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ТЕМАТИЧЕСКИЙ РЕФЕРАТИВНЫЙ СБОРНИК № 15-2

“Slow Moving Target Detection”
(«Обнаружение медленно движущихся целей»)

Публикации в трудах конференций

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"A region-growing based clustering approach for extended object tracking"

In the case a scenery consisting of multiple moving objects has to be observed and analyzed by using radar, it may occur that extended objects cause more than one observation. As a consequence, a conventional tracking algorithm, that bases on the assumption of point objects, has to process lots of observations, generates several tracks per object and thus is slowed down distinctly. Moreover, it is necessary to sort out and merge the tracks before they can be used. In order to avoid these problems, a clustering algorithm for radar-based object tracking is presented in this paper. The algorithm combines, assigns and discards observations before they are passed on to the tracking. Thereby not only the observations are utilized, but also the existing tracks. Furthermore, the method proposed and its benefits are tested in the example of an automotive object tracking system. [C1]

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

We present in this paper a regularized sparse signal recovery algorithm, referred to as sparse learning via iterative minimization (SLIM), to provide ground moving target indication (GMTI) through multiple-input multiple-output (MIMO) radar angle-Doppler imaging. A slow-time modulation scheme with code division multiplexing is employed to achieve transmit diversity. In this way, we avoid the high correlation properties of orthogonal waveforms and the Doppler ambiguity that is encountered with Doppler division multiplexing schemes. After removing jammer and clutter effects using semi-unitary projections, we show that SLIM, using primary data only, is able to form sparse angle-Doppler images and to provide for accurate target localization. [C2]

"Adaptive polarization processing for improved detection/classification of stationary targets"

A new technique for detection of stationary or slow-moving over-resolved targets on the ground, based upon a Hotelling T-squared test/generalized inner product (GIP) approach to signal analysis is presented. This robust detector separates radar returns from interference via a coherent process. This GIP-based processing can be applied to single-receiver channel systems, multiple spatial channel systems, multiple polarization channel systems or systems with multiple spatial and polarization channels. [C3]

"New detection manifolds for radar signal processing"

This paper examines direct data domain (DDD) moving target detection for multi-channel space-based radar (SBR). DDD techniques differ from data-adaptive processing methods in that they do not rely on statistically stationary and homogeneous training data in order to estimate and null out clutter or interference and thereby reveal potential targets; instead, they operate on each range-Doppler cell independently, after any necessary preprocessing to compensate for platform motion and/or array calibration. Prior work examined a maximum-likelihood angle-of-arrival (AOA) technique and the associated target power estimator to detect slow moving targets. In this paper, we extend that methodology and propose novel detection manifolds for optimally partitioning the two-dimensional statistical space. The two dimensions are formed by the passive AOA likelihood function and the estimated target power. A computer simulation of a space radar system and associated geometry is used to assess the characteristics and performance of the new concept. We show that the two-dimensional probability densities corresponding to the target absent and target present hypotheses (H0 and H1, respectively) occupy regions in this space that are not optimally separated by independent thresholds. This immediately leads to the novel detection manifolds (or curved boundaries between detections and non-detections) that improve the detection probability while also reducing the false alarm rate. [C4]

"UAV Search: Maximizing Target Acquisition"

In situations where a human operator is unable to perform tactical control of an unmanned aerial vehicle (UAV), it may be necessary to have the UAV make or suggest tactical decisions. The interaction of the UAV computers with those of the human decision makers requires that choices for the human decision maker be easy to interpret and intuitive to implement or approve. This paper provides closed-form solutions to maximize detection

of a slow-moving ground target by a UAV. The output of these solutions is a height at which the UAV should fly in order to maximize probability of detection, which informs the operator whether a single vehicle is sufficient. We assume that the UAV can travel faster than the ground target with some bounded speed (but no certain direction). The ground target is detected when it is inside a field of view which is a function of the state of the UAV, so the controller for motion affects whether the target will be detected. We also provide avenues for future work where we consider the impact of results for multi-UAV search and alternative sensor accuracy models. [C5]

"A Hotelling T-squared GIP test for detection of over resolved targets"

A new technique for detection and discrimination of stationary or slow-moving over-resolved targets on the ground, based upon a Hotelling T-squared test/generalized inner product (GIP) approach to signal analysis is presented. This robust detector separates radar returns from interference via a coherent process. This GIP-based processing can be applied to single-receiver channel systems, multiple spatial channel systems, multiple polarization channel systems or systems with multiple spatial and polarization channels. [C6]

"Automatic through the wall detection of moving targets using low-frequency ultra-wideband radar"

This paper presents a time-domain, Moving Target Indication (MTI) processing formulation for detecting slow-moving personnel behind walls. The proposed time-domain MTI processing formulation consists of change detection and automatic target recognition algorithms. We demonstrate the effectiveness of the MTI processing formulation using data collected by an impulse-based, low-frequency, ultra-wideband radar. In this paper, we describe our radar system and algorithms used for the automatic detection of moving personnel. We also analyze the false alarm and detection rate of four operational scenarios of personnel walking inside wood and cinderblock buildings. [C7]

"Odd-Symmetry Template based three-step detector for IR-UWB radar"

The detection scheme for robust detection and target location in the presence of interference is presented. The problem of detecting the slow-moving target at noisy background is addressed in this paper. A novel kind of Odd-Symmetry Template Correlation (OSTC) process is developed as the first-step of the detector. The OSTC method has a better performance due to interference suppression than traditional ones. The Range-Extended Constraint and Threshold Feedback technique is proposed as the second-step for detecting range-extended target and controlling the false alarm rate. The Multi-Cycle Fusion method completes the third-step detection procedure, and improves the detection reliability by reducing false alarms. Experimental results are given to demonstrate the efficiency of this approach. Moreover, the effectiveness of this method allows for real-time execution. [C8]

"Managing the areas of responsibility for collaborative undersea searchers"

In recent years the role of unmanned searchers in undersea search operations has been a topic of considerable interest. In particular, the use of multiple UUVs in the search for stationary or slow moving targets has raised a number of new research questions, one of which is how to effectively plan search operations. In this paper we develop a planning approach to improve trade-offs between search coverage and false search rates for a group of unmanned searchers operating in a bounded region of interest. This important trade-off is typically handled by setting an overall constraint on searcher false alarm rate and partitioning the search region among the individual search assets. We show that this non-collaborative coverage approach can be improved upon by allowing overlap in the areas of responsibility of the searchers, driven by increased sweep widths and independent confirmation requirements on target detection. Standard computational models for acoustic detection performance for the individual searchers are utilized as a function of detection threshold to control the trade-off between searcher sweep rate and searcher false alarm rate. Parametric explorations of the resulting system performance model are used to illustrate the design dependencies in numerical examples. [C9]

"Moving Target Detection Based on Reconfigurable Video Processing Technology"

Moving target detection algorithm is PC-based software programming method to implement. At present, with slow processing speed and small scope of application problems, this paper takes System Generator for the development tool, which is a system-level modeling tool developed by Xilinx Inc, and built a reconfigurable video detection algorithm of moving target in MATLAB/Simulink environment, which is available for the FPGA platform, to achieve the detection of interest moving targets in the video scene. The experiment has testified that this method has many advantages, such as simple operation, flexible design, and high efficiency and so on. [C10]

"Space-time adaptive processing for sea clutter and jamming suppression in radar seekers"

When radar seeker searches and tracks moving target on sea surface, sea clutter spectra severely spread out due to the strong effect of sea conditions. Conventional methods for suppressing sea clutter have achieved poor performance. This paper mainly analyzes the sea clutter characteristics in azimuth-Doppler domain and clutter spectra with different scanning angles. Then space-time adaptive processing (STAP) technique is applied to suppress sea clutter. Research results indicate that sea clutter spectra have some special characteristics in space-time distribution, and the proposed STAP algorithm can detect slow moving targets effectively as it can suppress sea clutter and strong jamming. [C11]

"Slow movement small target detecting method base on frame correlation"

For inter-frame motion characteristics of slowly moving small target, this paper is proposed a target detection algorithm based on relevant frames. This method use improved spatial high-pass filter for image pre-processing to improve signal to noise ratio of small targets; extract candidate target point by binary segmentation, and then conduct inter-frame correlation to binary image. Correlation is inter-frame corresponding to pixels in a neighborhood, and results stored in the tag matrix m, the matrix elements stand for the times of successful correlation. Here we use the rules of k/n rule to determine the output of the tag matrix, that is, if the n frames has k frames correlation successful, then the point is a candidate target. The advantage of this approach is: the short-term loss of target in the image sequence does not affect the detection effect, at the same time, overcome the high noise impact on small targets. Test results show that the method is a robust and efficient approach. [C12]

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

A MATLAB simulation was constructed to better study the effects of internal clutter motion on a notional X band monostatic airborne radar employing a ground moving target indicator (GMTI) algorithm to detect slow velocity targets of low radar cross section. A sample matrix inversion (SMI) fully adapted post-Doppler space-time processor (tapered and untapered) was utilized and the internal clutter motion model of Ward [1] was applied to the overall simulation. As one would expect, the untapered version yielded slightly better results but in all cases final minimum detectable velocities of about 1.0 meter/second were obtained. By judicious choice and implementation of a reduced rank/dimension algorithm, it should be possible to obtain similar MDV results. [C13]

