scattering properties. This algorithm uses a combination of a scattering model-based decomposition developed by Freeman and Durden and the maximum-likelihood classifier based on the complex Wishart distribution. The first step is to apply the Freeman and Durden decomposition to divide pixels into three scattering categories: surface scattering, volume scattering, and double-bounce scattering. To preserve the purity of scattering characteristics, pixels in a scattering category are restricted to be classified with other pixels in the same scattering category. An efficient and effective class initialization scheme is also devised to initially merge clusters from many small clusters in each scattering category by applying a merge criterion developed based on the Wishart distance measure. Then, the iterative Wishart classifier is applied. The stability in convergence is much superior to that of the previous algorithm using the entropy/anisotropy/Wishart classifier. Finally, an automated color rendering scheme is proposed, based on the classes' scattering category to code the pixels to resemble their natural color. This algorithm is also flexible and computationally efficient. The effectiveness of this algorithm is demonstrated using the Jet Propulsion Laboratory's AIRSAR and the German Aerospace Center's (DLR) E-SAR L-band polarimetric synthetic aperture radar images. [J243]

"Unifying regularization and Bayesian estimation methods for enhanced imaging with remotely sensed Data-part II: implementation and performance issues"

The fused Bayesian-regularization (FBR) method from a companion paper provides a rigorous theoretical formalism for optimal estimation of the power spatial spectrum pattern (SSP) of the wave field scattered from the probing surface as it is required for enhanced radar imaging of the remotely sensed scenes. Being nonlinear and solution-dependent, the optimal FBR method requires extremely complex nonlinear solution-dependent operator inversions and, therefore, cannot be recommended as a numerically realizable estimator of the SSP. Here, we design a family of robust easy-to-implement FBR algorithms, provide the relevant computational recipes, and discuss their performances. We comment on the practical aspects of the robustified FBR estimators, such as numerical implementation and improvement in the output SNR. The advantage in using the proposed robust FBR method is demonstrated through simulations of enhancing the SAR images formed using the conventional matched filtering of the trajectory signal. [J244]

"Consequence of incorrect sampling procedures in resonance-based radar target identification"

Radar target identification based on complex natural resonances is sometimes achieved by convolving a linear time-domain filter with a received target signature. The filter is constructed from measured or pre-calculated target resonances. The performance of the target identification procedure is degraded if the difference between the sampling rates of the target signature and the filter is ignored. The problem is investigated for the natural extinction pulse technique (E-pulse) for the case of identifying stick models of aircraft. [J245]

"Multiple radar targets detection by exploiting induced amplitude modulation"

This work deals with the problem of detecting and estimating multiple radar targets present in the same range-azimuth resolution cell of a surveillance radar system with a mechanically rotating antenna. In the first part of the work, we tackled the problem of estimating target complex amplitudes, Doppler frequencies, and directions of arrival, and a consistent estimator based on the asymptotic maximum likelihood (AML) method was derived. In this second part, we tackle the "detection problem," which consists of determining the number of targets. First, the target parameters are estimated, assuming a maximum number of possible targets. Subsequently, these estimates are used in a successive hypotheses test procedure. The statistic of the test at each step of the procedure is derived by using an asymptotic expression of the generalized likelihood ratio test (GLRT) statistic. Performance of the proposed algorithm is investigated through both asymptotical analysis (as concerning the probability of false alarm) and Monte Carlo simulation. [J246]

"Terrain elevation mapping results from airborne spotlight-mode coherent cross-track SAR stereo"

Coherent cross-track synthetic aperture radar (SAR) stereo is shown to produce high-resolution three-dimensional maps of the Earth surface. This mode utilizes image pairs with common synthetic apertures but different squint angles allowing automated stereo correspondence and disparity estimation using complex correlation calculations. This paper presents two Ku-band, coherent cross-track stereo collects over rolling and rugged terrain. The first collect generates a digital elevation map (DEM) with 1-m posts over rolling terrain using complex SAR imagery with spatial resolution of 0.125 m and a stereo convergence angle of 13.8°. The second collect produces multiple DEMs with 3-m posts over rugged terrain utilizing complex SAR imagery with spatial resolutions better than 0.5 m and stereo convergence angles greater than 40°. The resulting DEMs are compared to ground-truth DEMs and relative height root-mean-square, linear error 90-percent confidence, and maximum height error are reported. [J247]

"Exploration of factors limiting biomass estimation by polarimetric radar in tropical forests"

Direct inversion of radar return signals for forest biomass estimation is limited by signal saturation at medium biomass levels (roughly 150 ton/ha for P-band). Disturbing factors such as forest structural differences-and, notably, at low biomass levels, terrain roughness, and soil moisture variation-cause further complications. A new and indirect inversion approach is proposed that may circumvent such problems. Using multifrequency polarimetric radar the forest structure can be assessed accurately. Ecological relationships link these structures with biomass levels, even for high biomass levels. The LIFEFORM model is introduced as a new approach to transform field observations of the complex tropical forest into input files for the theoretical UTARTCAN polarimetric backscatter model. The validity of UTARTCAN for a wide range of forest structures is shown. Backscatter simulations for a wide range of forest structures, terrain roughness, and soil moisture clearly show the limitations of the direct approach and the validity of the proposed indirect approach up to very high levels of biomass. [J248]

"Role of polarisation in automatic target recognition using resonance descriptions"

The role of polarisation in late time complex resonance based target identification is investigated numerically for the case of an L-shaped wire. While repeated extraction of the resonances for varying polarisation allows for better signal-to-noise immunity, it is also found that there are preferred polarisations for each complex resonance. The first few of these polarisations are extracted for the sample target. [J249]

"Calculation of scattering from dielectric objects above half space"

The scattering cross-section of a dielectric target located above half space is calculated using the reciprocity theorem (RT), steepest descent method (SDM), and spatial domain dyadic Green's function (SDGF) obtained via the discrete complex image method with the generalised pencil of function method. Numerical results show that the RT and SDM results are in good agreement. However, the SDGF is able to provide accurate results on the scattered fields over most angles in the far-field region. [J250]

"Investigation of broadband electromagnetic induction scattering by highly conductive, permeable, arbitrarily shaped 3-D objects"

Operating as low as tens of hertz and as high as hundreds of kilohertz, new broadband electromagnetic induction (EMI) sensors have shown promise for classification of unseen buried metallic objects. The three-dimensional (3-D) and bodies-of-revolution (BOR) numerical studies reported here are designed to explain key scattering sensitivities that may either be useful in or may limit object classification capability. The target is excited either by a spatially uniform oscillating primary magnetic field or by the oscillating field from a loop antenna. The problem is formulated in terms of Poison's equation for scalar potential outside the object, where conductivity and electric field values are low and consequent conduction currents are generally negligible. The Helmholtz equation for vector potential applies inside the highly conducting and permeable object. In both regions, the electromagnetic phenomena of interest are magneto-quasi-static (MQS). The simulation algorithm uses the method of auxiliary sources (MAS), with auxiliary magnetic charges and auxiliary magnetic current elements distributed on auxiliary surfaces. These surfaces generally conform to but do not coincide with physical surfaces, providing extraordinarily efficient and accurate 3-D solutions. Comparisons to available analytical solutions and experimental data validate the solutions. The simulations and data illuminate broadband MQS scattering phenomenology for both magnetic and nonmagnetic metallic objects. Distinctive sensitivities are shown and signature effects analyzed relative to the scatterer's shape and aspect ratio, orientation, sharp points and edges, finite wall thickness in hollow bodies, and compound structure in which a geometrically complex body consists of a number of distinct sections, e.g., fins. [J251]

"Segmentation of textured polarimetric SAR scenes by likelihood approximation"

A hierarchical stepwise optimization process is developed for polarimetric synthetic aperture radar image segmentation. We show that image segmentation can be viewed as a likelihood approximation problem. The likelihood segment merging criteria are derived using the multivariate complex Gaussian, the Wishart distribution, and the K-distribution. In the presence of spatial texture, the Gaussian-Wishart segmentation is not appropriate. The K-distribution segmentation is more effective in textured forested areas. The validity of the product model is also assessed, and a field-adaptable segmentation strategy combining different criteria is examined. [J252]

"At what layer does mobility belong?"

