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**«Томский государственный университет
систем управления и радиоэлектроники»**

ТЕМАТИЧЕСКИЙ РЕФЕРАТИВНЫЙ СБОРНИК № 38-2

“Sea Radar Clutter”
(«РЛ отражения от морской поверхности»)

Публикации в трудах конференций

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ТЕМАТИЧЕСКИЙ РЕФЕРАТИВНЫЙ СБОРНИК № 38-2

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"3D Multiple Maneuvering Targets Tracking in Active and Passive Radar Composite Guidance"

Active and passive radar composite guidance has been developed into a promising technology for target tracking in the electronic counter measurements (ECM) environment. Based on the technology, this paper investigates the problem of 3D multiple maneuvering targets tracking in the presence of sea clutter and jamming. We present a set of algorithms and establish a complete tracking system composed of measurement generation, data association, track initiation, track filtering, track management, track correlation and missile guidance. The simulation results indicate that the proposed algorithms can offer significant tracking and anti-jamming performance. The ideas and methods presented will also bear important significance for developing similar tracking systems in practice. [C1]

"Ship Detection after Removal of Ambiguities by Using PolSAR Images"

Ambiguities in SAR image are very common phenomena. For maritime applications, as the high intensities of the ambiguities in low radar backscatter background of sea environments, they can be mistaken as targets and cause false alarms in ship detection. Thus, through the analysis of polarimetric characteristics of ships and ambiguities, we propose a ship detection method which applies the eigenvalue to differentiating the ship target and azimuth ambiguities. One set of Cband JPL AIRSAR polarimetric data covered Kojimawan Bay, Japan has been chosen to evaluate the method that can effectively remove false alarms caused by the azimuth ambiguities. [C2]

"ISAR imaging in sea clutter via compressive sensing"

We investigate the application of compressive sensing (CS) to inverse synthetic aperture radar (ISAR) imaging of moving targets. We present our results for a simulated target immersed in different levels of sea clutter. Comparison between traditional and CS approaches to ISAR imaging reveal that our based CS algorithm offers some advantages compared to traditional ISAR imaging under certain limited operating conditions that are nevertheless of practical interest. We conclude by pointing out directions for future work in extending the results of this paper. [C3]

"Low speed target detection with short CIT in HF surface wave radar"

High frequency surface wave radar can detect targets beyond the horizon. It needs long coherent integration time (CIT) to detect low speed targets, such as ships, in the environment with sea clutter. In order to improve the efficiency of the radar system, and avoid the Doppler broadening caused by long CIT, it is necessary to shorten coherent integration time. Modern spectrum estimation technique is adopted to extract Doppler information from HF radar echo signals. It can provide high resolution to realize ship detection in short CIT. The real data processing and analysis show that the autoregressive spectrum estimation technology is effective to detect low speed target in short CIT in high frequency surface wave radar. [C4]

"Target tracking in state dependent wake clutter"

Tracking methods attempt to follow the movement of a target of interest while suppressing irrelevant clutter. A particularly troublesome source of clutter is wakes that appear behind the target. This problem arises in sonar tracking of human divers, in the tracking of boats using surveillance radars, and also in radar tracking of ballistic missiles. Previous research has integrated a solution to this problem in the popular Probabilistic Data Association filter (PDAF). This paper proposes a new solution to this problem in the same framework. While previous research has used an approach described as probabilistic editing, the new solution solves the wake problem in a Bayesian framework by means of marginalization. Monte-Carlo simulations show that the new solution provides significantly increased robustness as compared to both the standard PDAF and the probabilistic editing approach. As the new solution has improved theoretical underpinnings, we hope that it can be useful for further research on tracking in the presence of wake clutter. [C5]

"Vessel detection and classification: An integrated maritime surveillance system in the Tyrrhenian sea"

In recent years a number of organizations, both national and international, have put significant efforts in developing knowledge-based integrated maritime surveillance (IMS) systems. The final aim is to have a clear picture of the position, classification, identification and movement of cooperative and non-cooperative targets entering and leaving the 200 nautical miles limit of the Exclusive Economic Zone (EEZ). Each sensor (i.e. satellite-based, ground-based, shipborne or airborne) has its own task and, in such a context, high frequency (HF) surface wave (SW) radars are inexpensive tools for long range early warning applications in open waters. They allow maximizing the effectiveness in dealing with fisheries protection, drug interdiction, illegal immigration, terrorist threats, search and rescue tasks. This paper focuses on the possibility of combining automatic identification system (AIS) data with HFSWR data for vessel detection and classification purposes. Three algorithms for target detection in compound Gaussian HF sea clutter are presented and their performance evaluated. The combined use of AIS plots provided by cooperative targets can allow the operator to discriminate non-cooperative targets and possible threats. The concurrent exploitation of AIS and HFSWR data is presented and discussed by means of real data recorded during the NURC experiment in the northern Tyrrhenian Sea in May 2009. [C6]

"On the detection of marine mammals with ship-borne polarimetric microwave radar"

Collisions between ships and whales are not rare occurrences. Apart from constituting a major cause of death for whale species which frequent busy oceanic areas such as the North Atlantic, such collisions often result in damage to ships. Thus there is keen interest in finding reliable means of detection of whales at sufficient range to ensure successful collision avoidance. In this paper we present the results of experiments aimed at establishing the potential of polarimetric microwave radar to provide such a means. The key element in our approach is the construction of a polarimetric filter which enhances the contrast between the disturbed sea surface around the whale and the ambient sea. The results suggest that detection can be achieved under conditions where conventional uni-polar radars such as those normally found on merchant ships would fail. [C7]

"Ground target position estimation in passive location"

Ground target tracking is difficult and actual problem. Because of the high target density and maneuverability, high clutter, low visibility due to terrain masking, etc., ground target tracking presents unique challenges that does not present in tracking of other targets types. But many tracking approaches have been developed for air targets and they work poorly for ground targets tracking. This article includes research work results in radar position estimation for passive range-difference location. Radio source is stationary and performs circular scan. Transmitted signal is received in three points. But beside true measurements of time difference of arrival (TDOA) there are false measurements originated by clutter. Usually clutter measurements are modeled as independed identically distributed. But real experimental data processing shows that in crosscountry its distribution may be multimodal. Therefore standard tracking algorithms are not efficient in this situation. Multimodal distribution is caused by re-reflected signal from underlying terrain. Some ground objects re-reflect signal and imitate additional (false) targets. We propose special approach to decide position estimation problem in such high clutter environment and verify it on experimental data [C8]

"Extraction of ionospheric clutter in HFSWR"

The two main applications of High frequency surface wave radar (HFSWR) are maritime surveillance of the Exclusive Economic Zone (EEZ) and the remote sensing of the sea. Ionospheric clutter strongly limits the detection capabilities of HFSWR. In order to analyze the effect of ionospheric clutter, a method based on image processing is proposed to extract ionospheric clutter. In this method, the Range-Doppler spectrum of radar echo was processed as image, and the color image segmentation technique was used to extract ionospheric clutter. By a preliminary analysis of the ionospheric clutter extract results, we can get that the average power of ionospheric clutter is big, and it occupies many Range-Doppler cells, and it has direction. The results provide a frame of reference for the ionospheric clutter assessment, suppression and frequency selectivity, etc. [C9]

"Surveillance and inversion of regional atmospheric duct from multiple radar stations"

The atmospheric duct is an anomalous refractivity structure which often occurs over large ocean surface. A surveillance and inversion method for regional atmospheric duct from multiple radar stations is introduced here. It has 1) a larger surveillance area for atmospheric ducts and 2) more accurate inversion results due to more inputted clutter information. In order to describe the M-profile for evaporation ducts more freely, an improved two-parameter M-profile is used. [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]

"Scattering-based I/Q signal simulation of sea clutter returns"

A fast Slope Summation Facet Model (SSFM) that derived from the original Bass and Fuks' two scale model (BFTSM) is proposed to describe the sea scattering including both the coherent and diffused incoherent features. This kind of facet implement can readily change the average line budget of sea return locally corresponding to the facet returns, so that it can be used to find the amplitude of each scatterer. Moreover, with the help of the approximate phase extraction procedure, the coherent radar sea clutter could be readily obtained, which easily leads to the final realization on the modeling of the radar return data of I/Q signal. [C12]

"Characterisation and cancellation of medium grazing angle sea clutter"

High grazing angle sea clutter data were collected and characterised using two different airborne radars with HH and VV polarisations. The ability to cancel sea clutter using single-channel and multi-channel coherent signal processing is investigated. [C13]

"Fractal based detection using blind box-counting method in high resolution radars"

Sea clutter refers to the radar returns from the sea surface. Accurate modelling of sea clutter and detection of low observable targets within sea clutter are major problems in remote sensing and radar signal processing applications. Recently fractal geometry is applied to the analysis of high range resolution radar sea clutters. The box-counting method is widely used to estimate fractal dimension but it has some drawbacks rarely considered in literature. We explain the problem of box size range and present a novel method to select an appropriate range. [C14]

"A Fit-to-Sine based processing chain to handle multiple-target scenarios"

The full coherent processing of non-equidistant sampled data has been the topic of many research activities. In this paper we propose a processing chain based on such an algorithm, the Fit-to-Sine function, which is able to handle multitarget and target/clutter radar signals. Starting from the computation of a least squares cost function in dependency of frequency, followed by a feature extraction method and the suppression of unwanted sidelobes, we conduct a simple noise/target distinction by utilizing basic fuzzy logic characteristics and operations. Finally we exemplify our processing chain and the achievable results on a real radar scenario with a target moving in strong clutter. [C15]

"Antenna size versus sea clutter rejection: A new analysis of coastal radar performances and optimization"

In the field of coastal surveillance radar, and more generally in maritime environment, the overall radar performance for the detection and tracking of small target is primarily linked to the capability of the radar to reject the sea clutter. Sea clutter is the radar signal return of the sea surface illuminated by RF waves and can often be a strong as the target radar return. A conventional method to counter sea clutter is to use very large antennas providing high angular resolution trying to optimize the signal to clutter ratio in the radar processing by defining the smallest possible illuminated cell of sea surface. This paper provides an in depth analysis of the pro and cons of large slotted waveguides antennas and shows that bigger is not better: Parasitic effects, correlated to antenna dimensions, in the beam forming process of big antennas tends to degrade the antenna performance and leads to the conclusion that the optimal antenna size is often smaller than the one currently used on existing coastal surveillance radars. [C16]

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

Maritime traffic surveillance radars are in use for several decades, they are mostly based upon magnetron pulse

emitters and simple non coherent signal processing. While the lack of coherent signal processing capabilities is compensated by strong pulse power, there is still a demand for improving detection and tracking performances especially in front of heavy sea clutter for detecting small and evasive targets. The solutions that address such demands are based upon the use of solid state transceivers which allow to generate and to process specifically designed waveforms incorporating for example frequency or phase codes. [C17]

"On the design of integrated HF radar systems for Homeland Security applications"

In this paper, HCAC's research and development efforts on the development of integrated and low cost HF radar for coastal surveillance and other Homeland Security applications are summarized. The proposed design incorporates electrically small antenna for rapid deployment, supports operation on floating platforms by using enhanced DSP algorithms to mitigate clutter, incorporates improved propagation modeling to more accurately select optimum frequency channels based on atmospheric conditions and overcome the errors due to terrain effects, utilizes Genetic Programming for automatic target recognition and classification, and provides for passive radar operation utilizing existing broadcast transmitters to enable covert operation. [C18]

"CFAR detector using GIS information"

In order to realize the constant false alarm ratio (CFAR) processing, the adaptive threshold should be used in radar signal detection. The threshold of the CFAR detector can be calculated using the clutter of range bins nearby the cell under test. In the real world, the clutter environments is always non homogeneous, which result in the performance degradation of the CFAR detector. In this paper, the CFAR detector using geographic information system (GIS) is proposed. With the knowledge of the clutter environment, the performance of the CFAR detector can be improved remarkably. The IPIX radar data are used to validate that the CFAR detector using GIS information is outperform the other conventional CFAR detectors. [C19]

"Improved range resolution for FMCW HF surface wave radar"

A modified signal processing for FMCW waveform has been proposed that yields an improved range resolution without increasing the transmitted signal bandwidth. The chirp duration is reduced by an appropriate factor while the interval of the beat signal sequence considered for the range transform is kept constant. This modification implies a range transform over several chirp sweeps and an interleaving technique for the Doppler transform. Range resolution is improved without affecting the maximum unambiguous Doppler. This is achieved on the expense of a reduction of the maximum unambiguous range. Actually, this is not a restriction for HF SWR systems where the maximum range is limited by surface wave attenuation. However, a minimum practical range bin size is given either by the size of the targets considered or by the acceptable size of range side lobe level coming along with increasing range resolution. With this approach first and second order sea clutter is reduced which is of significant interest for ship detection. [C20]

"Detection against the background of non-Gaussian clutter from underlying surface"

The method for the operating characteristics of the radio systems estimation based on using of model of non Gaussian clutter from underlying surface (sea, land plots) is proposed. This method was done by nested semi-Markov based processes. The characteristics of parametric (Neumann-Pearson, adaptive control of threshold and filter band of moving-target indication) and non-parametric (sign and linear rank) detectors are analyzed theoretically and are compared to results of the experimental investigations. [C21]

"Scan-to-scan sea-spikes filtering for radar"

High range resolution radars are often a solution to the problem of small target detection in the presence of sea clutter, however this solution leads to a high density of sea-spikes echoes. The number of false plots can be very high and need to be regulated in order to be able to control the tracking load and limit the number of false tracks. In this paper a solution for the Coast Watcher 10 and Coast Watcher 100 products is derived. The new patented scan-to-scan algorithm used to filter plots before tracking is presented. It uses the position and Doppler information of the plots on several scans to regulate the number of false plots at tracking level. [C22]

"The requirement of range sidelobe for dual-frequency precipitation radar on FengYun-3 precipitation measurement satellite"

Pulse compression as one of the key technologies for the dual-frequency precipitation radar (DPR), which will be installed on Chinese FengYun-3 (FY3) Precipitation Measurement Satellite, is being studied. Since the backscattered echo of the sea surface is much stronger than the rain echo, the surface clutter can also contaminate the rain echo through the range sidelobe. In this paper, the model of surface clutter interference

with the FY3 DPR is built, and the formulations of computing sea clutter with considering the effect of range weighting function are deduced. Based on the analysis of sea clutter, the requirements for range sidelobe level of the FY3 DPR are proposed. [C23]

"STAP performance in K-distributed clutter"

We investigate the impact of heterogeneous clutter on STAP performance. The K-distribution is a good fit for many clutter scenes of interest and will be the main focus of this paper. We introduce a cell-based model that can simulate realistic spikiness of heterogeneous clutter, allowing us to empirically measure the losses in detection performance. In particular, it is shown that, for a fixed false-alarm probability of 10-4, the adaptive matched filter attains a probability of detection of 0.55 in severely heterogeneous clutter, compared to the achievable probability of detection of 0.9 in homogeneous clutter. We subsequently investigate the causes for this deterioration in performance. [C24]

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

This paper proposes a continuous waveform to realize low transmitted power in a Radar system. The proposed waveform utilizes a pulsed compression scheme based on phase-coded modulation and linear FM which combines the desirable properties of both types of modulation. This paper also verifies waveform operation under channel effects such as multipath and noise. We determine power optimization due to waveform compression gain for given system specifications and use correlation values to detect both unambiguous range and Doppler shift. With a pre-determined noise and Doppler threshold, we can distinguish targets from sea clutter. Finally, we show the improvement in accuracy of elevation measurements by simulation when auto-correlation instead of signal strength ratios are used to determine target height. [C25]

"The HF surface wave radar WERA. Part II: Spectral analysis of recorded data"

This paper covers the second part of the analysis of data recorded by the surface wave (SW) over-the-horizon (OTH) WEllen RAdar (WERA). Data were collected by two WERA systems, on May 13th 2008, during the NURC experiment in the Bay of Brest, France. The principal aim of this work is to provide an accurate characterization of the spectral components of the received signal. Secondly, this information is exploited in order to provide a simple and reliable spectral modeling tool. For this reason, auto-regressive (AR) models, also known as linear prediction (LP) models have been investigated. Our results show that at long distances, when the clutter-to-noise power ratio (CNR) is small, the main components of the spectrum can be reasonably described by an AR(12) model, with a good compromise between accuracy and simplicity. As the CNR increases higher-orders are instead to be preferred. [C26]

"The Pareto distribution for low grazing angle and high resolution X-band sea clutter"

A radar pulse that impinges upon a radar resolution area of the sea surface produces backscattered returns which are called sea clutter. For low grazing angles and very fine radar cell resolution areas, the clutter intensity distribution departs significantly from the exponential distribution. In this case, the clutter is said to display spiky behavior and the distribution of the intensity develops a much longer tail relative to the exponential distribution. Statistical analysis of collected data near a grazing angle of 0.2° at X-band from the sea off the coast of Kauai, Hawaii are examined relative to the log-normal, Weibull and K distributions. Based on an analogy of sea clutter and other disciplines including computer networks and finance, we also apply the Pareto distribution to the collected data. We also compare the data to the WW and KK two-population mixture distributions. Maximum likelihood estimation of the parameters of the distributions are obtained from the measured data. In all cases, the two population mixture distributions and the Pareto distribution are more accurate than the three classical distributions. However the Pareto distribution has the advantage of being an analytically tractable two parameter distribution while having similar accuracy to the five parameter WW and KK at critical values. [C27]

"Evaluation and performance comparison of detection algorithms in a maritime environment"

In this paper, a framework will be proposed for the evaluation of detector algorithms in a maritime environment. Performance metrics and test cases will be defined to allow the impartial comparison of different detectors. In this framework the main approaches for detector comparison are numerical simulation and the use of recorded sea clutter and boat reflectivity data. Available data suitable to the fair comparison of different algorithms will be highlighted, with results for a selection of algorithms. The proposed framework, performance metrics and baseline cases give researchers and system engineers the ability to quantify system performance in a complex clutter environment and to evaluate the effectiveness of a particular detector (or radar design(s)) as compared to another. [C28]

"A New Model for Rain Clutter Cancellation in Marine Radars"

in this paper we propose a probability density function for signal contaminated by sea and rain non-stationary clutter and noise. Afterward, using the proposed pdf we estimated unknown parameters and using Hilbert transform and obtain an analytical signal to pass its imaginary part through a designed Hilbert filter. In the cell under test, we compare adaptive threshold output from the calculated real and imaginary parts of signal and make an automatic decision to whether anti rain clutter filter must be used or not. This algorithm will decrease adaptively destructive effects of rain clutter just in such cells that are contaminated with rain reflections. Our proposed algorithm is tested on real RADAR signature and implemented in a sea marine RADAR. Results show that the method has good performance in inhomogeneous clutter and different sea states. [C29]

"Performance Analysis of OSAP-CFAR Detector in K Distribution Background"

The OSAP-CFAR employs soft rule based on fuzzy logic to give better detection probability than that of OSGO and OSSO-CFAR detectors for Weibull clutter. However, studies show that the K distribution provides a better fit for many clutter situations. The performance of the OSAP -CFAR is studied and compared with OSGO and OSSO-CFAR for the Swerling II target model in K distributed clutter. The results represent that the detection performance of OSAP-CFAR detector is superior to that of OSGO and OSSO-CFAR detectors both in the homogenous background and in multiple interfering targets situations. [C30]

"Modeling and Simulation of Adaptive Thresholding in Marine RADARs"

In order to detect targets upon sea surface or near it, marine radars should be capable of distinguishing target reflections from the sea clutter. Our proposed method in this paper relates to detection of dissimilar marine targets in an inhomogeneous environment with clutter and non-stationary noises, and is based on adaptive thresholding determination methods. Variation and mean vales of the noise have been estimated in this paper, based on non-stationary, statistical methods and thresholding has been carried out using the suggested two-pole recursive filter. Fixating the rate of false alarm, the concerned threshold resolves the assumption problem of existence or absence of the signal. Performance of the mentioned algorithm has been compared with method known as CA-CFAR in terms of decreasing the losses and increasing calculation speed. The algorithm provided for detection of signal has been implemented at the end of signal-processing algorithms of sea marine radars. The results obtained from the algorithm performance in a real environment indicate appropriate workability of this method in heterogeneous environment and non-stationary interference. [C31]

"Performance prediction for a coherent X-band radar in a maritime environment with K-distributed sea clutter"

In this paper, theory is developed for the prediction of the false alarm (PFA) and detection (PD) performance of surface targets in K-distributed sea clutter detected by means of Doppler processing techniques. Vital to this analysis is the inclusion of the correlation properties of the sea clutter between all the pulses within a burst of pulses. The resultant technique allows for the prediction of PFAand PDfor each of the bins in the output of the Doppler processing stage of a fixed-threshold detector. The technique provides the ability to specify different thresholds for each of the Doppler bins. The analysis is extended to include Swerling type 1 and 2 targets for the calculation of PD. The performance of a noncoherent detector is provided for comparison. Results that demonstrate the application of the developed theory are also presented. [C32]

"HF radar performance analysis based on AIS ship information"

High-Frequency (HF) radars are operated in the 3-30 MHz frequency band. For oceanographic applications low transmit power HF radar systems have been developed, which use surface electromagnetic wave propagation along the salty ocean surface. The WERA HF radar system transmits a power of 30 watts but achieves detection ranges up to 200 km, which are far beyond the conventional microwave radar coverage. Hence the radar system can be used for coastal monitoring. Due to external noise, radio frequency interference, and sea clutter the radar detection capability is limited. Real measured radar data from the WERA system were recorded for a 12-hour period. The measured radar data were correlated with simultaneously available Automatic Identification System (AIS) information, which shows current ship position, speed, course and type. This paper presents statistical analysis of maximum detectable range and target reflectivity to estimate the radar performance in case of different cargo ship sizes. Based on the order-statistic constant false alarm rate (OS-CFAR) detection rule the potentially detectable target range and aspect angle of different ship categories were analyzed. [C33]

"A fast FRFT based detection algorithm of multiple moving targets in sea clutter"

On the basis of the detection and estimation model of multiple moving targets, a new algorithm based on

wavelet packet transform (WPT) and fractional Fourier transform (FRFT) is proposed for weak moving targets detection in sea clutter. The multi-resolution property of WPT and the characteristic of good energy concentration on LFM signals in FRFT domain are combined together. At first, optimal wavelet tree is calculated using "minimum Shannon entropy" and threshold censored method is used to suppress sea clutter of different frequency bands. Then, take the absolute amplitude of signals after FRFT as test statistic and search for peaks in two dimensions with the threshold. Grading iterative method is used for parameter estimation with fast calculation speed and the shading problem between multiple targets is solved through "CLEAN" method. In the end, simulations with IPIX data indicate that the proposed algorithm has good performance of detecting low-observable moving targets in sea clutter. [C34]

"Scan rate selection for coherent high-resolution maritime surveillance radar: An experimental study"

Scan rate selection has a crucial impact on the performance of maritime surveillance systems. In this work, a sea clutter database has been used to obtain experimental insight on the trade-off between within-scan and scan-to-scan integration. This paper extends the previous empirical studies to the case of sub-meter range resolution Ka-band coherent sea-clutter data. Results show a clear performance improvement for faster scan rates provided that the number of coherently integrated samples is high enough. [C35]

"MIMO radar detection and adaptive design in compound-Gaussian clutter"

Multiple-input multiple-output (MIMO) radars with widely separated transmitters and receivers are useful to discriminate a target from clutter using the spatial diversity of the scatterers in the illuminated scene. We consider the detection of targets in compound-Gaussian clutter. Compound-Gaussian clutter describes heavy-tailed distributions fitting high-resolution and/or low-grazing-angle radars in the presence of sea or foliage clutter. First, we introduce a data model using the inverse gamma distribution to represent the clutter texture. Then, we apply the parameter-expanded expectation-maximization (PX-EM) algorithm to estimate the clutter texture and speckle as well as the target parameters. We develop a statistical decision test using these estimates and approximate its statistical characteristics. Based on the approximation of the statistical characteristics of this test, we propose an algorithm to adaptively distribute the total transmitted energy among the transmitters. We demonstrate the advantages of MIMO and adaptive energy allocation using Monte Carlo simulations. [C36]

"Research on radar image overlay on ECDIS"

ECDIS is the core equipment in the ship's navigation system, and the navigation radar of the ship also plays an important role in navigation. The radar image overlay on ECDIS can not only improve the avoiding collision ability, but also improve the accuracy of navigation. So the overlay information is very helpful in navigation. The paper designs and realizes the radar image overlay on ECDIS system. Aiming at the sea clutter problem, this paper adopts the CA-CFAR Log-t method to restrain the sea clutter and improve detection ability of radar. Moreover, the DirectX Overlay technique is used to realize the overlay system, which makes the system greatly faster. [C37]

"Evolutions in naval phased array radar at Thales Nederland B.V."

Modern mission requirements for radar operation in complex littoral environments drive new requirement on fast and unambiguous detection of small objects in high clutter requirements. The Thales integrated mast concept provides a suite of several new radar systems, electro-optical sensors and communication antennas in a single integrated mast structure, in which uncomfortable performance compromises of traditional topside arrangements are solved and in which the impact of logistic and installation effort is significantly minimized. The paper focuses on key subsystems and on main technology developments for the integrated mast family. [C38]

"A high resolution FMCW X-band radar sensor for vessel underway replenishment at sea applications"

The accurate control of two vessels at sea whilst personnel and materials are transferred from one to the other is emerging as an important application in both military and civilian circles. This paper firstly introduces the `RadaScan' system, explaining how X-band FMCW radar technology has been combined with the use of transponders for the very accurate measurement of range and bearing to two or more locations. The paper will then describe how these measurements are combined in to a position and heading solution that is then supplied to a `dynamic positioning' system for vessel maneuvering control. This unique radar sensor combined with the computer control system allows one vessel to track and follow the other vessel at close quarters and in heavy sea states whilst the transfer operations are conducted. [C39]

"Ship detection using airborne SAR data acquired at X-band"

During the last years, the interest in maritime surveillance has been growing up, and spaceborne SAR systems may contribute to the improvement of security and safety at sea. As such, to allow observation of non-cooperative boats with revisit times compatible with the objectives of reactivity of maritime surveillance, the solutions proposed by CNES (French Space Agency) in SAR domain concern a radar operating at very wide swath, which implies grazing conditions of acquisition. Under CNES initiative, an acquisition campaign using SETHI, the ONERA airborne SAR sensor, took place over the Mediterranean Sea, south of France, in February 2009. The main objective of this dedicated campaign was to perform very precise measurements of sea clutter and ship RCS for numerous conditions of acquisition so as to improve the understanding of radar backscattering specially at grazing angles: incidence up to 87°. [C40]

"Ultra-wideband forward scatter radar fence for maritime surveillance-Initial experimental results"

The work described in this paper is a continuation of previous analytical work that has progressed to an experimental phase. The paper discusses the development of an ultra-wideband (UWB), forward-scatter radar (FSR) system for the detection and (ultimately) automatic recognition of low reflectivity maritime targets. Here we present the concept, developed hardware and selected initial experimental results. A number of novel ideas have been developed to reduce cost, size, prime power requirement, complexity and utilise the advantages of FSR operation. System benefits include increased target cross section (over conventional bi/monostatic radar), increased target detection capability, robustness to stealth targets, decrease in sea clutter effects from synthesis of extremely narrow beams whilst using omni directional antennas and sub-Hertz Doppler frequency measurement capability. The experimental work investigates the use of an UWB FSR fence for security, UWB propagation measurements, UWB sea clutter measurements at very low grazing angles, UWB spectral coverage and the synthesis of narrow beamwidth antennas using forward scatter pulse transmission. [C41]

"Comparison of PHD based filters for the tracking of 3D aerial and naval scenarios"

The Probability Hypothesis Density (PHD) filter is applied to realistic three-dimensional aerial and naval scenarios to illustrate its performance in detecting, initiating and terminating tracks in presence of clutter. Radar measurements are available every two seconds. A comparisons between different approximations of the PHD recursion, namely the sequential Monte Carlo and the Gaussian Mixture approximation, is given on different scenarios using the OSPA metric and different levels of clutter. [C42]

"Analysis of sea clutter distribution variation with Doppler using the compound k-distribution"

Sea clutter is the backscattered returns received by a radar system from the sea surface. Maritime radar signal processing has the ability to partially compensate for clutter to achieve effective detection of targets on or near the sea surface. This paper investigates the fit of the compound k-distribution model to sea clutter amplitude statistics, within individual Doppler bins across the Doppler spectra. The data used was recorded with a monostatic coherent X-band radar on an airborne platform; both horizontally and vertically polarized data has been analysed. The statistics of the sea clutter distributions have been evaluated using the probabilities of false alarm (PFA), which are the calculated from the sea clutter cumulative amplitude distributions. These curves are plotted as a function of detection threshold. K-distributions have been fitted to the PFAof the sea clutter across the Doppler spectrum. The variation of the fitted shape parameter with Doppler bin has been used to identify the relationship between backscattered sea clutter and Doppler. The results show a clear variation with Doppler of the shape parameter obtained from the fitted distribution. The variation is also found to change with polarisation. [C43]

"OTHR-SW Coordinate Registration method based on sea-land transitions: Clutter model definition"

In previous works we proposed a Coordinate Registration (CR) method of the received echo by pulsed, monostatic Over The Horizon Sky Wave Radar (OTHRsw). This method takes advantage from the a priori geo-morphological knowledge of the surveillance area (especially the coastline profile) and from the pronounced difference between the sea and land normalized backscattering coefficients. In this paper we present a model of surface clutter, its software implementation and its role in the simulation tool under development intended to recreate the complex OTHR scenario in order to analyze the performances of the proposed CR method. A brief introduction about the radar scenario is given; the main clutter model hypotheses are outlined; the adopted space-time distributions processes are motivated; the key-parameters for the model configuration are described; some examples of simulated clutter scenarios are proposed; the achieved results are finally shown. [C44]

"A novel CFAR detector for terminal guidance coherent radar"

In different Doppler channels, the amplitude distributions of sea clutter received by terminal guidance coherent radar are different. The Rayleigh distribution and Weibull distribution can be used to describe the amplitude distribution of different Doppler channel. A novel CFAR detector is proposed. Its performance is compared with column-window CFAR detector. The simulation results confirm that the proposed CFAR detector has a better detection probability compared with column-window CFAR detector. [C45]

"Ship detection based on compound distribution with Synthetic Aperture Radar images"

Considering the variability of Synthetic Aperture Radar (SAR) imaging (different sensor, resolution) and complex condition of sea surface, the traditional single statistical model may be no longer a good choice to fit the distribution of actual sea clutter in SAR image. Based on the characteristic of Gamma distribution which is suitable to model uniform area, and G0 distribution which is adaptive to the general homogeneous and heterogeneous area, this paper established a compound distribution of G0 and Gamma model to fit the characteristics of various types of sea conditions, and use the moment estimation to improve the computational efficiency as well. Meanwhile, the algorithm combines the Constant False Alarm Rate (CFAR) detection based on dichotomy method in order to figure out the difficulties in solving the analytical expression of compound distribution. TerraSAR-X and ERS-2 images were adopted for investigating the algorithm. Experiment results illustrate that the method can achieve good performance. [C46]

"The inversion of sea state based on the micro-Doppler analysis of sea-clutter"

The real sea-clutter data are always hard to analyze due to their instinct complexity, large scale non-stationary, and lack of fundamental understanding of the natural dynamics. Measurable modeling of sea clutter is an important precondition in many research areas and practical applications, such as salvage and marine radar signal processing. However, few works have been down on the time-frequency analysis of sea clutter, especially no effective method for sea state inversion from sea clutter has been proposed. In this work, the author take into account the motion model of sea surface in typical scenarios via time-frequency and micro-Doppler effect analysis. Different contributions of the waves' velocity may provide intuitionistic ISAR images and contain certain motion parameters, from which certain sea state parameters might be inversed. Both theoretical simulation and experimental results indicate the usefulness of the model and method proposed in this work. [C47]

"Cascade SVM Based Oil Detection in SAR Images"