"A tracking approach based on Dynamic Programming Track-Before-Detect"

Dynamic programming (DP) based track before detect (TBD) is an efficient algorithm to detect moving target with slow maneuvers when the SNR is low. After the integration process of DP algorithm, however, the track separation phenomenon is a prevalent problem for trajectory recovering. In this paper, a modified DP algorithm is used to process the data after the envelope detection of radar system. The track separation phenomenon is analyzed and also a tracking approach is presented to minimize the track separation. Simulations are made to show the good performance of this tracking approach. [C14]

"Detection of moving intruders from a moving platform using a Ka -band continuous-wave doppler radar"

A scanning-beam Doppler radar has been presented which can detect moving intruders from a moving platform. The limitations of the scanning-beam sensor in terms of platform velocity and rotation rate were discussed for a fixed antenna beamwidth. Targets moving at any velocity relative to the platform can be detected, even when the person is moving along with the platform, producing no Doppler return. Estimation and removal of the clutter return was demonstrated in order to detect slow-moving targets whose response is within the clutter bandwidth. The optimal threshold value was determined using performance metrics for classifiers under imbalanced data sets. [C15]

"WEAK target detection using dynamic programming TBD in CDMA based passive radar"

Long time integration is of great importance in weak target detection in passive radar systems. When an integration time of seconds level is used, a migration of Doppler and range may take place during the process of matched filtering. This paper presents a novel approach named DPA-TBD to obtain target parameters by taking full advantage of the target migration information. DBT and TBD methods are briefly compared in principle. Then a detailed mathematic description of DPA-TBD is introduced. A model of CDMA based passive radar is established with a slow maneuvering moving target. Two methods, CA-CFAR and DPA-TBD, are applied to target detection, revealing that the latter totally overwhelms the former. Finally, simulation results demonstrate the validity of the theoretical analysis. [C16]

"GMTI MIMO radar"

Multiple-input multiple-output (MIMO) extensions to radar systems enable a number of advantages compared to traditional approaches. These advantages include improved angle estimation and target detection. In this paper, MIMO ground moving target indication (GMTI) radar is addressed. The concept of coherent MIMO radar is introduced. Comparisons are presented comparing MIMO GMTI and traditional radar performance. Simulations and theoretical bounds for MIMO GMTI angle estimation and minimum detectable velocity are presented. The simulations are evaluated in the time domain, enabling waveform design studies. For some applications, these results indicate significant potential improvements in clutter-mitigation SINR loss and reduction in angle-estimation error for slow-moving targets. [C17]

"MIMO phased-array for SMTI radar"

Summary form only given. Waveform diversity techniques for radar have gained considerable interest over the past several years. Novel radar waveforms have been proposed to improve detection performance and metric accuracy (i.e., angle estimation performance). This paper explores the potential for using a waveform diversity technique known as Multiple Input, Multiple Output (MIMO) radar to improve the detection performance of slow moving surface targets from a moving radar platform. The MIMO radar system achieves superior performance by transmitting unique uncorrelated waveforms from each antenna subaperture as opposed to the traditional approach of transmitting a single coherent waveform across the entire aperture. The results show that the radar system minimum detectable velocity (MDV) can be reduced by exploiting the ability of a MIMO system to effectively increase the radar antenna aperture. [C18]

"Bistatic SAR using illumination from a tethered Ground Moving Target Indication Radar"

In order to limit the ground clutter obscuration of very slow moving targets, ground moving target indication (GMTI) radars can be operated from stationary platforms. These systems generally cannot detect stationary targets for surface target surveillance. However, by using a small unmanned air vehicle (UAV) as a bistatic adjunct to GMTI system, a synthetic aperture radar (SAR) image can be formed. Modeling of bistatic SAR with a stationary transmitter was carried out to determine limitations on waveform and receiver platform operational parameters. [C19]

"Fast-time STAP for clutter suppression between transmitter and receiver in bistatic radar"

Detection and localization of ground targets in the region between the transmitter and the receiver in bistatic radar is difficult due to strong interference from surface clutter and the direct transmitter signal. We have simulated fast-time (using channels of an array antenna and range bins) and slow-time (antenna channels and radar pulses) STAP (Space Time Adaptive Processing) and find that fast-time gives better interference suppression in this region. We also see that fast-time STAP is useful for all four cases of stationary/moving radar and stationary/moving target and that slow-time STAP with moving radar is useful for both stationary and moving target. [C20]

"Space-time adaptive processing with a half-cylinder faceted conformal antenna"

Conformal antennas, which assumes the shape of the platform, have several advantages, like reduced weight and space; aerodynamic design and increased field of view.We are interested in detection of moving ground targets with air-borne radar with three antenna geometries: faceted or smooth vertical half-cylinder and plane forward-looking. We study important clutter properties for suppressing the clutter with STAP (Space-Time Adaptive Processing) and find that the subarray division is more important than the antenna element positions, that the faceted and smooth antennas give similar clutter properties and that all three geometries have better clutter properties the smaller the subarrays are. The largest tested subarrays are probably useless for clutter suppression. [C21]

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

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

be more clearly separated from the clutter ridge in the angle-Doppler images and potentially more easily detected by MIMO radar than by its conventional single-input multiple-output (SIMO) counterpart. [C22]

"Detection of ground slow-moving targets in airborne fire-control radar using adaptive processing"

In the ground slow-moving target detection of airborne fire-control radar, the clutter spectrum varies with range due to the variation of elevation angle and shows high nonhomogeneity. In this case, good detective performance can not be obtained by using conventional method. In this paper, a new method based on "filter-then-adapt" is proposed for single channel airborne radar. The new method can weaken the nonhomogeneity and suppress the clutter returns adaptively. Experimental results with real data illustrate the good detection performance of the proposed algorithm for ground slow-moving target. [C23]

"Multi-object Tracking in Video Sequences Based on Background Subtraction and SIFT Feature Matching"

We have presented a method for tracking multiple objects in video sequences based on background subtraction and SIFT feature matching where camera is fixed and input video sequences are real time or self captured. Object is detected automatically by background subtraction, then successful tracking is performed by observing the motion and SIFT feature matching of the detected object. Many existing tracking methods are suitable for tracking slow moving object or the objects where object's motion is almost constant. For this reason, we have proposed an improved tracking method which is capable to track both single object and multiple objects where the object movement may be fast or slow. The tracking error of this proposed tracking method is very low. The experimental results demonstrate that the performance of the proposed method is superior as compared to existing algorithm. [C24]

"An improved ATI method on airborne SAR ground slow moving target detection"

Based on airborne dual channel SAR, this paper improved AT I technique, put forward a weighting factor from DPCA to AT I to improve ground slow velocity moving target detect capability, the method integrated the advantage of DPCA and ATI technique, using the weight value received from DPCA to weighting process the result of interferential ATI, further more, bringing forward a new moving target detect method. The outcome of computer emulation indicates that compared with ATI method, this paper's method can effectively decrease false target number and detect feebleness target efficiency. Compared with DPCA method, it can detect slower moving targets which DPCA cannot detect because of excessive counteraction. [C25]

"Multisensor background extraction and updating for moving target detection"

This paper proposes a new method for multisensor background extraction and updating aimed at surveillance and target detection applications. The background scene extraction is based on robust multisensor change detection of moving objects in the scene. An iterative mechanism updates the background estimate using this information thereby ignoring transient objects but allowing for slow changes in scene illumination. A new multisensor confidence framework is proposed that combines change information from all available sensors to greatly improve the reliability of true scene change detection therefore the reliability of the background image estimate. The proposed method is demonstrated on several sets of registered multisensor images. [C26]

"Range-Dependence Compensation Method for Bistatic STAP Radar"

In this paper, we study the problem of detecting slow-moving targets using space-time adaptive processing (STAP). The construction of the optimum weights at each range implies the estimation of the interference-plus-noise covariance matrix. This is typically done by straight averaging of snapshots at neighboring ranges. However, in most bistatic configurations, snapshot statistics are range dependent. Straight averaging results thus in poor performance. This paper proposes a new method of obtaining an estimate of the covariance matrix using power spectrum registration based on nonuniform frequency sampling technique. Simulation results show a significant improvement in processor performance as compared to conventional STAP methods. [C27]

"MIMO Phased-Array for SMTI Radar"

Waveform diversity techniques for radar have gained considerable interest over the past several years. Novel radar waveforms have been proposed to improve detection performance and metric accuracy (i.e., angle estimation performance). This paper explores the potential for using a waveform diversity technique known as multiple input, multiple output (MIMO) radar to improve the detection performance of slow moving surface targets from a moving radar platform. The MIMO radar system achieves superior performance by transmitting unique uncorrelated waveforms from each antenna subaperture as opposed to the traditional approach of transmitting a

single coherent waveform across the entire aperture. The results show that the radar system minimum detectable velocity (MDV) can be reduced by exploiting the ability of a MIMO system to effectively increase the radar antenna aperture. [C28]

"A W-band quasi-optical homodyne Doppler radar for detection of very slow-moving targets"