Internetworking is a complex problem, traditionally tackled by splitting responsibilities between several layers of protocols arranged in a stack. A shortcoming of the current Internet suite's layers is that the responsibilities of individual layers are somewhat ill defined. The result is that frequently a feature may cause problems for higher layers when it unexpectedly exists lower in the stack, or may be unnecessarily and inefficiently implemented in multiple layers. Mobility is one such feature with no well defined place in classical protocol stacks. If a link layer hands over between two distinctly administered networks, a network layer protocol will likely need to acquire a new address. Similarly, if mobility is implemented at the network layer, such as with mobile IP, transport layer protocols must be prepared to deal with a slew of problems (rapid changes in available capacity and delay, the asymmetry of triangle routes, and security policies, to name a few). Code for higher-level protocols (above transport) is less frequently reused, so higher-layer mobility schemes fail to leverage the large base of TCP sockets code. We discuss the various strengths and weaknesses of implementing mobility at three different layers of the protocol stack, concluding that a transport layer mobility scheme is likely to suit today's mobile Internet users best, and that ideally there should be more communication between layers to avoid conflict and inefficiency. [J253]

"Measurement system of complex permittivity of ornamental rocks in L frequency band"

The use of ground-penetrating radar (GPR) techniques at high frequencies for historical building investigations requires an accurate knowledge of the material complex permittivity. A new measurement system is presented, which by exploiting a resonance phenomenon, yields accurate values of permittivity and resistivity also in the case of low-loss materials. These parameters are obtained from an amplitude-only measurement of the transmission response curve of a rectangular waveguide cavity, loaded by the sample under test. The setup requires the availability of brick-shaped samples, which can be obtained easily in the case of rock materials. Permittivities and resistivities were measured in the frequency range 1.1-1.7 GHz on samples of marbles, sandstones, and limestones. The measurement method and the experimental results are presented and discussed. [J254]

"A graphical user interface (GUI) for plane-wave scattering from a conducting, dielectric, or chiral sphere"

Various numerical techniques have been developed for modeling electromagnetic field propagation in various novel complex media. The validity of these techniques is usually verified by comparison to the exact solutions of canonical problems. Recently, research has focused on chiral media, a subclass of materials known as bianisotropic materials, and numerical techniques have been developed in order to calculate the interaction of electromagnetic fields with chiral objects. One canonical problem for these techniques is plane-wave scattering from a chiral sphere. This work presents a software package that displays and saves the calculated data for the scattering from a chiral, dielectric, or perfectly conducting sphere using a friendly graphical user interface (GUI). [J255]

"Electromagnetic modeling of conformal wideband and multi-band patch antennas by bridging a solid-object modeler with MoM software"

The advantages of antennas that can resemble the shape of the body to which they are attached are obvious. However, electromagnetic modeling of such unusually shaped antennas can be difficult. In this paper, the commercially available software SolidWorks™ is used for accurately drawing complex shapes in conjunction with the electromagnetic software FEKO™ to model the EM behavior of conformal antennas. The application of SolidWorks and custom-written software allows all the required information that forms the analyzed structure to be automatically inserted into FEKO, and gives the user complete control over the antenna being modeled. This approach is illustrated by a number of simulation examples of single, wideband, multi-band planar and curved patch antennas. [J256]

"Sparse frequency transmit-and-receive waveform design"

A computationally efficient algorithm derives complex digital transmit and receive ultra-wideband radar and communication waveforms with excellent arbitrary frequency band suppression and range sidelobe minimization. The transmit waveform minimizes a scalar function penalizing weighted spectral energy in arbitrary frequency bands. Near constant power results from another penalty function for deviations from constant power, or constant power is enforced by a phase-only formulation. Next, a least squares solution for the receive waveform minimizes a weighted sum of suppressed band spectral energy and range sidelobes (for pulse and continuous wave operation), with a mainlobe response constraint. Both waveforms are calculated by iterative algorithms whose updates require only linear order in memory and computation, permitting quick calculation of long pulses with thousands of samples. [J257]

"Rain field and reflectivity vertical profile reconstruction from C-band Radar volumetric data"

Operating a meteorological radar is generally a challenging task when in presence of a significant beam blockage as in complex orography. Apart from enhanced ground clutter, mountainous obstructions of the radar beam can significantly reduce the radar visibility and, thus, its monitoring capabilities. Self-consistent adaptive techniques to reconstruct vertical profiles of reflectivity (VPR) and near-surface rain-rate fields from high-elevation reflectivity bins are here proposed, compared, and tested for ranges up to 60 km. The methodology is based on statistical estimators trained by a large reflectivity volumetric datasets, classified into stratiform and convective rain regimes and resampled onto a uniform Cartesian grid by means of a modified Cressman technique. For what concerns reflectivity vertical profiles, two methods, respectively named statistical nonlinear reconstruction (NSR) and neural network reconstruction (NNR), are considered. The NSR method is based on the principal component analysis, applied to the radar dataset, in order to extract significant reflectivity-profile variance. A retrieval technique, based on a nonlinear multiple regression scheme, is then used to infer near-surface reflectivity from available high-altitude echoes at a given range. The NNR is based on a three-layer artificial neural network trained by means a feedforward backpropagation algorithm. For what concerns the near-surface rain retrieval, besides a power-law reflectivity-rain-rate (ZR) approach, a three-layer neural network technique is also set up in order to estimate surface rain rate from reconstructed VPR. The proposed reconstruction techniques are here illustrated by using volumetric data acquired by the C-band Doppler single-polarization radar, operated in L'Aquila, Italy. A case study, related to a rainfall event that occurred during fall 2000, is discussed. Using a test area within 60 km from the radar site and simulating the presence of beam obstructions, a comparison of NSR and NNR with conventional area average reconstruction techniques shows that the percentage improvement of both NSR and NNR approaches is significant, both for the error bias (by 30% to more than 50%, depending on altitude) and variance (by 10% to more than 20%). A sensitivity test indicates that the VPR reconstruction procedure is fairly robust to missing data, especially in terms of error bias. The comparison of estimated radar rainfall with rain gauge data measurement is also illustrated. The mean field bias closer to its optimal value and an error variance much smaller is obtained when neural network techniques are applied than with conventional ZR methods for both techniques of reconstruction. With respect to the latter, the obtained improvement is more than 40% in terms of root mean square error and is comparable when estimating near-surface rain rate using either NSR or NNR methods to reconstruct the reflectivity vertical profiles. Limitations, potential, and future developments of the proposed adaptive reconstruction techniques are finally discussed. [J258]

"Three-dimensional inverse scattering of a dielectric target embedded in a lossy half-space"

A modified iterative Born method is applied for three-dimensional inversion of a lossless dielectric target embedded in a lossy half-space. The forward solver employs a modified form of the extended Born method, and the half-space Green's function is computed efficiently via the complex-image technique. Example results are shown, with all scattering data based on a computational model, utilizing a rigorous forward solver distinct from that employed in the inversion. In addition, distinct gridding schemes are used in the forward and inverse solvers. Simple Tikhonov regularization is found to yield adequate results for inversion of noisy data. [J259]

"Measurement of 2-D sea surface elevation fields using complex synthetic aperture radar data"

A method is presented to derive two-dimensional sea surface elevation fields from complex synthetic aperture radar (SAR) data. Applied to spaceborne SAR data as acquired by European Remote Sensing 2 (ERS-2) or the Environmental Satellite (ENVISAT), the method allows to analyze the structure of ocean wave fields, e.g., wave grouping or individual wave heights on a global scale. The technique, thus, provides wave parameters not obtained with common SAR wave retrieval schemes, which are designed to estimate the 2-D wave spectrum, i.e., second-order statistical moments of the wave field. Estimates of sea surface elevation fields are obtained based on the existing theory of SAR ocean wave imaging, i.e., the modulation of the SAR image intensity due

real aperture radar and motion-related effects. A power series expansion is derived for SAR intensity images that enables the analysis of nonlinear effects as well as to derive a quasi-linear approximation of the SAR imaging model in the spatial domain. A statistical analysis is performed based on a global dataset of 2D wave spectra provided by the European Centre for Medium-Range Weather Forecast. Distributions are given for the relative error of the quasi-linear approximation in the spatial domain. It is shown that the error can be reduced by smoothing the SAR image in the azimuthal direction at the cost of lower resolution. Smoothed elevation fields are retrieved by the minimization of a cost function defined in the Fourier domain based on the quasi-linear approximation of the imaging process. A multilook technique is applied to infer the information on wave propagation directions, which is required because the SAR transfer function is non-Hermitian, i.e., the SAR image is not determined by the "frozen" sea surface, but wave motion has a significant impact. The method is applied to simulated SAR images as well as to data acquired by ERS-2. The errors of the retrieved wave field due to image noise, uncertainties in the SAR imaging model, and bandwidth limitations are analyzed. In particular, the fact that the estimated elevation field is smoothed due to the finite system resolution and smearing effects associated with wave motion is discussed. A statistical test is proposed to check the homogeneity of the SAR image. T- he method makes sure that atmospheric effects are not misinterpreted as being caused by ocean waves. [J260]

"Three-dimensional SAR imaging of a ground moving target using the InISAR technique"

In this paper, a three-dimensional (3-D) interferometric synthetic aperture radar (ISAR) imaging method for moving targets is presented. This imaging method is based on the ISAR principle and the simple observation that all scatterers on a moving target move in tandem. The angular motion parameters in the cross-range directions could be estimated using the overall range profile of the moving target. Registration of the respective complex images at the two (or more) interferometric antennas can then be achieved via compensating the respective echoes at the raw data level, thus avoiding phase-unwrapping processing and image-resampling processing as required by conventional methods. Finally, a 3-D image of the moving target can then be reconstructed from the 3-D spatial coordinates of these scatterers. Furthermore, the method works well even for a target moving in heavily cluttered environments. [J261]

"Ship detection based on coherence images derived from cross correlation of multilook SAR images"