Synthetic aperture radar (SAR) is well adapted to detect ocean pollution independently from daily or weather conditions. Oil slicks have a specific impact on ocean wave spectra because the presence of oil slicks can induce a damping of the backscattering to the sensor and a damping of the energy of wave spectra. Thus oil slicks can be discernible from the radar image. Several algorithms are applied for local segmentation of oil slicks but most solutions are tailored for specific applications. This paper describes a multi-scale kernel-based fusion approach by using textural and statistical features. This cascade svm approach reduces the problems of speckle and sea clutter and preserves subtle variations of oil slicks. The experimental results carried out on SAR images prove the effectiveness of proposed approach. [C48]

"Application of particle filter for angle measure"

In anti-ship terminal guidance radar tracking system, the target echo is always corrupted by the sea clutter. When sea clutter is large at high sea state, the signal -to-noise ratio (SNR) of the target echo is usually relatively low as a result of the effect of sea clutter. The precision of angle error extraction in radar tracking servo is low, while the fluctuating error of angle measure is large in low SNR region. The radar antenna has to adjust itself very frequently to keep tracking its target. While it leads that the radar can not always hold on tracking the target steadily. To improve the precision of angle error extraction and steady off-boresight angle measure of the target, a novel angle measure method based on particle filter is proposed, which achieves off-boresight angle estimation by approximating the posterior probability diversity with particle set, and the steps of algorithm are presented. Finally the simulation experiment confirms the valid of the proposed algorithm. [C49]

"Measurements of microwave backscatter from sea surface using L-band multi-channel receiver"

The authors conducted a sea clutter trial using a DSTO (Defence Science and Technology Organisation, Australia) built, vertically polarised, L-band, 16-channel receive array in May 2008 on the Kangaroo Island, South Australia. This paper studies some properties of the collected sea clutter, with an emphasis on observations of the interaction of electromagnetic waves with changes of the sea surface due to changes in observation direction and/or variation of wind. [C50]

"Numerical study on the statistics of the phase in backscattered signals from time-evolving sea surfaces"

The linear and Creamer sea surface models are combined with the first-order small slope approximation (SSA1) technique and the method of ordered multiple interactions (MOMI) to study the statistics of the phase difference in backscattered signals from time-evolving sea surfaces. The impact of sea surface models and electromagnetic (EM) scattering computation methods on the backscattering signal phase is investigated. Numerical results are compared with theoretical distributions to validate the models and computational procedures proposed. Good agreements between simulated statistics and the theoretical counterparts demonstrate that the sea clutter returns are essentially joint Gaussian distributed on short time scales. [C51]

"Data acquisition of vessel ISAR data with assistance of automatic identification system"

In the past, imaging of moving vehicles using the principle of inverse synthetic aperture radar (ISAR) has typically been applied to ground moving vehicles or air and space borne objects. Nowadays, demands to image moving vessels on sea come along for both military applications and coastal surveillance. New processing algorithms have to be developed to focus ISAR data of vessels because of the complicated three-dimensional rotational motion and the sea clutter. Experimental data have to be available for the development process. To be able to acquire these data, the airborne radar sensor PAMIR of Fraunhofer FHR has been extended by integrating a receiver for automatic identification system (AIS) messages, which supports the system with position information of the vessels on sea. The paper shows the hardware integration and software implementation. Benefits of the information gained from the received AIS messages are discussed and results of first acquired data are presented. [C52]

"Spread clutter mitigation via knowledge-aided STAP in miltiple-input single-output system"

In Multiple-Input Single-Output (MISO) HF surface wave radar system, the fact that bistatic operation and the movement of the receiver platform causes the nonstationarity and spreading of sea clutter, which will lead to the difficulty in detecting those immerged targets. The space-time distribution of sea clutter in different geometry is firstly investigated; and a knowledge-aided STAP scheme is proposed for mitigating the clutter. The weights of different range bins are acquired from both the clutter priori and the prefiltered training data by direct data domain (DDD) algorithm. Numerical simulation shows the proposed scheme effective. [C53]

"An innovative spaceborne radar concept for global maritime surveillance: Description and performance demonstration"

The paper describes an alternative concept to conventional SAR instruments for ship detection over all ocean surfaces. The concept is specifically oriented for ship detection, and not for land or sea imaging. It allows wide swath coverage (as high as 1000 km). It exhibits high detection performances of small ships even in adverse sea states conditions. Its power consumption is reduced allowing a permanent operation all along the orbit. At least, it uses already developed and low cost technologies. [C54]

"Design of an ocean atmospheric duct signal processor"

The atmospheric refractive section plane retrieved from radar sea clutter is of importance for the might enhancement of military naval radar. In this paper, an atmospheric duct signal processor with hardware of an intermediate-frequency board and a high-speed DSP board, besides the arithmetic of clutter suppression and sea clutter extraction, have been designed and implemented to get radar sea clutter power, which works synchronously together with a Doppler weather radar in the science experiment of atmospheric duct sounding. Results show that this signal processor can perfectly implement the acquirement of radar sea clutter and its real-time arithmetic processing. [C55]

"Algorithm optimization of piecewise polynomial modeling for ionospheric perturbation correction"

Ionosphere phase perturbation made the clutter spectrum spread and influenced the precision of parameter inverse analysis for sky wave sea state radar. Recently, an algorithm based on piecewise polynomial signal (PPS) phase model and high-order ambiguity function has been applied to resolve this problem. The determination of the order for the polynomial phase is critical in the applications of the algorithm. Two order-selecting methods based on self-adaptive polynomial model are proposed and verified by simulation. The results indicated that the new methods (frequency-domain and time-domain) based on the characteristics of high-order ambiguity function (HAF) transformation improved greatly in accuracy and that the amount of calculation is reduced. The polynomial order can be judged exactly, especially at low signal-to-noise ratio (SNR) when

employing the frequency-domain method. [C56]

"Application of AIS in Marine Search and Rescue Radar"

Nowadays marine radar detects targets by Constant False Alarm Rate (CFAR). But the search and rescue efficiency is low in poor visibility or serious interference. In this paper, we reference learning mechanism, set up the AIS information for the sample and estimate the threshold t of the search targets with Maximum Likelihood (ML). Then any ship can be distinguished and searched. Experimental results show that using this method can improve the efficiency and accuracy of marine search and rescue radar searching the targets. [C57]

"FPGA based design and implementation of an Adaptive Binary Integrator"

Binary detection integrator is characterized by its simplicity, resistance against asynchronous interference, and its good detection performance. It suffers from detection loss due to non-homogeneous background. To overcome the limitations of binary integration, the Adaptive Binary Integrator (ABI) is used. ABI achieves the advantages of automatic detection and adaptive thresholding over the binary integrator. The presented adaptive binary integrator is designed and implemented using field programmable gate arrays (FPGAs). The performance of the proposed ABI is evaluated through the Receiver Operating Characteristic (ROC). The implemented hardware is evaluated experimentally under different conditions of noise, asynchronous interference, sea clutters, and rain clutters. High probability of detection is achieved by designing the Constant False Alarm Rate (CFAR) processor which is the first stage in the proposed ABI for relatively high probability of false alarm. The final probability of false alarm is then reduced by the effect of integration. [C58]

"Search Aid System Based on Machine Vision and Its Visual Attention Model for Rescue Target Detection"

The prompt search and rescue of lifesaving target is very important in the case that a marine casualty occurs. To detect the small target in the wide views over the sea, we have proposed a machine vision system to aid search and rescue on the sea, which combines remote sensing, radar, infrared with visual light technology. One of the detection methods in this system, which is based on visual attention mechanism, is proposed in this paper to find rescue target from visual light image. The color information, image intensity and other image properties are used to generate the feature maps that form the saliency map subsequently with the weighted integrating strategy. The experimental results show that the proposed method is efficient to detect the small target in cluttered ocean scene. [C59]

"Range tracking filter using measurements with uncertain delays"

In modern marine range tracking systems, both Doppler radar and range sensors are often used to enhance the detection and tracking performance against sea clutters. Due to the delays in communication links, however, the measurements of the sensors do not arrive simultaneously to the data processor where the tracking filter operates. Moreover, the magnitudes of the delays vary irregularly. To cope with this problem of uncertain time delays, in this paper, we propose a new range tracking filter algorithm by adding a ZSB (zero-scan-back) MAP (maximum a posteriori) delay estimator to conventional Kalman tracking filter. Computer simulations are carried out to demonstrate the performance of the proposed filter. [C60]

"Identifying ship echoes in CODAR HF radar data: A Kalman filtering approach"

Coastal nations have an interest in maritime domain awareness for applications in national security, coastal conservancy, fishery and stewardship of the exclusive economic zones (EEZs) along their coastlines. Maritime situational awareness involves knowing the location, speed and bearing of ships and boats in the EEZ. HF radar is a useful tool in providing ship information in real time. It is especially effective when combined with ship-borne AIS beacons. Our previously developed HF radar and AIS ship detection models estimate signal to noise ratio (SNR) as a function of range, including ducted propagation for the AIS radio signals. However, ship detection is hampered by the high variability of HF echoes from ships. This is due in part to the aspect dependence of ship radar cross-section and to the presence of clutter bands at known Doppler shifts from both the ground and ocean waves. Tracking ships using their HF radar echoes becomes the means for effectively monitoring the presence of ships in the coastal ocean. We explore the application of Kalman filtering to the ship tracking problem, following the techniques described by J. V. Candy. This approach is described and demonstrated with a simple example. [C61]

"Effects of objective functions on evaporation duct height estimation from radar sea clutter"

A new evaporation duct profile structure is presented by two parameters: evaporation duct height and strength.

Two different objective functions are also introduced and analyzed, which show that the objective functions are multi-peak and not sensitive to evaporation duct strength. Based on the new duct model and the two objective functions, the estimations are operated by using differential evolutionary (DE) algorithm. All the estimated results are obtained by 200 Monte Carlo simulations and statistically analyzed. The effects of population size (PS) and clutter to noise ratio (CNR) is also investigated. The analyzed results show that increasing PS can not effectively improve the accuracy of estimations. However, high CNR can obviously improve the accuracy. [C62]

"Detection performance of C-band radar in sea clutter"

In this paper a method of detection performance of C-band radar in sea clutter using radar equation is discussed. The compound K-distribution is employed to model sea clutter. GIT model provides the normalized clutter RCS. The results show that the detection performance does not always get worse as the range increases. This will give help to the development of maritime radar. [C63]

"Wave height dependence of L-Band small-grazing-angle sea clutter"

The representative semi-empirical sea clutter models (the GIT model and the TSC model) are not ideal applicability in littoral environments. In order to develop a really meaningful sea clutter model, relationship between sea clutter and parameters of sea conditions need to be studied. The wave height is a major influencing factor among these parameters of sea conditions. In this paper, experimental data of L-Band small-grazing-angle sea clutter were used to study the relationship between sea clutter and wave height. The parameters of relationship between wave height and sea clutter are obtained. These work play an important role in establishment of L-Band small-grazing-angle sea clutter model in littoral environment. [C64]

"Target detection above rough surfaces in microwave imaging using Compressive Sampling"

A subspace extraction approach for detection of targets embedded in the clutter is presented in this work. Subspace extraction approach that makes use of both Compressive Sampling and Principal Component Analysis (PCA) is presented in this paper. Inverse Synthetic Aperture Radar (ISAR) Imaging measurement data is used to validate the proposed approach. Experimental results of targets above rough surface with intermediate roughness are presented. Results showed the dimensionality of an intermediate scale rough surface is generally larger than the dimensionality of the finite size targets. Results showed that by compressing the dimensionality through compressive sampling and extracting the principal components, significant improvement in target subspace extraction can be achieved. [C65]

"Estimation of significant wave height from X-band marine radar images"

Radar images include abundant information about ocean waves. Sea state parameters and surface currents can be obtained by analyzing time series of radar images of the sea surface. Due to the non-linearity of the imaging mechanism of ocean waves, significant wave height (Hs) can not be determined directly from radar images. Applying a method to infer the Hsfrom synthetic aperture radar (SAR) images, the Hscan be estimated from marine radar images. Comparing the Hsobtained by this method with buoy data, the results show that it is feasible to obtain reliable data of the Hsfrom marine radar images. [C66]

"Retrieve the Surface Wave Information from X-Band Radar Images"

The sea clutter image from X-band radar contains many information of the sea surface. Applying three-dimensional Fourier transform to the time series of sea clutter images can obtain a three-dimensional (3-D) image spectrum of sea clutter. The radar return causes Doppler frequency-shift, because of the relative movement between the radar antenna and the sea surface. The surface current is obtained by minimizing the distance between the localization of the spectral energy in the image spectra of sea clutter and its theoretical position given by the dispersion relation for linear surface gravity waves. Using the modulation transfer function (MTF) between the image spectra of sea clutter and the wave directional spectrum, a directional wave spectrum can be acquired. Comparing the frequency spectra and the mean directional spreading which are respectively obtained from radar and buoy within the ground-based and ship-based experiments, it is available to obtain the reliable wave information using X-band radar images. [C67]

"A comparison of two CA-CFAR loss calculation methods in spatially correlated K-Distributed sea clutter"

Radar target detection of targets in sea clutter modelled by compound K-distribution is examined from a statistical viewpoint by Monte Carlo simulations. The target detection is processed by Cell Averaging Constant False Alarm Rate (CA-CFAR) processor and the performance evaluations are quantified by CFAR loss. Curves

for CFAR loss versus the spatial correlation and spikiness of sea clutter, number of cells of CA-CFAR processor and the number of non-coherently integrated pulses are presented. [C68]

"Investigations into high resolution mapping of precipitation features utilizing the TRMM precipitation Radar"

Precipitation measurements from the Tropical Rainfall Measuring Mission (TRMM) satellite's Precipitation Radar (PR) have been used to create high-resolution grids of precipitation features at a resolution of 0.05degrees. This grid size is on the order of a nominal PR instantaneous field of view (ifov) of 4.9km at nadir. Currently 12 years of data has been collected from the TRMM mission, resulting in sufficient sampling to begin these high-resolution studies. Precipitation fields at this resolution show detailed, local climatological features and comparisons with topographic data sets allow for the identification of potential problem areas in the retrieval algorithms. [C69]

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

Sea Normalized RCS, and Doppler spectra have been revised for HF-OTH Clutter Modelling. The Hasselmann model is firstly introduced to predict the sea directional spectrum of fetch-limited sea and results have been compared with the Pierson-Moskovitz model used for large scale ocean remote sensing. Results show that the closed fetch-limited sea has lower NRCS compared with ocean for similar wind intensity and direction. For this reasons RCS and Doppler spectra must be predicted taking into account of the fetch dimension. In future work we will generalize this interesting approach to fetch-limited wind, time-limited pulse, in order to show the waveform effect on Doppler spectrum. [C70]

"Identify Islands by Complex SAR Image"

The performance of interferometric synthetic aperture radar (INSAR)-based objects identifying in sea environment with clutter background is researched by many literatures, but most of them are mainly about detecting dynamic objects, such as ship targets. A new method is presented in this paper, which utilizes SAR image and point target analysis method to identify islands on sea surface in near and far range from mainland, especially for islets which can be confused with big ship or other objects such as floating, oil platform and so on. In the sea, either islands or islets is static objects, and other thing is dynamic characteristics, according to this characteristics, islands can be distinguished by spaceborne synthetic aperture radar (SAR) images joint point target analysis (PTA) method. The processing procedure includes three main phases: interferometric phase fringe, coherence evaluation, and sublook analysis. This method is applied with TerraSAR-X SSC image in HONHKONG area. [C71]

"Back Scattering from Target above Random Rough Surface"

This paper is concerned with an analysis of the back scattering of an electromagnetic wave by a target moving along just above a random rough surface such as desert, hilly terrain, sea surface and so on. First we introduce the discrete ray tracing method (DRTM) for the field analysis of back scattering. Second we investigate the effect of clutter due to back scattering from the random rough surface on the radar cross section (RCS) of the target. Finally we show some numerical examples for back scattering from a target above a Gaussian type of random rough surface with arbitrary height deviation and correlation length. It is demonstrated that the clutter is predominant in the back scattering and it is mainly caused by the diffraction related to reflection from the random rough surface. [C72]

"Broad beam high-frequency bistatic cross sections of the ocean surface"

For a bistatic high-frequency radar with a broad beamwidth receiving antenna, over the range-limited clutter cell, the deviations of bistatic angle and wind direction would bring about broadened bistiatic cross sections of the ocean surface in contrast to a narrow beam bistatic hf radar. Based on Eric Gill's narrow beam HF cross sections of the ocean surface, broad beam HF bistatic cross sections of the ocean surface were presented and the results were obtained by numerical simulation. The results showed that the broad beam bistatic cross sections of the ocean surface were the superposition of narrow beam and were broadened at the same time. [C73]

"Analysis of Return Signal Mechanism in Ship-Board Radar"

This paper analyzes interactions between return signals and ship-board radar. The corresponding theoretical model proves that the first-order, Bragg sea-wave spectrum's widened width in ship-board radar coincides with the theoretically spreading width analyzed in our model, creating a foundation for the research of signal resolution and clutter background statistics in ship-board radar. [C74]

"Efficiency of narrow band Doppler selection of the signal in presence of the scattering from the sea"

Efficiency of narrow-band Doppler selections has been considered. Characteristics of detectors with adaptation of a threshold and rank at various polarizations of radiation and reception are estimated. [C75]

"The detection performance of Neyman-Pearson detector for MIMO radar in K-distributed sea clutter"

Use of multiple transmit and receive antennas have become a popular research area in radar community after the success of the same concept in communication. It is shown by Fishler et al. in that multi-input multi-output (MIMO) radar has considerable advantages compared to traditional radar and phased array radar systems. In this paper, detection performance of MIMO radar using Neyman-Pearson detector is investigated in K-distributed sea clutter for a practical scenario. Also, spiki-ness of K-distributed MIMO radar clutter is discussed with respect to the number of nodes. [C76]

"Bistatic SAR along track interferometry with multiple fixed receivers"

This paper presents an along-track interferometry (ATI) study for a bistatic or multiestatic SAR configuration with fixed ground receivers. This technique can be useful for sea current estimation or for any problem of Ground Motion Target Indicator (GMTI). The proximity of the ground receivers to the scene allows to be very sensitivite to velocities with small baselines. This paper also proposes a multibaseline approach for ATI able to diferenciate among different velocity contributions in the same resolution cell. At the end of this paper, some results over real acquired bistatic data will be presented and discussed. The data have been acquired using the C-band SAR Bistatic Receiver for INterferometric Applications (SABRINA) and ESA's ENVISAT satellite, as a transmitter of opportunity. [C77]

"Automatic ship detection in sar images using aegir"

Aegir is an automatic ship detection tool developed at FFI. Now it analyses the different polarisation channels independently. The goal is to fuse the channels before the analysis starts, and to detect the ships in the fused channels. When dual-polarised data is available it is possible to look at the channels individually and combined. When fully polarised data is available, it is also possible to use the scattering matrix and decompose it in different ways. [C78]

"Composite scattering from electric-large target over randomly rough surface in numerical approaches"

Numerical study of radar echoes from the targets in environmental clutters has been of great interest in many applications. In this paper, the bidirectional analytic ray tracing (BART) method for composite scattering from three-dimensional (3D) electrically large complex target above a randomly rough surface is reported. Analytic tracing of polygon ray tubes in bidirectional tracing is developed to precisely calculate the illumination and shadowing of facets, which exempt large patches of the target from any finer meshing. It significantly reduces the complexity relevant to the target electric-size. Numerical examples of angularly composite scattering from a three-dimensional electrically large, e.g., a ship-like target over a randomly rough surface are presented and discussed. [C79]

"A MIMO technique for enhanced clutter selectivity in a multiple scattering environment: Application to HF surface wave radar"

The significance of multiple scattering processes whereby unwanted Doppler-spread energy can contaminate HFSWR remote sensing measurements has recently been reported. In this paper we present the results of quantitative calculations of the extent of the contamination, and then outline a solution based on the adoption of MIMO radar concepts which have been applied successfully in HF skywave radars. [C80]

"Spread E, F layer ionospheric clutter identification in range-Doppler map for HFSWR"

Wide range covering, strong intensity, time-variant, fluctuation and irregular distribution of the spread E, F layer ionospheric clutter badly affects the system performance of High Frequency Surface Wave Radar (HFSWR). A spread E, F layer ionospheric clutter identification method is proposed based on the region segmentation results and region characteristics of the clutter. First of all, convolution template is used for locating the edge of the clutter, then the ratio of the number of the samples belonging to some segmented region and the total number

of the samples in the region of interest (ROI) is used for setting the determinative threshold of the clutter region. Experiments with real data manifest that the proposed method can describe the effect of the spread ionospheric clutter to HFSWR. The quantitative analysis is consistent with the real data observation. The result can be used as a worthwhile reference for clutter mitigation, carrier frequency selection or radar system evaluation. [C81]

"Ship detection with RadarSat-2 Quad-Pol sar data using a notch filter based on perturbation analysis"

Target detection of marine feature is a major topic for the security and monitoring of coastlines. Synthetic Aperture Radar (SAR) has been shown to be particularly useful for this application because of its all-weather and night capability. In this paper a new ship and iceberg detection methodology is described. The algorithm proposed is based on a perturbation analysis in the target space recently developed and published by the authors, which was focused on land based target detection. The algorithm can be considered to be a negative filter focused on sea. Consequently, all the features which have a polarimetric behaviour different from the sea are detected. To demonstrate and validate the technique two RadarSat Fine Quad-Pol mode scenes were acquired off the south coast of the UK at Portsmouth harbour. An extensive ground truth campaign was also conducted that was coincident with these acquisitions. Portsmouth is one of the busiest harbours in the UK and this afforded the opportunity to capture a wide range of vessel sizes and types for analysis. [C82]

"Extraction of coastal wavefield properties from X-band radar"

The dynamic wave field in a high-energy coastal environment is investigated using frequency direction wave spectra obtained by nautical X-band radar imagery. Nautical radars are generally used for navigation and ship traffic control. Under various conditions (wind speed > 3m/s, significant wave height > 0.5m1), signatures of the sea surface (sea clutter) become visible in the near range (less than 3 nautical miles) of nautical radar images. Swell and wind sea waves become visible in nautical radar images as they modulate the sea clutter signal. Since standard X-band nautical radar systems scan the sea surface with high temporal and spatial resolution, they are able to monitor the sea surface in both time and space. The combination of the temporal and spatial wave information allows the determination of unambiguous directional wave spectra. Here, wave data collected from February-October 2005 at the US Army Corps of Engineers Field Research Facility (USACE-FRF) in Duck, North Carolina is presented. For the radar wave measurements the Wave and surface current Monitoring System WaMoS II was connected to a Furuno FR-7112 X-Band radar with a 6 feet open antenna and an update rate of 2.5s (24 rpm). The radar covers a range from 240m 2160m from the antenna with a spatial resolution of 7.5m. The wave analysis was carried out over an area of 3.7 km2located in relative homogeneous bottom topography, off the near shore breaker bar system, in a water depth of 8m -10m. The WaMoS II wave measurements were compared to those obtained from a pressure gauge array located in the same area. Earlier WaMoS II validations provide a general indicator of the quality of the measurement performance as they were carried out for standard integral wave properties over all existing wave systems such as mean or peak wave parameters. Here the XWaves ocean wave field analysis toolbox is used to compare data sets by means of a wave spectral partitioning analysis. This a--pproach provides a more detailed validation especially for bi-and multi modal sea states, allows for a comparison of the heights, periods and directions of individual wind sea and swell components, and tracking the evolution of specific wave systems. Such analysis methods have been successfully applied in a variety of wave model validations. The data comparison was carried out for different sea state and wind conditions. Preliminary results of the data comparison show that the WaMoS II system captures the temporal evolution of the individual wind sea and swell wave components entering the surf zone. A statistical error analysis of the isolated wind sea and swell wave systems provides a quantitative assessment of WaMoS II performance in a coastal setting. [C83]

"Space-time focusing of HF skywave radar signals with application to nonlinear scattering phenomenology"

Increasing the power density incident on a target without raising the radiated power may offer a number of benefits to HF skywave radar systems. Among these is the prospect of detecting nonlinear echoes, which could greatly enhance detection in sea clutter. Other prospects include improved detection of low RCS targets and more effective use of sub-apertures for multiple simultaneous task operations. In this paper we review the physics underlying these missions and assess the potential of various approaches to concentrating energy in localized regions within the illuminated zone. [C84]

"Overview of random rough surface scattering EM models: Application to the sea surface"

In this paper, we present in a first step an overview on different models of electromagnetic scattering by random rough surfaces especially the composite two-Scale Model-CTSM (in order one and two). The numerical results

computed for the bistatic radar cross-section from random rough surfaces especially from the sea surface using the Cox & Munk'slopes distribution and the sea surface spectrum of Elfouhaily. The results obtained by CTSM2 are compared with those given by the existing models (Small Slope Approximation, Weighted Curvature Approximation and CTSM1). These results will be used to examine the applicability of several bistatic reflectivity clutter models especially for near-grazing angles and for Ku-band. [C85]

"Detection of Weak Signal in Chaotic Clutter Using Advanced LS-SVM Regression"

In this study, detection of small target in chaotic clutter with unknown dynamics is presented. We achieve this in four steps: (i) by using db3 wavelet decomposition of the signals, (ii) using Takens delay embedding theorem and least-squares support vector machine (LS-SVM) prediction, including increase the symmetric constraint and improve the kernel function, (iii) wavelet reconstruction, (iv) separation the weak signals from the prediction error. Efficiency of the new approach is evaluated by computing the root mean square error (RMSE) and signal-noise-radio (SNR) of the estimation. Lorenz attractor and the data from the McMaster IPIX radar sea clutter database will be used in the simulation. It is demonstrated in the simulation that compared with conventional RBF neural network LS-SVM regression prediction method; this approach has stronger generalization ability and better accuracy. [C86]

"A New Type of Automatic Ship Detection Method"

A new type of automatic ship detection algorithm is proposed in this paper. By determining whether the local area is heterogeneous, simplex two-parameter CFAR algorithm based on Gauss-distribution or both two-parameter CFAR algorithm based on Gauss-distribution and two-parameter CFAR verification algorithm based on K-distribution are used to detect targets. This new type of algorithm keeps both the ability of traditional two-parameter CFAR algorithm' good features, such as small computation quantity, easy to implement and so on, and the detection accuracy in complex sea conditions at the same time. [C87]

"Over The Horizon Sky-Wave Radar: Simulation tool for Coordinate Registration method based on Sea-Land transitions identification"

We recently proposed a correlation method for the real time coordinate registration (CR) of the received echo by over the horizon sky wave radar (OTHRsw) based on a priori knowledge of the positions of the sea-land transitions within the radar coverage area. In this paper we present a software simulation tool developed to analyze the performance of the proposed CR method in different OTHR scenarios. The software tool simulates the monostatic OTH radar propagation using simplified ionospheric models and simplified models of surface clutter radar interactions. Simulation results assuming different surface clutter scenarios are presented and discussed. [C88]

"An Improved Automatic Ship Detection Method in SAR Images"

This paper provides an improved automatic ship detection algorithm, which uses two-parameter CFAR algorithm based on Gauss-distribution to process the homogeneous imaging local area, and uses two-parameter CFAR algorithm based on K-distribution to process the heterogeneous imaging local area again. This improved algorithm keeps both the ability of traditional two-parameter CFAR algorithm' good features, such as small computation quantity, easy to implement and so on, and the detection accuracy in complex sea conditions at the same time. [C89]

"Application of Radar Signal Processing System Based on DSP in the VTS"

Radar signal processing system is an important part of vessel traffic services. In order to overcome the shortcomings of traditional analog video system, this paper proposes a design solution for digital radar signal processing system based on DSP and a new method that is a constant false alarm rate algorithm based on wavelet transform. This method can suppress the interference of sea clutter without impairing the target resolution. Experimental results demonstrate this system can increase the detection accuracy and reduce the false alarm rate. Furthermore, the tracking performance can be improved. Radar signal processing system based on DSP plays an important role in the vessel traffic services. [C90]

"Simulation of the radar observation of a sea patch using the TLM electromagnetic method"

We propose the simulated rendition of the observation of a variety of small sea patches by radar. These patches include a random sea surface of variable state, with possibly the presence of a manufactured, metallic object in its middle. The simulation in itself draws upon two different techniques which are combined: for the free-space propagation, a simple geometrical ray tracing method is used. On the other hand, we rely on a discrete

calculation of the propagation of the electromagnetic waves in the vicinity of the sea surface, using the TLM method. Different aspects of this particular electromagnetic method are discussed in this paper. The originality of the approach is the combination of a geometrical calculation with a discrete, exact computation, each of them being devoted to a precise part of the simulation. Further matter in the article extends onto the explanation of some techniques developed for the need of our study, presentation and annotation of some results along with computation times, and overall discussion. [C91]

"Breaking wave study from in situ experiments"

This paper describes the setting of the experiment for in situ measurements of breaking waves. The aim is to provide an insight in the wave breaking mechanism and the possible outcome is a statistical description of this mechanism which will be used together with airborne radar (SAR) data acquired on the same spot. It is well known that when the sea-state is high (3 to 4) the radar clutter is displaying many spikes due to the breaking waves. So far this phenomenon is not correctly described and it is impairing the analysis of the sea surface, especially when possible targets are present. [C92]

"Detection of spatially extended objects in clutter"

Range-spread Doppler-spread signals in interference are readily discernable via the application of classical algorithms and architectures presented by Van Trees [1], and more recently by Kay [2] and others. However, when these returns emanate from stationary objects, the generalized inner product (GIP) offers a unique tool for detection and discrimination processing. This paper offers insight into how the GIP may be applied to optimize the detection of spatially extended fixed objects in clutter. [C93]

"A practical point of view: Performance of Neyman-Pearson detector for MIMO radar in K-distributed clutter"

Use of multiple transmit and receive antennas have become a popular research area in radar community after the success of the same concept in communication. It is shown by Fishler et al. that multi-input multi-output (MIMO) radar has considerable advantages compared to traditional radar and phased array radar systems. In this paper, detection performance of MIMO radar using Neyman-Pearson detector is investigated in K-distributed sea clutter for a practical scenario. Also, spikiness of K-distributed MIMO radar clutter is discussed with respect to the number of nodes. [C94]

"Active Learning Artificial Neural Networks Ensemble for HF Ground Wave Radar Sea Clutter Predicting"

Based on chaotic characteristic of high frequency ground-wave radar (HFGWR) sea clutter, a new adaptive artificial neural networks ensemble method for sea clutter predicting is presented in this paper. In phase space reconstructed, when one sea clutter sample is to be predicted, some artificial neural networks are choosed adaptively by evaluating their performance and error correlation in neighborhood of the sample, and outputs of these artificial neural networks are combining dynamically as the result of prediction for the sample. The adaptive artificial neural networks ensemble method is designed to improve precision of sea clutter predicting, and server sea clutter modeling in HF ground wave radar objects detecting. In order to improve the adaptive ability of the ensemble method and reduce computational complexity, the corresponding active learning algorithm is designed. Result of testing the sea clutter predicting method on practical echo data of HFGWR for objects detecting shows precision of sea clutter predicting and generalization ability can be impoved effectively by the adaptive artificial neural networks ensemble method. [C95]

"Characterizing Sea Clutter and Detecting Targets via Surrogate Test"

The surrogate test has been extensively employed in testing the nonlinear characteristics of time series. In this paper, surrogate tests are applied to the real-life IPIX radar data to detect targets within sea clutter. Surrogate tests show that sea clutter represents nonlinear tendency while the echoes of small targets show linear tendency. With their different physical properties, the small targets are detected reliably from sea clutter. Comparative experiments show that the proposed method is more accurate and robust than the detrended fluctuation analysis. [C96]

"Clutter-knowledge-based target tracking method in complex conditions"

High Frequency Ground Wave Radar (HFGWR) target tracking is a challenging task because of dense false alarms and missed/disturbed measurements caused by strong sea clutter. A clutter-knowledge-based tracking method is presented to cope with multi-target tracking in this kind of complex envionment. Modified initiation

methods based on characterestic anslysis of multiscan asssociation results are proposed to suppress false tracks. Then, the available sea clutter knowledge is exploited to filter tracks and special treatments with algorithm adjustments are executed to preserve tracks may be affected by the first order sea clutter. Simulated and real data are both processed to demonstrate that the presented method can greatly improve the formation and maintenance performance with a little increase of false tracks. [C97]

"Target detection based on correlation and power features in sea clutter"