A simple homodyne, quasi-optical W-band (99 GHz) Doppler radar utilizing free-space optics to reduce the number of expensive mm-wave components was designed, assembled, and characterized. The system exploited the low 1/f noise and high responsivity of a zero-bias Schottky diode detector. Target velocity as slow as 1.3 mm/sec was measured with a resolution of 94 mum/sec and an detection time of 16 seconds. A SNR greater than 20 dB was measured, off a target with a radar cross section of 11.3 cm2at a 1 m range and a total source power of -10 dBm, and was also detected with a target power as low as -26 dBm. From our measurements, a 1/f noise-limited maximum range was found to be 3.6 m at a total power of -10 dBm. [C29]

"A system for interactive virtual dance performance"

In the modern world, digital technology pertruded to many areas where it could not be used before because of the slow processing power. Todaypsilas fast processors can for example process video in real time, enabling novel possibilities for real time interaction by detection and tracking of human motion. In this paper we present an application of this technology to arts by introducing a framework that integrates dance and video in an interactive virtual dance performance. Our system allows to define a set of visual markers and to associate them with visual icons in the interactive video. By tracking the markers, dance moves are transferred to the interactive video on screen in real time. We used standard tracking methods and modified them to support fast moving markers, small markers and discontinuous tracking of markers. [C30]

"Evaluate the Performance of Underwater Target Detection System in Forward Scattering Zone"

The bistatic sonar can't detect the target nearby the baseline because of the effect of direct wave. The forward target strength is 15 dB above the other direction according to the Babinet's principle. This phenomenon could be utilized for target detection. The three key points including forward target strength, sonar coverage and system response time are discussed. The derivation of the forward target strength from the Babinet's principle is given. The result is consistent with the analytic solution for finite length cylinder. From the point of system design, the forward scattering sonar equation is given, the detection system coverage is evaluated. Further, the system response time using field fluctuation for slow moving target detection is analyzed. [C31]

"The representation of moving targets in multi-channel UWB SAR images and it's application in the generalization of image domain GMTI methods"

To generalize the image domain GMTI methods for slow moving targets to be suitable for detection fast moving targets with multi-channel ultra-wide band (UWB) SAR system, the representation of moving targets in multi-channel UWB SAR images is studied in this paper. By analyzing the local back projection (LBP) SAR imaging process for the moving target, this paper gives the analytic expressions of the moving target in the multi-channel UWB SAR images. Following the results, the image domain GMTI methods can be generalized to be suitable for fast moving targets that defocus in multi-channel UWB SAR images. This generalization is demonstrated via the ATI method. [C32]

"Ground slow-moving target adaptive processing for Airborne Radar"

Airborne fire-control radar is mainly equipped with forward looking antenna, which is characterized by high flight velocity, short wavelength and low PRF. Consequently, on one hand, ground clutter of airborne fire-control radar is non-homogeneous in range and multi-ambiguous in Doppler frequency; on the other hand, Doppler frequency spectrum of the clutter varies quickly with the cone angle and the bandwidth of the mainlobe is much spread. We focus on the features of the clutter and the ground slow-moving target for airborne fire-control radar at first Then it is pointed out that the mainlobe clutter is the most important factor which influences the detection performance. Finally, an adaptive processing algorithm, which is named FS-AMTI, is presented based on the frequency shift of the center of mainlobe clutter by adopting segmentation strategy. Experimental results with real data illustrate the good detection performance for slow-moving target of the proposed algorithm. [C33]

"An algorithm of SAR GMTI in the presence of blanketing jamming"

Jamming and clutter must be effectively suppressed for moving target detection. A method of detecting slow-moving ground targets based on three-aperture synthetic aperture radar (SAR) in the presence of blanketing jamming is presented. It uses two-aperture cancellation method to suppress SAR jamming to target then to

detect the moving ground targets. Firstly, spatial geometry model and echo signal model of three-antenna SAR were built, then an algorithm of SAR moving target detection based on clutter suppression interferometer (CSI) was derived, and the realization steps were presented. Finally, computer simulation results validate its effectiveness. [C34]

"A New Differential Clutter Map Processing in Modern Surveillance Radars"

In this paper we propose a new differential clutter map processing to reduce the false alarms from stationary ground clutter, sea clutter and improve the detection probability of the slow moving target with low Doppler frequency shift. The proposed clutter map is a scan to scan processing which receives the echo signal from Doppler filter bank tuned at lowest Doppler frequency, processes it and delivers the processed signal to the CFAR processing. The simulation results show that the false alarm rate is reduced by more than -30 db. The Clutter map also increased the probability of detection of low speed target, slower than 100 Km/hr. [C35]

"A Robust and Fast Motion Segmentation Method for Video Sequences"

In this paper, a robust and time-saving method for moving object detection in video sequences is proposed. Unlike methods based on complex background updating models which are computationally expensive, the proposed method can segment moving targets in real-time. It mainly includes three steps. In the first step, the background image is reconstructed by using the long-term and short-term background updating algorithms. The long-term updating algorithm detects the noisy motion regions and ghosts, while the short-term updating algorithm models the background pixel values with single Gaussian distributions, which can deal with slow lighting changes. In the second step, the shadows are removed via the color space based approach. Finally, different targets are located with the projection method. Experimental results prove that the presented method is robust to background noisy motions, shadows and scene changes, and can segment multiple objects precisely and quickly. [C36]

"Improvement of Slow-Moving Targets Detection in Sonar"

The given work presents the analysis of inner-period moving targets detection (MTD) possibilities for acoustic detection stations using inner-pulse periodic Linear Frequency Modulation (LFM) for sounding signals. The signal processing technique for achieving the detection of slow-moving targets within a single sounding pulse under conditions of the interfering reflections is proposed. As a preliminary evaluation, the Matlab model simulating sounding signals, reflections and target echoes is developed to demonstrate the efficiency of the proposed method and its robustness in the presence of interfering reflections. Simulation results demonstrating improvement of slow-moving target detection based on the usage of inner-pulse periodic LFM are represented. [C37]

"Robust radar detection of moving ground targets with STAP"

Airborne radar sensors are able to detect small and slow moving ground targets using short dwell times by distinguishing the weak target signature from the dominant ground clutter signal. The capability of a Ground Moving Target Indication (GMTI) sensor is principally governed by the Probability of Detection (PD). Other capabilities such as geolocation, tracking and recognition are derived from these detection data. One method used to enhance the PD for platforms with multiple phase centres is Space Time Adaptive Processing (STAP). In this paper we report an experimental assessment of a robust STAP algorithm [1, 5, 6] using the QinetiQ Enhanced Surveillance Radar (ESR) data. From our results it is apparent that robustness may be introduced if a selective training methodology is employed to estimate the data covariance. Results are given for both Pre- and Post-Doppler STAP [C38]

"A detection algorithm for the small moving target in infrared image sequences with the dynamic background"

An algorithm to detect the small moving target in infrared image sequences with the dynamic background is proposed in this paper. Based on the registration of four continuous frame images, the image sequences are processed by the 1D wavelet transform to separate the target from background. And then the images that contain the moving target information are multiplied by pixel so as to obtain the target enhanced images and extract the moving small target after segmentation. Results of this experiment indicate that the proposed algorithm can detect and locate both slow and fast small moving targets effectively. [C39]

"Development of a baseband signal ATI-SAR simulator for ground moving target indication"

Along-track SAR interferometry has long been used to measure ocean surface currents with small velocities.

There is a significant potential to employ this technique to detect slow ground moving targets with small radar cross-sections. In this paper, we present the development of a baseband signal simulator on ground moving target indication with along-track SAR interferometry. We summarize current state-of-the-art along-track SAR interferometry techniques and algorithm developments for ground moving target detection, and consider the case of an airborne SAR operated in the stripmap mode. And then we propose to investigate and develop advanced techniques for potential civilian and military applications in Australia. [C40]

"SBR sparse array performance with subarray orientation and timing errors"

Coherent multiple aperture radars have been proposed for ground moving target indication to improve tracking accuracy and for along-track interferometry for detecting slow moving objects. An alternate architecture is indicated for detection of very slow moving targets. The approach that promises the most effective detection of slow moving targets is along-track interferometry (ATI). The Air Force Research Laboratory's RLSTAP has been used to synthesize the clutter and target returns for a sparse space based radar array. This paper considers the limitations on along-track interferometry detection of moving targets, due to metrology on array orientation and coherency, and target motion. The effects of orientation between the two subarrays can be accommodated if accurate metrology and compensation are provided. [C41]

"Range-dependence Issues in Multistatic STAP-based Radar"

Multisatic radar systems offer the potential to overcome some of the limitations of the monostatic or bistatic systems. In particular, the ability to build larger apertures allows to increase spatial accuracy. Space-time adaptive processing (STAP) is a method of choice in the context of slow-moving target detection. However, the statistics of signals from multistatic radars are typically range-dependent. This range-dependence leads to major difficulties in estimating the interference plus noise covariance matrix required to perform STAP In this paper, we present a method able to compensate for the range-dependence of the signal statistics and we show that this method achieves near-optimal performance [C42]

"Analytical results in detecting broadband signals in reverberant dispersive environments"