A new simple technique is presented to extract ships from synthetic aperture radar (SAR) images. The procedure is to compute the cross-correlation values between two images extracted by moving windows of a small size from the multilook SAR intensity (or amplitude) images. A coherence image, consisting of the cross-correlation values of the intensity images, is then produced. Ships are deterministic targets, so that their interlook subimages possess higher degree of coherence than the uncorrelated random images of the surrounding sea surface. The main advantage of this method over the conventional constant false-alarm rate is its ability to detect, under favorable conditions, "invisible" images of ships embedded in the speckled image of the sea surface. The technique is tested using a RADARSAT-1 image in which one known and several unknown ships are present. The use of complex images and the exploitation of short decorrelation times of small-scale ocean waves to obtain an extra look are also discussed. [J262]

"Reflectivity estimation for multibaseline interferometric radar imaging of layover extended sources"

In recent years, there has been great interest in exploiting the advanced multibaseline operation of synthetic aperture radar interferometry (InSAR) for solving layover effects from complex orography, which can degrade both SAR and InSAR imagery of terrain radar reflectivity and height. In this work, the problem of retrieving radar reflectivity of layover areas is addressed. It is formulated as the problem of estimating a multicomponent sinusoidal signal corrupted by multiplicative complex correlated noise and additive white Gaussian noise. Application of nonparametric [e.g., Capon, amplitude and phase estimation filter (APES)], parametric [least squares, modern parametric RELAXation spectral estimator (RELAX)], and hybrid spectral estimators for amplitude estimation is investigated for a multilook scenario. In particular, the multilook extensions of RELAX and APES are applied to the interferometric problem. Performance analysis is investigated through a Cramer-Rao lower bound calculation and Monte Carlo simulation. The method of least squares, coupled with Capon's approach to spatial frequency estimation, multilook APES, and multilook RELAX turn out to provide accurate reflectivity estimates for undistorted multibaseline image formation of layover areas. [J263]

"Three-band biorthogonal interpolating complex wavelets with stopband suppression via lifting scheme"

Wavelet research has primarily focused on real-valued wavelet bases. However, the complex filterbanks provide

much convenience for complex signal processing. For example, in radar and sonar signal processing, the complex signals from the I/Q receiver can be efficiently processed with complex filterbanks rather than real filterbanks. Specifically, the positive and negative Doppler frequencies imply different physical content in the moving target detector (MTD) and moving target identification (MTI); therefore, it is significant to design complex multiband filterbanks that can partition positive and negative frequencies into different subbands. We design two novel families of three-band biorthogonal interpolating complex filterbanks and wavelets by using the three-band lifting scheme. Unlike the traditional three-band filterbanks, the novel complex filterbank is composed of three channels, including the lowpass channel, the positive highpass channel whose passband distributes in the positive frequency region, and the negative highpass channel in the negative frequency region. Such a filterbank/wavelet naturally provides the ability to extract positive frequency components and negative frequency components from complex signals. Moreover, a novel set of design constraints are introduced to manipulate the stopband characteristic of highpass filters and are referred to as stopband suppression, which strengthens the traditional constraints of vanishing moments. Finally, a numerical method is given to further lower stopband sidelobes. [J264]

"A least squares database approach for SAR interferometric data"

Presents a least squares (LS) approach for the retrieval of a temporal deformation sequence from a set of interferometric synthetic aperture radar images. The method uses a database of interferograms spanning different longand short-term intervals, and by solving all the deformations as a unique LS problem provides a chronologically ordered sequence, i.e. a picture of the development of the deformation pattern in time. The approach is illustrated in detail and discussed with respect to both the results of its application on a case study and to possible alternative methods. [J265]

"Fast and accurate algorithm for the short-pulse electromagnetic scattering from conducting circular plates buried inside a lossy dispersive half-space"

The method of moments in the Hankel transform domain is applied to the determination of the fields scattered by a conducting circular plate buried in a lossy dispersive half-space when the plate is illuminated by a plane wave. The scattered fields obtained in the frequency domain are used to model the time-domain short-pulse scattering via the inverse fast Fourier transform. The authors show that the choice of adequate basis functions in the approximation of the current density induced on the plate makes it possible to obtain very accurate results for the scattered fields while using low computer memory requirements and short CPU times. This implies that the algorithm developed for the particular problem treated in this paper provides a good benchmark for the validation of any other numerical algorithms dealing with the analysis of the scattering from buried conducting objects with more complex geometry. [J266]

"Statistical regularization in linearized microwave imaging through MRF-based MAP estimation: hyperparameter estimation and image computation"

The application of a Markov random fields (MRF) based maximum a posteriori (MAP) estimation method for microwave imaging is presented in this paper. The adopted MRF family is the so-called Gaussian-MRF (GMRF), whose energy function is quadratic. In order to implement the MAP estimation, first, the MRF hyperparameters are estimated by means of the expectation-maximization (EM) algorithm, extended in this case to complex and nonhomogeneous images. Then, it is implemented by minimizing a cost function whose gradient is fully analytically evaluated. Thanks to the quadratic nature of the energy function of the MRF, well posedness and efficiency of the proposed method can be simultaneously guaranteed. Numerical results, also performed on real data, show the good performance of the method, also when compared with conventional techniques like Tikhonov regularization. [J267]

"Using the matrix pencil method to solve phase unwrapping"

This correspondence presents a phase unwrapping (PU) algorithm based on the matrix pencil (MP) method. A brief discussion is given on the relationship between PU and instantaneous frequency estimation. The PU algorithm and its properties are presented in detail. Results show a significant improvement in PU with respect to previous algorithms. [J268]

"Efficient detection with arrays in the presence of angular spreading"

The spatial channel in applications such as radar, sonar, and wireless communications is typically characterized by complex signal scattering leading to multiple signal components arriving at the array from a spread of angles. This multipath angle spread is well known to lead to loss of spatial signal coherence, requiring complicated

combining schemes to achieve optimal performance, particularly when the signal is partially coherent across the receiving array. We show that the discrete Fourier transform serves as an efficient, robust, and asymptotically optimal spatial combiner for uniform linear arrays (ULAs) in multipath channels. In addition, the proposed spatial processing allows for convenient integration of conventional frequency-domain methods for angle-of-arrival searches. Simulation results show that the proposed combining scheme provides near-optimal performance at significantly less computation, even for arrays of moderate size. [J269]

"A test statistic in the complex Wishart distribution and its application to change detection in polarimetric SAR data"

When working with multilook fully polarimetric synthetic aperture radar (SAR) data, an appropriate way of representing the backscattered signal consists of the so-called covariance matrix. For each pixel, this is a 3Ч3 Hermitian positive definite matrix that follows a complex Wishart distribution. Based on this distribution, a test statistic for equality of two such matrices and an associated asymptotic probability for obtaining a smaller value of the test statistic are derived and applied successfully to change detection in polarimetric SAR data. In a case study, EMISAR L-band data from April 17, 1998 and May 20, 1998 covering agricultural fields near Foulum, Denmark are used. Multilook full covariance matrix data, azimuthal symmetric data, covariance matrix diagonal-only data, and horizontal-horizontal (HH), vertical-vertical (VV), or horizontal-vertical (HV) data alone can be used. If applied to HH, VV, or HV data alone, the derived test statistic reduces to the well-known gamma likelihood-ratio test statistic. The derived test statistic and the associated significance value can be applied as a line or edge detector in fully polarimetric SAR data also. [J270]

"Full-wave simulation of overland radar pulse propagation"

A simple and efficient method of high-frequency electromagnetic pulse simulation is proposed. An asymptotic solution yields a paraxial version of geometric optics with complex eikonals and amplitudes determined from numerical solution of the parabolic wave equation. As an example, radar pulse propagation over realistic irregular terrain is considered. [J271]

"CFAR edge detector for polarimetric SAR images"

Finding the edges between different regions in an image is one of the fundamental steps of image analysis, and several edge detectors suitable for the special statistics of synthetic aperture radar (SAR) intensity images have previously been developed. In this paper, a new edge detector for polarimetric SAR images is presented using a newly developed test statistic in the complex Wishart distribution to test for equality of covariance matrices. The new edge detector can be applied to a wide range of SAR data from single-channel intensity data to multifrequency and/or multitemporal polarimetric SAR data. By simply changing the parameters characterizing the test statistic according to the applied SAR data, constant false-alarm rate detection is always obtained. An adaptive filtering scheme is presented, and the distributions of the detector are verified using simulated polarimetric SAR images. Using SAR data from the Danish airborne polarimetric SAR, EMISAR, it is demonstrated that superior edge detection results are obtained using polarimetric and/or multifrequency data compared to using only intensity data. [J272]

"Almost translation invariant wavelet transformations for speckle reduction of SAR images"

Two wavelet transformations are used for speckle reduction and enhancement of synthetic aperture radar (SAR) images. First, a discrete wavelet transformation (DWT) based on oversampled filter banks is used. The oversampled DWT is called a double-density DWT (DD-DWT) and is based on a single-scaling function (low pass) and two distinct wavelet functions (high pass). Second, a discrete wavelet transformation based on two dual real wavelet trees is applied. Each tree produces a set of real DWTs, which together form the complex wavelet transformation (CWT), i.e., a transformation with both real and imaginary parts. Both of these DWTs are almost translation invariant and are useful for speckle reduction through their subband images, and the speckle reduction is obtained by thresholding the subband image coefficients of the digitized SAR images. A thresholding method based on the use of nonlinear functions, which are adapted for each selected subband, is used. The nonlinear functions are based on sigmoid functions. The denoising method presented shows great promise for speckle removal and, hence, can provide good detection performance for SAR-based recognition. [J273]