In this paper, an adaptive filter is presented for sea clutter suppression that is based upon the real-time median estimation of the power spectrum of sea clutter from the echoes of the detected cells and adjacent secondary resolution cells. The ACSF can suppress most sea clutter in a received time series while retaining possible echoes from a target with small distortion. Two features relevant to the correlation and average power of the filtered time series are proposed for target detection. With the real sea clutter data and simulated target echoes, the experiment results show that the proposed ACSF is effective, and the detector provides better detection performance than some existing methods do. [C98]

"Research on the scattering coefficient measurement method based on LFMCW"

This paper researches the scattering coefficient (Г‚Вї0) measurement method based on LFMCW radar. The measurement mechanism of the relative calibration measurement method is introduced. Barrier effect and different window functions' effect on the measurement precision is analyzed by simulation when processing the IF signal of the LFMCW radar digitally. An appropriate window function and the length of FFT is selected according to the requirement of measurement precision of the calibration object. The actual RCS of multiple scatters whose theoretical value is already known is obtained by simulation with the relative calibration method. The simulation results verify the scientificity and efficiency of the measurement method. Finally this method is applied to Г‚Вї0measurement of a crown. [C99]

"A class of Cramer-Rao optimal estimators for analysis of clutter"

Fisher information matrix can be seen as the metric of a Riemannian manifold, Fisher-Rao metric. As such it can be evolved through Ricci flow. For the case of the estimation of two parameters, the two dimensional manifold is also conformal. In this case we show that the Cramer-Rao bound is saturated as a scalar function always exists that is a also a solution of Liouville equation. This implies that in order to have an optimal estimation of parameters one have to solve this equation. This result can be extended in higher dimensions when the Fisher information matrix can be cast into a similar form as for the two-dimensional case and the estimator vector admits a potential field. Applications of this result are wide-ranging going from tracking to control theory and clutter analysis. We present an example for the analysis of sea clutter data. [C100]

"Estimation of radar observability of objects against background of sea clutter"

The method of estimation of radiolocation observability of marine objects and range of operation of radar station on requirement on non-Gaussian noise from sea is offered. The examples of estimation of observability of marine objects of different classes by different condition of the weather and uses of narrowband SMT Doppler system are given. [C101]

"Towards HF metamaterials"

Surface waves are a key point for high frequency radars. Our global objective is to improve or avoid their excitation depending on whether we operate surface wave radars or sky wave radars. This paper deals with suppression of surface wave for high frequency sky wave radar. We aim to develop periodic sub-wavelength structures like metamatrial ones. Indeed, considering HF wavelength, we have the opportunity to build objects with reasonable size and relatively poor accuracy constraints. We present first results of our studies. [C102]

"Statistical analysis of sea clutter spikes"

In this work a set of coherent and polarimetric sea clutter data is analyzed with a special interest for sea-spikes. Using three sea-spikes defining parameters, the spike amplitude, the minimum spike width and the minimum interval between spikes, it is possible to positively identify the spiking events from the background. This work shows a sample of results from a statistical and spectral analysis of a set of sea-spikes selected from the radar returns, focusing on their Doppler properties, the spike duration and the temporal interval between spikes. [C103]

"Performance analysis of the Probabilistic Multi-hypothesis Tracking algorithm on the SEABAR data

sets"

The probabilistic multi-hypothesis tracking (PMHT) algorithm is a batch type multi-target tracking algorithm based on the expectation-maximization (EM) method. Unlike other more popular methods (e.g., multi-hypothesis tracking, MHT) the computational burden of PMHT grows linearly in the size of the batch, the number of clutter detections, and the number of targets tracked. The SEABAR sea tiail was conducted by the NATO Undersea Research Center in 2007 to investigate the suitability of some experimental high gain deployed active sonar receivers for tracking underwater contacts of interest. The sea trial yielded several useful multi-static active sonar data sets. The purpose of the effort reported here is to assess the target tracking performance of PMHT using structured multi-static active sonar sea trial data collected during the SEABAR experiment. This study quantifies the effects of batch size on the ability of PMHT to hold track on constant velocity and maneuvering contacts to determine the values that provide acceptable tracking performance. Situations involving contact maneuvers or temporary loss of detection (a.k.a., drop outs) are of particular interest. Specifically, the ability of PMHT to hold track as a function of batch size for two multi-static active sonar sea trial data sets containing contact maneuvers and drop outs will be assessed. [C104]

"Optimized detection of spatially extended fixed objects in clutter"

Range-spread Doppler-spread signals in interference are readily discernable via the application of classical algorithms and architectures presented by Van Trees [1], and more recently by Kay [2] and others. However, when these returns emanate from stationary objects, the Generalized Inner Product (GIP) offers a unique tool for detection and discrimination processing. This paper offers insight into how the GIP may be applied to optimize the detection of spatially extended fixed objects in clutter. [C105]

"Recursive errors-in-variables approach for ar parameter estimation from noisy observations. Application to radar sea clutter rejection"

AR modeling is used in a wide range of applications from speech processing to Rayleigh fading channel simulation. When the observations are disturbed by an additive white noise, the standard least squares estimation of the AR parameters is biased. Some authors of this paper recently reformulated this problem as an errors-in-variables (EIV) issue and proposed an off-line solution, which outperforms other existing methods. Nevertheless, its computational cost may be high. In this paper, we present a blind recursive EIV method that can be implemented for real-time applications. It has the advantage of converging faster than the noise-compensated LMS based solutions. In addition, unlike EKF or Sigma Point Kalman filter, it does not require a priori knowledge such as the variances of the driving process and the additive noise. The approach is first tested with synthetic data; then, its relevance is illustrated in the field of radar sea clutter rejection. [C106]

"Suppression of anomalous clutter caused by evaporation duct propagation"

Microwave propagation is adversely affected by evaporation duct, which can occur as often as 85% of the time in the sea of the world. Evaporation duct propagation is the abnormal bending and diversion of electromagnetic radiation from the intended paths, that resulting in the problems of extended propagation of microwave signals well beyond the radio horizon, high probability of intercept, measurement errors, radar holes, and anomalous clutter. A kind of anomalous clutter caused by evaporation duct propagation is described through analysis of experimental data collected from an S-band search radar. To suppress the anomalous clutter, a MTI processing with entropy detection is proposed, which utilizes the weak correlation characteristic and the certain position relation between anomalous clutter echoes. Compared with normal MTI processing, it can suppress anomalous clutter effectively and the performance is validated by simulation of the experimental data. [C107]

"Two-dimensional adaptive processing for ionospheric clutter mitigation in High Frequency Surface Wave Radar"

High Frequency Surface Wave Radar (HFSWR) is a technology used for over-the-horizon detection of ocean vessels. This radar exploits the diffraction of electromagnetic waves around the curved surface of the Earth. To minimize the attenuation of the diffracted waves, the radar must operate at frequencies in the lower part of the high frequency (HF) band. However, radar signals at these frequencies also reflect from the Earth's ionosphere, which leads to radar clutter at ranges beyond 200 km. The linear broadside receive arrays used by conventional HFSWR systems cannot filter out this clutter as the arrays do not have any resolving power in elevation angle. Reported here are experimental investigations of the clutter suppression capability of one- and two-dimensional HFSWR adaptive processors. Three configurations are compared: one-dimensional spatial adaptive processing, two-dimensional spatial adaptive processing, and space-time adaptive processing. In all cases the number of adaptive degrees of freedom is 16. It is found that the best results are achieved by two-dimensional spatial adaptive processing, where a processing gain of up to about 20 dB can be achieved. [C108]

"Optimal inference of the inverse Gamma texture for a compound-Gaussian clutter"

We first derive the stochastic dynamics of a Gaussian-compound model with an inverse gamma distributed texture from Jakeman's random walk model with step number fluctuations. Following a similar approach existing for the K-distribution, we show how the scattering cross-section may be inferred from the fluctuations of the scattered field intensity. By discussing the sources of discrepancy arising during this process, we derive an analytical expression for the inference error based on its asymptotic behaviours, together with a condition to minimize it. Simulated data enables verification of our proposed technique. The interest of this strategy is discussed in the context of radar applications. [C109]

"Monte-Carlo Based Estimation Methods for Rapidly-Varying Sea Clutter"

We consider two Monte-Carlo based methods for characterizing the scattering function of rapidly-varying sea clutter. The first method uses multiple particle filtering to estimate the clutter space-time covariance matrix by exploiting the structure of the matrix. This method is then compared to a baseline approach that estimates the clutter covariance matrix based on the Weibull distribution approximation. Both methods are evaluated by formulating a detection problem that simulates a small moving target in heavy sea clutter. [C110]

"Sea Clutter Modeling Improvement and Target Detection by Tsallis Distribution"

Sea clutter is the backscattered returns from a patch of sea surface illuminated by a radar pulse and it's one of difficult domains in radar clutter modeling. A lot of efforts have been made to fit various distributions to the observed amplitude data of sea clutter. However, the fitting of those distributions to real sea clutter data is not good, and using parameters estimated from those distributions is not very effective for detecting targets within sea clutter. This may be due to the fact that sea clutter is highly non-stationary. Tsallis distribution is one of distributions that recommend in recent year for sea clutter modeling. This distribution is obtained by maximizing the Tsallis entropy. The Tsallis entropy is a generalization of the Shanon entropy. In this paper was found two weak points, by accomplished simulation analyses: a) By reason of using small step in parameters estimation, the time of modeling is long. b) By reason of using short segment of clutter data, decrease the target detection accuracy. By using the bigger step in this paper, increase the parameter estimation quickness and by using all sea clutter data and decrease performance, was improving the target detection accuracy. [C111]

"Using complex-valued ICA to efficiently combine radar polarimetric data for target detection"

Target detection in sea clutter is a challenging problem in radar detection, specifically, when the Doppler return of the target and clutter are collocated. Polarization diverse radars provide additional information that enhances target detection. In this paper, we use an effective independent component analysis (ICA) approach, adaptive complex maximization of non-Gaussianity (A-CMN), to efficiently combine polarimetric radar data prior to detection. We show that A-CMN estimates the polarimetric scatter coefficients for the single target in clutter case, thereby providing matched-filter performance without the need for clutter or target models. The detection performance using ICA is evaluated with sea clutter collected with the McMaster IPIX radar off the coast of Canada. We also demonstrates the ability of this approach to adapt to the changing sea clutter conditions using simulation results. [C112]

"Adaptive waveform design in rapidly-varying radar scenes"

We consider a waveform-agile sensing algorithm for designing transmitted waveforms in rapidly-varying radar scenes to improve target detection performance. Specifically, we first track the scattering function of rapidly-varying sea clutter in low signal-to-clutter ratios (SCRs) at each burst by estimating the clutter's space-time covariance matrix. Simultaneously, we schedule the waveform to be transmitted in the next burst by minimizing the sea clutter influence based on the estimated clutter statistics. The effectiveness of our waveform-agile sensing approach is demonstrated by detecting a moving target in heavy sea clutter using configured waveforms, and then comparing the resulting performance to that of detecting the target using fixed-parameter linear frequency-modulated w.aveforms. [C113]

"Research of Small Target Detection within Sea Clutter Based on Chaos"

In this paper, based on the prior knowledge of chaotic character of sea clutter, we discuss a method for detection of small target in sea clutter using neural network as a predictor. Neural network can capture the dynamics of strange attractor generating sea clutter. After the reconstruction of real-life radar data, BP and RBF networks are regularized, and then a set of sample data from real-life data is inputted into the networks to train the neural networks respectively. As a sequence, according the nature of neural networks, these trained

networks could approximate the model of dynamical system responsible for sea clutter. These networks can be used to detect small target within sea clutter as a predictor. [C114]

"Sea clutter power reduction in radar measurement systems by feedforward multilayer perceptrons with medium input data integration rate"

In radio measurement systems, the backscatter from what is not a target, i.e. the clutter, is usually not desired. So, these systems try to incorporate clutter reduction techniques as efficient as possible. In this way, different signal processing techniques can be used. The case of study presented in this paper shows how to reduce the level of sea clutter measurements in a marine radar. Due to linear linear signal processing is not suitable in these cases, nonlinear signal processing is used, which is achieved by neural networks. In this way, 7 cells to evaluate the output of each cell under test of a radar image (medium input integration rate) are selected. The processed radar images show very promising results from a subjective point of view. On the other hand, objective measurements are used to analyzed the system performance. Those measurements are based on the mean square error and the clutter and target powers at the input and output of the proposed clutter reduction system. Minimum and mean clutter reduction power rates of 7 dB and 10 dB are achieved, respectively. [C115]

"Performance of PDAF-based tracking methods in heavy-tailed clutter"

Harbor surveillance above and below the sea surface depends on sensors such as surveillance radar and multibeam sonar. These sensors attempt to detect and track moderately observable targets such as small boats or human divers in environments which often are characterized by heavy-tailed backgrounds. This paper provide simulation results which quantify the inevitable performance loss encountered in heavy-tailed environments. The results show that the performance loss can be reduced by accounting for heavy-tailedness in the detection and tracking processes, and by the utilization of Amplitude Information (AI). Two new amplitude likelihoods developed in a preceding paper come favorably out of this comparison. Furthermore, the evaluation of the Modified Riccati Equation (MRE) is outlined for the combination of AI and heavy-tailed clutter. The MRE can be used to decide the false alarm rate for the detection process preceding target tracking. [C116]

"Target tracking in heavy-tailed clutter using amplitude information"

Harbor surveillance above and below the sea surface depends on sensors such as surveillance radar and multibeam sonar. These sensors attempt to detect and track moderately observable targets such as small boats or human divers in environments which often are characterized by heavy-tailed backgrounds. Target tracking in heavy-tailed environments is challenging even for moderately strong targets due to the more frequent occurrences of target-like outliers. One strategy for increased robustness is to use the backscattered signal strengths together with the kinematic measurements in the tracking method. This paper proposes two new amplitude likelihoods for target tracking in heavy-tailed backgrounds. The first likelihood works by incorporating the uncertainty of the background estimate. The second likelihood explicitly treats the background as heavy-tailed using the K-distribution. [C117]

"CA-CFAR detection in spatially correlated K-distributed sea clutter"

Radar detection of targets in sea clutter modelled by compound K-distribution is examined from a statistical detection viewpoint by Monte Carlo simulations. The detection performance of Cell Averaging Constant False Alarm Rate (CA-CFAR) is compared with the performance of fixed threshold detection. The performance evaluations are quantified by CFAR loss. Curves for CFAR loss to the spatial correlation and spikiness of sea clutter, number of cells of CA-CFAR processor and the number of non-coherently integrated pulses are presented. [C118]

"Location of first-order sea echo for HFSWR with image feature information"

Influenced by ships, ionosphere interference and Bragg peak-splitting, it will be difficult of detecting or tracking HF first-order sea echo (Bragg peak) exactly. A new detection method is proposed which regards image feature of Bragg peaks in multi-scale space as indicative information and combines with global characteristics such as amplitude, symmetry, and continuity etc. Detection rules for both single and splitting Bragg peaks are also given based on characteristics knowledge. Experiment with real data shows that comparing to those classical algorithms the proposed method can detect and locate first-order sea echo more accurately in the environment with ionosphere interference, ships and clutter/noise smearing far from coast. [C119]

"An empirical sea clutter model for low grazing angles"

The most fundamental characteristic of sea clutter, as used in radar performance evaluation, is its apparent

reflectivity defined as sigma0(m2/m2). The word apparent is used here as a reminder that any measurement of sea clutter reflectivity inevitably includes the effects of propagation close to the sea surface. Sea clutter reflectivity depends on many factors including sea state, wind velocity, grazing angle, polarization, and radar frequency. A comprehensive tabulation of measurements from around 60 sources were included in the 1991 edition of Nathanson's book and this probably represents the most complete database of sea clutter reflectivity available. Also included in this book by Nathanson was a detailed description of an empirical sea clutter model proposed by Horst et. al., the so-called Georgia Technical Institute (GTI) model. This model has found widespread acceptance in the radar community although its technical basis may be somewhat vague. As pointed out by Nathanson, his tabulated measured sea clutter data does not agree too well with the GTI model, in particular at low sea states. While this difference qualitatively can be explained by measurement inaccuracies, unknown propagation conditions (such as ducting), and uncertainties in defining the underlying sea state, these discrepancies are at times quite large and may lead to overly optimistic radar performance predictions if the GTI sea clutter model is used. In this paper a new empirical model for sea clutter reflectivity at low grazing angles is developed. The model is defined as a function of radar frequency, polarization, sea-state, and grazing angle. The parameters of the empirical equation have been optimized such that the average absolute dB-deviation between the model and the experimental data tabulated by Nathanson is minimized for grazing angles up to 10 degrees. Subsequently we shall refer to this new model as the NRL sea clutter model. [C120]

"Fractal-based variable step-size least mean square algorithm for radar target detection in sea clutter"

This paper introduces fractal-based variable step-size least mean square(FB-VSLMS) algorithm and proposes a model for radar target detection in sea clutter. FB-VSLMS algorithm deals with a specific class of fractal signals and except one of the step-size parameters requiring time-varying constraints, the constraints on the remaining parameters are time-invariant. And the step-size matrix is determined completely with the knowledge of the deterministic Hurst exponent. The model based on this algorithm is suited for tracking signals from the family of fractal signals that are inherently nonstationary. In the end, the performance of the novel model is analyzed. By the verification of X-band real sea clutter, the model is shown to be effective for point target detection in sea clutter. [C121]

"Time-frequency entropy of Hilbert-Huang transformation for detecting weak target in sea clutter"

In this paper, Hilbert-Huang transformation is adopted for analyzing the sea clutter with the fixed weak target. It's found that the fixed target only affects the low frequency component of the sea clutter. So the time-frequency entropy of the low frequency component is applied for the weak target detection. Compared with another weak target detection method directly using the box dimension, the method proposed in this paper improves the effect of the fixed target on the sea clutter. And the detection performance of the fixed weak target is improved distinctly. [C122]

"Modelling X-band sea clutter with the K-distribution: Shape parameter variation"

Performance modelling techniques for maritime radar target detection problems typically make use of a parametric probability distribution for the background ocean backscatter. In this paper, measured X-band sea clutter is analysed by fitting a K-distribution and the variation of its parameters with radar resolution, polarisation, viewing grazing and azimuth angles and ocean wind and wave conditions is examined. Grazing angles lie in the range 10Г‚В° to 45Г‚В°. Earlier work has already characterised the variation in the mean of the distribution. Here, the shape parameter Г‚Вї is studied. Surprisingly, it is found that Г‚Вї exhibits a sinusoidal like variation with azimuth angle which is aligned with the direction of the wind waves rather than the swell. [C123]

"Comparison of estimation schemes for the K-distribution shape parameter"

Three commonly used estimators together with the maximum likelihood (ML) estimator for the shape parameter of the K-distribution are compared and evaluated. In particular the ML estimation scheme, which provides the most accurate estimate in theory, but which is rarely used in practice, is included and serves as a gage to the other schemes. Distributions of the estimates, as well as other statistical properties, are analysed. Advantages and shortcomings of the different estimators are discussed. [C124]

"Experimental validation of the compound Gaussian sea clutter model at sub-meter range resolution"

Compound models are widely used to describe high resolution radar sea backscatter. In this paper, experimental high resolution sea clutter data is used to assess the validity of the compound Gaussian model for range

resolution of centimeters. Results show that the central limit theorem is still applicable to local sea backscatter at very high range resolutions. [C125]

"Analysis of the KK-distribution with X-band medium grazing angle sea-clutter"

Robust maritime surveillance with radar requires an accurate description of the backscatter from the sea. An estimated probability distribution of the backscatter is commonly used to determine the threshold for separating targets from clutter at a given false alarm rate. Data collected at medium to high grazing angles by the Defence Science Technology Organisation (DSTO) Ingara fully polarimetric X-band radar demonstrates that the commonly used K-distribution is not always adequate for modelling the probability distribution. This is especially the case for the horizontal polarisation and in regions of high backscatter where target detection can be a problem. An alternative proposed as a more accurate model in this region is known as the KK-distribution. The analysis presented in this paper describes this model with the addition of multiple looks and a thermal noise component to produce greater accuracy in the mean and underlying shape. The threshold required to achieve a constant false alarm rate is then studied and compared with that derived from the K-distribution model. [C126]

"Modelling the shape parameter of sea clutter"

The variation of the radar sea clutter K distribution shape parameter with environmental and radar parameters is investigated using recorded data and scattering calculations. The results indicate that improvements to the current empirical model are possible, in particular with regard to its lack of dependence on wind speed and sea state. The extension of the model to littoral environments is also considered. [C127]

"Bi-static and multi-frequency experiments of HFSWR"

High Frequency Surface Wave Radar is currently a well-known surveillance system for the Exclusive Economic Zone. We are still trying to improve their performances and reliability. In this new research step, we are trying to assess the benefits of multi-static as well as multi-frequency configuration. The global ambition is obviously to overcome clutter issue and to increase the coverage for small target. Results presented here highlight the significant contribution of the proposed configuration. [C128]

"Surveying coastal ship traffic with LANDSAT"

A semi-automated algorithm was developed to detect ships in LANDSAT 7 images. The algorithm combines multispectral and pattern recognition methods to discriminate ships from ocean clutter. Automated processing enables us to process a large number of images and gather a statistical picture of ship traffic patterns. As a test case we applied the algorithm on 54 LANDSAT images in the area of Jacksonville, FL, from the period 1999-2003. The area and time period are the same as an earlier ship traffic study by Ward-Geiger et al. using ship reports in the Mandatory Ship Reporting System (MSRS). The similarities between the two studies suggest that LANDSAT is a good alternative for surveying nearshore ship traffic. [C129]

"The effects of reduced bandwidth on HF surface wave radar performance in ship detection"

Bandwidth reduction not only degrades the range resolution of a radar, but may also reduce the maximum detection range. In the clutter-dominated region, the target signal-to-clutter-plus-interference-and-noise power ratio (SCINR) is reduced by the same factor as the bandwidth, but in the external-interference-and-noise-dominated region, the SCINR is unchanged. A dataset from a monostatic pulse HF surface wave radar (HFSWR) operating between 3 and 5 MHz is used to illustrate the effects of a 3-dB bandwidth reduction on the radar performance. The results show that in the detection of large ships, the maximum detection range is essentially unchanged, but in the detection of small ships, the maximum detection range is reduced. [C130]

"A toolbox dedicated to the analysis of airborne SAR sea clutter data"

The characterization of the sea clutter spatial and statistical properties is a challenging problem for improving the detection performances of any radar system confronted with strong sea clutter perturbations. On the one hand, the use of radar scatterometry made it possible to precisely determine the behavior of the sea surface backscattering coefficient and to confirm electromagnetic models. On the other hand, the imaging of the ocean by radar has been studied extensively and has led to a mature theory of synthetic aperture radar (SAR) imaging of the ocean. Nevertheless the manipulations of SAR data are handicapped by the size of data. In order to analyze SAR data, we need a very flexible tool well adapted to these data. This paper briefly presents the inner functioning of a software (i.e. the different choices of class organization and how it is convenient to use them) based on a multilook philosophy (spectral sub bands processing) and on Octave script. Then we specify the type of operations and processings, we can perform using this software. Two examples of use are presented which

show the easiness of use of this software. [C131]

"Adaptive signal processing techniques for clutter removal in radar-based navigation systems"

The problem of background clutter remains as a major challenge in radar-based navigation, particularly due to its time-varying statistical properties. Adaptive solutions for clutter removal are therefore sought which meet the demanding convergence and accuracy requirements of the navigation application. In this paper, a new structure which combines blind source separation (BSS) and adaptive interference cancellation (AIC) is proposed to solve the problem more accurately without prior statistical knowledge of the sea clutter. The new algorithms are confirmed to outperform previously proposed adaptive schemes for such processing through simulation studies. [C132]

"GRADAR: A radar propagation modelling tool for frequencies from VHF to microwave"

Effective radar modeling requires consideration of the propagation effects of both surface topography and the atmosphere. This paper describes a propagation modeling tool that was developed to handle such effects. The tool is based on a Kirhhoff integral approach and the paper includes several examples that illustrate its capability. In particular, the paper shows that the approach can be very effective in the littoral environment. [C133]

"Ship detection with adaptive parameter based on detection background analysis"

Contaminated with various clutter, such as sea clutter, ionospheric interference, earth echoes, in HF surface wave radar (HFSWR), detection background seldom follows a uniform probability distribution. The ideal suppositions by the classical detection algorithms limit the detection performance of the operational system. Thus this paper proposes a new detection architecture which can classify and identify the detection background in real time to improve the detection performance. Firstly, the detection background is classified into five parts with a criterion based on the results of background region segmentation. Then, using the statistical analysis of the classified detection background, a detection method with adaptive parameters is proposed which can select the proper background distribution parameters based on the type of the reference cells. Finally, real data are used for verifying the advantages of the proposed method comparing with three detection algorithms for HF radar introduced in literature recently. [C134]

"OFDM MIMO radar for low-grazing angle tracking"

We develop a low-grazing angle (LGA) tracking method considering realistic physical and statistical effects, such as earth's curvature, vertical refractivity gradient of standard lower atmosphere, and non-Gaussian characteristics of sea-clutter. We employ a co-located multiple-input-multiple-output (MIMO) radar configuration using wideband orthogonal frequency division multiplexing (OFDM) signalling scheme. Apart from the frequency diversity provided by OFDM, we also exploit polarization to resolve the multipath signals by using polarization-sensitive transceivers. Thus, we can track the scattering coefficients of the target at different frequencies along with its position and velocity. We apply a sequential Monte Carlo method (particle filter) to track the target. Our numerical examples demonstrate the achieved performance improvements due to realistic physical modeling and OFDM MIMO configuration. [C135]

"Low-observable target detection in sea clutter based on fractal-based variable step-size least mean square algorithm"

This paper introduces fractal-based variable step-size least mean square(FB-VSLMS) algorithm and proposes a model for radar target detection in sea clutter. FB-VSLMS algorithm deals with a specific class of fractal signals and except one parameter requiring time-varying constraints, the constraints on the remaining parameters are time-invariant. And the step-size matrix is determined completely with the knowledge of the deterministic Hurst exponent. The model based on this algorithm is suited for tracking signals from the family of fractal signals that are inherently nonstationary. In the end, the performance of the novel model is analyzed. By the verification of X-band real sea clutter, the model is shown to be effective for low-observable point target detection in sea clutter. [C136]

"A real-time RFC system for radar coverage prediction"

This paper introduces a real-time Г‚Вїrefractivity from clutterГ‚Вї RFC system. Its aim is to predict the radar coverage by the inversion of the sea clutter in open sea. The method introduced here renders a real-time approximation of the refractive conditions with respect to the distance and the azimuth angles visible from the radar. Using this system, the radar coverage can be modeled in real-time on all the azimuths taking into account the refractive conditions. The inverted refractive conditions are an approximation of the real conditions. This

system has been tested and validated on data from the Wallops '98 measurement campaign. This paper shows the effect of the azimuthal variation of the refractive conditions on the radar coverage and how the developed system renders a result coherent with the azimuth. [C137]

"Study of the modeling of radar sea clutter using the KA distribution and methods for estimating its parameters"

Effective threshold signal detection in airborne radar systems operating above sea requires an accurate and tractable statistical modeling of the scattered returns from the sea surface, namely the sea clutter. When high resolution radars operate at small grazing angles, the statistics of the signal-generated clutter are highly non-Gaussian. When this is not taken into account, it leads to poor signal detection performance. This paper emphasises on the statistical description of the sea clutter using the KA distribution. The description includes the ambiant noise as well as the effect of the wave surface structure. The KA distribution lies on an appropriate combination of the Class A model, established by Middleton, and the description of the wave structure through the Gamma distribution. The use of the KA distribution as an accurate and tractable model for the scattered returns from the sea surface, embedded in the ambiant noise, has been established in an article by Middleton and in another one by Ward. However, the probability distributions of the two articles exhibit some differences on which the first issue of this paper is to shed light. The second issue of this paper is to illustrate that the KA distribution of Middleton, as it is now distinguished from Ward's, shows an excellent agreement with real experiments. This is done using airborne radar records in rough sea conditions. To estimate the distribution's parameters, an optimization algorithm is used as suggested in. An additional result is the derivation of the even moments of Ward's KA distribution. This result is given in the appendix because it is needed for the comparison of the KA distributions. [C138]

"Combining modern spectral estimation with Time-Frequency representation"

With Joint Time-Frequency Analysis (JTFA), one can estimate the speed of moving targets from Synthetic Aperture Radar (SAR) images. These targets are usually compact. JTFA estimation of water surface speeds is more difficult since the radar returns are weak and generated by Bragg scattering patches, randomly distributed within the radar's footprint, both in time and space. To increase the signal strength, JTFA is applied to multiple range lines, which requires a generalization of the Time-Frequency representation (TFR). To do this, modern spectral estimation (MSE) techniques, which depend on estimating the data covariance matrix, are weaved into the framework of a TFR. The resulting TFR formed along azimuth-lines naturally integrates the data across multiple range-lines. We discuss and illustrate this technique on simulated data and then apply it to estimate the speed of moving water in a single-phase center SAR image. This method also enhances the signal-to-clutter ratio (SCR). [C139]

"Sea Spikes Suppression for high range and high Doppler resolution radars"

High resolution in range and Doppler are recommended to border surveillance X-band radars for the detection of small RCS ground targets in a severe clutter environment. This kind of radars can also be employed for sea border control. However, in this case the radar processor should suppress the sea spike echoes that can be otherwise mistaken with small boats. In this paper a solution for mitigating the problem connected with sea spikes is proposed. A 2D CFAR that uses the information from both the range and Doppler characteristics of the echoes is presented. The performance of this algorithm is compared with the one of a classical CFAR which can instead be efficiently employed in a ground environment. [C140]

"Improving sea states monitoring of nautical radar using dispersion relation of nonlinear ocean waves"

The purpose of this study is to discuss the influence of nonlinearity upon X-band radar observations. For simplicity, the analytical dispersion relationship of finite amplitude ocean wave theory was applied and discussed. We found that the shallow water dispersion relation curve covers more ocean wave energy than deep water and linear dispersion relationship. However, the shallow water dispersion relationship filter can not derive the ocean spectrum from radar image spectrum. The accurate measurement of ocean wave amplitude and water depth may be contributed to the results. More data are needed to analyze the reasons. [C141]

"Clutter processing for digital radars based on FPGA and DSP"

Clutter processing is a key link for vessel traffic services. According to the shortcomings of traditional analog video system, this paper proposes a design solution for digital radar signal processing system based on FPGA and DSP and studies both related preprocessing method and constant false alarm rate algorithm based on

wavelet transform. This method can suppress the interference of sea clutter without impairing the target resolution. Experimental results demonstrate this design can decrease the false alarm rate, increase the detection accuracy and improve the tracking performance. Thus, signal processing system based on FPGA and DSP plays an important role in the vessel traffic services. [C142]

"A novel method for ship detection in polarimetric SAR images using gopce"

In this paper, a novel method for ship detection in fully polarimetric SAR images is developed. This method employs the Generalized Optimization of Polarimetric Contrast Enhancement (GOPCE) to maximize the target-to-clutter ratio in an image. For comparison, the traditional OPCE, Polarimetric Matched Filter (PMF) and Polarimetric Whitening Filter (PWF) are also used. Experiments results of the NASA/JPL AIRSAR C-Band image over Sydney Coast show that the proposed method has a considerably improvement as to enlarge the separation of ships and sea clutter, demonstrating a robust detection performance. [C143]

"A fast algorithm based on two-stage CFAR for detecting ships in SAR images"

Ship detection is an important application of SAR imagery in ocean surveillance. After analyzing the statistical characters of sea clutter, a fast algorithm of ship detection in SAR image is proposed in this paper. The method consists of two CFAR detection stages. The first step utilizes a lognormal based CFAR to sort out the potential target pixels at a high false alarm rate; in the second step, these potential targets are refined under a local process of K distribution based adaptive CFAR detection. Space-born SAR images are used to validate this fast detection algorithm, and results show great improvement on efficiency of the proposed method without decreasing detection performance. The fast algorithm satisfies application demands of ship detection in SAR images. [C144]

"The Chaotic Neural Network is Used to Predict the Sea Clutter Signal"

The study includes the correlation dimension and the largest Lyapunov exponent of sea clutter based on real radar data obtained with IPIX X-band polarimetric coherent radar, which proved that sea clutter has chaotic characteristics. A method of prediction about sea clutter signal based on chaotic neural network and theory of phase-space reconstruction is established, which has a in-depth analysis of the chaotic neural network and modulates the network parameters to improve the convergence rate of the network. The numerical results of prediction model demonstrate that chaotic neural network is better than traditional methods. [C145]