In previous work, the utility of using broadband waveforms was investigated as a means of improving active sonar performance against slow moving or stationary targets in littoral waters. This work was motivated by the fact that, in principle, the use of a wide spectrum permits the design of waveforms with nearly ideal "thumbtack-like" ambiguity functions. However, it is widely known that the ocean has dispersive characteristics in both time and frequency that can prevent the idealized broadband gains from being realized. These dispersive effects, or coherence losses, result in non-idealized signal-echo cross-ambiguity function properties. Currently, it is not well understood how coherence losses affect the cross-ambiguity function. Thus, the previous related effort, for a given fixed bandwidth and time duration waveform, studied and quantified the effects of coherence losses on detection in reverberation-limited environments, where coherence losses were assumed to be uniformly distributed. Given that, the work reported in this paper discusses the extension of previous results by investigating coherence losses for an arbitrary time duration and bandwidth waveform. Further, additional results have been obtained to simulate time/frequency dispersion losses that are assumed to be either uni-modally or multi-modally Gaussian distributed [C43]

"People tracking and following with mobile robot using an omnidirectional camera and a laser"

The paper presents two different methods for mobile robot tracking and following of a fast-moving person in outdoor unstructured and possibly dynamic environment. The robot is equipped with laser range-finder and omnidirectional camera. The first method is based on visual tracking only and while it works well at slow speeds and controlled conditions, its performance quickly degrades as conditions become more difficult. The second method which uses the laser and the camera in conjunction for tracking performs well in dynamic and cluttered outdoor environments as long as the target occlusions and losses are temporary. Experimental results and analysis are presented for the second approach [C44]

"Evaluation of antenna architectures for angle estimation of endo-clutter targets in airborne adaptive radars"

Adaptive beamforming techniques such as space-time adaptive processing (STAP) combine spatial and temporal degrees of freedom to detect slow moving targets in strong clutter backgrounds. Many techniques exist for choosing the spatial and temporal degrees of freedom. In general these techniques are typically evaluated based on their ability to provide good target detection performance using performance metrics such as signal to interference plus noise ratio (SINR). Since adaptive radars must also provide target location information it is important to also consider how the choice of spatial degrees of freedom will impact direction-of-arrival estimation

performance. This paper will investigate the DoA estimation performance of various airborne array architectures including elements and fixed beams (beamspace). It will be shown that in some interference scenarios the spatial degrees of freedom required for good detection performance differ from those required for good DoA estimation performance. [C45]

"Optimum target detection using illuminators of opportunity"

Unlike classical bistatic radars, passive radars make use of illuminators of opportunity to detect targets and to estimate target parameters. One existing radio transmission suitable for passive radar operation is the global system for mobile communication (GSM). For non-cooperative bistatic configurations, one of the major difficulties is the estimation of the reference signal which is required to perform detection. This reference signal, a priori unknown, can be extracted from the signal received at the antenna array provided the direction of arrival of the direct path signal is known. Conventional matched-filter based Doppler filtering offers the possibility of placing the target and interferences in a domain where they can be separated based on Doppler shift. However, slow moving targets residing near mainbeam clutter in the range-Doppler diagram, remain difficult to detect. Internal clutter motion (ICM) exacerbates this issue by spreading the clutter signal power in Doppler frequency. In this paper, we first present a method to estimate autonomously the direction of the illuminating GSM base station from measurements obtained with a two-element antenna array. We passively detect the azimuth of the transmitter without a priori knowledge of the environment. Spatial processing is then employed to attenuate the direct path signal and mitigate its influence on the target detection process. We then propose two methods able to cope with clutter echoes with non zero-Doppler components. We first propose an extension of a CLEAN-like algorithm. We also propose to extend adaptive matched filters to noise-like signals. The adapted matched filter can be used to suppress strictly static clutter but also clutter affected by ICM. These methods are validated by using actual clutter measurements obtained from a passive radar using a GSM base station as illuminator of opportunity. [C46]

"Knowledge-aided Heterogeneity-compensation Algorithm for STAP Applicable to Bistatic Configurations and Conformal Antenna Arrays"

Space-time adaptive processing (STAP) is a well-suited technique to detect slow-moving targets in the presence of a strong interference background. We consider the application of STAP in a bistatic radar configuration when the radar returns are recorded by a conformal antenna array (CAA). The secondary data snapshots used to estimate the optimum weight vector are typically heterogeneous, i.e., not identically distributed with respect to range, thus preventing the STAP processor from achieving its optimum performance. We present a novel knowledge- aided (KA), registration-based pre-processor that mitigates the heterogeneity of the secondary data. When applied to simulated data for a bowl-shaped antenna, this pre-processor is shown to provide enhanced performance when used in conjunction either with the standard sample matrix inversion (SMI) algorithm or with the more computationally- and data-efficient joint domain localized (JDL) algorithm. [C47]

"Real-time Detection of Slow Moving and Temporarily Stationary Objects"

Detection of moving objects is an important research topic in visual tracking applications. Among the moving object detection algorithms, the background subtraction based method is widely adopted due to advantages such as less computational load and high detection quality. However, it is sensitive to illumination changes and fluctuating backgrounds. Moreover, it cannot deal with slow moving and temporarily stationary objects. Although numerous works concerning background model initialization and adaptation have reportedly overcome the obstacles associated with illumination changes and fluctuating backgrounds, however detection of slow moving and temporarily stationary objects remains a challenging issue. Hence, this paper is aimed at developing a novel real-time motion detection algorithm that can deal with the aforementioned problem. Experimental results demonstrate the effectiveness of the proposed approach. [C48]

"A method of hybrid ATI and DPCA technique to detect moving target"

The technique of moving target detection is more important in surveillance and detection. Both the along-track interferometry (ATI) and displaced phase center antenna (DPCA) techniques can estimate the position and radial velocity of moving target; however they are used in different circumstance. In the paper we compare the detection performance of slow ground moving target using ATI and DPCA technique for the new model of distributed space-borne SAR in detail. And provide a method of hybrid ATI and DPCA technique to detect moving target. Some typical computer simulation results are presented which illustrate the problem convincingly [C49]

"Approaches of Single Channel SAR Combining ATI for GMTI"

This paper investigates a detector based on polynomial curve fit for slow ground moving target indication (GMTI) with a single channel synthetic aperture radar (SAR) multi-look along track interferometry (ATI). In addition to the steps of constructing multi-look using overlapped or unoverlapped windows, imaging, phase compensation and performing interferometric processing involved in common techniques of ATI used for single channel clutter suppression, the approach in this paper farther divides real parts of single channel ATI signals into numerous regions, calculates histograms of imagery parts of signals and adjudges threshold for special region by predetermined probability of false alarm (Pfa), and finally the detector is obtained by higher order polynomial curve fit throughout the data area. Another new method of moving target validation via multi-look sample covariance matrix is also proposed. Simulation results show the effectiveness of these methods in the detection of moving targets submerged in strong clutter [C50]

"Detecting Small Slow-moving Sonar Targets Using Bottom Reverberation Coherence"

The detection of small targets that appear suddenly or are moving slowly in strong bottom reverberation is a challenging problem for sonar surveillance in shallow water. Based on a new reverberation model, this paper proposes a target detection scheme that provides target sub-clutter visibility in the presence of reverberation. Experimental evidence shows that the bottom reverberation as seen by a stationary sonar is coherent, or at least partially coherent from ping to ping. Therefore, the bottom reverberation from a particular range cell is modeled as a complex signal composed of a stationary or slowly varying coherent component, plus a rapidly varying diffuse component. The coherent component is easily estimated using a recursive mean estimator and then removed by a simple subtraction so that the target need only compete with the diffuse component. Experimental results show a detection gain, as measured by the coherent-to-diffuse ratio, as high as 30dB [C51]

"Effects of geometry on clutter characteristics of hybrid bistatic space based radar"

For hybrid bistatic space based radar (HB-SBR) which is composed of a transmitter on a satellite and a receiver on an airplane, clutter is a serious problem for detecting slow moving target. The authors discuss the effects of geometry on clutter characteristics, such as Doppler-angle traces, isorange and isodoppler contours, Doppler ambiguities and so on, of HB-SBR which applies space-time adaptive processing (STAP) in this paper. It is shown that some unique clutter properties appear due to the great differences of platform speeds and heights between the transmitter and receiver in the hybrid mode. Some suggestions about bistatic geometry design are also made to improve he performance of moving target indication (MTI) [C52]

"Computationally-efficient range-dependence compensation method for bistatic radar STAP"

We address the problem of detecting slow-moving targets using space-time adaptive processing (STAP). The construction of the optimum weights at each range implies the estimation of the interference-plus-noise covariance matrix. This is typically done by straight averaging of snapshots at neighboring ranges. However, in most bistatic configurations, snapshot statistics are range dependent. Straight averaging results thus in poor performance. In an earlier paper, we proposed a range-dependence compensation method that provides optimum performance. However, this implies a large computational cost. In this paper, we adapt the method to provide optimum performance at low computational cost. [C53]

"A dual-threshold ATI-SAR approach for detecting slow moving targets"