"Polarimetric SAR speckle noise model"

Synthetic aperture radar (SAR) data are affected by speckle noise, originated by the SAR system's coherent nature. The problem of speckle noise in one-dimensional (1-D) data is already solved, as speckle has a multiplicative characteristic. SAR polarimetry represents an extension to multidimensional data by the use of polarization wave diversity. As a consequence of the existence of a correlation degree between the SAR images,

the 1-D speckle noise model cannot be extended to multidimensional SAR data. This paper is devoted to present a completely new speckle noise model for the complex covariance matrix describing polarimetric SAR data in the distributed scatterers case. As is shown, this new model is able to identify which are the noise mechanisms in all the covariance matrix elements. The speckle noise model is validated by using real L-band polarimetric data acquired with the German E-SAR sensor. [J274]

"Application of adaptive joint time-frequency algorithm for focusing distorted ISAR images from simulated and measured radar data"

An adaptive joint time-frequency algorithm has been applied and evaluated for focusing distorted ISAR (inverse synthetic aperture radar) images when the target motion is confined to a two-dimensional plane. It is shown that the adaptive joint time-frequency algorithm provides an effective method of achieving rotational motion compensation for ISAR imaging. Examples provided demonstrate the effectiveness of the adaptive joint time-frequency algorithm with both simulated and experimental ISAR data. Results show that if a target is moving smoothly, standard motion compensation generates a clear image of the target by using the conventional Fourier transform methods. However, when a target performs complex motion such as perturbed random motions, standard motion compensation is not sufficient to generate an acceptable image. In this case, the adaptive joint time-frequency algorithm provides an efficient candidate to resolve the image smearing caused by the time-varying behaviour and leads to a well focused ISAR image when the target motion is confined to a two-dimensional plane. The study also adds insight into the distortion mechanisms that affect the ISAR images of a target in motion [J275]

"On the use of complex SAR image spectral analysis for target detection: assessment of polarimetry"

The objective of this paper is to assess the joint use of the magnitude and the phase of a synthetic aperture radar (SAR) polarimetric image for point target detection and analysis. We first consider a single-look complex (SLC), single polarized radar image including point targets embedded in clutter. A series of sublooks are generated from this SLC image, both in azimuth and in range in order to analyze the inherent speckle effects. The two-looks internal Hermitian product (2L-IHP) is defined and is further shown to qualitatively increase the target/environment contrast. The processing of azimuth and range spectra preliminary to the 2L-IHP derivation (spectral whitening, generation and overlapping of sublooks) is described. A simulation tool is developed to model a point target behavior. Then, the polarimetric extension of the 2L-IHP is proposed, and the optimized polarimetric 2L-IHP is defined. The gain is twofold: in comparison with single polarization, polarimetry is shown to enhance detection capabilities, but also to provide additional information for target analysis. [J276]

"A new algorithm for the estimation of the frequency of a complex exponential in additive Gaussian noise"

The letter presents a new algorithm for the precise estimation of the frequency of a complex exponential signal in additive, complex, white Gaussian noise. The discrete Fourier transform (DFT)-based algorithm performs a frequency interpolation on the results of an N point complex fast Fourier transform. For large N and large signal to noise ratio, the frequency estimation error variance obtained is 0.063 dB above the Cramer-Rao bound. The algorithm has low computational complexity and is well suited for real time digital signal processing applications, including communications, radar and sonar. [J277]

"Terrain analysis using radar shape-from-shading"

This paper develops a maximum a posteriori (MAP) probability estimation framework for shape-from-shading (SFS) from synthetic aperture radar (SAR) images. The aim is to use this method to reconstruct surface topography from a single radar image of relatively complex terrain. Our MAP framework makes explicit how the recovery of local surface orientation depends on the whereabouts of terrain edge features and the available radar reflectance information. To apply the resulting process to real world radar data, we require probabilistic models for the appearance of terrain features and the relationship between the orientation of surface normals and the radar reflectance. We show that the SAR data can be modeled using a Rayleigh-Bessel distribution and use this distribution to develop a maximum likelihood algorithm for detecting and labeling terrain edge features. Moreover, we show how robust statistics can be used to estimate the characteristic parameters of this distribution. We also develop an empirical model for the SAR reflectance function. Using the reflectance model, we perform Lambertian correction so that a conventional SFS algorithm can be applied to the radar data. The initial surface normal direction is constrained to point in the direction of the nearest ridge or ravine feature. Each surface normal must fall within a conical envelope whose axis is in the direction of the radar illuminant. The extent of the envelope depends on the corrected radar reflectance and the variance of the radar signal statistics. We explore

various ways of smoothing the field of surface normals using robust statistics. Finally, we show how to reconstruct the terrain surface from the smoothed field of surface normal vectors. The proposed algorithm is applied to various SAR data sets containing relatively complex terrain structure. [J278]

"The effect of modified Markov random fields on the local minima occurrence in microwave imaging"

The application of a maximum a posteriori estimation method for microwave imaging that makes use of a Markov random field (MRF) a priori statistical model is presented. In particular, the MRF family adopted is generalized for complex profiles, characterized by a quadratic energy function and "modified" such to make it possible to statistically represent spatial interactions between real and imaginary parts. Thanks to its peculiarities, the use of this approach simultaneously favors in many cases well posedness and robustness against local minima occurrence, as well as high quality in the reconstructed images. Numerical results show the performance of the method. [J279]

"Effect of dielectric properties of moist salinized soils on backscattering coefficients extracted from RADARSAT image"

This paper presents the experimental results regarding changes in the dielectric properties of artificially moistened and salinized soils and on soil samples taken from a salt lake. The complex dielectric constants of soil samples were measured using a microwave network analyzer. We evaluated the real and imaginary parts of dielectric constants of artificially moistened and salinized soil samples prepared in the laboratory as a function of microwave frequency, salinity, and water content. The soil moisture strongly affected the real part of dielectric constant ε'. The frequency and the salinity of soils have little influence on the real part of dielectric constant ε'. The imaginary part of the dielectric constant ε'' is strongly affected by both the salinity and moisture of soil samples, especially at low frequencies. When f0backscattering coefficients extracted from a RADARSAT image (C-HH) that was acquired at same time with the soil sampling at the Jilantai Salt Lake area. We discovered that the correlation coefficient between σ0extracted from the RADARSAT image and ε'' measured in the soil sample is 0.70, whereas the correlation coefficient of σ0and ε' is 0.27. The correlation coefficient between σ0and the soil sample salinity is 0.69. This suggests that soil salinity has a significant contribution to the backscattering coefficient σ0recorded in a synthetic aperture radar (SAR) image. Consequently, a SAR image can be a useful tool for monitoring soil salinity. [J280]

"The use of fully polarimetric information for the fuzzy neural classification of SAR images"

Presents a method, based on a fuzzy neural network, that uses fully polarimetric information for terrain and land-use classification of synthetic aperture radar (SAR) image. The proposed approach makes use of statistical properties of polarimetric data, and takes advantage of a fuzzy neural network. A distance measure, based on a complex Wishart distribution, is applied using the fuzzy c-means clustering algorithm, and the clustering result is then incorporated into the neural network. Instead of preselecting the polarization channels to form a feature vector, all elements of the polarimetric covariance matrix serve as the target feature vector as inputs to the neural network. It is thus expected that the neural network will include fully polarimetric backscattering information for image classification. With the generalization, adaptation, and other capabilities of the neural network, information contained in the covariance matrix, such as the amplitude, the phase difference, the degree of polarization, etc., can be fully explored. A test image, acquired by the Jet Propulsion Laboratory Airborne SAR (AIRSAR) system, is used to demonstrate the advantages of the proposed method. It is shown that the proposed approach can greatly enhance the adaptability and the flexibility giving fully polarimetric SAR for terrain cover classification. The integration of fuzzy c-means (FCM) and fast generalization dynamic learning neural network (DLNN) capabilities makes the proposed algorithm an attractive and alternative method for polarimetric SAR classification. [J281]

"Herbaceous biomass retrieval in habitats of complex composition: a model merging SAR images with unmixed landsat TM data"

A remote sensing methodology for herbaceous areal above-ground biomass (AAB) estimation in a heterogeneous Mediterranean environment is presented. The methodology is based on an adaptation of the semiempirical water-cloud backscatter model to complex vegetation canopies combined with shrubs, dwarf shrubs, and herbaceous plants. The model included usage of the green leaf biomass volumetric density as a canopy descriptor and of cover fractions derived from unmixing Landsat Thematic Mapper image data for the three vegetation formations. The inclusion of the unmixed cover fractions improves modeling synthetic aperture radar backscatter, as it allows separation between the different radiation interaction mechanisms. The method was first assessed with reference to the reproduction of the backscatter from the vegetation formations. In the

next phase, the accuracy of AAB retrievals from the backscatter data was evaluated. Results of testing the methodology in a region of climatic gradient in central Israel have shown a good correspondence between observed and predicted AAB values (R2=0.82). This indicates that the methodology developed may lay a basis for mapping important and more advanced ecological information such as primary production and contribute to better understanding of processes in Mediterranean and semiarid regions. [J282]