"Range-Doppler measurements based target locating for active radar seekers"

This paper focuses on the estimation of the missile-target relative position using range-Doppler measurements. Firstly, we analyze the observability of the relative position for different trajectories in depth, and arrive at a very interesting conclusion: the missile must have the acceleration component `not aiming at target' to obtain the 3-D relative position of the target. Secondly, the relative position estimation methods, using measurement series, is presented. Through the computation of Cramer-Rao Lower Bound, we can see the effects on the location errors of the observation series length, the initial missile-target range, the cross-range and radial velocity of the missile, and the cross-range acceleration of the missile, respectively. [C146]

"Applicability of sea clutter models in nonequilibrium sea conditions"

This paper presents the comparative analysis between the sea clutter models and the recorded data to evaluate the limitations of the models. The availability and applicability of these models in nonequilibrium sea conditions are discussed. The results show that these models underestimate sea clutter scattering coefficient in upwind and downwind conditions. In the strongly local crosswind conditions, the TSC model can obtain good match results by inputting separately parameters of wind speed and wave height instead of sea state number. [C147]

"Analysis of sea clutter in distributed shipborne OTH radar"

In distributed shipborne high frequency (HF) surface wave over-the-horizon radar (DS-OTHR) system, the movement of radar can make the system more complex. In this paper, we analyze the geometrical change of the distributed shipborne system with the T-Rnmechanism and its effect to the echoes of target and sea. Then we discuss the method to get the range and velocity of target in this dynamic system, make a detailed analysis on the broadening spectrum of first-order sea clutter. Moreover, we study the space-time distribution characteristics of first-order sea clutter and research the azimuth difference of the target and sea clutter with the same Doppler frequency. Finally, simulation proves the correctness of the analysis of the first-order sea clutter in this system. [C148]

"Fuzzy fractal algorithm for low-observable target detection within sea clutter"

In this paper fuzzy fractal algorithm for discrete signal processing is introduced. The two major concepts of the algorithm are fuzzy fractal dimension and grade of fractality, which merge fuzzy theory and fractal theory. The fuzzy concept of fractality in discrete time series can be reconstructed as a kind of fuzzy set and the objective short time series can be used by a new membership function. In order to process long time series, sliding measurement is adopted. In the end, the local grade of fractality is applied to X-band real sea clutter and the performance of the detection algorithm is analyzed. [C149]

"Chaos-based target detection from sea clutter"

The feasibility of applying chaotic features to the maritime target detection is studied in this paper. Experimental results on measured IPIX data shows that embedding dimension, box dimension and correlation dimension, which are not sensitive to the sea state, can reflect the difference between targets and clutter effectively. Such characteristics provide a new idea for further research in obtaining robust maritime target detector. [C150]

"Retrieving surface-based duct parameters from radar sea clutter using a particle swarm optimization approach"

This paper describes a technique to retrieve, from radar sea clutter, parameters defining a surface-based duct using a simple improved PSO approach. The whole PSO optimization procedure is divided into two steps. Firstly, all four parameters are optimized using a standard PSO. Secondly, three of them are fixed and only the last one is optimized to maximum iterations using a standard PSO. And a model of radar cross section different from that used in previous papers is introduced. Simulation results show that PSO gets a better performance than GA method, where the results are obtained from 200 Monte Carlo simulations. [C151]

"Characteristic study of ionospheric clutter in high-frequency over the horizon surface wave radar"

The presence of ionospheric clutter in high-frequency over the horizon surface wave radar may extremely affect the performance of radar system and degrade the capability of detecting target. The characteristic analysis of ionospheric clutter is the foundation of studying method to suppress ionospheric clutter. By using the MUSIC algorithm to analyze plentiful radar echoes data, directivity characteristic of several major kinds of ionospheric clutter has been summarized and the superposition situation that two kinds of ionospheric clutter exist at the same altitude has been discussed, moreover, the pertinence between directivity characteristic of ionospheric clutter and the working frequency has been studied. All these works provide convenience for advancing and realizing ionospheric clutter suppression methods based on directivity characteristic of ionospheric clutter. [C152]

"Airborne radar depth sounding of fast flowing glaciers"

Sea-level rise will affect populations worldwide with considerable and lasting consequences in the not-too-distant future. Accurate measurement of fast flowing outlet glaciers in Greenland and Antarctica are of vital importance to ice sheet models that predict the course of sea-level rise. The Center for the Remote Sensing of Ice Sheets (CReSIS) has developed a suite of tools designed for use with data collected by CReSIS depth sounding radar platforms. This suite includes algorithms for removing clutter and noise from coherent radar data, and the results show successful sounding of some of these fast-flowing glaciers for the first time. [C153]

"Ship detection from polarimetric sar images"

SAR image from sea can constantly contain ships and their ambiguities in azimuth and range directions. For maritime applications, the ambiguities are visible due to their strong intensities in a low backscattering background of sea environment. Thus, the ambiguities can be often mistaken as ships and cause false alarms. Many approaches have been proposed for reducing the azimuth ambiguities in single channel SAR image. This paper analyzed scattering mechanisms of the azimuth ambiguities for PolSAR images and proposed a method for detecting ships from PolSAR images. By using eigenvector-eigenvalue decomposition, three eigenvalues can be used to differentiate ship targets, azimuth ambiguities and sea clutter. One C-band JPL AIRSAR polarimetric data have been chosen to evaluate the method. The experimental results show that the proposed method can effectively reduce false alarms caused by the azimuth ambiguities. [C154]

"Swell influence on ocean surface roughness and radar scattering from the ocean surface"

Swell effects of surface roughness spectral properties, including their wind speed dependence and modification of components characterizing Bragg resonance and surface tilting in radar application, are investigated. Computations of radar cross sections are performed with four different spectral models with various degrees of

swell consideration. Swell impact on the resulting radar return is illustrated. [C155]

"Velocity estimation of moving targets on the sea surface by azimuth differentials of simulated-SAR image"

Since the change in Doppler centroid according to moving targets brings alteration to the phase in azimuth differential signals, one can measure the velocity of the moving targets using this. In this study, we will investigate theoretically measuring velocity of an object from azimuth differential signals by using range compressed data which is the interim outcome of treatment from the simulated Synthetic Aperture Radar (SAR) Raw data of moving targets considering sea clutter. Also, it will provide evaluation for the elements that affect the estimation error of velocity from a single SAR sensor. In the concrete, by making RADARSAT-1 simulated image, the research includes comparisons for the means of velocity measurement classified by directions of movement as in the four following cases. 1. A case in which the object that becomes the target exists independently, 2. When there is a tidal current of 1 m/s, 3. When there exists moving targets of different velocity on the azimuth, 4. When the target is contiguous to the land where it has high back scatter factor. As a result, when the object, which becomes the target, independently exists on SAR image in the range of 128 pixels, the velocity of object could be measured with high accuracy. However, when there existed other moving targets in the range of 128 pixels or when the target was contiguous to the land of high back scatter factor, the velocity was in error by 10% at the maximum. This is because in the process of assuming the target's location, an error occurred due to the disturbed signals affected by the scatterers. [C156]

"Advances in unsupervised ship detection with multiscale techniques"

This paper constitutes an example of analysis proving that new satellite borne full polSAR data is favorable for automatic ship detection purposes. In particular, this paper is based on a multiscale method for automatic ship enhancement based on the wavelet transform on single channel data and it proposes its extension to full polSAR images. Then, the enhancement of contrast of the ships with respect to the background sea reached with the method proposed is compared to that obtained by the classical polarization entropy. [C157]

"Sea-clutter analysis at multiple wavelengths (L, C, X) for target-clutter contrast assessment in littoral waters"

This study is aimed at quantifying the statistics and nature of sea-clutter as seen from spaceborne platforms and assessing the target-clutter contrast in the Adelaide harbor area of South Australia. To this end a series of images in mixture of polarizations were collected over this area in typical wide area surveillance mode-ScanSAR single polarization images from TerraSAR-X, Dual-Polarization Wide Beam images from RadarSAT-2 and Full and Dual Polarization images from ALOS-PALSAR. Synchronized with the acquisitions (dawn/dusk orbit of SAR satellites) video over flights with a low light camera were performed to record the sea-state. AIS data was collected for the information on the larges vessels and meteorological buoy readings for surface wind, wave height and swell were noted. [C158]

"Oil slick spot detection using K-distribution model of the sea background"

A new method is proposed to get the segmentation threshold and detect the dark spot in oil-spill images. The method is inspired from the Γ,Bï-distribution model of sea background, which is widely accepted to describe the ocean clutter. By comparing the histograms of oil-spill region and the sea background, it is found that the oil slicks break the Γ,Bï-distribution model, but there is still some information unchanged-the relative probability ratios among the pixel values in 95%~99% CDF extent, which is used to deduce the original Γ,Bï-distribution model. Finally, the intersection of the original histogram of the oil spill image and the deduced sea background PDF is selected to be the threshold. Experiment in RADARSAT-2 image shows the effectiveness of the method. [C159]

"Target Detection Based on Sea Clutter Model Using Neural Network"

A novel method to detect small target embedded in sea clutter is presented for high frequency (HF) radar. The method is rooted in different characters between instantaneous radial velocity of sea current and moving target, and relies on the neural network for its implementation. By estimating the instantaneous velocity of sea current and target, we find that a spatial nonlinear model rather than deterministic chaos model is more appropriate to describe the relationship among radial velocities of neighbor sea areas. Then we built a neural network model to approach to a predictor for sea clutter. So an incoming target will be detected for its more predicted error than a certain threshold. The method performs well on ocean echo data acquired by the HF radar system OSMAR2003. [C160]

"Detection of ship wakes in SAR images based on Radon transform"

The Radon transform is widely used to detect ship wakes in synthetic aperture radar (SAR) images. Ship wakes have linear features in the image, and correspond to peaks and troughs in the Radon transform. Therefore, the ship wakes can be detected by searching for peaks and troughs in the Radon transform. In this paper, a novel algorithm based on the Radon transform is presented to detect ship wakes in SAR images. Considering the variation of the sea clutter, this algorithm uses a locally-adaptive method to search for peaks and troughs in the Radon transform. In addition, a maximum directional-derivative method is used to locate the starting points of the detected ship wakes. The algorithm is tested on real SAR images, and the results demonstrate its effectiveness. [C161]

"A wavelet smoothing CFAR processor"

Characteristics of airborne high grazing angle high resolution X-band sea clutter, collected by the DSTOpsilas Ingara system, are presented. Upper and lower boundary distributions of multi-look K-distributed data are discussed. A wavelet smoothing (WS) technique is proposed for estimating the local mean. Unlike other constant false-alarm rate (CFAR) schemes, such as cell-average (CA) and its variants, which inherently produce CFAR loss, the proposed WS-CFAR scheme is always able to generate CFAR gains, even for uncorrelated data. When tested with the correlated sea clutter, WS-CFAR outperforms CA-CFAR and provides CFAR gains of 1 to 3 dB at the false-alarm rate of 10-4to 10-5. [C162]

"Sea target detection using passive DVB-T based radar"

This paper presents a new approach to passively detect targets using noise-like emitters of opportunity. This method combines Wiener filtering to improve clutter rejection and an adapted direct data domain (D3) method. This theoretical approach is confirmed by the detection of a boat by a bistatic radar using a digital video broadcasting terrestrial (DVB-T) transmitter. [C163]

"Coherent scattering from distributed targets"

Based on the formulation for coherent backscattering from distributed targets previously published by the first author, this paper presents a unified formalism for incorporating the small amplitude, the small slope, the physical optics as well as a ldquotwo-scale modelrdquo approximation into analyses of backscattering by irregular air-dielectric interfaces. The distinguishing feature of this approach is that it takes explicit account of the antenna radiation properties and provides a direct means of numerically assessing the effects of spatial coherence of the surface irregularities on the receiver response. In particular, this leads to a generalization of the normalized backscattering cross-section which becomes dependent on both the antenna radiation properties and surface scattering characteristics. Numerical results obtained under the small amplitude approximation show that spatial coherence of the surface irregularities can lead to significant deviations from the classical Bragg scattering formula. [C164]

"Empirical Study on Ultra-Wideband Vehicle Radar"

High range-resolution radar using ultra wideband radio attracts considerable attention as a short range automotive radar. Radar echo from a target often contains unwanted echoes called as clutter, which make it difficult to detect the target. In order to suppress the clutter, therefore, it is important to investigate the clutter distribution and to develop the clutter model. In this paper, traffic road clutter is measured and characterized for various bandwidths from 10 MHz to 5 GHz. It is also quantitatively compared with the model of log-normal, Weibull and log-Weibull. [C165]

"HAF-based spectral analysis of first-order sea clutter in bistatic shipborne surface wave radar"

Doppler frequency shifts of sea echoes in bistatic shipborne surface wave radar (BS-SWR) are simultaneously modulated by the velocity components projected from the motion of both platforms, and therefore the Doppler spectrum is much more complex than its counterparts in monostatic mode. In this paper, based on the dynamic geometric relationship among bistatic platforms and first-order sea clutter interferences, we claim that there exist dynamic Doppler-broadening components due to the unavoidably different motion of bistatic platforms. Then based on the built signal model of sea echoes only containing the first-order components, we analyze the time-varying characteristic via the high-order ambiguity function (HAF) method in both first- and second-order spectrum. By simulation results, finally, not only the above analysis is demonstrated, but also the difference are shown before and after attenuating the first-order sea clutter via an existing time-space cascaded filtering algorithm in both Doppler and acceleration domain, respectively. [C166]

"Long memory models for the analysis and simulation of multi-channel airborne radar measurement (MCARM) data"

The performance of STAP algorithms are usually evaluated using both simulated and measured airborne radar data. Data simulation allows the effectiveness of STAP methods to be estimated on larger data sets which normally rely on an assumption of spatial homogeneity and temporal stationarity. Further, synthetic data corresponding to particular radar or terrain characteristics that contribute to degrade STAP performance (e.g. internal clutter motion (ICM), antenna array misalignment and channel mismatch) can be easily generated. Simulated clutter space-time snapshots usually rely on an assumption of identical distribution and statistical independency (IID). The aim of this paper is to analyze multi-channel airborne radar measurement (MCARM) data in order to estimate the spatial correlation of space-time snapshots in real clutter environments. Our experimental results show that clutter measured space-time steering vectors exhibit long-range dependence (LRD) characteristics. The final goal of this work is to define a reliable LRD model for strong correlated clutter space-time snapshots. An accurate characterization of clutter in multi-channel airborne/spaceborne radar data is important, because it can lead to the development of STAP algorithms with improved performance. The presented method demonstrates reliable results when applied to MCARM data files including either spatially homogeneous or nonhomogeneous clutter. [C167]

"Multipath spread-Doppler clutter mitigation for over-the-horizon radar"

This paper discusses two adaptive spatial processing approaches that have been recently proposed for mitigating spread-Doppler clutter in skywave over-the-horizon (OTH) radar. The first is slow-time MIMO (SLO-MO) STAP which uses conventional waveforms that are phase-coded so as to be orthogonal after Doppler processing at the receiver, i.e. in ldquoslow-time.rdquo SLO-MO STAP is proposed as a means of mitigating transmit array sidelobes without costly redesign of legacy transmit or receive OTH radar hardware. The second approach is wavefront adaptive sensing (WAS) which uses a horizontally stratified ionospheric model to motivate a new application of blind source separation (BSS) methods for discriminating targets of interest from spatially distributed Doppler spread clutter. Comparison of these two approaches suggests they each may offer significant performance gains under different ionospheric propagation conditions. [C168]

"Some preliminary experiments with distribution-independent EVT-CFAR based on recorded radar data"

The statistics of the radar clutter are often characterized by heavy-tailed distributions. Usually in CFAR design it is assumed that the clutter distribution belongs to some parameterized class of probability distributions. Contrary to that, according to the extreme value theory (EVT), the tail distribution of virtually any distribution can be uniquely modeled by the generalized Pareto distribution. Based on this property it is possible to approximate the tail of the radar clutter distribution and design a CFAR detector that would be distribution-independent. The parameters of the generalized Pareto distribution can be efficiently estimated using the method of L-moments. In this paper, the performance of the EVT-CFAR is compared to that of conventional cell-averaging CA-CFAR for recorded radar data with Gaussian quadrature clutter components and artificial K-distributed clutter intensity. [C169]

"Radar sea clutter suppression and target detection with α-β-γ filter"

Sea clutter refers to the radar returns from a patch of ocean surface. When a radar detects targets on or above the sea surface, it has to overcome the interference from sea echo itself. Sea clutter presents obviously non-Gaussian, non-stationary for many diverse factors, such as radar polarization mode, working frequency, antenna visual angle, sea state and wind direction, which limit the detection capability of radar. In this paper, we elaborate the production mechanism of sea clutter in detail and propose a new alpha-beta-gamma filter to suppress sea clutter and detect targets. In addition, the performance analysis and parameter choosing standard are given and the algorithm is proved to be effective with real data. [C170]

"Radar: Reflections and speculations"

This paper discusses three diverse topics in radar that have little relationship to one another, other than they represent what might be interesting for further exploration. These topics are: (1) a suggested origin for microwave sea echo (something not currently understood), (2) a different type of phased array radar architecture based on digital beamforming that can overcome a serious weakness of current multifunction phased array systems, and (3) recognition that the electromagnetic spectrum available for radar might be considerably reduced by the insistent demands of non-radar users of the spectrum. None of these can be said to be completed studies at present. [C171]

"Impact of measurement model mismatch on nonlinear Track-Before-Detect performance"

The sensitivity of track before detect processing to the choice of clutter model in the measurement correction stage was examined through processing of real and simulated data containing radar echo returns of a small maritime target in sea clutter. The potential for achieving significant detection performance improvements by utilizing K and KA distributed clutter models in place of the simpler Rayleigh distribution was demonstrated through analysis of simulated data representing spiky sea clutter. In contrast, additional analysis using real data revealed that a more accurate clutter model does not imply better performance. Specifically, significantly degraded performance is observed when K and KA based processing is used in place of a Rayleigh based processor utilizing a simple likelihood limiting step to compensate for model mismatches due to sea clutter spikes. [C172]

"Inverse methods for Refractivity From Clutter"

Predicting the radar coverage in low troposphere is a critical problem for detection of the low above sea flying or floating targets. To predict the radar coverage, the electromagnetic wave propagation can be modeled using parabolic wave equation resolution methods, but a description of the refractive index of the medium is required. Refractivity from clutter is a method to obtain this refractive index from the backscattered power received by the shipborne radar. An advantage of the method is that it does not require additional equipment. This paper presents a comparison of four inversion methods, whose two recent, in the refractivity from clutter purpose on ideal simulated data and shows the feasibility of a system using inversion methods based on pre-generated databases. [C173]

"Non-stationary sea clutter: Impact on disturbance covariance matrix estimate and detector CFAR"

In this paper we present an analysis of sea clutter non-stationarity with respect to clutter covariance matrix estimation and its impact on the constant false alarm rate (CFAR) property of the normalized adaptive matched filter (NAMF). Three estimators have been considered in the analysis, the sample covariance matrix (SCM), the normalized sample covariance matrix (NSCM), and the fixed point (PF) estimators. The impact of non-stationarity, that emerges in the statistical analysis of the clutter data, is measured in terms of differences between NAMF nominal probability of false alarm (PFA) and probability of detection (PD) and quantified by processing measured clutter data recorded by the X-band IPIX radar. [C174]

"Analysis of the sea clutter structure using temporal sequences of X-band marine radar images"

This work analyses the spectral structure of the sea clutter obtained from temporal sequences of radar images of the sea surface. The images were acquired by ordinary marine radars, which work in X-band and horizontal polarization. The study analyses the different contributions to the sea clutter spectrum due to those phenomena, such as ocean waves, speckle due to sea surface roughness, etc. that causes the final clutter image in the radar screen. [C175]

"Adaptive selection of HF radar operating channels"

The high frequency (HF) band load information processing technique is proposed in order to select HF radar operating broadband channels in permanently tangle electromagnetic environment and to estimate their efficiency in the presence of sea clutter. [C176]

"adaptive mitigation of spread clutter in high frequency surface-wave Radar"

High frequency surface-wave (HFSW) radars are cost-effective systems for maritime surveillance and sea-state mapping of ocean areas in the Exclusive Economic Zone (EEZ). The effective mitigation of disturbances, either from interference sources or unwanted radar echoes scattered from the ionosphere, is fundamental to ensure the successful operation of such systems. This paper addresses the mitigation of ldquoionospheric clutterrdquo spread in delay (i.e. range) and Doppler frequency by adaptive spatial filtering for the problem of target detection in surveillance applications. An alternative adaptive processing method that jointly exploits the spatial and temporal information of range-gated signals, over receivers and pulses, is proposed and applied to experimental data from an Australian HFSW radar. Target detection performance is compared against conventional and standard adaptive beamforming techniques. The author thanks the High Frequency Radar Branch of the Defence Science and Technology Organization (DSTO), Australia, for supporting this work and making the experimental data available. [C177]

"Refractivity from sea clutter applied on VAMPIRA and Wallops' 98 data"

For coastal and ship-borne survey radars, coverage prediction is a critical question. In sea environment, the spatial variations in temperature conditions involve refractive index gradients and create atmospheric ducts. These events modify the radar coverage in the lower troposphere. A means to retrieve the refractive index gradients in the low troposphere is to use the Refractivity From Clutter (RFC). The principle of RFC is to compute the propagation factor from the radar received power, thus to process it in order to retrieve the refractive index profiles. In this paper, the RFC is applied on data obtained from VAMPIRA and Wallopspsila98 measurement campaigns. Since refractive index quickly varies, fast inversion methods based on a pre-generated database of propagation factors are used. [C178]

"Modelling X-band sea clutter at moderate grazing angles."

This document reports on work undertaken at DSTO towards modelling the mean ocean backscatter coefficient at low to medium grazing angles for X-band radar. The particular range of angles used lies within the so-called plateau region where Bragg scattering dominates. The motivation for the work is to consider future maritime radar surveillance from high altitude airborne platforms. The requirement is for a model which takes account of radar polarisation, imaging geometry and ocean surface conditions. In order to assess modelling performance, a comprehensive set of ocean backscatter data was collected using Ingara (DSTOpsilas airborne multi-mode radar system.) Several candidate backscatter models were assessed against this data set and found to be unsuitable. Consequently, a new empirical model was developed which provides a significantly better fit to the measured data than the existing models. This paper reports on the measured data, the creation of the new model and the comparison against the existing models. [C179]

"Small-target detection in sea clutter based on the Radon Transform"

Small target detection in sea clutter is a challenging problem. This paper presents a novel and heuristic approach based on the application of the Radon Transform to a set of consecutive range profiles. The performance of the detection technique has been tested with real sea clutter data, acquired with a high resolution CWLFM (continuous wave linear frequency modulated) millimetre-wave radar demonstrator. Results show that performing the detection on the Radon domain makes the detection of very small targets possible while keeping the false alarm rate controlled. [C180]

"Low power High Frequency Surface Wave Radar application for ship detection and tracking"

High-frequency (HF) radars are operated in the 3-30 MHz frequency band and are known to cover ranges up to some thousand kilometers. Sky wave over-the-horizon radars (OTHR) utilize reflection by the ionosphere, but they require a transmit power up to 100 kilowatts. Especially for oceanographic applications, low power high frequency surface wave radar (HFSWR) systems have been developed, which use ground wave propagation along the salty ocean surface. The WERA HF radar system transmits a power as low as 30 watts, but achieves detection ranges up to 200 kilometers, which are far beyond the conventional microwave radar coverage. Due to external noise, radio frequency interference, and different kinds of clutter, special techniques for target detection have to be applied. This paper describes a new signal processing approach based on a curvilinear regression analysis for thresholding combined with a constant false-alarm-rate (CFAR) algorithm for detection. The target locations detected by the HF radar are passed to a tracking filter utilizing range, azimuth, as well as radial and azimuthal velocities to track the ship locations. For a 12-hour period real HF radar data from the WERA system were processed and secondary ship locations were recorded from the automatic identification system (AIS). This data set is used to assess the performance of the HF radar detections. Comparisons have been made for a maximum distance of 5 km between AIS and radar detected locations. The deviation between AIS and radar detected locations was below 1 kilometer in 77% of these comparisons. A number of ships was detected and tracked by the radar, but could not be used for comparisons due to the lack of AIS information. [C181]

"Maritime UWB forward scattering radar network: Initial study"

A scenario for an ultra-wideband (UWB) forward scattering radar (FSR) network for detection of low radar cross section (RCS) maritime surface targets is suggested. A chain of buoys equipped with transceivers which forms a FSR for target detection is considered. In this paper, the first stage of the study is described and major aspects of future work are discussed. It was shown that the high level of surface clutters related to FSR might be reduced by utilisation of UWB technology. As a preliminary further investigation, a numerical simulation of the 3-D RCS for comprehensive models of small maritime targets is obtained and comparisons with simplified target models are made. [C182]

"Statistical measures of S-band sea clutter and targets"

We conducted a low grazing angle S-band sea clutter trial in November 2006 on the Kangaroo Island of South

Australia using a quad-polarised S-band radar developed by DSTO. This paper reports some statistical measures of S-band sea clutter, including range profiles, sea clutter coefficients, temporal and spatial correlation and distribution properties, and as well as Doppler spectra for both the HH and VV sea clutter. Strong and weak target signals are also analysed and classified into Swerling models accordingly. Differences between the HH and VV sea clutter as well as target signals are shown. [C183]

"Aspect dependence of the polarimetric characteristics of sea clutter: II. Variation with azimuth angle"

The dependence of the spatial, temporal, Doppler and polarization characteristics of monostatic microwave radar sea clutter on the direction of observation relative to the prevailing sea direction has been the subject of many investigations. In most instances, though, the data and interpretation have focussed on the upwind/downwind and cross-wind directions, rather than exploring the detailed azimuthal variation. Such a policy certainly establishes the key qualitative differences in radar signature which reflect the influence of scattering geometry on scattering characteristics, but is not adequate to guide the optimization of viewing geometry for specific missions. For example, it may be that the scattering properties are simplest over some range of intermediate angles, with benefits to echo interpretation as well as providing a means to validation of modeling techniques. To address this issue, we conducted an experiment at Ardrossan, in Gulf St Vincent, near Adelaide South Australia, where X-band sea clutter was measured over 270deg of azimuth with 4deg beams at ~ 22.5deg spacing. This paper presents the initial results of an investigation of the azimuthal variation of the polarimetric structure of the dominant clutter returns. A companion paper explores the variation with the angle of incidence in the vertical plane. [C184]

"Non-coherent radar signal detection based on Bayesian theory"

This paper presents a non-coherent radar signal detection technique with a constant false alarm rate (CFAR), where a heterogeneous clutter such as a sea is considered. In this technique, the Bayesian theory is applied for the adaptive estimation of the local clutter power in the cell under test. With a noninformative prior, the proposed technique achieves the detection with no prior knowledge of the sea clutter. In order to investigate the detection performance, the Monte Carlo simulations are carried out. The results show that the proposed technique provides a higher detection probability than conventional ones such as the CA-CFAR. [C185]

"Maritime target cross section estimation for an ultra-wideband forward scatter radar network"

Preliminary investigation has shown that a chain of buoy based ultra-wideband (UWB) forward scattering radar (FSR) transceivers could potentially be used to overcome clutter problems for the detection of small marine targets on the sea surface. As one stage of a more in depth system investigation, it was deemed that a thorough analysis of the forward scatter radar cross section (RCS) of typical small maritime targets is required for full understanding of the radar system performance. This paper describes the preliminary results of this study, through use of numerically simulated 3-D FS RCSpsilas of complex target models and comparisons with a proposed simplified analytical FS RCS description. [C186]

"Signal detection against the background of non Gaussian clutter from underlying surface"

The method for the operating characteristics of the radio systems estimation based on using of model of non Gaussian clutter from underlying surface (sea, land plots) is proposed. The method use half Markov combined processes. The parameters of parametric (Neumann-Pearson, adaptive control of threshold and filter of selection stopband) and non-parametric (sign and linear rank) detectors are analyzed. The loss value of signal to noise ratio is appeared owing to non Gaussian of clutter parameters is estimated. [C187]

"Performance of excision switching-CFAR in K distributed sea clutter"

In this paper a new CFAR detector which is composed of an excision processor and a switching-CFAR detector, in an environment with K distribution, has been introduced. The new detector is named an excision switching CFAR Performance of EXS-CFAR is derived and compared with the some other detectors like CA-CFAR, GO-CFAR and SO-CFAR for Swerling I target model in homogeneous and non-homogenous noise environments such as those with multiple interferes and clutter edges. The results show that EXS-CFAR detectors considerably reduce the problem of excessive false alarm probability near clutter edges while maintaining good performance in other environments. [C188]

"A site-specific radar simulator for clutter modelling in VTS systems"

A general site-specific method is used to predict land/sea clutter strengths for low-angle monostatic radars

involved in vessel traffic services (VTS). In order to characterise each specific environment and solve the electromagnetic problem, the simulation tool makes use of physical optics (PO), in particular the Kirchhoff approximation, and digital terrain models (DTM), and provides both the plan position indicator (PPI) clutter map and the A-scope power versus range or time profile. A data-acquisition system consisting of a commercial maritime radar and an A/D converter is used to validate the developed software by comparison between simulations and measurements in the same environments. Some specific results for a maritime scenario, both measurements and simulations, are discussed and finally, a statistical analysis of the simulated clutter is presented. [C189]

"The duty cycle and contrast ratio trade-off in the design of interrupted HFSWR waveform"

This paper studies the trade-off existing, from a Pareto optimality point of view, between duty cycle and minimal contrast ratio when designing optimal interrupted waveform for monostatic high frequency surface wave radar. The study takes into consideration the surface wave propagation loss and the effect of receiver blanking during transmission. Results are compared with the performances of equivalent conventional trains of pulse. [C190]

"RadarStation: A site-specific tool for simulating clutter-limited radar systems"

This paper presents the RadarStation program. A general analytical method is used to predict land/sea clutter strengths for low-angle monostatic radars in each particular scenario. In order to characterise the environment and solve the electromagnetic problem, RadarStation makes use of Physical Optics (PO), in particular the Kirchhoff approximation, and Digital Terrain Models (DTM), and provides both the power versus range profile and the Plan Position Indicator (PPI) clutter map. A data-acquisition system consisting of a commercial maritime radar and an A/D converter is used to validate the developed software by comparison between simulations and measurements in the same environments. Some specific results for a maritime scenario, both measurements and simulations, are discussed and finally, a statistical analysis of the simulated clutter is presented. [C191]

"Comparison of Ship Detectability Using SAR Polarization Data: Envisat ASAR AP Mode"

Preliminary results are reported on ship detection using coherence images computed from cross-correlating images of multi-look-processed dual-polarization data of ENVISAT ASAR. The traditional techniques of ship detection by radars such as CFAR (Constant False Alarm Rate) rely on the amplitude data, and therefore the detection tends to become difficult when the amplitudes of ships images are at similar level as the mean amplitude of surrounding sea clutter. The proposed method utilizes the property that the multi-look images of ships are correlated with each other. Because the inter-look images of sea surface are covered by uncorrelated speckle, cross-correlation of multi-look images yields the different degrees of coherence between the images and water. The polarimetric information of ships, land and intertidal zone are first compared based on the cross-correlation between HH and HV. In the next step, we examine the technique when the dual-polarization data are split into two multi-look images. [C192]

"MIMO radar detection of targets in compound-Gaussian clutter"

Multiple-input multiple-output (MIMO) radars with widely-separated transmitters and receivers are useful to discriminate a target from clutter using the spatial diversity of the scatterers in the illuminated scene. We consider the detection of targets in compound-Gaussian clutter fitting for example scatterers with heavy-tailed distributions for high-resolution and/or low-grazing-angle radars in the presence of sea or foliage clutter. First, we introduce a data model using the inverse gamma distribution to represent the clutter texture. Then, we apply the parameter-expanded expectation-maximization (PX-EM) algorithm to estimate the clutter texture and speckle, as well as the target parameters.We develop a generalized likelihood ratio (GLR) test target detector using the estimates and show the advantages of MIMO using Monte Carlo simulations. [C193]