The high false alarm associated with conventional along-track interferometric synthetic aperture radar (ATI-SAR) is a big concern for any valuable military radar. To reduce the false alarm rate, this paper proposes a dual-threshold approach that combines the conventional interferometric phase detection with the SAR image amplitude detection. This yields two results: (1) the interferometric phase map (including target velocity information) obtained by applying the interferometric phase detection only to the pixels selected by the amplitude detection; and (2) the amplitude map (including target strength information) obtained by applying the amplitude detection only to the pixels selected by the interferometric phase detection. The concept is illustrated by the results obtained using the Jet Propulsion Laboratory's (JPL) AirSAR ATI data, collected in the Monterey Bay area, California. The ATI-SAR processing requires also a precise calibration of the platform's crab angle. This paper presents a simple blind-calibration method that does not require any knowledge of the background and/or the actual crab angle. [C54]

"Detection of slow moving targets in SAR images using STAP processing with two-channel sigma-delta antenna"

To obtain moving target detection in SAR images, strong signals from nonmoving objects (ground clutter) have to be removed. In the classical approach for single channel SAR data, simple FIR filtering or frequency-domain

filtering is used. The disadvantage of this approach is significant weakening or masking of moving target echo (by either wide transition band or limited attenuation in stopband), which makes the detection possible only for targets that are strong and well separated in frequency domain. This can be overcome by STAP technique for multi channel SAR data. In this paper, the analysis of channel mismatch influence on slow moving target detection is performed for the case of two channel sigma-delta antenna [C55]

"Design and representation of suboptimum methods for radar space-time adaptive processing (STAP) techniques using a canonical framework"

Space-time adaptive processing (STAP) is a technique used by moving radars to detect slow moving targets. The goal is to reject interference and noise. However, rejection requires a great number of training samples and a large computational cost. To keep the task manageable, suboptimum STAP methods (SOMs) have been proposed by several authors. We have developed a framework to encompass all these methods in a canonical structure. In the appendices, some famous SOMs will be described using the canonical framework. The canonical framework can also be seen as a tool that can be used to design new techniques. This paper is a guideline for designing suboptimum STAP techniques using the framework. Choices that designers have to make are presented in regard with the impact of these choices [C56]

"The Detection and Classification of Broadband Signals in Reverberant Dispersive Environments"

The use of broadband waveforms has been suggested as a means of improving active sonar performance against slow moving or stationary targets in littoral waters. In principle, the use of a wide spectrum permits the design of waveforms with nearly ideal "thumbtack-like" ambiguity functions. However, the ocean has dispersive characteristics in both time and frequency that can prevent the idealized broadband gains from being realized. These dispersive effects or coherence losses result in nonidealized signal-echo cross-ambiguity function properties. At present, it is not well understood how coherence losses affect the cross-ambiguity function. The objectives of this paper are to investigate the study and quantify the effects of coherence loss on detection in reverberation-limited environments and provide insight into the maximum tolerable coherence losses and optimum sonar receiver design [C57]

"Filter algorithm for 3D pose estimation of maneuvering target"

This work presents a filter algorithm for more accurate 3D pose estimation of a maneuvering target. First, by analyzing the error propagation from the 2D images to the target pose, linear measurement equations are derived. Then, two filter schemes are proposed. The first filter uses the maneuver detection technique, in which two detectors fit for fast and slow maneuvers are deduced respectively, and limited memory filtering is adopted for maneuver correction. In the second filter, a robust dynamic model is constructed by the numerical differentiation technique, and an adaptively estimated fading factor is imported to restrain the filter divergence. Finally, the two filter modules are combined for more accurate estimation. Superior to previous approaches that were limited to the slowly and smoothly moving target, this algorithm is applicable for a maneuvering target that acts in an unknown manner. Simulation results show the capacity of this algorithm. [C58]

"Limited memory filter for 3D relative position orientation estimation of maneuvering target"

In a vision-based positioning system, noise in the image features results in errors in 3D reconstruction, and thereby, causes a serious degradation in individual 3D object pose (position and orientation) estimation. To find a solution for this problem, a filter approach is presented for more accurate relative 3D pose estimation of a moving object with respect to the vision sensor system. Different from previous schemes that were limited to the assumption that the relative motion between the target and the camera is smooth and slow, this approach is implementable for a maneuvering target without a prior knowledge about its dynamics. And the computation load is much reduced by avoiding the need of EFK. This filter is composed of a maneuver detector and a filter updater. First, by analyzing the effect of image noise on the pose estimate error, linear measure equations relating the nominal pose parameters (obtained by 3D reconstruction) and the true ones are proposed. Then, a maneuver detector of maximum detection probability is deduced, and two sub-optimal detectors for quick maneuver and slow maneuver are further developed respectively. When a maneuver is declared, updating is performed with limited memory filtering. Experiment results verify the effectiveness of this approach. [C59]

"Moving target indication"

The function of the moving target indication is to suppress the radar returns from static or slow-moving unwanted objects and to pass, for further processing, the echoes from the aerial or sea surface moving objects or targets. The moving target indication adaptability facilitates the radar sensor to adjust its operational capabilities to the current weather conditions in the area swept by radar surveillance envelope. [C60]

"The Earth rotation effect on a LEO L-band GMTI SBR and mitigation strategies"

Space based radars (SBR) have been used to accomplish a number of civilian and military missions. Most recently, SBR concepts have been considered to perform ground moving target indication (GMTI) radar modes. Unlike airborne surveillance platforms, SBR clutter returns are affected by the high satellite velocity and Earth rotation. The phenomenology of the Earth's rotation, and its impact on clutter Doppler returns, are discussed for a Low Earth Orbit (LEO) L-band radar concept. The USA Air Force's Research Laboratory Space Time Adaptive Processing Tool (RLSTAP) high fidelity radar modeling tool is used to provide simulated data in order to demonstrate the Earth rotation effects, and resulting clutter rejection impact on slow moving target detection. [C61]

"Non-coherent detection of slow-moving targets in high-resolution sea clutter"

The radar detection of targets in the presence of sea clutter has historically relied heavily upon the radial velocity of targets with respect to the radar platform, either by estimating the relative target Dopplers (such as for STAP) or by examining the path which targets traverse from scan to scan. However, for targets with little or no radial velocity component, it can become quite difficult to differentiate targets from the surrounding sea clutter. The paper addresses the detection of slow-moving targets in sea clutter and develops an approach for the non-coherent detection of such targets when high range resolution is available. [C62]

"Canonical framework for describing suboptimum radar space-time adaptive processing (STAP) techniques"

We address the problem of detecting slow moving targets from a moving radar system using space-time adaptive processing (STAP) techniques. Optimum interference rejection is known to require the estimation and the subsequent inversion of an interference-plus-noise covariance matrix. To reduce the number of training samples involved in the estimation and the computational cost inherent to the inversion, many suboptimum STAP techniques have been proposed. Earlier attempts at unifying these techniques had a limited scope. In this paper, we propose a new canonical framework that unifies all of the STAP methods we are aware of. This framework can also be generalized to include the estimation of the covariance matrix and the compensation of the range dependence; it applies to monostatic and bistatic configurations. We also propose a new decomposition of the CSNR performance metric that can be used to understand the performance degradation specifically due to the use of a suboptimum method. [C63]

"A filter method for pose estimation of maneuvering target"

A filter method is presented for 3D pose (position and orientation) estimation of an arbitrary moving target from a monocular image sequence. Problem considered here is error propagation from image features to pose parameters. To this end, we have derived a combination of two filter schemes. The first filter scheme uses maneuver detection technique, in which the criterion of an optimal detector is deduced, two detectors suitable for fast and slow maneuvers are analyzed, and limited memory filtering is adopted for maneuver correction. In the second filter, a robust model is established via Lagrange interpolation and numerical integration, and the possibility of filter divergence is avoided by employing an adaptively estimated fading factor. Finally, generalized pseudo Bayes algorithm is employed to combine the two filter models for better filter performance. Superior to previous approaches that were limited to slow and smooth motion, this filter method is applicable for a maneuvering target that acts in an unknown manner. Moreover, it is suitable for real-time environment in terms of the following aspects: the structure of the filter is simplified by avoiding the need of EKF, the computational cost is much reduced by running six filters on the six pose sequences in parallel; the process to extract the feature points is simplified due to the predicted feature locations; time efficiency is increased because the sequence of image frames is allowed to be at unequal intervals. Simulation results and implement of a system for multi-mobile robots formation show the capacity of this algorithm. [C64]

"L-band SBR moving target detection in SAR-GMTI modes"

Space Based Radars (SBR) are being considered for a wide range of area surveillance tasks due to the global, all weather capability to image and detect moving targets. SBR has the capability of detecting either slow moving ground targets or high speed airborne targets, in addition to the familiar synthetic aperture radar (SAR) imaging mode. However, due to the high satellite velocity and long wavelength of an L-band SBR, detection of slow moving targets is very difficult. Two radar modes are being considered: Multiple-Channel Ground Moving Target Indication Space Time Adaptive Processing (GMTI STAP), and Along Track Interferometry (ATI) SAR. The system implications and mode requirements are reviewed for efficient wide area surveillance. [C65]

"Detecting multiple slow-moving targets in SAR images"