"A comparison between different polarimetric measurement schemes"

The usefulness of polarization information in remote sensing applications has been clearly demonstrated in the last two decades. Land covers and meteorological targets are complex and their backscatter returns are time varying. Their polarimetric characteristics should be determined in terms of second order statistics of scattering matrix elements. These are contained. in the polarimetric covariance matrix. Estimation of polarimetric covariance matrix elements has been addressed by different authors based on different scattering matrix measurement methods. The most widely used and implemented method consists in the alternate transmission of two orthogonal polarizations while. receiving with both. Recently, a method that considers simultaneous transmission of two orthogonal polarizations, which are phase coded with orthogonal signals, has been proposed. Another method, specifically developed to obtain the polarimetric covariance matrix, is based on transmitting three different polarizations and receiving their corresponding co-polar and cross-polar counterparts. Different data sets result from each measurement technique and different estimators of polarimetric covariance matrix elements have been developed for the different data sets available. These various methods are investigated in here. Based on simulated data the performance of the different estimators under different working conditions are analyzed. Effects on the estimators of operation frequency, pulse repetition frequency (PRF) and temporal properties of targets are discussed [J283]

"Multicarrier radar signal-pulse train and CW"

A multicarrier complementary phase-coded (MCPC) radar signal employs N subcarriers simultaneously. The subcarriers are phase modulated by N different sequences that constitute a complementary set. The subcarriers are frequency-separated by the inverse of the duration of a phase element tb. An NЧM MCPC pulse achieves pulse compression ratio of NM. When an NЧM MCPC signal is used in a coherent train of N pulses (e.g., in order to allow Doppler processing), it is advantageous to use pulse diversity. Each pulse is constructed using a different cyclic frequency shift of the first pulse. Such pulse diversity eliminates recurrent lobes at multiples of the pulse repetition interval. The constant volume property of the ambiguity function is maintained by shifting volume from the recurrent lobes to the sidelobe pedestal strips. However, if the sequence ordering along frequencies in the N pulses are arranged to create a complementary set in each frequency as well as in each pulse, the sidelobe level around the main autocorrelation lobe is dramatically reduced. Preferred MCPC coding for CW mode (contiguous MCPC pulses) and their delay-Doppler response are also discussed [J284]

"Uncovering nonlinear dynamics-the case study of sea clutter"

Nonlinear dynamics are basic to the characterization of many physical phenomena encountered in practice. Typically, we are given a time series of some observable(s) and the requirement is to uncover the underlying dynamics responsible for generating the time series. This problem becomes particularly challenging when the process and measurement equations of the dynamics are both nonlinear and noisy. Such a problem is exemplified by the case study of sea clutter which refers to radar backscatter from an ocean surface. After setting the stage for this case study, the paper presents tutorial reviews of: (1) the classical models of sea clutter based on the compound K distribution and (2) the application of chaos theory to sea clutter. Experimental results are presented that cast doubts on chaos as a possible nonlinear dynamical mechanism for the generation of sea clutter. Most importantly, experimental results show that on timescales smaller than a few seconds, sea clutter is very well described as a complex autoregressive process of order four or five. On larger timescales, gravity or swell waves cause this process to be modulated in both amplitude and frequency. It is shown that the amount of frequency modulation is correlated with the nonlinearity of the clutter signal. The dynamical model is an important step forward from the classical statistical approaches, but it is in its early stages of development [J285]

"A statistical modeling approach to location estimation"

Some location estimation methods, such as the GPS satellite navigation system, require nonstandard features either in the mobile terminal or the network. Solutions based on generic technologies not intended for location estimation purposes, such as the cell-ID method in GSM/GPRS cellular networks, are usually problematic due to their inadequate location estimation accuracy. In order to enable accurate location estimation when only inaccurate measurements are available, we present an approach to location estimation that is different from the prevailing geometric one. We call our approach the statistical modeling approach. As an example application of

the proposed statistical modeling framework, we present a location estimation method based on a statistical signal power model. We also present encouraging empirical results from simulated experiments supported by real-world field tests. [J286]

"Adaptive noise reduction of InSAR images based on a complex-valued MRF model and its application t o phase unwrapping problem"

We propose a new adaptive noise reduction method for interferometric synthetic aperture radar (InSAR) complex-amplitude images. In the proposed method, we detect residues (singular points) in the phase image as well as their neighbors at first. Normal areas that contain no residue are used for the estimation of correct pixel values at the marked residues according to 5th order non-causal complex-valued Markov random field (CMRF) model. The process is performed block-wise with the assumption of a locally stationary condition of statistics. Using a CMRF lattice complex-valued neural-network, the error energy defined as the squared norm of distance between signal and estimated values is minimized by LMS steepest descent algorithm. Eventually, the number of residues is decreased. An application is also presented. An InSAR image around Mt. Fuji is processed by the proposed technique and then phase-unwrapped by the branch-cut method. It is found that after the application of the proposed method, a better phase unwrapped image can be obtained successfully [J287]

"Interferometric SAR image restoration using Monte Carlo metropolis method"

We present a novel method of interferometric synthetic aperture radar (InSAR) image restoration. An InSAR image is modeled as a complex-valued Markov random field (CMRF). Corrupted parts, which are indicated by residues in phase data, are restored by using the Monte Carlo Metropolis (MM) method based on their uncorrupted neighbor's CMRF parameter values. The system is implemented as a complex-valued neural network. The restoration process reduces the residue number, which is useful in the phase unwrapping process. The advantage of the method is demonstrated in the unwrapping process of an InSAR image that contains highly dense residues [J288]

"High range resolution profiling using phase-coded, stepped-frequency waveforms"

A phase-coded stepped-frequency (PCSF) waveform with high range resolution (HRR) processing is presented as an improvement to stepped-frequency (SF) processing. By combining intrapulse phase and interpulse frequency modulations, the PCSF technique enables larger frequency step sizes than SF processing-system effective bandwidth is traversed more quickly, allowing shorter burst times while decreasing Doppler sensitivity. The PCSF framework presented and corresponding HRR simulation results for complex targets are shown consistent with the ideal SF response and demonstrate Doppler sensitivity reduction [J289]

"A study of two-channel complex-valued filterbanks and wavelets with orthogonality and symmetry properties"

We investigate two-channel complex-valued filterbanks and wavelets that simultaneously have orthogonality and symmetry properties. First, the conditions for the filterbank to be orthogonal, symmetric, and regular (for generating smooth wavelets) are presented. Then, a complete and minimal lattice structure is developed, which enables a general design approach for filterbanks and wavelets with arbitrary length and arbitrary order of regularity. Finally, two integer implementation methods that preserve the perfect reconstruction property of the filterbank are proposed. Their performances are evaluated via experimental results [J290]

"Cramer-Rao bound on the estimation accuracy of complex-valued homogeneous Gaussian random fields"

This paper considers the problem of the achievable accuracy in jointly estimating the parameters of a complex-valued two-dimensional (2-D) Gaussian and homogeneous random field from a single observed realization of it. Based on the 2-D Wold decomposition, the field is modeled as a sum of purely indeterministic, evanescent, and harmonic components. Using this parametric model, we first solve a key problem common to many open problems in parametric estimation of homogeneous random fields: that of expressing the field mean and covariance functions in terms of the model parameters. Employing the parametric representation of the observed field mean and covariance, we derive a closed-form expression for the Fisher information matrix (FIM) of complex-valued homogeneous Gaussian random fields with mixed spectral distribution. Consequently, the Cramer-Rao lower bound on the error variance in jointly estimating the model parameters is evaluated [J291]

"Mapping performance of curved-path SAR"

Synthetic aperture radar (SAR) mapping is usually performed along a straight path. Curved paths away from the

target area will increase the mapping rate significantly. Drawbacks are more complex signal processing and decreased azimuth resolution due to the reduced dwell time. In this paper, curved SAR mapping is analyzed in more detail, including squinted beam geometry. Relationships are derived how the SAR resolution and mapping rate are influenced by the curved SAR path. The nonlinear phase error, which defocuses the SAR image, is more accentuated than for straight-line SAR, in particular at squinted observation angles. Simulation examples show how the nonlinear phase error depends on side acceleration and mapping geometry after scene center motion compensation. [J292]

"On demand network-wide VPN deployment in GPRS"

Mobile Internet requires enhanced security services available to all mobile subscribers in a dynamic fashion. A network-wide virtual private network deployment scenario over the General Packet Radio Service is proposed and analyzed from a security viewpoint. The proposed security scheme improves the level of protection that is currently supported in GPRS and facilitates the realization of mobile Internet. It secures data transmission over the entire network route from a mobile user to a remote server by utilizing the default GPRS ciphering over the radio interface, and by deploying an IP VPN over the GPRS core, as well as on the public Internet. Thus, on-demand VPN services are made available for all GPRS network subscribers and roaming users. The VPN functionality, which is based on the IPsec framework, is outsourced to the network infrastructure to eliminate the potential computational overhead on the mobile device. The VPN initialization and key agreement procedures are based on an Internet Key Exchange protocol proxy scheme, which enables the mobile station to initiate VPN establishment, while shifting the complex key negotiation to the network infrastructure. The deployed VPN operates transparently to the mobile subscribers' movement. The required enhancements for security service provision can be integrated in the existing network infrastructure; therefore, the propose security scheme can be employed as an add-on feature to the GPRS standard. [J293]