"Morphological operator and Empirical Mode Decomposition for clutter mitigation"

Maritime surveillance of the Exclusive Economic Zone (EEZ) is a present military and civilian challenge. The High Frequency Surface Wave Radar, as its coverage range is not limited by the radio horizon, is well-suited to fulfil this task. Effect of ionospheric clutter can, however, strongly limits target detection. Ionospheric clutter results from disturbance in ionization. In previous works we proposed using wavelets to remove the clutter. We are now considering another multi-scale analysis. Indeed, we wondered if an evolving basis could overcome the issue. Empirical Mode Decomposition (EMD) might offer such a possibility. The initial idea is still using multi-scale analysis to turn to good account the differences in variation scales of targets and ionospheric clutter. Apart from the fact that basis functions is self-determined by the EMD. We have also tried to associate morphological operators and EMD. We are presenting here the first results of our investigations. [C194]

"Removing ping timing ambiguity via data association"

This paper considers the use of a multiple ping active sonar approach in order to track multiple targets. In most underwater target tracking applications that rely on active sonar observations, the sonar sends out a single ping at each scan interval and receives returns that might either be from target(s) or due to clutter. We propose to use a multi-ping paradigm, with the idea that the better detectability of more pings can, assuming a high clutter density, lead to better localization of targets. However, this introduces a timing ambiguity in the ping returns adding a new level of complexity in the data association. In this paper we propose a multi-ping data association (MPDA) algorithm as a solution. MPDA formulates the assignment problem as a linear program, which could then be solved using a primal-dual interior point approach. A comparison is made between three different scenarios: (a) the sonar sends out a single ping in each scan interval; there is no timing ambiguity (which return is due to which ping), (b) the sonar sends out multiple pings within a scan interval and the timing ambiguity is avoided by using orthogonal waveforms for each ping, (c) when the sonar sends out multiple pings, each ping being an identical waveform, within each scan, leading to a timing ambiguity. A well known multiple target tracking technique such as the JPDA is used in cases (a) and (b), while the MPDA algorithm is used to solve the assignment problem in case (c), and is shown to perform better than case (a) in high clutter densities. Case (b), the unrealizable bogey, performs best. [C195]

"Measuring and Modeling the NRCS of the Sea for Backscatter"

Recent ship-based measurements using a calibrated, coherent, dual-polarized, X-band radar illuminated the behavior of the normalized radar cross section of the sea, NRCS or s0, at incidence angles of 88deg to 89deg. For wind seas s0(VV) at these incidence angles behaves much like those at lower incidence angles while s0(HH) behaves very differently, being largest looking upwind and smallest looking downwind. Fits of a multiscale scattering model to these data and data at lower incidence angles show that over the range of incidence angles from 0deg to 89deg, s0(VV) is adequately explained by the model while s0(HH) is generally higher than the model predicts at incidence angles above about 45deg. Thus scattering phenomena exist on the ocean that affect HH backscatter very strongly at high incidence angles while impacting VV backscatter only slightly. We show that when the ocean surface is disturbed by currents s0(HH) can exceed s0(VV) by as much as 15 dB for long periods of time and over large spatial areas. We examine phenomena that might account for this behavior and how they might affect the wind sea case. [C196]

"P-band Polarimetric Ice Sounder: Concept and First Results"

ESA has assigned the Technical University of Denmark to develop an airborne P-band ice sounding radar demonstrator. The intention is to obtain a better understanding of the electromagnetic properties of the Antarctic ice sheet at P-band and to test novel ice sounding techniques in preparation for a potential spaceborne ice sounding radar. The airborne system is a coherent, high-resolution and fully polarimetric radar. Aperture synthesis is applied in the along track direction and an experimental surface clutter suppression technique based on a multi-aperture antenna can be applied in the across track direction. In May 2008, a proof-of-concept campaign was organized in Greenland, where data were acquired over the ice sheet. The system proved capable of detecting the bedrock under 3 km thick ice and of mapping the internal ice layers down to a depth of at least 1.3 km. In this paper, the system concept is outlined and first results are presented. [C197]

"Small targets detection in low resolution sea clutter"

A kind of EWNI method is proposed in this paper. It can decrease the detectable SCR of small targets contrasted with normal noncoherent integration. To suppress false alarms, MHT method is adopted to reach the le-6 Pfa. The scheme proposed in this paper is suitable for S band marine surveillance radar to detect small targets in sea clutter. [C198]

"Adaptive processing in High Frequency Surface Wave Radar"

This paper investigates the use of space-time adaptive processing (STAP) for high frequency surface wave radar (HFSWR) systems. STAP has hitherto been investigated in great detail for airborne radar systems; the majority of the adaptive algorithms that have been developed have been designed with a bias towards such applications. HFSWR systems are characterized by the severely limited number of data samples available to train the adaptive filter. In this paper we report on investigations in applying low-complexity STAP algorithms to HFSWR systems. In particular we focus on applying such algorithms on HFSWR data cube measurements heavily corrupted by ionospheric clutter. We then reflect on the implications of the results. [C199]

"Airborne radar STAP using long-memory clutter models"

Traditional analysis of airborne adaptive radars usually assumes the ideal condition of statistically independent and identically distributed (IID) secondary data. To the contrary, measured clutter data are spatially correlated and exhibit long-memory characteristics. In addition, clutter can appear heterogeneous and so the secondary data are no longer IID. The aim of this paper is to define an efficient simulator of long-range dependence (LRD) homogeneous or non-homogeneous clutter space-time steering vectors. To this end, multi-channel airborne radar measurement (MCARM) data have been analyzed to estimate the power spectral density (PSD) of space-time snapshots in real clutter environments. In this paper we will refer to the considered long-memory clutter models as to the LRDSTAP clutter models. LRDSTAP models extend the simplified general clutter model (GCM) by including the LRD characteristics of clutter PSDs. Simulated data from LRDSTAP are used to evaluate the impact of long-memory data on the convergence measure of effectiveness (MOE) of the sample matrix inversion (SMI) STAP processor. The presented method demonstrates reliable results when applied to MCARM data files including either spatially homogeneous or nonhomogeneous clutter. [C200]

"Parameter estimation of texture in high-resolution radar clutter by Mellin transform"

Modulation in the mean value of power (sigma0) from diffuse radar backscattering necessitates a compound model for high-resolution clutter statistics. Non-stationary internal structures in the scene under observation result in strong fluctuations in sigma0, and are identified as textures in the backscattering. Texture detection in clutter leads to interpretation of the surface structures present in the high-resolution cells under observation. This paper presents a method of simulating such texture, and estimation of its parameters by the application of Mellin transform. [C201]

"The effects of sea clutter on the performance of HF Surface Wave Radar in ship detection"

This paper presents a study of the effects of sea clutter on the performance of HF surface wave radar (HFSWR), operating in the band between 3 and 5 MHz, in the detection of two classes of ships: large freighters with gross registered tonnage (GRT) in the order of several tens of thousands of tons and small vessels with a GRT of about 1000 tons. The radar returns from both large and small ships are estimated from the measured returns from the Canadian Coast Guard Ship (CCGS) Teleost, based on the differences of their radar cross section (RCS) estimated in [10]. The estimated returns are then extrapolated in range using the propagation attenuation calculated for the sea condition under which the measured returns were obtained. These extrapolated returns were compared with the sea echoes measured from the same radar to assess the detection capability of the radar. The conclusions of the study are that, in the detection of large ships, the radar performance is independent of sea state, but in the detection of small ships, the radar performance is dependent on sea state. It is shown that if a radar employing conventional linear beamforming methods is to maintain the detection capability for the small ships, then the aperture of the receive array cannot be reduced from its current value. [C202]

"Limits on the detection of low-Doppler targets by a High Frequency hybrid sky-surface wave radar system"

A high frequency (HF) radar system comprising a skywave transmit channel and surface wave receive channel is studied. Simple analytic expressions for the resolution of this radar system are determined by considering the spreading of radar signals in Doppler and angle during the ionospheric propagation. The detection of ocean surface targets within the patch of ocean surface illuminated by the radar beam is then determined by comparing the radar cross section of the ocean patch with typical vessel radar cross sections. It is shown that a hybrid sky-surface wave radar can detect low-Doppler ships down to 30 dBm2cross section during the day and down to 40 dBm2at night, during calm ionospheric conditions. During periods of spread F ionospheric turbulence, where the temporal correlation time decreases by an order of magnitude, the corresponding vessel detection capability decreases by two orders of magnitude. [C203]

"Advances in SAR interferometry for sentinel-1 with TOPS"

The introduction of a novel scanning technique, named terrain observation by progressive scan (TOPS) allows the improvement of the DTAR in multi swath radar images. The trade off between resolution in range and revisit time (the number of swaths) is very efficient. Some results of the modeling and simulation of this technique are discussed, as well as an application to ship traffic monitoring, revisiting twice the same swath after a few seconds, to be able to evaluate the ship velocity even with strong sea clutter. [C204]

"Detection of known targets in Weibull clutter based on Neural Networks. Robustness study against target parameters changes"

The coherent detection of targets in presence of clutter and noise is considered in this study. Several clutter models are proposed in the literature, although the commonly used for sea and land clutter returns is the Weibull one. Our case of study involves that the target is known a priori, the clutter is Weibull-distributed and a white Gaussian noise is present. In this case, obtaining analytical expressions for the optimum detector is very difficult, so suboptimum solutions are taken as reference. One of this solutions is the target sequence known a priori (TSKAP) detector. This detector has several problems because it is designed for specific target and clutter parameters. So, in order to reduce these problems, a new solution is proposed, which is based in neural networks (NNs). The NNs selected are the MultiLayer Perceptrons (MLPs), which are able to learn from different environments. But, what does it happen if the radar (target or clutter) testing conditions are different of the design ones? In this case, a robustness study with respect to the target Doppler frequency is done for different radar conditions, which shows that the behavior of the proposed solution against this changes is better than the detector taken as reference, the TSKAP detector. [C205]

"Sea and ground radar clutter modeling"

The modeling of the clutter echoes is a central issue for the design and performance evaluation of radar systems. The aim of this paper is to describe the state-of-the-art approaches to the modeling and understanding of land and sea clutter echoes and their implications on performance prediction and signal processors design. The tutorial is mainly divided in 5 parts: (i) Radar sea and ground clutter phenomena, measurements and measurement limitations, at high and low resolution, high and low grazing angles. (ii) Statistical and spectral models for windblown vegetation and sea surfaces. (iii) Experimental validation of statistical and spectral models, for both sea and land clutter, using recorded data sets. (iv) Impact of the clutter models on radar performance for detection and imaging, there including the effect on CFAR techniques and high resolution SAR imaging. (v) Radar clutter simulation for radar performance evaluation. [C206]

"Analysis of EM scattering from electrically large target over 2-D sea surface"

The mechanism of composite scattering from complex electrically large target over the two-dimensional (2-D) randomly rough sea surface is researched based on the modified ldquofour-path modelrdquo. Kirchhoff approximation and the method of equivalent edge currents are applied to analyze the backscattering of the sea model generated with the Monte Carlo method and the electrically large target respectively. The issue of the coupling field between the target and the sea surface is solved with the principle of image. A model of the composite scattering from the complex target over the sea surface is proposed to analyze the affects of sea background to the scattering characteristics of the target. The EM scattering characteristics of the electrically large target in the sea clutter background is discussed with the numerical results. [C207]

"A Combined Denoising Algorithm Approach to Sea Clutter in Wave Monitoring System by Marine Radar"

X-band marine radar images are usually corrupted by noise due to random interference of electromagnetic waves. The noise degrades the quality of the images and makes interpretations and analysis of marine radar images harder. Therefore, noise reduction is necessary prior to the processing of marine radar images. In this paper a novel combined denoising algorithm approach to sea clutter in wave monitoring system by nautical radar is proposed. Firstly, the logarithmic transformation is used to convert the multiplicative noise model to an additive model. Secondly, the radar image is transformed with one-scale discrete wavelet transform (DWT). Thirdly, according to the noise characteristic the LL sub-band image is dealt with Wiener median filter, HL and LH sub-band images are dealt with mean filter, HH sub-band image is dealt with median filter. Finally, the wavelet inverse transformation and logarithmic inverse transformation are used to reconstruct the filtered image. The experimental results show that the proposed algorithm improves the denoising performance significantly. [C208]

"Martime radar detection perfromance of fast and slow scan radars using frequency agility"

The relative detection performance of fast scan and slow scan radars utilizing frequency agile waveform transmission is examined. A real, wide bandwidth, sea clutter data set is compressed using a set of contiguous narrowband compression filters to create data sets corresponding to three or ten frequency steps. Both a non-coherent and coherent Kelly detection scheme are implemented and tested. A detection performance advantage is demonstrated for the fast scan configuration for both frequency agile sets under coherent Kelly detection. The non-coherent detector case is less clear-cut with a superior fast scan performance noted for the three frequency agile set but equivalent performance noted for both fast and slow scan rates with the 10 frequency agile set. [C209]

"Analysis of medium grazing angle X-band sea-clutter Doppler spectra"

Doppler analysis of radar sea-clutter is typically performed from a static cliff top location looking out to sea. This constrains the grazing angle to low values and the radar look direction with respect to the wind. Current research at the DSTO is interested in the properties of sea-clutter at medium to high grazing angles, over all azimuth directions, full polarisation and different spatial resolutions. The sea clutter Doppler spectrum investigated in this paper was collected by an airborne platform and analysed using the three component Walker scattering model modified to include Doppler shifts from the moving platform. The modelling results enable the underlying Doppler spectrum and autocorrelation of the sea clutter to be estimated. This will enable future analysis into the performance of medium to high grazing angle target detection algorithms in the maritime environment. [C210]

"Analysis of sea state parameters and ocean currents from temporal sequences of marine radar images of the sea surface"

This work uses ordinary X-band marine radars to extract directional wave spectra and their related sea state parameters, as well as speed and direction of ocean surface currents, including tidal information. The used method analyzes the structure in frequency and wave number vector of the image spectra derived from of temporal sequences of marine radar images of the sea surface acquired by a marine radar system. The presented data and the related results were measured from a research platform located in the North Sea. In addition, the work presents some comparisons between sea state parameters derived from the marine radar analysis and the equivalent sea sate parameter obtained from in-situ wave sensor records. [C211]

"Full digital High Frequency Surface Wave Radar: French trials in the biscay bay"

Assessment of actual detection capabilities obtained with high frequency surface wave radar (HFSWR) is a key issue for the global surveillance of the exclusive economic zone (EEZ). ONERA (The French Aerospace Lab) has just finished a ten month trial cycle of its new full digital HFSWR system. This system uses digital signal generation, digital receivers, high computational power workstations and low power transmitters. All results extracted from the trial database are compliant with the theory in particular concerning sea clutter and ionospheric clutter. Moreover, the detection of vessels up to 170 km and aircrafts up to 75 km (results obtained with cooperative targets and ground truth data) shows the over the horizon capabilities of the system. Finally, clutter reduction prospects are also presented. [C212]

"A Monostatic Ocean Scattering Cross Section for the Case of Surface Wave Radar Operating from a Floating Barge"

An understanding of the parameters affecting the high frequency surface wave radar (HFSWR) cross sections of the ocean surface is essential to employing such formulations in remote sensing models. Available techniques to date have not explicitly included the effect of antenna motion on the ocean clutter spectra derived from HF Doppler radar data. Here, a model, which assumes the incident radiation to be a simple pulse and accounts for the fact that there may be antenna motion in the radar look direction, is presented. Simulations indicate that the motion of the antennas may give rise to additional, significant spectral content which cannot be ignored when the Doppler spectra are used for ocean parameter estimation. [C213]

"Multi-scale Modeling Approach for Detecting Low Observable Targets within Sea Clutter"

Sea clutter refers to the radar backscatter from the ocean surface. Accurate modeling of sea clutter and rough sea surface is an important problem in radar signal processing and applications, as it facilitates robust detection of low observable targets within sea clutter, which has significant importance to coastal security, navigation safety and environmental monitoring. Great efforts have been made to model sea clutter. However, the nature of sea clutter is poorly understood and the important problem of target detection within sea clutter remains a tremendous challenge. We propose a systematic, multi-scale approach to model sea clutter. By extensively utilizing available real data, we (1) develop methods to better fit non-stationary and non-Gaussian sea clutter, (2) characterize correlation structure of sea clutter on multiple time scales, and (3) develop accurate and readily implementable methods to detect low observable targets within sea clutter. [C214]

"Foliage Clutter Modeling Using the UWB Radar"

In this paper, we propose that the foliage clutter follows log-logistic model using maximum likelihood (ML) parameter estimation as well as the root mean square error (RMSE) on PDF curves between original clutter and statistical model data. The measured clutter data is provided by Air Force Office of Scientific Research (AFOSR). In addition to investigating the log-logistic model, we also compare it with other popular clutter models, namely log-normal, Weibull and Nakagami. We show that the log-logistic model not only achieves the smallest standard deviation (STD) error on estimated model parameters, but also has the best goodness-of-fit and smallest RMSE.

Further, the performance of detection at presence of foliage clutter is theoretically analyzed. [C215]

"Detecting targets of variable acceleration with High Frequency Surface Wave Radar"

According to the conventional hypothesis, the velocity of target in the coherent integration time (CIT) is invariable in the application of utilizing high frequency surface wave radar to detect target. First, this paper proposes a more proper hypothesis in which the velocity and acceleration of target are treated as time-varying. However the acceleration of target can be regarded as invariable within the small fraction of coherent integration time. Then the model of echo signal in the hypothesis is analyzed. Considering the disadvangtages of some conventional methods of time-frequency analysis such as short-time Fourier transform (STFT) and Wigner-Ville distribution (WVD), the paper proposes the method of time-frequency analysis based on chirplets signal decomposition which can improve the time and frequency resolution simultaneously and solve the cross-term problem in WVD method. Firstly, we process the small fraction of coherent integration time with the chirplets signal decomposition. Then according to the differences between target signal and ocean clutter echo, the BP neural network classifier can be exploited to suppress ocean clutter. The different fractions of coherent integration time are composed together with the method of the nearest correlation. Lastly, the feasibility of the method for detecting targets of variable acceleration is proved by its processing the actual data. [C216]

"Practical problems with covariance matrix estimation for adaptive MTI and space-time adaptive processing for target detection in HF surface wave radars"

Surface wave over the horizon radar systems have a potential to detect targets, that are hidden under optical horizon. This possibility is, however, difficult to implement as a result of first and second order clutter scattered from the ocean surface in combination with interferences. In this paper we compare adaptive MTI and space-time adaptive processing algorithms applied to the surface wave high frequency radar system data. The aim of the experiments was to evaluate different techniques and their usefulness to detect targets at distances 50-200 km off shore. In the experiments authors used the data from an oceanographic, surface-wave, high frequency system WERA, designed to perform continuous monitoring of sea currents and waves. Data were collected at the west coast of France, in Brittany. [C217]

"Radar Sea Clutter Modelling and Simulation-Recent Progress and Future Challenges"

This paper reviews current developments in sea clutter modelling, covering both statistical models, mainly based on empirical observations, and modelling of electromagnetic scattering from simulated sea surfaces. The emphasis throughout the paper is on the modelling of low grazing angle microwave radar backscatter in relation to airborne and surface maritime surveillance radar. As well as reviewing current knowledge in these areas the paper also highlights areas where further research is needed. [C218]

"Front Cover"

The following topics were dealt with: radar sea clutter modelling; SIRP and Gaussian models; airborne pulse Doppler radar; adaptive clutter models; space-time adaptive processing. [C219]

"Simulation of Coherent Clutter"

This paper provides a brief overview of methods used to simulate sea clutter. It then offers a simple and flexible way of generating coherent sea clutter that matches the statistics of real clutter in the time domain, as well as the shape and intensity distribution within the Doppler domain. Results confirm that the signal intensity can also be K distributed. [C220]

"Modelling Radar Sea Clutter in the Littoral"

A model is presented for low grazing angle sea clutter in littoral environments. It is based on a simple characterisation of the clutter in terms of scattering from ripples riding on long waves (the composite model) and from breaking waves; both being subjected to obscuration and multipath illumination. In littoral environments changes to the ocean waves are caused by limited fetch, wave refraction, current variations and enhanced breaking in shallow water. Simple models for these phenomena are described along with their effect on clutter radar cross section (RCS). [C221]

"The Clutter SIRP and Gaussian Models: a Brief Overview and a Comparison"

At low grazing angle and/or high resolution radar, sea clutter is not Gaussian due to the apparition of spikes. It is then generally seen as a spherically invariant random process (SIRP). When the covariance matrix is assumed

to be known, the Neyman-Pearson optimal receiver can be derived. Nevertheless, in order to implement it, the SIRP characteristic probablity density function (PDF), that is to say the texture PDF, has to be known. Its asymptotical form, which does not depend on the texture PDF, is then often prefered. We show in this paper that the asymptotic detection in a SIRP is equivalent to the generalized likelihood ratio test (GLRT) in a Gaussian correlated clutter of unknown level, and discuss about the interest of SIRP model and optimality. [C222]

"Characterisation of low-PRF X-band sea-clutter doppler spectra"

Understanding the characteristics of the sea is critical in forming a picture of the sea-clutter as seen by a radar. Current research at the DSTO is interested in the properties of sea-clutter at medium grazing angles, over all azimuth directions, with full polarisation and differing weather conditions. This paper builds on previous work which studied the Doppler spectrum over all azimuth directions using the three component Walker scattering model. An improved model is presented here which includes the aliasing present in low pulse repetition frequency (PRF) data collected using Ingara-the DSTOpsilas X-band synthetic aperture radar (SAR). This enables a large number of data sets to be analysed with differing grazing angles and weather conditions. The goal of this work is to characterise the sea-clutter and improve the fidelity of future analysis into the performance of medium grazing angle target detection algorithms in the maritime environment. [C223]

"Improved covariance matrix estimation in spectrally inhomogeneous sea clutter with application to adaptive small boat detection"

Asymptotically optimal coherent detection techniques yield sub-clutter visibility in heavy-tailed sea clutter. The adaptive linear quadratic detector inherently assumes spectral homogeneity for the reference window of the covariance matrix estimator. This paper investigates the validity of this assumption on real data that have been recorded with a medium resolution X-band radar. Proving empirically that this basic assumption is the exception rather than the rule, the effects of spectral inhomogeneity are investigated. Various improvements to the current estimator and detector are suggested and evaluated. This is specifically applied to the detection of small rigid inflatable boats, with empirical results presented for a range of boat manoeuvres. A specific example highlights the vulnerability of the chosen detector to self-masking. [C224]

"Moving ship detection in presence of sea clutter from temporal sequences of marine radar images"

This work presents a method to filter sea clutter features for radar images acquired from ordinary marine radar sensors, which are incoherent radars working in X-band and horizontal polarization. The proposed method considers short temporal sequences of consecutive sea clutter images. This method is based on the acquired experience about the spectral structure of the sea clutter obtained from the use of marine radars to detect ocean wave fields and the related sea state parameters. [C225]

"Effect of integration time on detection performance of MTI and STAP algorithms in HF radar"

Surface wave over the horizon radar systems have a potential to detect targets falling far beyond optical horizon. Unfortunately, first and second order clutter scattered from the ocean surface, in combination with interferences, can prevent successful deployment of such systems. In this paper we compare different adaptive MTI and space-time adaptive processing algorithms applied to the surface wave high frequency radar system data. The aim of the experiments was to detect small targets (20-30 m long) at distances about 50 km. Radar system used in the experiments is an oceanographic, surface-wave, high-frequency system WERA, designed to perform continuous monitoring of sea currents and waves. System used in this research is located at the east coast of France, in Brittany. Main task of the system is to provide continuous, real-time information about currents and waves in the English (La Manche) Channel entry area, where heavy ship traffic is present. [C226]

"The Euler decomposition and its application to sea clutter analysis"

Re-examining the Euler decomposition technique we indicate that some previous decomposition algorithms are incomplete and contain errors. We provide a correct and complete set of decomposition formulae in this paper. Our second contribution is the elimination of the so-called decomposition ambiguity by using LpsilaHospitalpsilas rule so that the mapping between a scattering matrix and its Euler parameters is unique for all scattering mechanisms. As a precursor to ship detection studies, we apply the decomposition to sea clutter analysis. We find that the scattering mechanisms of the highest VV and HH returns from sea spikes can be interpreted as vertically and horizontally oriented thin wires, respectively. [C227]

"Aspect dependence of the polarimetric characteristics of sea clutter: I. Variation with elevation

angle"

The polarisation dependence of radar scattering from the sea at low to moderate angles of incidence has been studied extensively and has shown Bragg scatter to be the dominant mechanism for these geometries. At high angles of incidence the polarimetric scattering behaviour is rather more complicated, with numerous mechanisms active. The transition region where the characteristics of the radar scattering from the sea changes, is not so well understood, due partly to the scarcity of experimental data from the open sea. Wave tank measurements have addressed some aspects, but it is not always easy to extrapolate these results to the natural environment. In this paper we examine the transition from Bragg scattering at low incidence angles to the more complicated scattering which occurs at high incidence angles by examining the changes that occur to the distribution of points in the partitioned H-alphamacr space. [C228]

"Radar investigations of ocean surface geometry and dynamics"

Radars can be used to measure and characterise the shape and motion of the ocean surface. Recent developments in our understanding of the geometry and dynamics of the surface can be exploited to enhance radar performance generally, as well as suggesting new capabilities. [C229]

"Radar sea clutter: Recent progress and future challenges"

This paper reviews current developments in sea clutter modelling, covering both statistical models, mainly based on empirical observations, and modelling of electromagnetic scattering from simulated sea surfaces. The latest developments in detection processing are also discussed, within the framework provided by these models. The emphasis throughout the paper is on the modelling of low grazing angle microwave radar backscatter in relation to airborne and surface maritime surveillance radar. As well as reviewing current knowledge in these areas the paper also highlights areas where further research is needed. [C230]

"Modelling radar sea clutter in littoral environments"

A model is presented for low grazing angle sea clutter in littoral environments. It is based on a simple characterisation of the clutter in terms of scattering from ripples riding on long waves (the composite model) and from breaking waves; both being subjected to obscuration and multipath illumination. In littoral environments changes to the ocean waves are caused by limited fetch, wave refraction, current variations and enhanced breaking in shallow water. Simple models for these phenomena are described along with their effect on clutter radar cross section (RCS). [C231]

"Clutter cancellation in a weather radar using an adaptive array antenna"

High resolution windspeed profile measurements are needed in a weather radar to provide the reliable information of rapidly changing weather conditions. The commonly used pulse pair method is quite attractive when processing an enormous amount of weather radar data in real time since it is considered the fastest algorithm available[1] [2] [3] [4]. However, it is necessary to remove both stationary and moving clutter to obtain the accurate pulse pair estimates. The use of the conventional pulse pair canceller or other high-pass Doppler filters may be effective for the removal of ground clutter but the moving clutter occurring from airplanes, vehicles or turbulent sea surfaces cannot be eliminated. To make matters worse, even the removal of stationary ground clutter is not an easy task because of Doppler spectrum spread due to antenna rotation and phase noise. [C232]

"CFAR loss and gain in K-distributed sea-clutter and thermal noise"

Setting the detection threshold in a radar operating in a maritime environment is critically dependent upon the characteristics of the sea clutter. Analysis is presented in this paper of the performance of the cell-averaging CFAR in K-distributed sea clutter. It is demonstrated that in spatially uncorrelated, spiky clutter the CFAR loss is very high, but may be reduced in some circumstances by increasing the radar system noise level. It has previously been reported [5] that in spatially correlated clutter the CFAR loss may be reduced by optimising the cell averager length, which is some cases leads to a 'CFAR gain' rather than a loss. Here, it is shown how added thermal noise affects this performance. [C233]

"Analaysis of calibrated sea clutter and boat reflectivity data at C- and X-band in South African coastal waters"

The temporal characteristics of low grazing angle sea clutter and boat reflectivity are considered for both fixed and stepped frequency waveforms under a range of environmental conditions and geometrical configurations. Detectability of boats using an asymptotically optimal detector is evaluated empirically, as well as the influence of

the local sea on boat reflectivity. Measurements were conducted with a calibrated, coherent, staring, pulsed radar system at C- and X-band frequencies ranging from 6.9 GHz to 10.3 GHz. [C234]

"High grazing angle X-band sea clutter distributions"

This paper investigates the statistical properties of sea clutter at grazing angles higher than traditionally used for airborne maritime radar surveillance, i.e. 10°-45°. Specifically, we study the spatial distribution of X-band, high resolution and high grazing angle polarimetric sea clutter data. We found that among the VV, HV, and HH polarisations, the VV data is least spiky and the K distribution usually provides a good fit. The HH data is spikiest and its distribution exhibits a sudden departure from the K distribution in the upper tail region, which usually requires the KA or similar distributions to achieve a better fit. Due to drawbacks of the KA distribution, this paper proposes a combination of two K distributions to fit the distribution of sea clutter with spikes. Referred to as the KK distribution model, it is found to provide the best overall fit. [C235]

"Statistical Estimation of Refractivity from Radar Sea Clutter"

This paper summarizes current developments in the refractivity from clutter (RFC) techniques and describes the global parametrization approach in estimation of the lower atmospheric electromagnetic sea ducts. RFC uses radar clutter to gather information about the environment the radar is operating in. Range and height dependent atmospheric index of refraction (M-profile) is statistically estimated from the sea-surface reflected radar clutter. These environmental statistics can then be used to predict the radar performance by taking multidimensional integrals of the posterior probability density. All of the following methods use a Bayesian framework and use split-step fast Fourier transform based parabolic equation approximation to the wave equation as the propagation model. Environmental parameters are inverted using genetic algorithms, Markov chain Monte Carlo samplers, and a hybrid genetic algorithm -Markov chain Monte Carlo technique. The methods are compared with respect to their estimated maximum a posteriori accuracy, speed and ability to sample correctly from posterior density. The inversion algorithms are implemented on S-band radar sea-clutter data from 1998 Wallops Island, Virginia experiment. Reference data are measured as range-dependent refractivity profiles obtained with a helicopter. The inversions are assessed by comparing the propagation predicted from the radar-inferred refractivity profiles and from the helicopter profiles. [C236]

"A Kirchhoff Integral Approach to Radar Propagation Modelling and its Application to the Estimation of Clutter"

Anomalous propagation, such as that experienced in evaporative ducts, can have a marked effect upon microwave radar clutter. Not only is the clutter strength affected by a change in propagation losses, but the backscatter coefficient is affected through the dependence of grazing angle upon propagation conditions. It is shown that a Kirchhoff integral approach to anomalous propagation can provide an effect means of calculating both propagation loss and grazing angle, hence providing a useful tool for clutter calculations. [C237]

"Space-Time Adaptive Processing in the presence of non-Gaussian sea clutteR"

Space-Time Adaptive Processing (STAP) is an optimum technique for target detection in the presence of Gaussian clutter [1,2]. However, for high resolution sea surveillance radar, clutter statistical properties are different [5]. Therefore classical STAP must be redefined. It can be done in the framework of the theory of Spherically Invariant Random Process (SIRP). In this paper a simple method of improving STAP performance in the presence of non-Gaussian clutter is proposed. Results are validated using simulated data. [C238]

"Maximizing Detection Performancewithwaveform Design for Sensing in Heavy Sea Clutter"

In this paper, we consider a radar system capable of adaptively adjusting its transmitted waveform to mitigate the effect of the environment and improve detection performance. We thus bring the potential of waveform agility to bear on the challenging problem of target detection in heavy sea clutter. Using a two-stage procedure, we first estimate the statistics of the sea clutter in the vicinity of a predicted target. A phase-modulated waveform is then designed and transmitted so as to maximize the generalized likelihood ratio at the predicted target location, thus improving the signal-to-clutter ratio (SCR). Employing the compound-Gaussian (CG) model, we exploit a subspace-based approach to further mitigate sea clutter and deliver improved detection performance. Simulations illustrate the effectiveness of our method. [C239]

"A Clutter Canceller for Continuous Wave GPR"

In this work an innovative clutter canceller for Continuous Wave GPR (Ground Penetrating Radar) has been designed and implemented. An IQ modulator has been used to build up the central part of the device. The IQ

modulator replaces more expensive components like digital controlled phase shifters and attenuators. This device also have wider dynamics with respect to linear vectorial modulator. To prove the feasibility of the system, the effect of signal feedthrough for IQ modulators is studied. Tests and measurements of the complete device are exposed. [C240]