Ground moving target indication (GMTI) radars can detect slow-moving targets if their velocities are high enough to produce Doppler frequencies distinguishable from the surrounding stationary clutter. However, no reliable technique is currently available to detect targets that fall below the minimum detectable velocity (MDV) of GMTI radars. Detecting slow moving targets in synthetic aperture radar (SAR) images has also not ceded a reliable solution. Reflected energy from the target is spread over many pixels in the image due to its motion, degenerating the detection process. The addition of clutter from surrounding stationary objects or ground features further complicates detection. Several techniques for SAR imaging of moving targets have been attempted. These techniques require pre-detection, which, in turn, requires sufficient signal-to-stationary ground clutter ratio (SCR). Other attempts such as adaptive, model-based approaches face exponential combinatorial complexity. Exponential computational cost results from having to consider a large number of combinations between multiple target models and the data. The dynamic logic algorithm (DLA) presented below detects multiple slow-moving targets simultaneously in SAR images with low signal-to-clutter ratio, no minimum velocity requirement, and without combinatorial complexity. The mathematics underlying the algorithm is based on biologically inspired signal processing concepts. [C66]

"The united detection of the stationary or slow-moving-speed targets in the clutter based on the high range resolution (HRR) and Doppler beam sharpening (DBS) technique"

During air-to-ground guided missile scanning of the area of interest and detection of targets, mass ground clutter enters the radar receiver with the target echoes, so that the radar cannot distinguish targets from the clutter. Therefore, the radar's detection capability is seriously influenced by the clutter. Because the ground clutter has a space-time two-dimensional property, traditional detection techniques cannot be used. The paper presents a united detection technique based on high range resolution (HRR) and Doppler beam sharpening (DBS) to fulfill the detection. The united detection technique uses simplified range-Doppler arithmetic to get the signal-to-clutter ratio gain and get the two-dimensional multiple scatterer image, thereby improving the radar's detection capability in clutter. A computer simulation has been done and the results demonstrate that the united detection technique achieves good results, and the technique is valid and easy to perform. [C67]

"Radar clutter suppression using adaptive algorithms"

Radar clutter is the extraneous return waveform from the radar background environment. Because the clutter has a large cross-section, radar clutter can seriously degrade target detection. Conventional radar systems assume the clutter is stationary with its energy concentrated at low frequencies. Thus, a fixed high pass filter (HPF) is used to filter out the clutter. This approach has two major problems: (1) it degrades detection of a slow moving target, and (2) it cannot filter out the high frequency clutter. To overcome the difficulties of conventional radar clutter suppression algorithms, This work proposed two adaptive clutter suppression schemes to enhance the target detection probability. Computer simulations are used to evaluate the performance of the proposed clutter suppression algorithms. [C68]

"New solutions to the problem of range dependence in bistatic STAP radars"

We address the problem of detecting slow-moving targets using a space-time adaptive processing (STAP) radar. The construction of optimum weights at each range implies the estimation of the clutter covariance matrix. This is typically done by straight averaging of neighboring data snapshots. However, in bistatic configurations, these snapshots are range-dependent. As a result, straight averaging results in poor performance. After reviewing existing methods exploiting the precise shape of the bistatic direction-Doppler curves. [C69]

"Activity recognition using the dynamics of the configuration of interacting objects"

Monitoring activities using video data is an important surveillance problem. A special scenario is to learn the pattern of normal activities and detect abnormal events from a very low resolution video where the moving objects are small enough to be modeled as point objects in a 2D plane. Instead of tracking each point separately, we propose to model an activity by the polygonal 'shape' of the configuration of these point masses at any time t, and its deformation over time. We learn the mean shape and the dynamics of the shape change using hand-picked location data (no observation noise) and define an abnormality detection statistic for the simple case of a test sequence with negligible observation noise. For the more practical case where observation (point locations) noise is large and cannot be ignored, we use a particle filter to estimate the probability distribution of the shape given the noisy observations up to the current time. Abnormality detection in this case is formulated as a change detection problem. We propose a detection strategy that can detect both 'drastic' and 'slow' abnormalities. Our framework can be directly applied for object location data obtained using any type of

sensors-visible, radar, infrared or acoustic. [C70]

"A moving target detection filter for an ultra-wideband radar"

A time modulated ultra-wideband (TM-UWB) through-wall impulse radar currently has been developed at Time Domain Corporation, Huntsville, AL, which detects the motion of people in range and azimuth through non-metallic walls. The radar operates in real-time with 3Hz update rate. In order to detect the motion of people moving with different velocities, a digital moving target detection (MTD) filter has been developed which is implemented in the software of the radar. The MTD filter is an IIR high-pass filter and it helps reject the stationary (time history invariant) clutter. Results on the time vs. slow-frequency (Fourier transform of slow-time response) distribution for targets moving at different velocities are presented for a given update rate. The transfer function of the MTD filter as a function of a target velocity is also presented for a given update rate. [C71]

"Time series processing of FLIR imagery for MTI and change detection"

The paper addresses the problem of calibrating FLIR images of a scene that are acquired at different time points to construct information for moving target indication (MTI) and change detection. A signal model is developed to identify variations and imperfections of an FLIR sensor in time. This model is utilized to compensate for relatively slow variations of a bias in the FLIR sensor via a Fourier-based processing. Furthermore, a two-dimensional adaptive filtering method is developed to compensate for variations of the image point response (IPR) of a FLIR sensor as well as sub-pixel changes in the relative coordinates of the sensor-target over time. Results with time series FLIR, data of a scene with an airborne helicopter and a ground target are provided. [C72]

"New methods for handling the range dependence of the clutter spectrum in non-sidelooking monostatic STAP radars"

We address the problem of detecting slow-moving targets using a non-sidelooking monostatic space-time adaptive processing (STAP) radar. The construction of optimum weights at each range implies the estimation of the clutter covariance matrix. This is typically done by straight averaging of neighboring data snapshots. The range-dependence of these snapshots generally results in poor performance. We present two new methods that handle the range-dependence by exploiting the geometry of the direction-Doppler curves. [C73]

"Identification and tracking of dim moving targets in FLIR using artificial neural networks"

One of the important challenges in automatic target recognition system is to identify and track slow moving targets under heavy background clutter and noise. The problem becomes more complicated when the moving target is dim and spatially distributed over only a few pixels. In this paper, we propose a novel technique based on artificial neural networks (ANNs) for the identification and tracking of dim moving targets in forward looking infra-red (FLIR) imagery. The ANN is used in a neural adaptive line enhancer (NALE) configuration to identify and detect the dim moving target. First, we used a multilayer perceptron (MLP) for this purpose. The performance of the MLP is found to be satisfactory. Next, we introduced a computationally efficient single layer functional link ANN (FLANN). Performance comparison of the two ANNs was carried out through extensive computer simulation and showed that the FLANN provides satisfactory result with substantial reduction in computational complexity. [C74]

"Multiresolution GMTI radar"

The detection and tracking of ground moving vehicles from airborne radar can be challenging at slow target velocities due to the close space-time (angle-Doppler) proximity of strong competing mainbeam clutter. Moreover, in complex non-stationary clutter environments, conventional space-time adaptive processing (STAP) cannot be relied upon to provide precision ing. In this paper, we re-examine GMTI radar from a multiresolution perspective resulting in a hybrid radar mode combining elements of synthetic aperture radar (SAR) with STAP GMTI. In particular, acute sources of clutter interference are resolved via quasi-SAR processing, and then combined with STAP GMTI to significantly reduce minimum detectable velocities, reduce the required DOFs, increase available training set size, and lower SINR loss and false alarms. [C75]

"Dim point target detection"

Presents a method to incorporate jitter information to a precise position score function that allow us to detect very slow moving targets. For analyzing the TBD algorithm output data, we suggest building a filter that would match the target signature and test similarity between it and suspected high local maximas. Running that algorithm, we achieved detections within 90% of higher similarity scores for SNRs>2. These results are very promising and we now intend to examine the described algorithms for more difficult scenarios and conditions.

[C76]

"Performance of order statistic clutter map CFAR"

Cell average clutter map CFAR (CACM-CFAR) is analyzed at first. CACM-CFAR has better performance in the inhomogeneous clutter environment, but is affected by interference and self-masking which will cause the low probability of detection. To solve these problems, a novel algorithm named order statistic clutter map CFAR (OSCM-CFAR) is proposed, in which the clutter map is updated by the k-th ranked cell in the clutter map cell. The performance analysis shows that the probability of detection for slow moving targets is increased by using the OSCM-CFAR algorithm. And the same case occurs in the multi-target environment when the new method is used. [C77]

"Results of flight tests of a two-channel radar system with real-time MTI processing"

In synthetic aperture radar (SAR), only fixed targets are mapped on their correct positions. Moving targets are displaced in azimuthal direction due to the Doppler frequency shift caused by target velocities. The detection and correct positioning of moving targets within SAR images is a problem that can be solved by using multiple antennas and multi-channel receivers. For the detection of slow moving targets or moving targets that are backfolded into the clutter spectrum, a good suppression of fixed target echoes is necessary to gain subclutter visibility. Space-time adaptive processing (STAP) shows good performance in clutter suppression and is state of the art. However, the main disadvantage of conventional STAP techniques is the very high computational load. Therefore, performing STAP in real-time for the purpose of on-board subclutter moving target indication (MTI) requires special techniques. To estimate the true azimuthal positions of moving targets, phase differences between receiver channels can be evaluated e.g. by using the well-known monopulse method. Alternatively, STAP can be applied to solve this problem as well. STAP in real-time is discussed for two applications. First, STAP can be used for suppressing clutter and jammers. Moreover, clutter filter coefficients gained by STAP can be used for the purpose of correct positioning of moving targets within SAR images. Results of this real-time STAP technique as well as results of the moving target repositioning technique are presented: the clutter suppression quality and the moving target repositioning accuracy are demonstrated with real SAR data and moving targets recorded during a measurement campaign. [C78]