"Modeling and reduction of SAR interferometric phase noise in the wavelet domain"

This paper addresses the problem of interferometric phase noise reduction in synthetic aperture radar interferometry. A new phase noise model in the complex domain is introduced and validated by using both simulated and real interferograms. This noise model is also derived in the complex wavelet domain, where a novel noise reduction algorithm, which is not based on a windowing process and without the necessity of phase unwrapping, is addressed. The use of the wavelet transform allows to maintain the spatial resolution in the filtered phase image and prevents to filter low coherence areas. By using both, simulated as well as real interferometric phase images, the performance of this algorithm, in terms of noise reduction, spatial resolution maintenance, and computational efficiency, is reported and compared with other conventional filtering approaches. [J294]

"Preceding vehicle recognition based on learning from sample images"

Preceding vehicle recognition is an important enabling technology for developing a driver assistance system and an autonomous vehicle system. However, this is difficult for computer vision to achieve because of the variety of shapes and colors in which vehicles are made. In this paper, we propose a novel vision-based preceding vehicle recognition method, which has the capability of recognizing a wide selection of vehicles. In the proposed method, classifiers learned from "vehicle" training samples and "nonvehicle" training samples are used to enable recognition. We also propose a novel classification method, the "multiclustered modified quadratic discriminant function" (MC-MQDF). The MC-MQDF is capable of estimating the complex distribution due to the variety of different possible appearances for preceding vehicles. In order to confirm the feasibility of recognizing various vehicles, and to demonstrate the advantage of the MC-MQDF over the MQDF, classification experiments were carried out using the images of various vehicles. In a complex distribution test including a variety of vehicles, the classification rate for the MC-MQDF was approximately 98%, whereas the classification rate for the ordinary MQDF technique was approximately 93%. This supports the superiority of the MC-MQDF technique over the MQDF technique, and demonstrates the feasibility of recognizing a variety of different vehicles. [J295]

"Stochastic versus deterministic models in the analysis of communication systems"

When trying to analyze a complex communication system, scientists often apply concepts from stochastic modeling and analysis to obtain a description of the system, frequently assuming that this will supplement our knowledge and improve our understanding. The philosophy is to obtain a result that would occur on the average, when this system is working under normal conditions. However, we must consider the fact that the introduction of probability in communication-system analysis often involves invoking certain assumptions and additional information about the system, which may not be valid. Hence, under these circumstances one may obtain a result that may not be commensurate with the conceived communication system. The objective of this paper is to

highlight the basic assumptions that are invariably associated with the signal analysis in a system using stochastic analysis, and the introduction of probabilistic methods. Surprisingly, in many cases, analysis using stochastic methods may provide results equivalent to those obtained using deterministic methods. Examples are presented to illustrate our approach, and to explain the basic assumptions and formulate the mathematical framework associated with a stochastic analysis. We also demonstrate the equivalence between a random and a deterministic process, and under what conditions they approach the Cramer-Rao bound. Analysis using stochastic models to describe a system may be superior to a deterministic description. However, such a characterization comes with a large cost: namely, one must have more definitive knowledge about the system, knowledge that is often unavailable. For convenience, with the application of a random model, the concepts of stationarity and ergodicity are used to simplify the mathematical analysis of measured data. It is shown that the introduction of ergodicity in probability is similar to a deterministic analysis of a single waveform, and, in both cases, characterizes the entire underlying mathematical agenda. An example is presented to illustrate the salient features of an ergodic process as opposed to a deterministic process. It is seen that for practical problems, it might be easier and more relevant to introduce a deterministic model and to then carry out a stochastic analysis. However,- this may not be practical, since the underlying ensemble is not available nor are its probability density functions. Moreover a deterministic solution may present the best solution for a given data set, whereas the stochastic approach yields an "average" solution for all the waveforms in the ensemble. Hence, the stochastic solution may not be the desired solution for the given data set. However, when accurate statistics are available, a better solution may be obtained using probabilistic methods. [J296]

"Multidomain pseudospectral time-domain simulations of scattering by objects buried in lossy media"

A multidomain pseudospectral time-domain (PSTD) method with a newly developed well-posed PML is introduced as an accurate and flexible tool for the modeling of electromagnetic scattering by 2-D objects buried in an inhomogeneous lossy medium. Compared with the previous single-domain Fourier PSTD method, this approach allows for an accurate treatment of curved geometries with subdomains, curvilinear mapping, and high-order Chebyshev polynomials. The effectiveness of the algorithm is confirmed by an excellent agreement between the numerical results and analytical solutions for perfectly conducting as well as permeable dielectric cylinders. The algorithm has been applied to model various ground-penetrating radar (GPR) applications involving curved objects in a lossy half space with an undulating surface. This multidomain PSTD algorithm is potentially a very useful tool for simulating antennas near complex objects and inhomogeneous media. [J297]

"Biophysical forest type characterization in the Colombian Amazon by airborne polarimetric SAR"

Fully polarimetric C-, L-, and P-band data were collected by NASA's AirSAR system in May 1993 at the Araracuara test site, a well-surveyed forest reserve in the center of the Colombian Amazon. The area is characterized by a high diversity of forest types, soil types, and flooding conditions. In this paper a polarimetric classification technique is used to assess AirSAR's potential for forest structural type mapping and, indirectly, forest biophysical characterization. Field observations were made at 23 0.1 ha plots to obtain additional quantitative descriptions on forest structure and ground surface conditions, but also to assess the suitability of existing map legends for synthetic aperture radar (SAR) mapping. It could be shown that a new type of legend leads to physically better interpretable results. it method based on iterated conditional modes is introduced and is shown to yield radar-derived classifications with a high level of agreement with the landscape-ecological map, as well as with the ground observations. The following results may indicate the high level of accuracy obtained: 15 classes can be differentiated, the average radar classification agreement ranges from 68% to 94% (depending on the type of classification and approach), and for only a few classes the agreement is less than 70%. The relation between physical forest structure and polarimetric signal properties is studied explicitly using polarimetric decomposition. A new method is introduced based on the decomposition of polarimetric coherence, instead of power. It is based on simple physical descriptions of the wave-object interaction. The accuracy of the complex coherence estimation is described using the complex Wishart distribution. Thus, several interesting physical relations between polarimetric signal and forest structure can be revealed. The physical limitations of this technique and its relation with sample size are indicated. [J298]

"Estimating the effective number of looks in interferometric SAR data"

The probability density function (pdf) of the multi-look interferometric phase between two complex synthetic aperture radar (SAR) images is parameterized by the number of looks and the complex correlation coefficient. In practice, adjacent pixels in a real SAR interferogram, are statistically dependent due to filtering, and hence, the number of looks is usually smaller than the number of samples averaged. It has been shown that compensation with an effective number of looks, rather than an intractable rederivation of the pdf, can account for the statistical dependence. This paper addresses the challenge of how to determine a suitable value for the effective number

of looks. It is shown that an optimum value can be found via a maximum-likelihood estimator (MLE) based on the interferometric phase pdf. However, since such an MLE is computationally intensive and numerically unstable, an estimator based on the method of moments (MoM) possessing similar fidelity is proposed. MoM is fast and robust and can be used in operational applications, such as determining constant false alarm rate (CFAR) detection thresholds for moving-target detection in SAR along-track interferometry. [J299]

"Virtual benchmarking and model continuity in prototyping embedded multiprocessor signal processing systems"

The complexity of hardware/software codesign of embedded real-time signal processing systems can be reduced by rapid system prototyping (RSP). However, existing RSP frameworks do not provide a sound specification and design methodology (SDM) because they require the designer to choose the implementation target before specification and design exploration and they do not work together coherently across development stages. This paper presents a new SDM, called MAGIC, that allows the designer to capture an executable specification model for use in design exploration to find the optimal multiprocessor technology before committing to that technology. MAGIC uses a technique called "virtual benchmarking," for early validation of promising architectures. The MAGIC SDM also exploits emerging open-standards computation and communication middleware to establish model continuity between RSP frameworks. This methodology has been validated through the specification and design of a moderately complex system representative of the signal processing domain: the RASSP Synthetic Aperture Radar benchmark. In this case study, MAGIC achieves three orders of magnitude speedup over existing virtual prototyping approaches and demonstrates the ability to evaluate competitive technologies prior to implementation. Transfer of this methodology to the system-on-a-chip domain using Cadence's Virtual Component Codesign infrastructure is also discussed with promising results. [J300]

"Simulator for advanced fighter radar EPM development"