"The Short-Time Multifractal Spectral Analysis Based on the Singularity Exponents"

In this paper, a short-time multifractals models has been proposed, which is an extension of multifractals models. In the section 2, the mind of short-time multifractal spectrum has been introduced. In section 3, the short time multifractal spectrum based on the singularity exponents have been proposed. In section 3 is the calculation method of short time multifractal spectrum, and we analyzed the short-time multifractals characteristics of sea clutter, the simulation shows that the multifractal spectrum is time-varying, and the short-time multifractal spectrum is a new tools on complex fractal signal. [C241]

"Modelling sea clutter temporal correlation in detection calculations"

The calculation of target detection performance in a combination of K-distributed sea clutter and radar system noise has, to date, been limited to the case where the clutter speckle component is independent from pulse to pulse (as sometimes occurs with frequency agility). Recent advances in computational techniques reported here allow the speckle and noise to have different correlation times, thereby allowing fixed frequency and limited frequency agility radars to be modelled at all ranges and at all clutter to noise ratios. [C242]

"Retrieving evaporation duct heights from measured propagation factors"

The knowledge of refractivity is very important for coverage prediction. This problem is common above sea, where the particular atmospheric conditions lead to atmospheric ducts which strongly modify the range of the radar compared to the standard atmosphere coverage. The most common duct which is almost always present is the evaporation duct. The aim of this paper is to present two inversion methods to retrieve the evaporation duct height from the propagation factor measured along the propagation path during the Vampira campaign 2004. The two inversion methods considered are the simple quadratic regression and the least-squares support vector machine. [C243]

"SCANTER 4000/4100: A multi purpose surveillance radar"

This paper presents the background for and the main features of the multi purpose SCANTER 4000 and SCANTER 4100 surveillance radar systems, recently being developed at Terma A/S for air and sea surveillance. The SCANTER 4000 system is for stationary applications, while the SCANTER 4100 radar system is intended for use on a moving platform, e.g. a vessel. The paper describes the highlights in terms of the measured performance obtained and gives an overview of the radar system. [C244]

"Radar Scattering from Partially-Submerged Objects in Ducting Environments"

This paper describes the ducted ocean surface scattering integral equation routine (DOSSIER). DOSSIER is a numerically-efficient high-fidelity numerical model for calculating scattering from partially-submerged targets in ducting environments. The model is based on a hybrid 2D-3D integral equation formulation where the 2D formulation is used to propagate the radar energy to the target location, while the 3D model is used to calculate the backscattered field from the target and its proximity. The combined model effectively accounts for shadowing, multipath, and ducting effects on the effective target reflectivity in such a complex environment. [C245]

"Nanosecond Gigawatt Radar: Indication of Small Targets Moving Among Heavy Clutters"

For indication of low-RCS targets moving among natural clutters, radars with short high-power transmitted RF pulses are known (Skolnik, 2001) to be advantageous over radars with relatively long broadband-coded pulses of the same energy. In accordance with the theory(Skolnik, 2001), an experimental X-band nanosecond-gigawatt-pulse radar proved to be efficient for detection, recognition and tracking of ~1 m2RCS planes, helicopters and motor boats moving within forest and sea clutters. Further upgrades of the radar are possible. [C246]

"A Co-Channel Signal Detector Based on Phase Tracking for Pulse Doppler Radar"

Doppler processing is routinely applied to isolate targets from noise, clutter and interference in conventional pulse-Doppler radar. If a target is co-located in range and azimuth and has a similar radial velocity (co-channel) as another target (or interference), that target may not be detected. This is because only amplitude or power information is used in the detection stage, which does not provide sufficient information to discriminate co-

channel signals from each other. In this paper we propose a detector which can resolve co-located targets (or target with interference) with similar Doppler frequencies. Instead of only using phase information for the coherent integration, our proposed detector tracks the phase modulation differences of the co-located, co-channel, targets. The amplitude information of the targets can also be estimated and forwarded to the tracker. One application of this method is HF radar where a target may have a Doppler frequency similar to a Bragg line-first order sea clutter. The Bragg lines are generally dominant at all ranges and exist in all directions. Conventional processing fails to discriminate when targets radar features are similar to the Bragg lines. Simulations of the proposed method show promising results that targets with Doppler frequencies near Bragg lines can be detected. [C247]

"Atmospheric Refractivity Tracking From Radar Clutter Using Kalman and Particle Filters"

This paper addresses the problem of tracking the spatial and temporal lower atmospheric variations in marine and coastal environments. The method tracks the evolution of the range and height-dependent index of refraction using the sea clutter measured from sea-borne radars operating in the region. A split-step fast Fourier transform based parabolic equation approximation to the wave equation is used to compute the clutter return in complex environments with varying index of refraction. In addition, regional statistics are incorporated as prior densities, resulting in a highly nonlinear and non-Gaussian tracking problem. Various tracking algorithms such as the extended Kalman, unscented Kalman and particle Alters are used for tracking surface-based electromagnetic ducts frequently encountered in marine environments. Tracking performance of each Alter is also calculated and compared using the posterior Cramer-Rao lower bound. Even though the tracking performance of the Kalman Alters was limited by the high non-linearity of the parabolic equation, particle Alters proved to be very promising in tracking even the abruptly changing environments. [C248]

"Improving Detection in Sea Clutter using Waveform Scheduling"

In this paper, we propose a method to exploit waveform agility in modern radars to improve performance in the challenging task of detecting small targets on the ocean surface in heavy clutter. The approach exploits the compound-Gaussian model for sea clutter returns to achieve clutter suppression by forming an orthogonal projection of the received signal into the clutter subspace. Waveform scheduling is then performed by incorporating the information about the clutter into the design of the next transmitted waveform. A simulation study demonstrates the effectiveness of our approach [C249]

"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. [C250]

"A new method of ship and chaff polarization recognition under rain and snow cluster"

In Warfare on the sea, passive interferences include not only chaff but also surrounding atmosphere such as rain and snow, these factors will influence final recognition of targets. This paper solves the problem by polarization theory. This method is based on the radar which can receive both left and right circularly polarized wave and obtain the full polarization information of echoes. Firstly, the path influence of rain and snow from polarization power matrix is eliminated in order to correct the power matrix of targets. Secondly, the distinguishing rate of targets from chaff is increased employing non-linear polarization transformation to increase the polarization range ratio of echoes. Finally, Simulation experiments show the method is effective. [C251]

"Wavelets: a Versatile Tool for the High Frequency Surface Wave Radar"

Widely used in image processing, wavelets seem to be a promising versatile tool for the high frequency surface wave radar (HFSWR). HFSWR is based on the ability of HF waves (3 MHz to 30 MHz) to propagate along the earth curvature. HFSWR can detect targets up to few hundred kilometers beyond the horizon. The two main applications of the HFSWR are the maritime surveillance of the exclusive economic zone (EEZ) and the remote sensing of the sea. Beside the classical noise which affects all radar signals, the detection capabilities of HFSWR suffer from two limitations: the sea clutter and the ionospheric clutter which are target masks. However sea clutter can be used to perform remote sensing of the sea. In this paper we are studying how wavelets may contribute to the improvement of radar signal processing. We consider general de-noising feature for radar signals, we carry out a wavelet-based improvement of remote sensing of oceanographic parameters and we

show the first results of a wavelet-based processing for ionospheric clutter mitigation. [C252]

"Ionospheric clutter mitigation with knowledge aided pre-whiten in High Frequency Surface Wave Radar"

Ionospheric clutter has proven to be the greatest impediment in high frequency surface wave radar (HFSWR). It influences most range bins, all Doppler bins and beams. Knowledge-aided ionospheric clutter mitigation using multiple coherent processing interval (CPI) data was described. The approach is based on estimation of the near vertical incidence clutter by past CPI data to provide improved knowledge of clutter statistics. Knowledge aided pre-whitening filter was used to cancel both near vertical incidence clutter and the range wrap clutter. Experimental results demonstrate that the algorithm is able to suppress the ionospheric clutter whilst preserving the desired characteristics of the target echoes. [C253]

"Adaptive detection of moving target based on velocity synthetic aperture radar"

By dividing a vector sampling at a specified pixel into three components, namely target, clutter, and noise, a novel parametric statistical model is proposed in the multi-channel and multi-look image domain of velocity synthetic aperture radar (VSAR). With the proposed parametric model, an adaptive moving target detection method is also obtained for VSAR, based on which the optimum improvement factors may be achieved. Furthermore, discussions are given for some VSAR systemic parameters. Some detailed numerical experiments are provided to demonstrate the effectiveness of the proposed model and the parametric methods of target detection. [C254]

"An Analysis of Measurement Derived Sea Clutter Simulations at Very Low Grazing Angles, in the Presence of Surface Based Ducting"

Sea clutter can have significant performance impacts on shipboard radar systems, particularly against low flying targets. It is essential to the evaluation of shipboard radar system performance, for engineers to have available very accurate sea clutter simulation models, which include the effects of anomalous propagation, as well as rough surface scattering, on the clutter return. In at-sea-tests, sea clutter returns from long ranges have been measured which are larger than the current sea clutter models have predicted. Not only do such large undesirable returns interfere with detection performance, but the presence of strong surface based ducting can result in extended range clutter folding, which may limit the usefulness of clutter mitigation approaches. The importance of the key parameter, grazing angle, in the computation of sea clutter cannot be overstated. Within the horizon the grazing angle is well understood, beyond the horizon grazing angle is a topic of considerable discussion (D.E., Barrick, 1998). The sensitivity of the sea clutter reflectivity models to grazing angle, within the context of trans-horizon ducted propagation is the focus of the issue being raised by this paper. In addition to the trans-horizon grazing angle issue, the difficult decision of selecting the height at which the propagation factor is modeled, is also discussed. [C255]

"Signal Detection using the Correlation Coefficient in Fractal Geometry"

Using the Fractal Geometry in Signal processing has been extended nowadays. They have found several applications in signal detection and recognitions. They use the chaotic feature of the noise and clutter and try to distinguish between the noise, clutter and the desired target. Recent works show that lots of clutters like sea and ground clutters have fractal behavior so this kind of approach to the signal detection has been extended these days. In this paper we have used the Box-Counts of a signal rather than the Fractal dimension of a signal as will be defined later in the text. By applying the new defined concept we have developed different methods of signal detection. We use the correlation coefficient of the Box-Count and the time domain range for different ranges. By using the difference in the behavior of these coefficients when we have or don't have a target, we can set statistics from these variables and set up some detectors to determine whether the received signal contains a target or not just by comparing the statistics with some thresholds. One of the applications of the method is in high resolution radars. The received signal contains the Range Profile of the target which is unknown in our point of view. So using matched filters cannot be such helpful. In this paper the proposed detectors can act much better the common detectors of these signals. We have shown the advantage of the new methods. They bring us about 3 db increases in SNR. [C256]

"Order Statistic and Maximum Likelihood Distributed CFAR Detectors in Weibull Background"

Non-Rayleigh clutter statistics result when sea or ground are viewed with resolution radars (pulse width < 0.5 mus) at low grazing angle (phi < 5deg). In this paper, we consider the problem of maximum likelihood (ML) and order statistic (OS) constant false alarm rate in distributed detection systems using fuzzy fusion rules in Weibull

clutter with a shape parameter known. We derive the appropriate membership functions for ML and OS as local detectors and use different fuzzy rules in fusion centre. Simulation for the "algebraic product", "algebraic sum", "union", "intersection" fuzzy fusion rules are conducted to assess the detection performance and the results are presented and discussed. [C257]

"Coastal applications of X-band radar to achieve spatial and temporal surface wave monitoring"

In this paper wave data from two different coastal stations will be discussed with respect to spatial inhomogeneities in the wave field. Effects of the changes in the local topography and strong tidal currents are reproduced in the radar data. The discussion will focus on the potentials of these data to monitor spatial and temporal variabilities of the sea state in coastal approaches. As an example, dissipation, refraction, and reflection of waves will be analysed. [C258]

"Distributed target detection in SAR images using improved chaos-based method"

Detection of distributed targets such as internal wave or ship wake on sea surface in Synthetic Aperture Radar (SAR) images is an important application of ocean microwave remote sensing. The chaotic characteristic of sea clutter gives some clues to targets detection on sea surface. Speckle, the inherent noise of SAR image, will affect the predictive accuracy of sea clutter adversely and reduce the detection performance of radar. In order to apply the chaotic characteristic of sea clutter to targets detection in SAR images more effectively, an improved chaos-based detection method is proposed in this paper. First, speckle noise is suppressed by undecimated wavelet transform (UWT), and then targets are detected on the basis of the chaotic characteristic of sea clutter from the denoised SAR images. Experimental results prove that the method proposed in this paper is effective for the distributed targets detection in SAR ocean images. [C259]

"A FEXP model Short Range Dependence analysis for improving oil slicks and low-wind areas discrimination in sea SAR imagery"

Starting from a consideration of the Long Range Dependence (LRD) behavior of sea SAR image spectra, an overview is given of the LRD approaches currently being used to achieve reliable sea surface anomalies discrimination from high resolution sea SAR images. In this paper, the problem of SAR image analysis to discriminate oil slicks from low wind areas on the sea surface is addressed by employing fractional exponential (FEXP) models and short range dependence (SRD) parameters. The presented method demonstrated reliable results when applied to European remote sensing 2 (ERS-2) SAR precision images (PRI) and ERS-2 SAR ellipsoid geocoded images (GEC) of the Atlantic and the Pacific Oceans. [C260]

"High resolution millimeterwave SAR for the remote sensing of wave patterns"

High resolution imaging of the ocean swell was performed using data collected with the polarimetric millimetre wave synthetic aperture radar MEMPHIS. The data, representative for a region off the south Spanish Atlantic coast in spring, have been evaluated using imaging and non-imaging statistical methods. The influence of high resolution processing on the clutter statistics for the Ka- and the W-band is discussed. [C261]

"Tracking atmospheric ducts using radar clutter: evaporation duct tracking using kalman filters"

This paper addresses the problem of tracking evaporation ducts in marine environments. The method tracks the evolution of the range and height-dependent index of refraction using the radar sea clutter. A split-step fast Fourier transform (FFT) based parabolic equation (PE) approximation to the wave equation is used to compute the clutter return in complex environments with varying index of refraction. Tracking is obtained using an extended Kalman filter (EKF). [C262]

"Continuous-discrete filtering for dim manoeuvring maritime targets"

Real radar data containing a small manoeuvring boat in sea clutter is processed using a grid based finite difference implementation of continuous-discrete filtering. Both two dimensional diffusion and four dimensional constant velocity models are implemented using Gaussian and Rayleigh sea clutter models. Superior performance is observed for the constant velocity model and significant sensitivity is noted due to mismatches between actual clutter characteristics and Gaussian and Rayleigh models. A simple likelihood ratio thresholding technique is shown to provide a significant performance improvement. [C263]

"Surface clutter analysis and ranging sidelobe level requirements for spaceborne meteorological radars"

Pulse compression techniques are very attractive in the development of new-generation spaceborne meteorological radars, because it has the advantages to reduce the transmit power requirements and improve the measurement precision by increasing incoherent average samples. Compared with TRMM, which employed a pulsed-CW signal, it is very important to analyze the effect of surface clutter from ranging sidelobes of the returned signal after pulse compression. In this paper, the effect of surface clutter with different antenna sidelobe levels and different ranging sidelobe levels are analyzed in details. Based on the analysis of surface clutter, the requirements for antenna sidelobe level and pulse compression range sidelobe level are proposed. [C264]

"Assessment of Millimeterwave Propagation over Sea by Experiment and Simulation"

To be able to assess the capability of maritime radars under different conditions at differing radar bands simulation programs for the refractivity profile of the atmosphere and the wave propagation, based upon a solution of the parabolic equation have been developped. These have been used to model the propagation for a series of measurements which have been conducted using an experimental radar operating simultaneously at frequencies of 10 GHz, 35 GHz and 94 GHz against reference reflectors onboard a vessel for outbound and inbound courses. Simultaneously environmental measurements using wavebuoys and meteosonds have been conducted to generate a complete data set. Moreover an approach was initiated to retrieve the vertical profile of the refractive index from sea clutter data by an inversion method. The method is based on the LS-SVM (Least-Squares Support Vector Machines) theory. The paper describes the experimental approach and the simulation methods. Results of simulations retrieved from the classical method and the new inversion approach are compared. [C265]

"Adaptive Sensing of Dynamic Target State in Heavy Sea Clutter"

We propose an adaptive estimation method for the spatio- temporal covariance matrix of sea clutter. The motivation is to enable adaptive detection approaches that rely on accurate estimation of this matrix. The method involves vectorization of the equations for the dynamical system model governing the temporal evolution of the clutter matrix followed by a multiple particle filtering approach to deal with the high dimensionality of the formulation. The estimated sea clutter covariance matrix is applied to the problem of detection of a small target in heavy clutter; effectiveness is demonstrated via simulations. [C266]

"Performance analysis of maximum likelihood CFAR detection for Gaussian mixture type clutter"

In a previous work, we have proposed to use a generalized Gaussian Mixture (GM) distribution for modelling the sea clutter. In this work, we analyze the performance of the proposed method for the CFAR and non-CFAR cases. In order to evaluate the performance of the proposed method, we derive the probability of false alarm Pfa. The Cramer Rao Bound (CRB), which is used to predict the performance of a given system is also given. [C267]

"Properties of polarimetric sea clutter at 35 GHz"

The FGAN operated MEMPHIS radar was used to measure the backscatter behaviour of sea clutter at 35 GHz. The resulting fully polarimetric, carefully calibrated reflectivity data were analysed with respect to their temporal and spatial characteristics. Temporal decorrelation is fast, accordingly the polarimetric persistence is very low. As to spatial statistics, several well-known probability density functions like redistribution or log-normal are compared to each other. It is found that none of them is ideal. There is always a number of outliers that statistically behave differently. By eliminating them the goodness of the fit can be improved. [C268]

"Sea clutter measurement with airbone synthetic aperture radar"

In this paper, we consider the surface motion as an important factor governing behaviours of the sea clutter observed in SAR images. Therefore, we propose a model for SAR-acquisition of time varying scenes. Then we derive from this model the 2nd order statistical properties of an acquired scene in terms of a time-dependant reflectivity q. We also introduce the sea surface elevation and we complete the reflectivity description by applying small slope approximation (SSA) of the wave scattering from rough surface . [C269]

"A Simulation of the Synthetic Aperture Radar Observation of a Manufactured Object in Sea Clutter using Finite Differences"

A simulation of the synthetic aperture radar (SAR) observation of a complex sea scene is proposed. The observed sea patch consists of sea clutter and a metallic, steady object. The simulation process is based on a local, discrete calculation using the finite difference method in the time domain. This approach turns out to be relevant when considering precise, complex scenes such as depicted in the study, despite a few drawbacks that

are enlightened in the article. Antenna synthesis is performed upon a series of simulations using finite differences, and leads to the formation of a SAR image of the studied scene. [C270]

"Target Detection Using HF Radar Data"

High frequency (HF) radar systems have a potential to detect targets which are located beyond the optical horizon on the sea surface. Unfortunately sea clutter may be strong enough to prevent such detection. In this work we present results of applying space-time adaptive processing (STAP) to this problem. Real, registered signals were used for numerical experiments. [C271]

"Backscattering Polarization-Spectral Specific Features in Determining Movement Direction of Objects"

A possibility has been demonstrated experimentally that directions of moving objects relative to radars may be determined according to the sign of the derivative of the scattered signal crosscorrelation function on parallel and orthogonal polarizations. [C272]

"Tracking atmospheric ducts using radar clutter: surface-based duct tracking using multiple model particle filters"

An accurate knowledge of radio refractivity is essential in many radar and propagation applications. Especially at low altitudes, radio refractivity can vary considerably with both height and range, heavily affecting the propagation characteristics. This paper addresses the problem of high variability in tracking surface-based ducts in marine and coastal environments. The method tracks the evolution of the range and height-dependent index of refraction using the radar sea clutter. A split-step fast Fourier transform (FFT) based parabolic equation (PE) approximation to the wave equation is used to compute the clutter return in complex environments with varying index of refraction. [C273]

"Radar Track-Before-Detect Algorithm of Multitarget Based on the Dynamic Programming"

For detecting and tracking multitarget under the background of low SCR, a radar track-before-detect algorithm of multitarget based on the dynamic programming is presented. This algorithm can exactly estimate the number of targets in the observed region, and optimally separate the tracks of these targets. Therefore it can solve the problems of missed alarms and false alarms, which usually arise, when the pervious track-before-detect algorithm are used to detect multitarget with unknown number of targets [C274]

"Prediction of Sea Clutter Based on Chaos Theory with RBF and K-mean Clustering"

Artificial neural network (ANN) has been widely applied in time series analysis, typically, it can give an effective method to solve complicated problems which are too complex to understand in physic and statistic method, or observation data varied statistically and the data generated in nonlinear mechanism. Based on the underlying dynamic mechanism of the sea clutter, to reconstruct the nonlinear model of dynamical phase space, correlation integral (also called C-C method) and Cao method are used to get time delay tau and embedding dimension min this paper. Furthermore, an algorithm of radial basis function (RBF) with k-mean clustering to adjust and modify the networks is also presented to predict the nonlinear characteristic sea clutter for the goal of detecting the weak target signals beneath the sea clutter. With the new algorithms, computation complexity can be deduced while its reliability can be greatly improved. It also can satisfy the real-time requirement in real application. More detailed calculates and test results are presented [C275]

"The Cao Method for Determining the Minimum Embedding Dimension of Sea Clutter"

To verify whether sea clutter has chaotic character or not, the minimum embedding dimension and time delay in phase space reconstruction are needed. This paper discusses two defects of false nearest neighbors (FNN) for calculating embedding dimension: noise sensitivity and effect of subjective parameter. It was confirmed that Cao method could overcome these limitations and settle on a suitable embedding dimension of time series and distinguish deterministic signals and stochastic signals clearly. It is concluded that sea clutter is composed of stochastic component and determined component together [C276]

"An Improved Target Detection Method on Wavelet-Based Fractal Scaling Analysis"

Wavelet-based fractal scaling analysis is a new method based on fractal geometry for detecting small targets within sea clutter. But the fractal dimension of sea clutter is affected by not only the presence of a target but also sea wave propagation directions, which will degrade accuracy of detection under various sea and weather

conditions. An improved method using spatial Hurst parameter differences is provided to overcome the above drawback. Experiments with IPIX real-life radar data have shown that the novel method is more robust and accurate than wavelet-based fractal scaling analysis method [C277]

"Sea Clutter Suppression Based on Radon Transform at High Grazing Angles"

During final guidance, as radar working over sea surface at a very high grazing angle, it is hardly to distinguish target from clutter background due to the strong reflection of the sea surface. A novel method is presented to suppress the sea clutter in this paper. The proposed method based on Radon transform utilizes edge detection technique to find a boundary to separate the target and sea clutter in range-Doppler map. Simulations for sea clutter suppression and target three-dimensional imaging on the sea are conducted. Results show the effectiveness of our method [C278]

"A method or radar targets position acquisition based on Possibilistic C_means algorithm"

Targets position acquisition is a key technique in radar data processing system. The existence of sea clutter result in the coupling of targets in radar video which lead to the distortion of targets position acquisition. A method for radar targets position acquisition based on possibilistic C_means algorithm is used to solve the problem. During marking different targets by the connectivity and combination algorithm, a method based on possibilistic C_means algorithm is presented to segment coupled targets. The result of the experiment showed that this method can use azimuth and range of radar video simultaneously to realize target position acquisition which can overcome the targets splitting caused by conventional method based on one-dimensional acquisition and can segment coupled targets caused by several factors effectively, thus improving the accuracy of targets position acquisition [C279]

"Small Target Detection in Sea Clutter Based on Doppler Spectrum Features"

Small target detection in sea clutter is a challenge problem in radar signal processing community. Based on the analysis of sea clutter Doppler spectrum characteristics, two target detection algorithms are proposed, namely, a Bayesian detection algorithm based on joint Rayleigh distribution model and a feature detection algorithm based on the entropy feature extracted from signal's Doppler spectrum. The detection performances of the proposed algorithms are evaluated based on the data collected by the McMaster IPIX radar at the east coast of Canada [C280]

"Analysis of First-order Sea Clutter in a Shipborne Bistatic High Frequency Surface Wave Radar"

The features of the first-order sea clutter in a shipborne bistatic high frequency surface wave radar (HFSWR) are analyzed. Some formulas of the first-order Bragg frequency are firstly presented derived from the radar geometry, and then the broadening mechanism of the first-order spectrum is discussed. The distributions of the first-order peaks are represented by computer simulations. The processing results of experimental data confirm partially the theoretic analysis. Finally, the author discusses the seeming conflicts between theoretic and experimental results [C281]

"Geometric Analysis on Moving Targets and First-order Sea Clutters in Bistatic Shipborne SWR"

The geometric relationship between a bistatic radar and targets is highly complicated when they are moving with different velocities and headings. Target motion equations, which are used to describe the complex dynamic system's characteristics, is derived based upon the Cartesian coordinate systems established both on the transmitter (CCST) platform and on the receiver (CCSR) platform of the bistatic radar system. The results show that the instantaneous ranges between a target and the transmitter platform (TP) and the receiver platform (RP) contain a time-variable tangential component and a time-variable radial component. The Doppler-broadening mechanism of first-order sea clutters in bistatic shipborne surface wave radar (SWR) is analyzed based on the results derived above, and the conclusion shows that there exists dynamic broadened component in the broadened Doppler spectrum resulted from the difference of the motion between TP and RP [C282]

"Simulation of Coherent Correlation K-distribution Sea Clutter Based on SIRP"

The method of spherically invariant random process (SIRP) allows independent control of the margin probability density function (PDF) and the autocorrelation of clutter, which overcomes the infection of zero memory nonlinear (ZMNL) on autocorrelation. The simulation model of coherent correlation K-distributed clutter using SIRP, with the modeling of coherent pulsed radar clutter, was presented and simulated on computer. The validity of scheme is proved by our simulated results [C283]

"New Method for the Simulation of Coherent K-distributed Clutter"

In this study, a new method for the simulation of coherent K-distributed clutter is presented. This method is based on the principle of each quadrature component of K-distributed clutter can be modeled, exactly or approximately, by a weighted sum of products of two independent Gaussian variables. This method can generate correlated coherent clutter with arbitrary complex ACF (autocorrelation function). At the same time, compared with the classic methods ZMNL (zero memory nonlinear) and SIRP (spherically invariant random process), it doesn't need solving nonlinear equations, so the algorithm complexity is decreased dramatically [C284]

"Interference Suppression for Ship-Based Passive Synthetic Impulse and Aperture Radar"

Interference statistic characteristic is theoretically analyzed in ship-based passive synthetic impulse and aperture radar (SIAR) scenario. Covariance matrix at interested range bin is estimated using echoes from some positive and all negative frequency range bins after stretching with cosine weight for co-channel interference suppression. Thereafter, Karhunen-Loeve transformation is applied to the echo received for co-channel interference suppression provided that its power is stronger than radar echoes. Meanwhile, the suppression approach of nonstationary interference owing to multipath propagation is proposed whereby fast-time STAP updated for PRI to PRI, while the slow-time statistical properties of first order sea clutter output are unaffected by fast-time STAP fluctuation. Effectiveness of interference suppression is confirmed by real data [C285]

"Target Detection in Abruptly Non-Stationary Doppler-Spread Clutter"

This paper addresses the problem of target detection in the presence of Doppler spread clutter which is neither stationary during a coherent integration time (CIT) interval nor across different range bins. This phenomenology occurs, for example, in over-the-horizon skywave HF radar where propagation through moving ionospheric inhomogeneities spreads the surface clutter and the clutter statistics can change quite abruptly during a CIT and across range bins. In these cases, the performance of conventional adaptive techniques suffers from a lack of adequate training data. The method proposed here breaks the full CIT into smaller sub-CIT's which are then extrapolated using low order AR models. The Doppler spread clutter is thus effectively modeled as an abruptly time varying autoregressive (ATVAR) process. Subsequent Doppler processing and coherent combining of the extrapolated sub-CIT's is then performed with improved signal-to-clutter gain since only a small proportion of the sub-CIT's are corrupted by abrupt non-stationary behavior. Moreover, nearly full coherent signal gain against noise is maintained. Initial processing on experimental radar clutter data with injection of a simulated target illustrates that this approach can provide an SCNR improvement of more than 5 dB compared to conventional Doppler processing [C286]

"Detection of targets in bandlimited and spatially correlated clutter"

This paper describes the preliminary analysis of an unconventional approach for detecting targets in band limited clutter that exhibits some degree of spatial correlation from range bin to range bin. The receiver processing chain utilizes a lattice predictor (LP) filter to remove clutter at the output of a Doppler filter bank. Subsequently, an order-statistic (OS) constant false alarm rate (CFAR) processing stage is used to threshold the data and a binary integrator creates a binary image of threshold crossings accumulated over several coherent processing intervals (CPIs). A novel technique is applied for removing noise from the binary image using morphological filters, thereby exposing tracks created by any moving targets. Once a track has been detected, the corresponding target is declared present. Test results based on measured clutter data will be presented that suggest the proposed processing techniques may improve detection performance in a clutter environment. [C287]

"A versatile bistatic & polarimetric marine radar simulator"

We present a versatile simulator for marine radars that can, in particular, be used in multistatic configurations. Today, most simulators modelize the sea clutter by a random noise; however, no obvious relation exists between physical parameters (e.g. wind speed or salinity) and the shape of the probabilistic law of noise. On the contrary, we modelize the whole acquisition chain: antennas and their polarization, the shape of the emitted signal, etc. Realistic sea surfaces are generated using the two-scales model on a semi-deterministic basis, so as to be able to incorporate the presence of ship wakes. We present pseudo-raw signals obtained with our simulator. These signals can be further processed and fed to a ship detection and tracking chain. We aim at using this simulation as a tool to benchmark these algorithms and improve them by adding knowledge on the physical uncertainties and the sensor imprecisions. [C288]

"Distributed Pre-Processed CA-CFAR Detection Structure For Non Gaussian Clutter Reduction"

This paper deals the cell averaging constant false alarm rate (CA-CFAR) distributed RADAR detection of targets embedded in a non Gaussian clutter. We develop a novel pre-processing algorithm to reduce spiky clutter effects, notably a non linear compression procedure. This technique is similar to that used in non uniform quantization where a different law is used. Two approaches to combine data from the pre-processed CA-CFAR detectors are proposed The performance characteristics of the proposed CA-CFAR distributed systems are presented for different values of the compression parameter. We demonstrate, via simulation results, that the pre-processed procedure combined with distributed systems when the clutter is modeled as alpha-stable distribution, are computationally efficient and can significantly enhance detection performance [C289]

"Feature Based Plot Classification using a Bayes Algorithm"

Many fielded state-of-the-art radars suffer from excessive false alarm rates, at least at times. The radar concerned in this paper is intended for automatic tracking of objects for maritime surface surveillance, one of the difficult scenarios for automatic tracking. The algorithm first corrects for the ship's motion and then builds a plot map, which stores the long term probability density functions of features of the observed echoes. Through the Bayes algorithm the conditional probability that a plot belongs to each of the four classes "moving clutter", "fixed clutter", "ship" or "other object" is established. The result is a significant reduction of the clutter plots and only a modest reduction of the ships' plots. Although the method presented here is intended as a classifier for prioritizing plots in the case of data overload, it could also be used in the initiation phase of new tracks in order to classify tracks in either of the mentioned classes [C290]

"Impulsive Interference Mitigation in High Frequency Radar"

An effective method for impulsive interference mitigation in high frequency (HF) radar based on the detect-excise-and-extrapolate idea is presented. The key to the method's success is suppressing the ocean clutter in the time domain prior to detecting the impulsive interference. The method performed well on ocean echo data acquired with the HF radar system OSMAR [C291]

"Fractal Stochastic Signal Processing Based on the Affine Spectral Correlation Method"

This paper proposed a new time-scale representation-"the wavelet spectral correlation function (WSCF)", and analyzed the property and the relation between SCF and WSCF. Based on the analysis of WSCF of fractal stochastic noise and WGN and the SCF of WGN, the property of fractal stochastic noise in the WSC domain is studied. Considering the actual sea clutter, a fractal noise AM-FM model was proposed, furthermore, its relation in frequency spectrum with the narrowband WGN AM-FM jamming is analyzed, and the WSCF of the sea clutter was analyzed, which presents the advantage of the WSCF in the processing of the sea clutter. The signal recognition of pseudo random code pulse trains was simulated, including the width and repeating period of the sub pulse, which showed the value of theory and application of WSCF in the signal recognition and estimation [C292]

"Integrated Marine Mammal Monitoring and Protection System (IMAPS): Gray Whale Target Strength Measurements and the Analysis of the Back-Scattered Response"

The central IMAPS objective is to establish a global solution for systematic assessment and protection of the marine environment for the Navy, offshore industry, and scientific research community, through the development and implementation of a comprehensive, modular tool. The limitations of current technologies are that they are individually inadequate to fully achieve mitigation objectives. Visual monitoring, passive location, high frequency active sonar, and radar all have their inherent limitations such as weather conditions, a necessity for vocalizations, maximum detection range, and sea state limitations. Therefore, there is a need for all the sources of information related to the detection and classification of marine mammals to be fused and to operate in real-time in order to provide a robust protection, assessment, and research system. The other IMPAS direction is concentrated on the design and development of the active sonar modality representing just one component of the global system. The active sonar was designed, built and tested during the Marine Mammal Active Sonar Test (MAST 04), producing whale detections and whale tracks. The experiment was conducted in January 2004 off the coast of California. One of the objectives is to distinguish whale backscattered responses from the ones generated by the environmental clutter in a waveguide. Furthermore, it aims to identify and analyze the target signature features that are necessary for enhanced active sonar detection and classification of marine mammals. Over the years there have been very few documented attempts to capture and analyze the backscattering response of whales using an active sonar system. Nevertheless, whales, mostly owing to their size, their motion, and the aspect dependence of their backscattered field, possess desirable properties that help distinguishing their scattered response from clutter and other environment related false alarms. As an initial step, data collected during the MAST04-- experiment is presented, and gray whale target strength measurements are obtained.