"Effect of ambiguities on GMTI radar"

We focus on the effect of range and Doppler ambiguities on the ability to detect slow moving targets by STAP radar. This work has been conducted in the context of international projects such as SOSTAR and AMSAR.The detection of moving targets by a moving radar (air- or spaceborne) is seriously degraded by strong clutter returns. Space-time adaptive processing (STAP) techniques can implicitly compensate for the motion induced Doppler shift and thereby improves the capability of slow target detection. The effect of ambiguities on the target tracking capability of a STAP radar is discussed in conjunction with a companion paper by Koch (see Radar 2002, Edinburgh, Scotland, October 2002). [C79]

"A planar antenna for omnidirectional GMTI radar"

For airborne surveillance and early warning radars 360° coverage is a desirable feature. Future military airborne radars will have omnidirectional coverage combined with ground moving target indication (GMTI) capability, for instance by using STAP (space-time adaptive processing) for detection of slow moving targets. In this contribution a randomly thinned array antenna for use with STAP is proposed. For achieving 360° azimuthal coverage subarrays including dipoles with rotational symmetry are used. Real-time STAP processing is achieved by using an overlapping subarray concept. It can be shown also that range ambiguous clutter returns are cancelled through vertical ing. The slow target detection performance is analysed, and the directivity patterns are shown. [C80]

"Doppler compensation for JDL for airborne bistatic radar"

In airborne bistatic radar the clutter Doppler is range dependent. STAP processor using training data from other range gate will experience widening of clutter notch. Widening of the clutter notch causes a major problem in detecting slow moving target. In this paper, Doppler compensation using interpolation in the angle-Doppler domain, for joint domain localised processor (JDL) is proposed. Comparison is made with Doppler compensated processor proposed by Kreyenkamp and Klemm (see IEE Proceedings: Radar, Sonar and Navigation, vol.148, no.5, p.253-58, 2001). Significant improvement in processor performance is observed across the whole frequency spectrum. [C81]

"Detection of quadratic phase coupling in shallow underwater channel"

This paper addresses the problem of detection of quadratic phase coupling (QPC) at the receiver when the source signal has traversed through an underwater channel. The channel has been numerically modeled using normal mode theory In a bounded underwater channel, the phase associated with each frequency varies with range as well as due to the characteristics of the channel. We have performed extensive simulations of the received signal of moving and stationary targets in shallow underwater channel, to arrive at a robust algorithm for detection of QPC. The algorithm takes advantage of the slow variation of the bispectrum phase of the received signal which is due to the channel characteristics. Specifically, the detector is based on the zero crossings of the bispectrum phase of the received signal across observation intervals. The proposed detector is observed to be robust in several typical shallow underwater channels. We will present detailed results of the detection performance of the algorithm in different SNR conditions. [C82]

"Moving target imaging in foliage using polarimetric multi-frequency antenna array SAR"

Because of the low signal-to-clutter ratio, it is a difficult problem to detect and image moving targets in foliage. A multi-frequency multi-aperture polarimetric SAR (MFMA POLSAR) system is proposed for imaging of moving targets in foliage. The MFMA POLSAR extends the multi-frequency antenna array SAR (MF-SAR) system to multiple polarizations. Full polarization is used in MFMA POLSAR to achieve an optimal polarization adaptive to the environment, such that the images obtained by different apertures are of the best coherence that is used to obtain the highest accuracy of the phase estimation. It is also shown that the MFMA POLSAR can not only accurately locate both slow and the fast moving targets, but also reveal moving targets in foliage [C83]

"Adaptive radar clutter suppression"

The clutter return presents a severe problem in target detection for radar systems. Conventional radar systems assume the clutter is stationary, with energy concentrated in the low frequency domain. To minimize the effect of clutter, radar systems use a fixed high pass filter (HPF) to eliminate the clutter. When the target Doppler frequency is below the cutoff frequency of the high pass filter, or the clutter energy does not concentrate on the low frequency domain, the performance of radar system is severely degraded. This paper proposes an adaptive clutter suppression scheme. This scheme provides more efficient clutter suppression for non-stationary clutter and provides the ability to detect a slow moving target. The computer simulation is presented to compare the performance of this adaptive clutter suppression technique and the fixed clutter suppression filter [C84]

"Space time adaptive processing for domain factorised element-digitised array radar"

Due to limitations of current radar system hardware, digitisation and adaptive beamforming are usually performed at the subarray level of large phased array radar. In the long term, technology will permit development of element digitised array radar (EDAR), although this may not necessarily lead to adaptive processing being performed at the element level. The large computational requirements for adaptive processing, which vary with the cubed power of the number of digital channels, and the large data training set required, will restrict the number of digital channels employed. However, with element digitisation we are free to choose arbitrary degrees of freedom (DOF) reduction schemes to maximise adaptive beamformer performance. It has already been shown that DOF reduction schemes using domain factorisation (DF) give performance advantages in high clutter airborne intercept (AI) environments. We extend the DF technique described by Paine (see IEE Proceedings Radar, Sonar & Navigation, vol.148, no.2, p.81-88, 2001) to space-time adaptive processing (STAP) and demonstrate the detection of slow moving targets that are ambiguous with main beam and strong nadir clutter [C85]

"Space-time adaptive processing (STAP) for wide-band airborne radar"

STAP is a technique used to reject clutter returns in airborne phased array radar systems. This paper presents an investigation of the performance of STAP in wideband scenarios. It is shown that, under these circumstances, narrowband STAP is often sufficient for clutter rejection with sideways looking arrays, but that a wideband STAP architecture is needed to reject mainlobe jamming and/or to achieve slow moving target detection with a forward looking array. The effect of time delay pre-steering on STAP performance is also examined [C86]

"The future of surface surveillance-revolutionizing the view of the battlefield"

The early stages of a revolution in real-time surface surveillance and attack are here. Advances in radar, information algorithms, high performance processing, wideband communications, geolocation capability, attack sensors and smart weapons have set the stage for a fundamental change in military capability. The successful deployment of Joint STARS has been the operational catalyst that has spawned a mutually supportive family of real time surveillance programs from D-II in space down through tactical UAV. Stovepipe exploitation systems

each dedicated to a particular sensor are disappearing in favor of intelligent nodes consisting of advanced recognition and manipulation tools and algorithms implemented largely in commercial high performance processors. Weapon systems and weapons are obtaining the capability to meaningfully employ this battlefield Internet to select and engage challenging targets in real time with pinpoint precision. The radars supporting the warfighter are achieving a continuum of functionality, from imaging of fixed targets to detection of both slow and fast moving surface targets. Single function radars are not the future. The challenge for the radar designer is to merge the SAR technology requirements for accurate platform motion compensation and increased bandwidth with the GMTI technology requirements for clutter rejection and increased power. The challenge for the information system architect is to synergistically combine SAR, GMTI, and other sensors together into a layered network to provide continuous, on-demand, surveillance and enable direct weapon engagement of the most difficult of military targets [C87]

"Moving targets in synthetic aperture images: a Bayesian approach"

This paper presents a novel method to determine the complete velocity vector of a moving target using a single synthetic aperture radar (SAR) sensor. The method exploits the structure of the returned echo from a moving target: in the slow-time frequency domain, it is a scaled and shifted replica of the antenna radiation pattern immersed in Gaussian noise; the scale and the shift are related with the slant-range and the cross-range velocities, respectively. A Bayesian approach is then adopted to derive an estimator for the velocity vector. Simulation results illustrating the estimator effectiveness are presented [C88]

"Simulated STAP performance for multi-channel SAR processing"

Interest in slow target imaging lead the authors to the synthetic space-time aperture radar (SAR) simulation and performance evaluation developed of Space-Time Adaptive Processing (STAP) clutter suppression technique for SAR processing. In multi-channel STAP system the side-lobe of echo is very high and the integrated radar cross section (RCS) is too large to neglect the side lobe clutter as the side lobe illuminates a very large area of ground. The authors use the STAP to suppress the side lobe clutter. Suppressed clutter powers in signal to clutter ratios (SCR) and the improvement factor (IF) are measured in this numerical experiment and presented. This investigation offers a guide to the SCR requirement on the next-in-line processors such as time frequency estimation and target imaging [C89]

"Simulated DPCA performance for dual-channel SAR processing"

Interests in slow target imaging lead us to the synthetic aperture radar (SAR) simulation and performance evaluation of the dual-channel displaced phase center antenna (DPCA) clutter suppression technique for SAR processing. The Doppler chirp signature of a moving target signal is altered by the DPCA and has to be restored by a correction factor. Suppressed clutter powers in signal-to-clutter ratios (SCR) the improvement factors (IF) are measured in this numerical experiment and presented. This investigation offers a guide to the SCR requirement on the next-in-line processors such as parameter estimation [C90]