In order to develop electronic protection measures (EPM) for airborne intercept radars, it is necessary to fully understand the often complex effects of different types of electronic countermeasure (ECM) techniques on the radar operation. To aid in this effort, a software-based high-fidelity simulator called SAFIRE has been developed. SAFIRE models target clutter and ECM signal returns on a pulse-by-pulse basis for arbitrarily long scenario durations. Conventional air-to-air processing modes that are typically used in airborne intercept radars for search and track functions are also modelled. The capabilities of SAFIRE are described, with particular emphasis on the ECM model. The ECM model is based on a modern coherent jammer which uses digital radio frequency memory (DRFM) technology to generate false targets and “smart” noise for sophisticated ECM techniques. Sample results from SAFIRE are presented to illustrate its utility in analysing the effects of such ECM techniques on the radar processing. Benchmark timing results for SAFIRE code execution are also provided, which indicate that for many jamming scenarios of interest, the code execution is only about five times slower than real time. This is a significant feature since the scenario durations that are required for these studies are often relatively long [J301]

"Compression of SAR raw data through range focusing and variable-rate trellis-coded quantization"

There is an ever-growing interest in the compression of SAR data because of the huge resources required for storage and transmission. This is especially true for spaceborne sensors, given the limited capacity of the downlink channel. Unfortunately, SAR data lack the useful properties on which compression algorithms rely; indeed, these are present in the focused images, but focusing is too complex for on-board implementation at this time. Poggi et al. (2000) proposed to perform on the satellite only the low-complexity range focusing, which increases the data correlation and better concentrates their energy. These properties were then exploited by adopting a variable-rate vector quantizer, with a clear performance improvement with respect to reference techniques. However, vector quantization (VQ) is too complex for actual on-board implementation, and therefore, here we replace VQ with trellis-coded VQ. To limit complexity, only small vectors are used, which reduces VQ's ability to exploit data dependencies; on the other hand, trellis coding allows one to encode large blocks of data at once, and to obtain a better partition of the input space. Experiments on real SAR data show that the overall performance is comparable to that of Poggi et al., but the complexity is much lower, making on-board implementation possible [J302]

"Real-time three-dimensional modular SAR preprocessor design"

The architecture design for a high-speed front-end video prefiltering is described, this being part of an effort to develop a real-time range-doppler digital SAR processor to produce image maps of the scanned area immediately as raw data are collected. The evolved architecture consists of three-dimensionally interconnected planes of modified transverse FIR parallel tapped elements. Both the range and azimuth prefilterings are performed simultaneously in a continuous input-output flow without the need to consider corner turning. The

computation load has been reduced to one complex multiplication and two complex additions [J303]

"Effects of the ground surface on polarimetric features of broadband radar scattering from subsurface metallic objects"

Throughout the world, the problem of buried unexploded ordnance (UXO) poses an enormous, persistent, and expensive problem. While UXO generally consists of sizable bodies of ferrous metal and can therefore be detected, with current technology it is extremely difficult to distinguish them reliably from typically widespread pieces of clutter. Thus the problem is one of subsurface discrimination. The authors previous modeling work on scattering of ground penetrating radar (GPR) from metallic objects surrounded by an infinite soil-like medium has suggested the utility of a number of key discriminants in broadband fully polarimetric sensing. In particular, resonance structure, induced field rotation and ellipticity, and bistatic observation of scattered signals were shown to offer key information about target shape and size. The authors investigate the effects on signature features of the proximity of a ground surface to the target, for the common case of shallow burial (<1 m). Overall, their analyses suggest that the key discriminants seen in scattering in an infinite medium survive the complex interactions with the ground surface. In some instances, these revealing signatures appear to be strengthened by the presence of a nearby surface. Multiposition backscatter also allows fundamental inferences about target elongation and symmetry when those cannot be obtained from single position viewing [J304]

"Time-averaged subspace methods for radar clutter texture retrieval"

Subspace approaches have become popular in the last two decades for retrieving constant amplitude harmonics observed in white additive noise because they may exhibit superior resolution over the FFT-based methods, especially with short data records and closely spaced harmonics. We demonstrate that MUSIC and ESPRIT methods can also be applied when the harmonics are corrupted by white or wideband multiplicative noise. The application context is the retrieval of texture information from high resolution and low grazing angle radar clutter data affected by wideband colored speckle that is modeled as complex multiplicative noise. Texture information is fundamental for clutter cancellation and constant false alarm rate (CFAR) radar detection. A thorough numerical analysis compares the two subspace methods and validates the theoretical findings [J305]

"Quantitative comparison of classification capability: fully polarimetric versus dual and single-polarization SAR"

Addresses the land-use classification capabilities of fully polarimetric synthetic aperture radar (SAR) versus dual-polarization and single-polarization SAR for P-, L-, and C-band frequencies. A variety of polarization combinations are investigated for application to crop and tree age classification. Based on the complex Wishart distribution for the covariance matrix, maximum likelihood classifiers for all polarization combinations are used to assess quantitative classification accuracy. Thus, this allows optimally selecting the frequency and the combination of polarizations for various applications [J306]

"Time-delay estimation for sinusoidal signals"

The problem of estimating the difference in arrival times of a complex sinusoid received at two spatially separated sensors is considered. Given the sinusoidal frequency, a simple delay estimator using the phase difference of the discrete-time Fourier transforms of the received signals is devised. Using the periodogram, the algorithm is extended to estimate the delay when the frequency is unknown. The minimum achievable delay variances for the cases of known/unknown frequencies and constant/rectangular envelopes are also derived. Extension to time-delay estimation using real sinusoids is also investigated. The effectiveness of the method is demonstrated by comparing it with the performance bounds for different frequencies, envelopes and noise conditions [J307]

"Quasi-ray Gaussian beam algorithm for time-harmonic two-dimensional scattering by moderately rough interfaces"

Gabor-based Gaussian beam (GB) algorithms, in conjunction with the complex source point (CSP) method for generating beam-like wave objects, have found application in a variety of high-frequency wave propagation and diffraction scenarios. Of special interest for efficient numerical implementation is the noncollimated narrow-waisted species of GB, which reduces the computationally intensive complex ray tracing for collimated GB propagation and scattering to quasi-real ray tracing, without the failure of strictly real ray field algorithms in caustic and other transition regions. The Gabor-based narrow-waisted CSP-GB method has been applied previously to two-dimensional (2-D) propagation from extended nonfocused and focused aperture distributions through arbitrarily curved 2-D layered environments. In this 2-D study the method is applied to aperture-excited

field scattering from, and transmission through, a moderately rough interface between two dielectric media. It is shown that the algorithm produces accurate and computationally efficient solutions for this complex propagation environment, over a range of calibrated combinations of the problem parameters. One of the potential uses of the algorithm is as an efficient forward solver for inverse problems concerned with profile and object reconstruction [J308]

"Unsupervised classification of multifrequency and fully polarimetric SAR images based on the H/A/Alpha-Wishart classifier"

Introduces a new classification scheme for dual frequency polarimetric SAR data sets. A (6Ч6) polarimetric coherency matrix is defined to simultaneously take into account the full polarimetric information from both images. This matrix is composed of the two coherency matrices and their cross-correlation. A decomposition theorem is applied to both images to obtain 64 initial clusters based on their scattering characteristics. The data sets are then classified by an iterative algorithm based on a complex Wishart density function of the 6Ч6 matrix. A class number reduction technique is then applied on the 64 resulting clusters to improve the efficiency of the interpretation and representation of each class. An alternative technique is also proposed which introduces the polarimetric cross-correlation information to refine the results of classification to a small number of clusters using the conditional probability of the cross-correlation matrix. These classification schemes are applied to full polarimetric P, L, and C-band SAR images of the Nezer Forest, France, acquired by the NASA/JPL AIRSAR sensor in 1989 [J309]

"Adaptive beamformer orthogonal rejection test"

Research in the area of signal detection in the presence of unknown interference has resulted in a number of adaptive detection algorithms. Examples of such algorithms include the adaptive matched filter (AMF), the generalized likelihood ratio test (GLRT), and the adaptive coherence estimator (ACE). Each of these algorithms results in a tradeoff between detection performance for matched signals and rejection performance for mismatch signals. This paper introduces a new detection algorithm we call the adaptive beamformer orthogonal rejection test (ABORT). Our test decides if an observation contains a multidimensional signal belonging to one subspace or if it contains a multidimensional signal belonging to an orthogonal subspace when unknown complex Gaussian noise is present. In our analysis, we use a statistical hypothesis testing framework to develop a generalized likelihood ratio decision rule. We evaluate the performance of this decision rule in both the matched and mismatched signal cases. Our results show that for constant power complex Gaussian noise, if the signal is matched to the steering vector, ABORT, GLRT, and AMF give approximately equivalent probability of detection, higher than that of ACE, which trades detection probability for an extra invariance to scale mismatch between training and test data. Of these four tests, ACE is most selective and, therefore, least tolerant of mismatch, whereas AMF is most tolerant of mismatch and, therefore, least selective, ABORT and GLRT offer compromises between these extremes, with ABORT more like ACE and with GLRT more like AMF [J310]

"Frequency estimation in the presence of Doppler spread: performance analysis"