Results are compared to the previously published whale target strengths. Additionally, an investigation is conducted in an effort to provide whale feature identification points suitable for automated detection and classification, as means of relating gray whale active acoustic signatures to their inherent characteristics and their motion. During the MAST04 experiment, the active sonar component feasibility has been demonstrated, while the second generation system is being developed for the MAST 07 experiment. Tracking and classification algorithms are being further developed and they will be implemented and tested during the upcoming MAST 07 experiment. MAST 07 will feature a lighter, autonomous, fuel cell powered active sonar system, implementing real time marine mammal detection, tracking and classification algorithms [C293]

"Decision Tree Based FPGA-Architecture for Texture Sea State Classification"

The target detection process in sea clutter background involves the use of different types of CFAR (constant false alarm rate) algorithms. These algorithms and their parameters should be configured to obtain the maximum detection probability and minimum false alarm probability at the current sea state (Beaufort scale). This paper present an FPGA-architecture for automatic classification based on texture recognition of sea states. The sea state texture classification allows select the appropriate CFAR algorithm and its parameters for the target detection process. The paper is centered in the hardware implementation for sea state texture classification, based on decision tree. The rules for decision tree are obtained from the analysis of the grey levels co-occurrence matrix features applied in an image of the sea state obtained in a radar scan. Results with simulated and real data are presented and discussed [C294]

"Modeling sea clutter as a nonstationary and nonextensive random process"

Sea clutter is the backscattered returns from a patch of the sea surface illuminated by a radar pulse. It is of great importance to develop statistical models that properly characterize radar clutter returns. A lot of effort has been made to fit various distributions to the observed amplitude data of sea clutter. However, the fitting of those distributions to real sea clutter data is not excellent, and using parameters estimated from those distributions is not very effective for detecting targets within sea clutter. This may be due to the fact that sea clutter data is highly non-stationary. This non-stationarity motivates us to perform distributional analysis on the data obtained by differencing amplitude data of sea clutter. By systematically analyzing differenced data of 280 sea clutter time series measured under various sea and weather conditions, we show that differenced data of sea clutter are well fitted by the Tsallis distribution. The latter is obtained by maximizing the Tsallis entropy, a generalization of the Shannon (or Boltzman-Gibbs) entropy. Interestingly, we find that the nonextensitivity parameters estimated from the Tsallis distribution may be used to help detect low observable targets within sea clutter. [C295]

"New aspects to knowledge-aided clutter analysis"

Digital signal processing allows improvements in site-specific clutter prediction. With digital terrain maps and a flight obstacle register, land clutter origin can be solved. An efficient, knowledge-aided approach to extracting homogeneous clutter from radar signal is presented. Once homogeneous clutter's statistic has been recognized, also mixture models can be constructed. The suggested aspects are illustrated through an air surveillance radar simulation. The enhancement attained in clutter analysis and thus in clutter models is the novelty of the presented aspects. [C296]

"Non-stationarity analysis of real X-Band clutter data at different resolutions"

This work deals with the problem of providing a statistical model of the backscattering from marine surface for low-grazing angle and high resolution radar systems. Based on the electromagnetic two-scale model, we analyzed both the amplitude and frequency modulations induced on the small-scale Bragg resonant waves by the large-scale surface tilt and advection, due to the swell presence. Evidence of marine clutter non-stationarity and the relationship between the variations of clutter texture, Doppler centroid and bandwidth have been investigated by processing measured data, recorded by the IPIX radar of McMaster University in Grimsby, Ontario, Canada. Our results demonstrate that sea/lake clutter at different range resolutions is non-stationary and is better modeled by a hybrid AM/FM modulated process. [C297]

"Suppression of Ionospheric Es Clutter in HFSWR"

Ionospheric clutters from sporadic E-layer are often observed in 200 km-coverage HFSWR. One kind of the Es-layer clutters is found to have coherent time much longer than that of sea echoes. The feature is exploited in the proposal of a new algorithm to suppress this kind of clutter based on eigen value decomposition and subspace projection [C298]

"Space-Time Adaptive Processing analysis for the moving target on the sea surface indication purpose"

Space-time adaptive processing (STAP) can improve target detectability in a presence of a ground clutter for airborne radar. Ground clutter echo has a wide spectrum as a result of the radar platform (airplane or satellite) motion. To reject clutter echo and preserve target echo, STAP employs antenna array. Simultaneous filtering in both spatial (angle) and frequency domain can improve performance. In this paper we propose a new application of STAP. Assuming an antenna array standing on a sea shore, the objective is to detect targets on the sea surface. Unfortunately sea clutter has different statistical properties compared to airborne clutter. As a consequence, basic STAP algorithm is not optimal in any sense. Future research will face the problem of evaluating performance of STAP applied to sea clutter. We hope to develop a new algorithm that can perform better in the presence of sea clutter. [C299]

"Detection of Targets in Sea Clutter Using Adaptively Truncated Interleaved Spectral-Temporal Interferometry"

A new method is introduced to detect targets in the presence of sea clutter. Most previous analysis methods have worked almost exclusively in the spectral domain, but the new method uses a combination of band-pass spectral filtering, autocorrelative algorithms and time-series analysis for target detection. The procedure is well adapted to deal with scenarios involving accelerating targets and de-accelerating targets, and outperforms traditional methods in this area. impulsive RF noise can also be effectively ignored. The method is at least the equal of traditional methods for uniformly moving craft. The method also has some advantages in detection of slowly moving targets in the presence of low frequency sea-clutter. The procedure is called Adaptively Truncated Interleaved Spectral-Temporal Interferometry (ATISTI). [C300]

"Radar Detection of Small Sailing Yachts"

Paper describes measurements in the real sea conditions of the maximum radar detection and tracking distances of small sailing yachts without radar reflectors and equipped with different types of radar corners by contemporaneous ship and shore based radar equipment. Researches were conducted on order of the Maritime Office in Gdynia. [C301]

"Clutter Suppression Techniques for River Surface Current Measurements"

First Page of the Article [C302]

"Suppression of Surface Clutter Interference with TRMM Precipitation Radar Observation"

First Page of the Article [C303]

"Polarimetric Characteristics of X-Band SAR Sea Clutter"

First Page of the Article [C304]

"Knowledge-Based Adaptive Processing for Ship Detection in OTH Radar"

This paper is concerned with adaptive Doppler processing in high frequency (HF) over-the-horizon (OTH) radar to improve the detection of slow-moving ships against clutter. A knowledge-based adaptive detection approach that exploits additional information to identify the surfaces that scatter clutter in each radar resolution cell (i.e. land, sea or land-plus-sea) is proposed to guide the selection of training data for the adaptive algorithm. The practical performance of the KB scheme is compared with conventional FFT-based Doppler processing and a traditional adaptive algorithm that does not exploit additional information. [C305]

"A Case Study on the design of a cluttermap based plot classification mechanism"

Many fielded state-of-the-art radars suffer occasionally from excessive false alarm rates. Various mechanisms have been devised in order to improve the signal-to-clutter ratio in general, but control of false alarms remains to be an issue of concern for the designers. This paper discusses a post-detection mechanism that splits the total offer of plots into four classes, such that each of these classes may be utilized by the tracking algorithm in order to have control over the false track rate. The mechanism has been developed for maritime sea-surveillance radar having a logarithmic receiver and a sliding window video extractor. It is basically a plot map performing a two-dimensional feature based classification. The features exploited are the signal-to-noise ratio and the target extent. The parameters in the algorithm are tuned based on a learning set from the radar operating in real life and tested using the same parameter values on a test set, also recorded during real life

operation. The results suggest that a mechanism like proposed can be effective in controlling the false alarm rate', however sometimes at the expense of loosing some detections of real targets. [C306]

"Spatial-Temporal Differential Analysis for GMTD with Airborne Radars, Part 2: First Experimental Results"

We consider an application of the spatial-temporal differential analysis (STDA) technique to the ground-moving target detection (GMTD) using airborne radars with multiple receive channels. STDA is a new approach, suitable to processing multiple radar signals which utilizes spatial and temporal scintillations in the instantaneous signal power. To test the practical potential of STDA, we used multi-channel airborne radar measurements (MCARM) database, which was developed to test and improve space-time adaptive processing (STAP). In particular, we processed the MCARM file rd050575, obtained from flight 5, cycle d, and acquisition 575. The goal was to detect the Sabreliner airplane flying towards the radar-carrying airplane BAC 1-11 in the presence of urban, land, and sea clutter. Second-order structure functions for multiple radar signals were used for the processing. This simplified STDA technique applied in the time domain only provides a good performance by detecting the Sabreliner with a false alarm rate below 10' in the same range bin where it was previously detected using several STAP variants. [C307]

"Verification of the Radar Visibility of Small Objects"

Minimal and maximal distances of radar visibility and tracking of small objects were measured in different weather conditions in the Gulf of GdaГ‚Вїsk and at high sea on big tanker ship and s/v "Dar MГ‚ВїodzieГ‚Вїy". Radars working in S and X band were used. Different small objects, including buoys, hydrofoil boats and high-speed crafts, were observed and tracked on different radars in different weather conditions. Results of these experiments will be presented in this paper. [C308]

"Simple Sea Clutter Canceller for Noise Radar"

In the last decade the noise radar technology is intensively investigated. The low transmitting power and nonspecific waveform makes that the noise radar has very god LPI properties. The simultaneous emission and reception of signals in such kind of radars make them sensitive to near-far problem. Strong echoes, originated from ground clutter can completely mask the weak target return. In case, when the radar is placed on a vessel, except of zero-Doppler ground returns the dominant part of return power consists of Doppler-spread sea cutter echoes. The papers present a simple adaptive sea clutter canceller, which can be used to mitigate near-far problem "on the sea". [C309]

"Comparison of the Detection Performance of an FMCW Coastal Surveillance Radar for V and H Polarizations"

The present work supports the use of V-polarization instead of H-polarization under CFAR detection in FMCW coastal surveillance radars due to its statistical advantage. The sea clutter reflectivity, sigma0, is about 3-5 dB less for H-polarization than for V-polarization. However, the sea clutter echoes are spikier for H-polarization than V-polarization for a high resolution radar. It has been suggested that for a high resolution radar V-polarization is to be preferred over H-polarization for a fixed threshold detection below a critical radar height (Watts, 1996). The new numerical results for the detection performance of an FMCW radar with CFAR detection supporting the above argument will be given in the following sections. [C310]

"Lightning Interference Cancellation in High-Frequency Surface Wave Radar"

The performance of high-frequency surface wave radar (HFSWR) is known to suffer from the lightning impulsive noise. In this paper, the characteristics of lightning interference in range, Doppler and spatial domain are analyzed and a new Doppler-domain cancellation scheme based on adaptive beamforming is proposed. The new scheme has no special requirement for the distribution of ocean/ground clutter in range-Doppler map and therefore is more preferable in practical HFSWR environments [C311]

"Modelling evaporation duct effects on microwave propagation with experiment validation"

Microwave propagation is adversely affected by evaporation duct, which can occur as often as 85% of the time in the sea of the world. Evaporation duct propagation is the abnormal bending and diversion of electromagnetic radiation from the intended paths, that resulting in the problems of extended propagation of microwave signals well beyond the radio horizon, radar holes, and anomalous clutter. This paper describes a software package, evaporation duct propagation-parabolic equation (EDP-PE), a MATLAB-based implementation of the parabolic equation(PE).The EDP-PE provides a PE solution for propagation loss in the inhomogeneous atmosphere and

the rough sea surface, which is more useful in the coastal regions where topographically-induced changes in refractive index profiles are common place. To validate the purposes the paper shows a comparison between EDP-PE calculations and the measurements. The calculated path loss for several evaporation duct profiles shows an excellent agreement with the measurement. Coverage diagram examples presented serve to illustrate the complicated nature of the propagation patterns which arise from evaporation ducting layers. [C312]

"Ionospheric Clutter Suppression in HF Surface Wave Radar OSMAR"

Experimental trials conducted from 2003 to 2005 in east China sea demonstrated that HF surface wave radar (HFSWR) OSMAR (ocean state monitor and analysis radar) could be strongly affected by scattering from ionospheric structures and irregularities. A large database acquired during those trials has been used in detailed investigations of the phenomenology of this ionospheric clutter, leading to the development of effective mitigation techniques based on the characteristics of ionospheric clutter. In this paper the 2-D angle of arrival of ionospheric clutter has been analyzed and the spatial adaptive processing based on 2-D antenna array is introduced to suppress ionospheric clutter. Experimental results confirm that the above technique can achieve effective ionospheric clutter suppression using the field experimental data recorded by the OSMAR2003. [C313]

"Ship Wakes Detection in SAR Images Based on the Joint Radon Transform and Entropy"

In order to distinguish true ship wakes from other spurious linear feature effectively, a novel method of ship wakes detection based on the Radon transform (RT) and on the entropy, and named joint Radon and entropy detection algorithm (JRE) is proposed. The proposed approach extracts all possible peaks in Radon transform space with a low threshold, then computes the entropies centering around each peak and identifies the true ship wakes from spurious ones. Furthermore, the method can increase the detection probability and reduce the false alarm probability. Theoretical analysis and experimental results show that the method is capable of detecting synthetic aperture radar (SAR) ship wakes precisely and reliably in the presence of both strong noise and sea clutter [C314]

"A method for automatic spotting using water column"

This paper addresses the method for automatic measurement of projectile target deviation using water columns cause by underwater explosion. The detection and tracking of water column is operated according to the transformation of RCS of a water column. A model of water columns is described here, and a bi-parameter sea-clutter map was used as detection background in order to distinguish water columns from sea-spikes and low-velocity targets. Finally, the paper gives the actual experimental result that proves the correctness of the method [C315]

"Estimation of Refractivity Profile from Radar Sea Clutter and Key Problems"

The estimation of atmospheric refractivity profile from radar sea clutter is called RFC. RFC can really get atmospheric refractivity profile from radar sea clutter. Compared with the traditional numerical prediction models based on meteorological parameters, it has a better performance. This paper introduces basic principle and research state of RFC. Key problems of RFC are also discussed [C316]

"Utilization of Support Vector Machine based on Neural Network to Suppress Ocean Clutter and Zero Frequency Disturbances"

The paper proposes a new multi-classifier for pattern recognition by combining neural network with SVM (support vector machine). The multi-classifier has the advantages of SVM and NN (neural network). According to the properties of Bragg peak, zero frequency disturbance and the target of moving with time-varying velocity among the echo signal of HFSWR (high frequency surface wave radar), the multi-classifier is utilized to process the result of decomposing radar echo with chirplet atom and separate them. Then the ocean clutter and zero frequency disturbances can be suppressed according the result of classifying. A new means by utilizing HFSWR to detect the target moving with time-varying velocity is provided in the paper. [C317]

"Detecting Weather Radar Clutter by Information Fusion With Satellite Images and Numerical Weather Prediction Model Output"

A method for detecting clutter in weather radar images by information fusion is presented. Radar data, satellite images, and output from a numerical weather prediction model are combined and the radar echoes are classified using supervised classification. The presented method uses indirect information on precipitation in the atmosphere from Meteosat-8 multispectral images and near-surface temperature estimates from the DMIHIRLAM-S05 numerical weather prediction model. Alternatively, an operational now casting product called

'Precipitating Clouds' based on Meteosat-8 input is used. A scale-space ensemble method is used for classification and the clutter detection method is illustrated on a case of severe sea clutter contaminated radar data. Detection accuracies above 90 % are achieved and using an ensemble classification method the error rate is reduced by 40 %. [C318]

"A First Study on the use of TerraSAR-X for Meteorological Purposes"

In this paper we present the predicted performance of the TerraSAR-X for meteorological purposes. Principally, the study focuses on the possibility of measuring rain over ocean and forest. Regarding the acquisition geometry, we investigate the rain volume and voxel resolution, the signal-to-noise ratio and the signal-to-clutter ratio. The clutter interference has been evaluated for intra- and inter-pulse ground returns. Measurement of rain for nadir-looking geometry looks promising over forest and ocean under almost all conditions. However, for side-looking geometry, rain detection could be only possible at very high rain rates. [C319]

"Radar coverage prediction over ocean: Duct mapping using least squares support vector machines"

Sea environment is a complex and changing medium which causes important variations on shipborne radar coverage. Actually, the electromagnetic wave propagation sustains strong refractive effects due to the presence of ducts, and diffraction effects due to the sea surface. However, efficient two-dimensional prediction models for wave propagation based on parabolic wave equation (PWE) are available nowadays, but a relevant description of the refractive index profile is needed to feed these models. The idea, first introduced by Rogers and Gerstoft and known as "refractivity from clutter" (RFC), is to exploit the sea clutter in order to retrieve the refractive index profile. The aim of this paper is to propose a new inversion method to obtain the vertical variations of the modified refractivity from the knowledge of the range-dependent propagation losses. These latter can be deduced from the sea clutter collected by the radar. Whereas Rogers and Gerstoft used a genetic algorithm (GA) to find the modified refractivity profile parameters, least squares support vector machines (LS-SVM) are used here. This method produces good results with the great advantage of quickness. [C320]

"Sequential Detection for a Target in Compound-Gaussian Clutter"

Sequential detection allows the analysis of an incoming data flow and the detection of changes in the distribution of these measurements. In this paper, we develop the sequential detection algorithm for a target under compound-Gaussian clutter. Both the target and clutter parameters are assumed unknown. We first derive estimates for these parameters, then discuss the sequential detection algorithm for two cases: target parameter is known and unknown. We consider detections for both the target appearance and disappearance. We examine the relationship between several performance measurements for the sequential detector, including the false-alarm rate and the average detection delay. In the numerical example part, we first illustrate the performance of our algorithms. Then we present an example of the optimal polarimetry design in the sequential detection. [C321]

"A Subspace-Based Approach to Sea Clutter Suppression for Improved Target Detection"

A key issue in detection of small targets on the ocean surface using active radar is low signal-to-clutter ratio (SCR), particularly in situations involving low grazing angle and high sea state. When sufficiently high pulse repetition rates are available, it is possible to obtain several samples of the clutter in a time interval short enough that key contributors to the clutter remain approximately stationary. This paper develops an approach to estimate the clutter subspace in such scenarios and exploit this estimate for clutter suppression and improved detection performance. [C322]

"Theoretical aspects on a method for terrain scattered interference mitigation in radar"

Hot clutter (terrain-scattered interference (TSI), terrain-scattered jamming (TSJ) or jammer multipath) are signals from jammers which are reflected on the ground or sea before they are received by a radar. In the mainbeam an often weak target signal has to compete with hot clutter. Hot clutter is a significant problem today to military airborne radar systems and should be suppressed. This paper is a theoretical analysis of a hot clutter suppression method which consists of 1) estimating the direct jammer signal, 2) estimating the linear system created by the multipath (the "reflection system") and 3) removing an estimate of the reflected jammer signal from the main received radar signal. The paper can give a better understanding of the method and guidance on how to design the method for the best result. The results of the work in this paper are: both with white and colored noise, we can state and solve optimal estimation problems for the reflection system and give expressions for the bias and covariance. We can also see how the model order, the number of data etc. influences the estimation quality. [C323]

"Study on clutter modeling and computer simulation of PD fuze"

The ground clutter and sea clutter has a significant impact on aerial defense missile, which is mostly working in the look down mode [M. Diani et al., April 1996]. It is necessary to analyze the clutter jamming on fuze and to enhance the jam proof ability. In this paper, according to the working characteristic of the pulse Doppler (PD) radio fuze, we study and build up the clutter model and bring forward an analysis method of clutter signal intensity in the cell of fuze distance-Doppler frequency, and also give an example to explain the method. Finally, the validity of the method has been proved by the simulation results. [C324]

"An analysis of phase array radar system on a moving platform"

In this paper, we derive a time-varying model for the steering vector of a phased array pulse Doppler radar system installed on a moving platform. Six oscillating motions are included in the derived model as well as the forward motion of the platform. We also present the sensitivity analysis of the derived model and analyze the effect of the perturbation between the true and measured array manifold on the accuracy of the motion compensation algorithm. From the simulation, it can be shown that the platform motions have no prominent effects on the target's power spectrum in moderate sea states (up to 3). However the barge's forward motion is a problem if the targets fall in the spreading spectral region of the sea clutter. [C325]

"Sporadic-E ionospheric clutter suppression in HF surface-wave radar"

The unwanted radar echoes from the ionosphere are collectively called ionospheric clutter. It has proved to be the greatest impediment to achieving consistently good performance in long-range detection of surface vessels and sea state monitoring for HF surface wave radar (HFSWR). Ionospheric clutter can mask target/sea echoes having similar Doppler shifts. Main characteristics of sporadic-E ionospheric clutter (Es-layer clutter) are described. A new time domain coherent side-lobe cancellation (CSLC) algorithm based on subarrays is proposed to suppress this type of ionospheric clutter. Experimental results confirm that the general algorithm can achieve effective ionospheric clutter suppression while not decreasing the strength of the first-order sea echo using the data recorded by the OSMAR2003 (ocean state monitor and analysis radar, manufactured in 2003), located near Zhoushan in Zhejiang China. [C326]

"Background noise distribution after high-resolution processing in ship-borne radar"

When high-resolution algorithm is applied in ship-borne radar, high-resolution algorithm's non-linearity and distributional characteristics before high-resolution processing determine background clutter's distributional characteristics after high-resolution and detector design afterwards. The statistical model of first-order Bragg lines and second order components of sea clutter is put forward. Then by using higher-order cumulative quantity's statistical verification of actually measured data, it is concluded that background noise before high-resolution conforms to normal distribution in ship-borne radar. The numerical domains distribution after high-resolution is determined by improved minimum entropy clutter characteristics recognition method based on rule AIC. This identification method has higher recognition rate. It is verified that background noise after high-resolution by pre-whitened-MUSIC conforms to lognormal distribution. [C327]

"Multiplicative multifractal modeling of sea clutter"

Sea clutter refers to the radar returns from a patch of ocean surface. Accurate modeling of sea clutter and robust detection of low observable targets within sea clutter are important problems in remote sensing and radar signal processing applications. In this paper, we introduce a multiplicative multifractal process for modeling the sea clutter. Through analysis of 392 amplitude time series of 14 sea clutter datasets measured under various sea and weather conditions, we show that the data are consistent with multifractals over certain time scale range, and that the generalized dimension spectrum Dqaccurately detects low observable targets within sea clutter. The method is computationally very fast and practically easily implemented. These attributes strongly suggest that the method may be developed into an automated target detector within sea clutter. [C328]

"Power-law sensitivity to initial conditions in sea clutter"

Understanding the nature of sea clutter is crucial to the successful modeling of sea clutter as well as to facilitate target detection within sea clutter. To this end, an important question to ask is whether sea clutter is stochastic or deterministic. In the past decade, Haykin et al. have carried out analysis of some sea clutter data using chaos theory, and concluded that sea clutter was generated by an underlying chaotic process. Recently, their conclusion has been questioned by a number of researchers. To reconcile ever growing evidence of stochasticity in sea clutter with their chaos hypothesis, Haykin et al. have further suggested that the non-chaotic feature of

sea clutter could be due to many types of noise sources in the data. To test this possibility, McDonald and Damini have tried a series of low-pass filters to remove noise; but again they have failed to find any chaotic features. While most of these studies are conducted by comparing measured sea clutter data with simulated stochastic processes, we use the direct dynamical test for deterministic chaos developed by Gao and Zheng to analyze 280 sea clutter data measured under various sea and weather conditions. The method offers a more stringent criterion for detecting low-dimensional chaos, and can simultaneously monitor motions in phase space at different scales. However, no chaotic feature is observed from any of these scales. But more interestingly, we find that sea clutter can be conveniently characterized by the new concept of power-law sensitivity to initial conditions (PSiC), which generalizes the defining property for chaotic dynamics, the exponential sensitivity to initial conditions (ESIC). We show that PSIC offers a powerful method for detecting targets within sea clutter. [C329]

"The physics and modelling of discrete spikes in radar sea clutter"

This paper first examines the physical source of sea clutter spikes from considerations of oceanographic principles and electromagnetic scattering; it is shown how electromagnetic scattering theory can be used to predict the characteristics of discrete spikes in backscatter from the sea. The spikes can also be modelled statistically as extensions to the standard K-distribution model for sea clutter, as proposed by K.D. Ward et al. (1990). In this paper, the work in K.D. Ward et al. (1990) is extended to include the addition of thermal noise and it is also shown how the parameters of this model can be matched to real data. Results are presented for recorded airborne radar data, showing how the model can accurately match the characteristics of real clutter-plus-spikes-plus-noise, including the effects of pulse-to-pulse integration with frequency agility. [C330]

"Detection of low observable targets within sea clutter by structure function based multifractal analysis"

Sea clutter is the backscattered returns from a patch of the sea surface illuminated by a radar pulse. Robust detection of targets within sea clutter is of significant importance to our coastal and national security, to navigation safety, and to environmental monitoring. However, no simple and reliable methods for detecting targets within sea clutter have been proposed. We apply the structure function based multifractal theory to analyze 392 sea clutter datasets measured under various sea conditions. The method developed is mathematically rigorous, conceptually elegant, computationally fast, and, practically, easily implementable. Our results demonstrate that the method can robustly detect low observable objects within sea clutter. [C331]

"A new maximum a posteriori CFAR based on stability in sea clutter state-space model"

A new constant false alarm rate (CFAR) for the marine environment based on a stability in sea clutter state-space model is proposed. In this CFAR, based on observation samples in the reference window, a maximum a posteriori (MAP) estimation for clutter power in the test cell is utilized for setting a threshold. The compound K model is the best model for high resolution sea clutter that includes a phenomenological insight into clutter formation, and it is most frequently cited in the literature. The compound model for sea clutter is considered to be the multiplication of two independent processes. This multiplicative model is linearized to form a state-space model for the sea clutter evolution. This state-space model is established in the logarithmic domain. By introducing a stable distribution for innovations in the state-space model as a priori, we derive a new MAP estimator for the clutter power. The performance of the new CFAR, named SLMAP-CFAR (stable linear MAP CFAR), is then compared to the existing LMAP. [C332]

"Comparison of a trans-horizon littoral clutter model with shipboard radar data"

Standard radar clutter reflectivity models such as the GIT sea clutter model (Ewell G.W. et al., 1979) (Horst M.M. et al., 1978) and the Billingsley land clutter model (2002) are based upon many measurements, in part to remove the effects of varying propagation environment, in order to predict radar reflectivity for standard propagation. It has been known for some time that radars on ships operating in regions near land are often subject to clutter amplitudes that vary significantly from these models, and this is due to anomalous propagation, or ducting. This paper describes the littoral clutter model (LCM) developed by Naval Surface Warfare Center Dahlgren Division and its validation against recorded radar data. LCM includes propagation modeling and is an extension of both the GIT sea clutter, and Billingsley land clutter models. The model compares favorably to measured land and sea clutter amplitudes in the presence of ducting. [C333]

"An improvement of the SNR during MTI-tracking at low elevations"

In order to maintain a stable track during low-altitude tracking Saab has developed a signal processing method. The stability of this method requires the signal-to-noise ratio (SNR) to be above a certain level. By utilizing the

knowledge of the speed of the tracked target the moving target indication (MTI) filter response can be optimised and, hence, the SNR can be increased. [C334]

"Wind aspect factor in sea clutter modeling"

The TSC and GTRI sea clutter models are empirical models with a theoretical dependency for wind direction. Observations collected during at-sea testing have forced a reappraisal of the wind aspect factor, as predicted and observed minima in the crosswind direction were not treated by the model. We modified the wind aspect factor to reflect theory and observation, and now have excellent agreement among model, theory, and observation. [C335]

"Two new approaches for detecting a maneuvering air target in strong sea-clutter"

Two new approaches for detecting a maneuvering air target in strong sea-clutter are proposed in this paper. One is based on the adaptive chirplet decomposition, and the other is inspired by the spectral subtraction. Experiments with real-world data samples show that both methods presented in this paper can effectively enhance the Doppler radar signals from maneuvering air targets though each has different strength and weakness. [C336]

"Multidimensional superresolution ISAR reconstruction techniques in sea-cluttered environnement"

For high-resolution radars (as the ones used for radar imagery tasks are), sea clutter is difficult to characterize, especially for low grazing angles. According to the physical model of sea surface, the echo signal is best described as the product of a Gaussian process, with rapid variation (the speckle component), and of a slow varying component (the underlying component). The K-compound distribution is used for the statistical characterization of the clutter echo. Standard target complex signature simulations techniques (based on the well-known scattering center model or using geometric primitives) are combined with synthetic sea clutter, allowing us to generate realistic signals. The MUSIC 2D super-resolution reconstruction method, presented in the paper, is used to generate ISAR target images. A comparative study of robustness of MUSIC and Fourier type images is then performed. The obtained results show the validity of both clutter simulation engine and super-resolution reconstruction methods. The problem of naval targets, subject to particular simulation conditions, is also discussed in detail. [C337]

"Low-angle reflectivity modeling of sea clutter using LS method"

Radar sea clutter (SC) reflectivity is important for predicting the performance of radar engaged against a low-angle target at sea. Existing techniques to resolve the reflectivity estimate are mainly based on radar clutter theory and the LS approximation method. A more practical reflectivity model for SC is presented through data (Nathanson, F.E. et al., "Radar design principles: signal processing and the environment", McGraw-Hill, 1991). Throughout the reflectivity modeling, the idea of inductive reasoning is used. By using it, the functional relations between radar parameters and radar surface clutter backscattering are analyzed. In calculating the unknown parameters in the presented models, simplification of limit conditions are used so properly that the LS method can be employed. From the comparisons analysis, we can obtain that, generally, the presented SC model approximates that of Nathanson et al. better than others. Considering the accuracy and complexity for a more complex prediction of radar performance, the presented SC reflectivity model is preferable. [C338]

"Numerical Study of Low Grazing Range-Resolved Radar Backscatter from the Sea Surface"

Statistical properties of X-band sea clutter are studied using 2-dimensional direct numerical simulations. Surfaces are modeled as realizations of a Gaussian random process with the Pierson-Moskowitz or Elfouhaily spectrum. Creamer transform is applied to reproduce the lowest-order non-linearities. Backscattered field at a given frequency is found using the first-principles integral equation technique. Calculations are repeated at a number of frequencies allowing to synthesize surface response to a pulse as short as 2.2 ns. The study is focused on the incidence angle of 85^ circ 5^ circ grazing), with an example at moderate 60^ circ incidence considered as well. Probability density functions (pdfs) for vertically and horizontally polarized clutter are obtained using Monte Carlo trials. The effects of variations in wind speed (sea state) and radar resolution are investigated. The technique also allows isolating and examining the impact of certain electromagnetic and hydrodynamic approximations. Simulated pdfs are compared to Weibull and K distributions. [C339]