"Changeable sampling processing for chirp signals in the SAR"

Aimed at the chirp signal resulting from a moving target in SAR, this paper puts forward a signal processing method for changing sample ratios and gives theoretical analyses and the results of a simulation experiment. The results show that the method is very effective, practical and clearly separates a moving target, especially a slow-moving target [C91]

"Target detection enhancement using target motion discrimination"

The significant challenge in shallow water environments is performing reliable target detection and classification while maintaining a reasonable false alert rate. Recent Navy operational experiences in shallow water environments have shown that existing active sonar systems experience excessive amounts of clutter and false alerts which result in a significant reduction in platform tactical advantage and survivability. A target motion discriminator (TMD) technique based on the Interacting Multiple Model (LMM) estimation algorithm is presented to exploit the consistency of position and motion information observed over multiple pings to form a robust classification decision. Several motion class models reside within the TMD, to provide accurate target state estimates and target likelihood functions for both maneuvering and non-maneuvering contacts. Classification performance is dramatically enhanced by using a “no target model” to reject contacts which exhibit erratic motion, i.e., inconsistent with a target motion model while promoting contacts with consistent motion. The accurate estimation of target dynamics obtained by the IMM approach provides the capability to reject stationary clutter resulting from surface and bottom reverberation and reliably detect the slow moving threat. A robust sequential likelihood ratio test which minimizes the classification decision time and improves classification

performance is developed and demonstrated using sea test data collected in various environments [C92]

"Airborne ground moving target indication using non-side-looking antennas"

It is well known that detection of moving targets using an airborne radar is complicated by platform-induced spectral spreading of clutter returns. As a result, conventional pulse Doppler radars require a target to have a minimum detectable velocity (MDV) to be clear of mainbeam (and sidelobe) clutter. Extensive research into side-looking, multi-channel (i.e. multi-aperture) radars employing space-time adaptive processing (STAP) and displaced phase centre antenna (DPCA) processing techniques has been conducted, in order to reduce the requirement on MDV for airborne early warning (AEW) radar applications. GMTI (ground moving target indication) radars like JSTARS also employ similar techniques to detect slow ground moving targets such as tanks and jeeps. Most of the literature deals with side-looking airborne radars (SLAR), which is the case when the aperture phase centres lie along a line parallel to the flight path. This paper considers the design and performance of GMTI radars for the general, non-SLAR case, where the array is oriented away from the side, the extreme case being a forward-looking airborne radar (FLAR). A non-SLAR GMTI radar is attractive because it is applicable to mechanically rotated antenna arrays, often used for wide-angle surveillance; and, as a result, can be considered as an upgrade to existing surveillance radars [C93]

"STAP for circular forward looking array antennas"

Future multifunction air- and spaceborne radar systems will have the capability of detecting slowly moving targets on the ground. This problem can basically be solved by space-time adaptive processing (STAP) techniques. Previous work has shown how the antenna array configuration can be optimized for optimum detection of slow targets. In practice there are, however, constraints on the antenna design which may originate from other radar functions. The effect of certain antenna configurations on the STAP performance is discussed. Furthermore, the effect of space-time clutter filtering on the antenna beampatterns is analysed. The results of this study will contribute to the trilateral AMSAR project [C94]

"Autofocusing of (inverse) synthetic aperture radar for motion compensation"

Ground imaging from an airborne synthetic aperture radar (SAR) and conversely aircraft imaging from a ground based radar (ISAR) require the knowledge of the motion of the antenna relative to the target, with an accuracy of a fraction of the wavelength upon a time span of seconds. This information is not necessarily directly available from navigation/tracking data and must be recovered from the radar data itself using the technique well known as autofocus. The approach described in this paper divides the problem into two time scales. The fast disturbances (antenna vibrations, tracking noise) of the motion with respect to the nominal trajectory are handled before range compression by the complex valued correlation technique. The slow disturbances (inertial drifts, error accumulation) are handled by a frame drift-like technique, derived from image sequence analysis. As side effect, this method may also provide alternative techniques for moving target detection and for accurate odometry (measure of the ground speed of the carrier aircraft) [C95]

"Space-based radar signal processing demonstrator: preliminary experimental results"

Space-based radar (SBR) is capable of providing flexible wide-area coverage of air, land, and sea targets. A real-time demonstrator system has been developed to carry out experiments that will be used to evaluate the performance of the SBR under a variety of system and environmental configurations; the demonstrator system is called the SBR signal processing demonstrator (SPD) system. Some preliminary simulation results are presented pertaining to three different experiments, when a phased array antenna is employed as the primary sensor. In the first experiment, the performance of displaced phase centre antenna (DPCA) is examined in terms of its ability to detect slow-moving targets in mainbeam and sidelobe clutter. In the second experiment, the performance of ECCM techniques is examined in the presence of clutter. Finally, the third experiment examines the impact on the system performance as a function of the grazing angle associated with the surveillance fence [C96]

"Tracking weak targets with a grid search approach using spatially distributed sensors"

This paper investigates the performance and robustness of two grid search algorithms; the space-time integration (STI) technique and the integrated grid search localisation and tracking algorithm (IGLOO) which both combine data from spatially separated sensors. The algorithms are applied to two different scenarios; a target moving in a straight line through a sonobuoy field; and a target undertaking a major course change. Although most techniques will track a target moving in a straight line quite successfully many have difficulty tracking the target as it manoeuvres through a slow turn. The advantages of data fusion are highlighted using the IGLOO algorithm where the results using bearings only, frequency only and combined bearing/frequency information are

provided [C97]

"Real-time adaptive airborne MTI. I. Space-time processing"

Space-time adaptive processing (STAP) has shown to be an efficient tool for detection of slow targets (moving target imaging, MTI) in a strong clutter environment by air- or spaceborne radar. STAP algorithms have the attractive property of implicitly compensating for the clutter Doppler spread induced by the radar platform motion. STAP techniques have been discussed for application with sidelooking (SL) and forward looking (FL) radar configurations. It is desirable to suppress clutter returns on board the radar platform in real-time. In this paper a tutorial overview of a variety of space-time processing architectures for real-time processing is presented [C98]

"Reliable motion detection of small targets in video with low signal-to-clutter ratios"

Studies show that vigilance decreases rapidly after several minutes when human operators are required to search live video for infrequent intrusion detections. Therefore, there is a need for systems which can automatically detect targets in live video and reserve the operator's attention for assessment only. Thus far, automated systems have not simultaneously provided adequate detection sensitivity, false alarm suppression, and ease of setup when used in external, unconstrained environments. This unsatisfactory performance can be exacerbated by poor video imagery with low contrast, high noise, dynamic clutter, image misregistration, and/or the presence of small, slow, or erratically moving targets. The paper describes a highly adaptive video motion detection and tracking algorithm which has been developed as part of Sandia's Advanced Exterior Sensor (AES) program. The AES is a wide-area detection and assessment system for use in unconstrained exterior security applications. The AES detection and tracking algorithm provides good performance under stressing data and environmental conditions. Features of the algorithm include: reliable detection with negligible false alarm rate of variable velocity targets having low signal-to-clutter ratios; reliable tracking of targets that exhibit motion that is non-inertial, i.e., varies in direction and velocity; automatic adaptation to both infrared and visible imagery with variable quality; and suppression of false alarms caused by sensor flaws and/or cutouts [C99]

"Harbor control search processing for detection of slow moving ships in adverse conditions"

Two land based harbor control search signal processors are numerically evaluated using actual recorded sea clutter data which contain different weather conditions, sea states, and various degrees of land background. The first processor is based on an inverse digital MTI (IDMTI). The second approach forms a series of narrow band filters across the clutter region. The detection performance using both actual and calibrated targets is also quantified [C100]

"Evaluation of noise and clutter induced relocation errors in SAR MTI"

A synthetic aperture radar (SAR) is a side looking airborne radar designed to produce two dimensional high resolution radar images. Moving targets are displaced in azimuth on a SAR map. A separate SAR-MTI process is therefore used for the detection and relocation of moving targets. Errors in estimating the angular positions of the detected moving targets are referred to as relocation errors. A two port interferometer antenna whose baseline lies along the flight direction allows the detection of slow moving targets that are otherwise masked by main lobe clutter. A model for evaluating relocation errors in a two port interferometer SAR-MTI scheme is developed. The effects of various parameters such as aircraft speed, antenna beamwidth, squint angle, radar PRF and the target to noise and clutter ratios are evaluated [C101]

"Automatic target detection in dynamic clutter from incoherent ISAR data"

This paper presents a method for automatic detection of targets with nonlinear motion embedded in dynamic clutter. This is achieved via processing the targets' incoherent ISAR data that are less vulnerable to multiplicative noise (phase errors). It is shown that the incoherent ISAR signature of a target scene may be viewed as its baseband ISAR signature. Thus, the magnitude of an ISAR database that is severely contaminated with phase errors, i.e., incoherent ISAR data, may be used for ISAR detection of moving targets. Incoherent ISAR data in the fast-time and slow-time domain are transformed into another two-dimensional domain. The signature of a target in the transformed domain is shown to be localized based on its mid-point range and speed. This localized statistic is suitable for automatic, i.e., machine-based, detection of stationary as well as moving targets in the scene [C102]

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