We are concerned with the estimation of the frequency of a complex sinusoid that has been corrupted by complex-valued multiplicative and additive noise. This problem is important in many applications including array processing in the case of spatially distributed sources and synchronization in the context of time-selective channels. The multiplicative noise smears the spectral line due to the sinusoid. This smearing, which is often called Doppler spreading, may significantly degrade the estimation accuracy. The goal of this paper is to analytically assess this degradation. The finite-sample Cramer-Rao bounds (CRBs) are derived, and closed-form expressions are given for the large-sample CRB. The latter gives insights into the effective coherent and noncoherent SNRs for frequency estimation. We then analyze the accuracy of frequency estimators that are based on the angles of the sample covariances. Simulations results are presented to illustrate the theoretical results [J311]

"Feature-enhanced synthetic aperture radar image formation based on nonquadratic regularization"

We develop a method for the formation of spotlight-mode synthetic aperture radar (SAR) images with enhanced features. The approach is based on a regularized reconstruction of the scattering field which combines a tomographic model of the SAR observation process with prior information regarding the nature of the features of interest. Compared to conventional SAR techniques, the method we propose produces images with increased resolution, reduced sidelobes, reduced speckle and easier-to-segment regions. Our technique effectively deals with the complex-valued, random-phase nature of the underlying SAR reflectivities. An efficient and robust numerical solution is achieved through extensions of half-quadratic regularization methods to the complex-valued SAR problem. We demonstrate the performance of the method on synthetic and real SAR scenes [J312]

"Estimation of the mean radar reflectivity from a finite number of correlated samples"

The authors compare estimators of the mean radar reflectivity on images with different spectral properties. By working on complex data rather than detected images, they can take the speckle correlation into account and thus obtain more accurate estimates. A robust and computationally efficient approximation of the optimal estimator is proposed [J313]

"Moving target feature extraction for airborne high-range resolution phased-array radar"

We study the feature extraction of moving targets in the presence of temporally and spatially correlated ground clutter for airborne high-range resolution (HRR) phased-array radar. To avoid the range migration problems that occur in HRR radar data, we first divide the HRR range profiles into low-range resolution (LRR) segments. Since each LRR segment contains a sequence of HRR range bins, no information is lost due to the division, and hence, no loss of resolution occurs. We show how to use a vector auto-regressive (VAR) filtering technique to suppress the ground clutter, Then, a parameter estimation algorithm is proposed for target feature extraction. From the VAR-filtered data, the target Doppler frequency and the spatial signature vectors are first estimated by using a maximum likelihood (ML) method. The target phase history and direction-of-arrival (DOA) (or the array steering vector for an unknown array manifold) are then estimated from the spatial signature vectors by minimizing a weighted least squares (WLS) cost function. The target radar cross section (RCS)-related complex amplitude and range-related frequency of each target scatterer are then extracted from the estimated target phase history by using RELAX, which is a relaxation-based high-resolution feature extraction algorithm. Numerical results are provided to demonstrate the performance of the proposed algorithm [J314]

"An improved calibration technique for free-space measurement of complex permittivity"

A calibration technique for free-space measurement of the permittivity and conductivity has been developed, taking account of antenna-medium coupling. Thus, the accuracy is improved compared to previously used calibration. Two examples are given to illustrate this improvement [J315]

"Using sources of opportunity to compensate for receiver mismatch in HF arrays"

The spatial processing performance of adaptive sensor arrays is often limited by the nonidentical frequency responses of the receivers in the array over the passband of interest. Addressed here is the problem of estimating digital compensation for mismatches between receiver passbands in high frequency (HF) antenna arrays using interference sources of opportunity. A mathematical model of ionospherically-propagated multipath HF interference is used to develop an adaptive algorithm which estimates the receiver frequency response corrections for each receiver. The effectiveness of the proposed algorithm is experimentally demonstrated and compared against (1) a commonly used least squares technique, and (2) a highly accurate calibration system using data collected by the receiving antenna array of the Jindalee over-the-horizon radar near Alice Springs in central Australia [J316]

"Three-dimensional subsurface analysis of electromagnetic scattering from penetrable/PEC objects buried under rough surfaces: use of the steepest descent fast multipole method"

The electromagnetic scattering from a three-dimensional (3D) shallow object buried under a two-dimensional (2D) random rough dielectric surface is analyzed. The buried object can be a perfect electric conductor (PEC) or can be a penetrable dielectric with size and burial depth comparable to the free-space wavelength. The random rough ground surface is characterized with Gaussian statistics for surface height and for surface autocorrelation function. The Poggio, Miller, Chang, Harrington, and Wu (PMCHW) integral equations are implemented and extended. The integral equation-based steepest descent fast multipole method (SDFMM), that was originally developed at UIUC, has been used and the computer code based on this algorithm has been successfully modified to handle the current application. The significant potential of the SDFMM code is that it calculates the unknown moment method surface electric and magnetic currents on the scatterer in a dramatically fast, efficient, and accurate manner. Interactions between the rough surface interface and the buried object are fully taken into account with this new formulation. Ten incident Gaussian beams with the same elevation angle and different azimuth angles are generated for excitation as one possible way of having multiple views of a given target. The scattered electric fields due to these ten incident beams are calculated in the near zone and their complex vector average over the multiple views is computed. The target signature is obtained by subtracting the electric fields scattered from the rough ground only from those scattered from the ground with the hurled anti-personnel mine [J317]

"Complex natural resonances of conducting planar objects buried in a dielectric half-space"

A scheme is presented to incorporate a mixed potential integral equation (MPIE) using Michalski's “formulation C” with the method of moments (MoM) for analyzing the scattering of a plane wave from conducting planar objects buried in a dielectric half-space. The robust complex image method with a two-level approximation is used for the calculation of the Green's functions for the half-space. To further speed up the computation, an interpolation technique for filling the matrix is employed. While the induced current distributions on the object's surface are obtained in the frequency domain, the corresponding time domain responses are calculated via the inverse fast Fourier transform (FFT). The complex natural resonances of targets are then extracted from the late time response using the generalized pencil-of-function (GPOF) method. The authors investigate the pole trajectories as they vary the distance between strips and the depth and orientation of single, buried strips. The variation from the pole position of a single strip in a homogeneous dielectric medium was only a few percent for most of these parameter variations [J318]

"Three-dimensional interferometric ISAR imaging for target scattering diagnosis and modeling"

Two-dimensional (2-D) inverse synthetic aperture radar (ISAR) imaging has been widely used in target scattering diagnosis, modeling and target identification. A major shortcoming is that a 2-D ISAR image cannot provide information on the relative altitude of each scattering center on the target. In this paper, we present an interferometric inverse synthetic aperture radar (IF-ISAR) image processing technique for three-dimensional (3-D) target altitude image formation. The 2-D ISAR images are obtained from the signature data acquired as a function of frequency and azimuthal angle. A 3-D IF-ISAR altitude image can then be derived from two 2-D images reconstructed from the measurements by antennas at different altitudes. 3-D altitude image formation examples from both indoor and outdoor test range data are demonstrated on complex radar targets [J319]

"Recognition technology for the detection of buried land mines"

As described by Zadeh, recognition technology refers to systems that incorporate new sensors, novel signal processing, and soft computing. In this paper, we discuss these principles applied to the problem of land mine detection. We describe a complex recognition system that is evolving from basic research into a fielded system. Some components of this system have been field tested with excellent results, whereas other components have achieved such results in the laboratory. Fuzzy set-based information fusion algorithms are central to the excellent results obtained. Multiple-detection algorithms are applied to signals acquired from an innovative ground penetrating radar that produces volumetric sub-surface imagery. The outputs of the detection algorithms are combined using the fuzzy logic and Sugeno and Choquet fuzzy integrals to produce overall detection scores. Experimental results are provided on training data and on completely blind test data collected in the field and scored by the US Army [J320]

"Simulation of dependent samples of symmetric alpha-stable clutter"

Discrete-time samples of isotropic clutter with symmetric alpha-stable (SαS) distribution are generated by modulating a complex correlated Gaussian sequence with a nonnegative sequence with skewed stable distribution. The quadrature components of such simulated clutter are uncorrelated, yet dependent, with uniform phase. The statistical dependence between samples of the modulating sequence is induced by employing an autoregressive moving-average scheme with nonnegative stable innovations. A simple autoregressive scheme is analyzed in more detail, and a special technique for simulating isotropic Cauchy clutter is presented [J321]

"A new subaperture approach to high squint SAR processing"

A high squint subaperture (HSS) algorithm was developed from the perspective of a strip map synthetic aperture radar (SAR) system and has the ability to focus SAR data at extremely high squint angle of 55° with less than 1.27% mainlobe expansion or even higher squint angles if larger mainlobe expansion can be tolerated. The unique characteristic of this algorithm is that the subapertures are formed by multiplying the received signal with a set of overlapped complex conjugated reference signals where the chirp rate varies in the azimuth direction. This is done to solve the range focus problem that arises after the azimuth input signal undergoes the range walk removal procedure. As the IISS algorithm only involves short fast Fourier transforms (FFTs) and avoids interpolation, it is computationally efficient and allows for small data buffers and facilitates hardware real-time implementation. The distinct feature of this algorithm is its simplicity of implementation, which is vital in real time processing and motion compensation when the squint angle may be changing continuously [J322]

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