"A multiple intelligent software agent based technique for improving radar detection of low observable small craft in sea clutter"

The current method of detection of a radar target is based on the setting of a threshold determined by the

average of the background returns in the region of interest. Problems arise with this method when attempting to detect small targets in littoral waters since in designing the detector it is necessary to make assumptions concerning the statistical behaviour of the background clutter. Since only long term data is available and short term prediction is required there is an inevitable missed detection/false alarm problem. The problems associated with detecting low observable targets using track-before-detect systems based on Hough transform or dynamic programming techniques are reviewed. An alternative self-adaptive spatio-temporal CFAR system and a multiple hypothesis tracker based on multiple intelligent software agents are described. The process is not perfect but, by assuming that there will be too few data measurements to establish the clutter statistics accurately, a robust sub-optimal solution is formed. The process reported is not restricted to radar returns but has potential applications in infra-red and electro-optical systems, and for processing images in particle physics and astronomy. [C340]

"Numerical study of wide-band low-grazing HF clutter from ocean-like surfaces"

Backscattering of a vertically polarized, ultra-wide band HF pulse (3-30 MHz) from one-dimensional Pierson-Moskowitz impedance surfaces is studied using method of moments (MoM)-based numerical simulations. With the field source located near the surface, low-gazing regime is realized for the most of the illuminated region. The direct numerical solution is compared to approximate calculations based on the small perturbation method (SPM). Once the Norton surface wave effects are included in the SPM scattering coefficient, average clutter levels as well as waveform shapes generally show good agreement. As the sea state increases, backscatter returns from farther ranges exhibit larger discrepancies. In such a situation, using the "effective surface impedance" (that accounts for surface roughness) brings SPM-based average clutter levels in agreement with their MoM counterparts: however, the differences in waveform shapes persist. Future studies will use the simulation capability described in this paper to investigate the ability of a short-pulse, ultrawideband HF radar to image ocean waves, measure surface currents and surface current shear, and detect targets. [C341]

"The modelling and exploitation of spatial correlation in spiky sea clutter"

A physically based sea clutter model is used to calculate the statistics of sea clutter. The mean radar cross section (RCS) is found to match experimental results and the second moment is found to be consistent with the resolution dependence of the clutter shape parameter. The correlation structure predicted by the model is found, on average, to be consistent with real data, but the latter also shows significant transient coherence. This property may be exploited for sea spike suppression and target detection improvement [C342]

"The non-stationary characteristic analysis and model of sea clutter of fuze"

Considering the actual sea clutter, a fractal noise AM-FM model is proposed. Based on the observed data of the sea clutter of fuze, for the first time, the fractal characteristics of fuze including the fractal dimension and multi-fractal are investigated. Experimental results indicate that the sea clutter of fuze have the properties of fractal. Compared with radar oceanic backscattering, the sea clutter of fuze possesses higher fractal dimension and less range of dimension variety, which shows that the fractal theory can be applied to sea clutter of fuze. The wide sense power spectrum of sea clutter was analyzed, which is similar to the power spectrum of narrow-band GWN AM-FM. The SCF and the WSCF of the sea clutter of fuze are analyzed. Both theory analysis and the simulation present the sea clutter of fuze can be effectively restrained by the WSCF, which is useful to the signal processing involved of sea clutter. [C343]

"Sonar processing for short range, very-high resolution autonomous underwater vehicle sensors"

In an attempt to improve manual and automated sea mine classification results, autonomous underwater vehicles (AUV) are being outfitted with short-range, very high-resolution sonar sensors. To improve pattern classification results in this regime, artifacts caused by platform motion, sonar beam pattern, and the ocean bottom clutter are first removed from the image. Several preprocessing steps for high-resolution imagery are developed and integrated to help isolate and discover the enduring features of high value targets. Classical denoising, segmentation, and feature-based equalization preprocessing techniques for target localization are adapted and demonstrated. [C344]

"An antichaff technique for tracking radar"

The critical interference in radar systems is unwanted echo named clutter. Some important clutter includes echoes from land, weather (particularly rain), sea and deliberated chaff. Therefore, a military radar designer is faced with the problem of how to reject interference. In this paper, chaff elimination methods such as Doppler processing and log-FTC are discussed and then an antichaff algorithm suitable in transient and steady descending state is introduced. Also, this technique is applicable and independent on chaff type and central frequency [C345]

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"Polarimetric analysis of fine resolution X-band SAR sea clutter data"

{no data available} [C347]

"Naval radar in a littoral environment"

The changed political situation in the world forces navies to reconsider their roles and missions. As a consequence, the naval operation areas shift from warfare on the open sea to littoral warfare. In modern scenarios full scale, multiple engagements attack on a naval convoy is less likely. Instead, the threat is more likely to come from weapons launched from the land or small, high-speed ships. Additionally, detection and tracking of surface targets becomes a more important sensor function. This paper discusses the impact of littoral warfare on the design of naval radar. The main aspects discussed in this paper are the benefit of accurate Doppler information, high radar stability, use of Doppler-polarimetry and sensor flexibility. [C348]

"Automatic detection of targets using fractal dimension"

{no data available} [C349]

"A novel approach for the detection of punctual isolated targets by means of the wavelet transform"

The detection of an isolated localized structure in a noisy background, with no a priori information about its presence, nor its shape presents multiple drawbacks. Nevertheless, this problem is present in a great number of applications as, for instance, ship detection from satellite radar imagery. Conventional algorithms for ship detection are conceived to discriminate an exceptionally bright localized pattern according to an established decision rule, expressed by the determination of a threshold. But the adjustment of thresholds involved in the decision step is complicated and relies on the existence of a considerable contrast between the vessels and the surrounding sea clutter which is not always reached. Thus, a novel method, based on the intrascale dependencies between wavelet coefficients in the different subbands, is proposed, justified and successfully tested on simulated and real images. [C350]

"Target detection in Rayleigh-distributed sea clutter environment based on Hough transform"

The detection and false alarm probabilities of the Hough transform-based detector for nonfluctuating and four types of Swerling fluctuating targets in the Rayleigh-distributed sea clutter environments are derived in this paper. Simulation scenario and procedure are designed. Then random data obeying Rayleigh distribution is generated as surrogate of the sea clutter. The performance of target detection in surrogate data environment based on Hough transform-based detector is analyzed through Monte Carlo simulation runs. The simulative results show that, for a specified PD which is greater than 0.5, the target model sorted ascending for the required SCR is Swerling II, IV, nonfluctuating, Swerling III, I. [C351]

"Linear and nonlinear spatial selection methods for small low speed target in sea clutter observation improvement"

In the process of detection of small surface objects in clutter, some specific problems appear. The main cause is the fact that useful signal amplitude is commensurable and in some cases is less than the amplitude of reflections. Most of all, for slow surface objects the desired signal spectrum is situated inside the sea clutter one. In that case, both spectral and amplitude selection and detection methods become ineffective. As is known, signal reflected from the sea surface is characterised by spatial periodic structure. At the same time, sizes of most surface objects do not exceed a radar resolution element and they can be considered as dotted ones. Therefore, to improve radar observation of small objects in sea clutter, it is possible to use information about noise spatial performances. The usage of spatial periodicity of sea-echoes allows one to improve efficiency of the small low speed targets in sea clutter observations. [C352]

"Passive multichannels millimeter-waves imaging system"

32-channels passive imaging system is developed in the frequency range 33...38 GHz. The system contains multibeams quasi-optical scanning antenna with an array of low noise direct detection receivers. New type of scanning mechanism on the base of asynchronous three-phase motor is used. The software-hardware complex has been created to control scanning mechanism and to process the receiving information. Simultaneous receiving of signals from different parts of scene allows to form a good quality image on the monitor screen in 3 seconds. The developed imaging system can be used to provide navigation on the ground or at sea, especially at short distances where surface radar clutter is high, for remote sensing in space and air investigations, for all-weather surveillance, for objects discovering, and many other commercial applications. [C353]

"Anomaly detection based on an iterative local statistics approach"

We introduce an iterative anomaly detection algorithm. The algorithm is based on an iterative characterization of the clutter in a feature space of principal components, and a single hypothesis scheme for the detection of anomalous pixels. The iterative procedure gradually reduces the false alarm rate while maintaining a high probability of detection. Morphological operators are subsequently employed for extracting the sizes and shapes of anomalous clusters in the image domain, and identifying potential targets. Experimental results demonstrate the robustness of the proposed approach with application to sea-mine detection in sonar imagery. [C354]

"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. [C355]

"Analysis of clutter distribution in bistatic high frequency surface wave radar"

In high frequency surface wave radar (HFSWR), surface target detection is mainly limited by ocean clutter and ionospheric clutter. In order to investigate further the nature of both clutters and to develop potential strategies to enhance target detection, an experiment was conducted to operate a radar simultaneously in both monostatic (transmitter and receiver are co-located) and bistatic (transmitter and receiver are far from each other) modes. Experimental results from bistatic HFSWR are compared to those from monostatic HFSWR. It is shown that the ionospheric clutter has different distributions for the two modes. This difference may potentially be exploited to enhance the performance of the radar. A comparison between the predicted Bragg frequency and measured Bragg frequencies has been undertaken and it is shown that the Bragg frequency has a curvature along the range due to the side scattering experienced in bistatic operation. [C356]

"Performance assessment of along-track interferometry for detecting ground moving targets"

Along-track interferometry (ATI) is an interferometric synthetic aperture radar technique that can be used to measure Earth-surface velocities. As such, the ATI technique holds promise for the detection of slowly moving ground targets. However, the models often used to characterize ATI performance were developed mainly in the context of mapping ocean currents, and they do not necessarily apply to the case of discrete, moving ground targets amidst clutter. We provide expressions for more accurately modeling the behavior of an ATI system in the context of ground moving target indication. Analysis and design equations are given for topics including target defocus, signal-to-noise and signal-to-clutter ratios, interferometric correlation, interferometric phase bias, target detection, geolocation accuracy, and area coverage rate. [C357]

"Site-specific simulation of clutter-limited radar systems"

This paper presents a new simulator for predicting the performance of low-angle radars involving the study of the limiting land/sea clutter signal in the receiver. Physical optics (PO) in conjunction with digitized terrain elevation data (DTED) allow the environment to be characterised and the scattering problem to be solved, providing both the power versus range profile and the plan position indicator (PPI) clutter map. A data-acquisition system, consisting of a commercial maritime radar and an A/D converter, is used to validate the developed software by comparison between simulations and measurements in the same environments. Some particular results, both measurements and simulations, belonging to a maritime scenario are presented. [C358]

"Modelling of sea clutter with Gaussian mixtures and estimation of the clutter parameter"

In order to model sea clutter, we propose to use a generalized distribution which is valid for different background

statistics, like low and high sea states. The envelope detector's input statistics are assumed to be a Gaussian-mixture (GM). A new background probability density function (pdf) resembles Rician mixtures. In order to detect targets using adaptive techniques, clutter background statistics should be known a priori. In practice, however, background statistics are typically not known a priori. Thus, a joint estimation and detection process is employed whereby the background statistics are estimated before target detection. We estimate the parameters using a maximum likelihood (ML) based method from the output of the envelope detector. Performance analysis is presented using real sea clutter data. [C359]

"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. [C360]

"A hybrid approach for target detection using CFAR algorithm and image processing"

In ship detection, a key aspect is to keep a low level constant false alarm rate combined with a high detection probability in presence of clutter background, caused by reflections from wave tops on the sea, rain, snow or fog. Generally, the constant false alarm rate (CFAR) algorithm is applied, which is based on the assumption that clutter background can be modeled using a Gaussian distribution, generating a high level of false alarms in presence of non Gaussian clutter. This problem has been addressed under two independent approaches: modeling the environment noise (sea clutter) with independent non Gaussian models or using variations of CFAR detection algorithm. Both approaches provide good results only for specific characteristics of clutter. We discuss a hybrid approach for target detection that use three probabilistic models of clutter associated to sea state (Gauss, Weibull and K distributions), detection algorithms with adaptive threshold for CFAR, classification algorithms that associate a noise model with a specific CFAR algorithm according to the sea state, and low level morphological operations to generate an image of targets. The goal of this approach is provide an automatic mechanism to associate a clutter model with a specific CFAR algorithm according to sea state in order to obtain radar images without clutter. The proposed detection approach is evaluated by high level simulation. Results are presented and discussed. [C361]

"Control of false track rate using multiple hypothesis confirmation"

A modem surveillance radar system is likely to return several hundred plot detections per radar scan, especially if the system is searching for targets of low radar cross section such as sea skimming missiles against a background of sea clutter. The track extractor must take this plot data and present a track picture that is sufficiently clean of false and clutter tracks that it can be readily understood. Techniques based upon "tentative tracks" are shown to have limitations in their ability to confirm tracks in clutter, and multiple hypothesis techniques are demonstrated that overcome these problems. [C362]

"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. [C363]

"HF ground wave radar sea clutter cancellation based on chaotic prediction"

In the background of signal detection for HF radar, the sea clutter is quite significant and can mask some weak target signals. This paper reports a chaotic local prediction based sea clutter cancellation method to improve the SNR of the target. Recent observation shows that HF sea clutter may be modeled as a nonlinear deterministic dynamical system. Then it can be assumed that the chaotic prediction error of target echo is greater than the prediction error of sea clutter. A local chaotic predictor is used to construct a sea clutter cancellation technique. Real sea clutter, simulated target data and real target data were used to show that a chaotic prediction based clutter cancellation method is a promising technique to suppress sea clutter and enhance target detection. [C364]

"High resolution scatterometer based on vector network analyzer"

For a scatterometer, based on the Hp8520c vector network analyzer, used for high resolution radar clutter measurements, the system parameters must be redesigned to fulfill the request. A relationship exists among the range resolution, minimum ambiguous range and sample point number, and the scope of parameters is limited, so a tradeoff must be considered. At the same time, as the range resolution increases, the illuminated area reduces and the return echo power falls, so the equipment sensitivity or the maximum range must be consider too. The design procedure is introduced. A sea clutter measurement has been done by this project. It is found that the scattering coefficient at 1 GHz bandwidth is greater than that at 0.2 GHz bandwidth when the grazing angle is less than 10°. The preliminary results show that the project for high resolution is viable. [C365]

"Modeling and simulation of radar sea clutter using k-distribution"

First Page of the Article [C366]

"Target detection improvement using blind channel equalization OTHR communication"

In this paper, we introduce a blind channel equalization method for over-the-horizon-radar (OTHR) system based on the sea clutter signal. First, we establish that the radar signal, at different time recurrences, can be represented by a MIMO model taking into consideration the propagation parameters (Doppler, delay and attenuation) of the multipath channel. Then, we show that thanks to the Doppler diversity, one can separate the two components of the sea clutter (referred to as Bragg lines) which allows us to reduce the problem to a SIMO one. A CMA-like blind equalization algorithm is then applied to invert the system and combine coherently the channel multipaths. The channel and Doppler information are finally used to mitigate the sea clutter interference and the multipath effect and hence improve the detection and Doppler estimation of the desired target signal. [C367]

"Preliminary research on target detection in first-order peaks with adaptive cancellation"

HFSW radar can detect oceanographic parameters based on electromagnetic waves diffracting along the sea surface. A difficulty arises in detecting slowly-moving targets because of the strong ocean clutter. For wide-beam HF radar, broadened first-order peaks complicate target detection further, so no effective detection algorithm in first-order peaks has yet been put forward. The paper examines the Bragg peaks of wide-beam HF radar. The reason why the first-order Bragg peaks are broadened is analyzed, and then the conclusion that the two first-order peaks from a distant sea cell with unitary current are profile-correlative is drawn. Based on the conclusion, a new method is presented for target detection in first-order peaks. The method performs well both on simulated data and on real data with the HF system OSMAR2000. [C368]

"The effect of phase noise on the remote sensing of ocean surface currents"

This paper studied the phase noise effect on the range spectrum and Doppler spectrum measured by high frequency (HF) radar which was used for remote sensing of sea surface state parameters. The presence of phase noise in the master oscillator caused a widening of the range spectrum and clutter velocity spectrum, degrading the range and velocity resolution. In this paper, a practical phase noise model is presented, and based on it, the relationship between the phase noise power spectrum density (PSD) and cumulative phase noise is investigated. Then, the basic minimum requirements for the PSD are calculated to maintain radar performance. The results show that a commercial off the shelf oscillator can meet the phase noise requirements. [C369]

"Iceberg and ship discrimination with ENVISAT multipolarization ASAR"

Spaceborne synthetic aperture radar (SAR) can provide wide area and all-weather surveillance for iceberg and ship targets. However, the discrimination between icebergs and ships in SAR imagery, especially in the single polarization imagery that has been available over the past decade, is not always reliable. This is especially true when vessel and iceberg size are on the order of the pixel spacing. Present requirements for ocean surveillance with SAR data include a high detection and classification accuracy due to the necessity of comparable performance with other reconnaissance methods, such as aerial. ENVISAT advanced SAR (ASAR) data offers a potential solution to the iceberg-ship discrimination problem. ASAR data has comparable swath and resolution to other operational SAR systems and in addition offers an alternating polarization (AP) mode. AP targets offer more information than single polarization with respect to radar scattering mechanisms. The AP ship and iceberg targets in this study were observed to have considerably different polarization responses. In particular, ship targets in the HH and HV channels were comparable. In contrast, iceberg targets had at best, weak HV

responses compared to the HH channel. Two methods for target discrimination were investigated: a multipolarized area ratio and HV signal-to-clutter ratio (SCR). [C370]

"Suppression of surface clutter interference with precipitation measurement from space by the Dual frequency Precipitation Radar"

A new method to suppress the surface clutter interference with precipitation measurement from space by the Dual frequency Precipitation Radar (DPR, 13.8 GHz and 35.5 GHz) is introduced for the Global Precipitation Measurement (GPM) mission, which is planned in succession to the Tropical Rainfall Measuring Mission (TRMM). The DPR has very high sensitivity and its minimum detectable rain rate is designed to be 0.3mm/h(attained by the 35.5 GHz radar) at the rain top. In this study, the radiation pattern of the slotted wave guide planar phased array antenna was calculated by considering the Taylor distribution with random errors in excitation current. The signal (S) to clutter (C) power ratio (S/C ratio) was evaluated for the antenna pattern given by the Taylor distribution (designed peak side lobe level=-35 dB, n=6, ; these values are same as the TRMM PR), where the S means received power from rain scattering volume, and the C means the backscattered power from sea/land surface. A uniform rain rate of 0.3 mm/h was assumed for the calculation of signal S at 35.5 GHz and 0.5 mm/h for S at 13.6 GHz. A side lobe clutter interferes the rain echo severely when the strong side lobe illuminates the nadir direction, where the specular component of the scattering coefficient of sea/land surface is dominant. The introduced method to suppress the side lobe clutter is to tilt the antenna beam a few degrees in coordinate plane determined by the satellite flight direction and the nadir direction. The radiation pattern of the phased array antenna is characteristic in that the region of the strong side lobe arises in crisscross. By tilting the antenna beam, the strong side lobe illuminates the off nadir direction. So that makes it possible to suppress the side lobe clutter. Calculation results show that the surface clutter interference is suppressed well at the main beam tilt angle 2 degrees. [C371]

"Spaceborne P-band radar for ice-sheet sounding: design and performances"

The Antarctic ice sheet is one of the most prominent physical features on our planet. It represents an area of about 14 millions km2. The average ice thickness being around 2200 m (and up to 4500 m), the Antarctic ice sheet contains a 30 million km3ice volume corresponding to about 70 m of sea level. However, this huge reservoir of water is still partially unknown and due to its large extent, only observations from space can give some global insight into the structure of the ice sheet. The Antarctic ice sheet is an exceptional archive of the past climates and a major actor of the Earth water cycle. Each ice layer corresponding to one period of time keeps its own chemical characteristics linked to past atmospheric events. The typical temporal scale involved allow for a description of past climate over a few climatic cycles, or a few 100000-year events. A dedicated mission has been proposed to European Space Agency as a candidate for an Earth Explorer Opportunity mission. This mission is based on a P-band radar instrument with a nadir-looking geometry, working at 435 MHz with a bandwidth of 6 MHz (imposed by ITU regulation), allowing to sound the vertical structure of the ice from the surface down to the bedrock. A feasibility study of the mission was done in Alcatel Space under ESA contract with an emphasis on the radar instrument. For coherent reflection and deep sounding (corresponding to the so-called Fresnel zone), the useful signal coming from any ice layer or from the bedrock overlap with lateral incoherent surface scattering. The surface clutter is reduced by the antenna pattern in the across-track direction (typical aperture is lower than 5°) and by Doppler filtering in the along-track direction. These beam requirements impose to have a very long antenna in the across-track direction. The typical dimension of the antenna is 10 m Ч 1 m. This work summarizes the principle of the instrument, and the associated antenna solution. Main performances are also presented. [C372]

"Naval radar in a littoral environment"

First Page of the Article [C373]

"Naval radar in a littoral environment"

First Page of the Article [C374]

"Low elevation sea-surface target tracking using IPDA type filters"

The integrated probabilistic data association (IPDA) type filters provide estimates of the underlying target probability of existence/perceivability/visibility, apart from track state maintenance. These quantities are conveniently used as a track quality measure and can be used for track confirmation and termination. The sea-surface induced multipath fading reduces the detection probability of the target at certain ranges, which can lead to track loss. In this paper, we use IPDA type filters for tracking a target in such a scenario. The primary results presented in this paper are encouraging for a further study in the future. [C375]

"Ship and shipwake enhancement in coastal surveillance radar systems using target back propagation technique"

Rotating incoherent radar systems are usually used for coastal surveillance of vessels. Signal to clutter/noise enhancement is obtained by averaging a number of scans. Because the vessels move and thus migrate out of the radar resolution cells, the number of scans that can be averaged is limited by this effect. This paper exploits a target back propagation technique to overcome this problem. Measurements show that a significant enhancement of the ship image quality is achieved using this technique. Also the ship wake is made clearly visible and is subject for further study in the wavenumber domain and Radon transform domain for detection and feature extraction. [C376]

"Efficient reiterative censoring of robust STAP using the FRACTA algorithm"

This paper presents further developments of the FRACTA algorithm (S.D. Blunt et al, NRL Tech. Rep. 10.059), which has been shown to be robust to nonhomogeneous environments containing outliers. The focus here is on the efficient implementation of the FRACTA algorithm. The key development is a censoring stopping mechanism whereby the number of reiterative steps can be minimized and computation is reduced. We introduce a data-dependent stopping rule that demonstrates excellent results as evidenced by the detection of targets in the KASSPER challenge data cube. We also present some other enhancements to the FRACTA algorithm that further improve both efficiency and performance. [C377]

"Ship echo discrimination in HF radar sea-clutter"

HF radar can provide over the horizon detection of ships on very large oceanic areas. Normally, the Doppler shift produces by ships is small, of the same order of magnitude as the Doppler shift of the sea clutter. Consequently, it is not always easy to discriminate a ship line from a sea clutter line. In this paper the coherence of sea clutter is considered in the context of a radar interferometer. It is shown that the coherence function can be useful to discriminate between a ship line and sea clutter spectral peaks. The dependence of the coherence value with the signal to clutter ratio is also studied. [C378]

"Adaptive modelling of sea clutter and detection of small targets in heavy clutter"

This paper describes and compares three methods for detection of low RCS radar targets in heavy sea clutter using a high PRF radar. Two methods are based on auto-regressive processes, one on Karhunen-Loeve decomposition. Experiments have been performed on DSTO sea clutter dataset using these methods and the results are presented in this paper. [C379]

"Stochastic modeling and simulation studies for the surface wave high frequency radars: problems and challenges"

Modeling and simulation strategies for the Surface Wave High Frequency Radars (SWHFR) are discussed in this tutorial paper. Their potential application areas are summarized, together with problems related to ground wave propagation, radar cross section (RCS) prediction, clutter elimination, noise and interference cancellation, etc. Challenges in SWHFR system design, antenna requirements, signal processing techniques as well as detection and tracking approaches are reviewed. [C380]

"HF surface wave radar operation in adverse conditions"

For the past 12 years the Canadian Department of National Defence and Raytheon Canada Limited have collaborated on a cost-shared programme to develop an Integrated Maritime Surveillance (IMS) system based on HF Surface Wave Radar (HFSWR). The primary objective behind the programme was to demonstrate the capability of HFSWR to continuously detect and track surface targets (ships and icebergs) as well as airborne targets, at all altitudes, to ranges in excess of 200 nautical miles, reliably and consistently in real time and in all weathers. A secondary objective was to demonstrate the concept of IMS, involving the fusing of data from HFSWR radars and other sensors. This paper reviews techniques and methods used in the processing of HFSWR data to ensure that performance is maintained, even under adverse operating conditions. [C381]

"CFAR techniques for over-the-horizon radar"

Since the OTHR background noise is too strong, the target echoes would be embedded in sea clutter and environment noise. In order to detect targets such as ships or aircrafts from radar returns, a range Doppler CFAR schemes is presented, the identical Doppler frequency resolution cells over adjacent range or azimuth

resolution cells are used to form a sliding window for targets detection. Since the OTHR range resolution cells is very large and so do the azimuth resolution cells, the total number of range Doppler resolution cells that forms sliding window is limited in order to guarantee stationary. Some CFAR algorithms such as CA, CM, TM, BLU and QBW methods that are suitable for OTHR are compared and analyzed versus different total range or azimuth resolution cells number. If the total range Doppler resolution cells number is small (less than 12), CA-CFAR is preferred in order to get the good detection performance. In multiple targets situation, CM-CFAR or TM-CFAR are suggested which trims the largest samples that possibly be interfering targets. [C382]

"Measurement of S band clutter statistics using quasi-deconvolution filter for a phase coded waveform"

This paper describes a signal processing technique by which radar clutter data collected with a derivative phase modulated waveform was used to evaluate sea clutter statistical parameters. Two processing options for recovering full bandwidth clutter samples from the radar return signal are matched filter and deconvolution. Both processors may be implemented in the form of a transversal filter (finite impulse response or FIR). The FIR matched filter output contains certain errors, such as filter time sidelobe responses, which are not present at the output of a pure deconvolution process. A transversal filter approximation to deconvolution, quasi-deconvolution, contains similar errors but greatly reduced in magnitude. We have shown that the use of quasi-deconvolution (QD) filters make it possible to accurately estimate two key amplitude distribution statistics for surface clutter: mean and mean/median ration. [C383]

"Experimental modified reflectivity of backscatter from the sea surface, at very low grazing angles, compared to a ducted sea clutter model used in navy radar simulations"

This paper presents the results of a comparison between a high fidelity clutter reflectivity model that includes the effects of anomalous surface propagation and surface clutter reflectivity measured using the U.S. Navy AN/SPY-1A radar system. [C384]

"Proceedings of the 2003 IEEE Radar Conference (Cat. No. 03CH37474)"

First Page of the Article [C385]

"Sea spike demographics at high range resolutions and very low grazing angles"

Because the wideband spiky sea clutter that is frequently observed at low grazing angles and high resolution plays a critical role in the performance of modern naval radars, it is necessary to analyze two important quantities: (1) the mean spike duration and (2) the mean interval between spikes. These analyses need to be conducted with representative examples of such wideband clutter taken from a suitable database. Microwave backscatter (X-band, 9.5-10.0 GHz) observed at near grazing incidence (0.2 degrees) from the sea off the coast of Kauia, Hawaii, was measured with a wideband radar characterized by a high spatial resolution in range (0.3 meters) and a high temporal resolution (2000 Hz pulse repetition frequency). Extensive amounts (over 20 minutes duration per measurement) of both vertically and horizontally polarized wideband sea clutter data were taken with upwind and crosswind transmit geometries during the data collection exercise. The analyses of the dependence of the mean spike duration and the mean interval between spikes upon three parameters: (1) the spike amplitude threshold, (2) the minimum spike width, and (3) the minimum interval between spikes, were carried out. This was done using all of the extensive data within a number of selected individual range cells for both vertically and horizontally polarized clutter, measured with an upwind transmit geometry. [C386]

"Simulation of coherent radar backscatter from dynamic sea surfaces"

Direct numerical simulations are used to evaluate the properties of sea clutter at low grazing angles. Electromagnetic calculations are based on iterative solution to the frequency-domain integral equation for the surface current. Performing calculations at multiple frequencies and for sequential surface profiles, range-resolved time-varying radar response from the dynamic surface can be simulated. At present, ocean surface is generated using spectral-based slightly nonlinear model that accounts for interactions of smaller ripples with longer waves but does not include any wave breaking. We address the computational aspects of the simulations and discusses initial results of Monte Carlo study of low grazing surface clutter. While calculations have to be limited to a two-dimensional space, they serve as a useful benchmark for analytical models and have direct application for commonly occurring three-dimensional geometries. [C387]

"Maximum likelihood angle extractor in the presence of sea-surface multipath"

In the presence of sea-surface multipath, the standard monopulse ratio technique to extract elevation angle of

target produces large bias. In this paper we propose a maximum likelihood (ML) angle extraction technique for low elevation targets above the sea surface, of known average signal strength having a Rayleigh fluctuation. The procedure is then modified for targets having unknown average signal strength. The resulting modified angle extractor has only a small performance degradation compared with the known average signal strength case, but it performs much better than the monopulse ratio based estimator. This angle extractor reduces the root mean square error (RMSE) by more than 50% in the signal processing stage when used for low flying target tracking scenarios. Further improvement is achieved by using the predicted average target signal power in dynamic scenarios where a significant reduction in the tracker RMSE performance can be achieved, as shown in the simulations presented. [C388]

"Target detection in sea clutter using convolutional neural networks"

A detector based on convolutional neural networks is proposed for radar detection of floating targets in highly complex and nonstationary cluttered environments. This detector is coherent and monocell, i.e. it works with the complex envelope of the echoes from the same range cell. It includes a pre-processing time-frequency block implemented by the Wigner-Ville distribution, which provides a constant false alarm rate (CFAR) behavior regarding the clutter power when normalization is utilized. Simple theoretical models for the clutter and targets were allowed to study the impact of the correlation and Doppler of both target and clutter on its performance. This detector has also been tested with real-life sea clutter with an improved performance compared to classic detectors. [C389]

"Clutter simulation in maritime environments"

Knowledge of clutter characteristics are an important factor in determining radar system performance, especially for target detection. Clutter may be modelled as a random process, with the clutter characteristics embodied in the statistics of the process. Most modern pulsed-Doppler radars utilize range-Doppler maps in their detection schemes, and so it is crucial to understand the statistical properties of clutter in these maps in order to develop effective target detection algorithms. In this paper, we discuss the simulation of the sea clutter seen on the range-Doppler map or an X-band pulse-Doppler radar operating in a maritime environment. We shall implement the compound K-distribution model for maritime clutter returns and incorporate temporal and spatial correlations in clutter map realizations. [C390]

"A study of the X-band entropy of breaking ocean waves"

In this paper we develop a simple model for the polarimetric radar backscatter from breaking ocean waves. We show that the dynamics of the breaking process lead to characteristic variations in the wave depolarization processes. We compare the model prediction with X-band grazing incidence radar data collected for breaking ocean waves in the surf zone. [C391]

"Improving on the monostatic radar cross section of targets by employing sea clutter to emulate a bistatic radar"

Aircraft that employs radar cross-section reduction techniques typically have a significantly larger bistatic radar cross-section. This paper discusses the possibility of utilising an airborne monostatic radar configuration over an oceanic region to emulate a bistatic radar. This is achieved by employing the reflective nature of the ever-present sea clutter to effectively create a "pseudo-transmitter" on the sea's surface. In addition to improving the radar cross-section of targets, this emulated bistatic radar system reduces the target's capability to locate the airborne receiver. The reflection and scattering characteristics of the sea's surface are also discussed and rudimentary models reflecting these characteristics with regard to the forward scatter region are developed. [C392]

"A performance evaluation of autoregressive clutter mitigation methods for over-the-horizon radar"

Wide-area surveillance over-the-horizon radar (OTHR) requires minimizing the dwell time in each search region without compromising Doppler resolution of targets from clutter. Low-order autoregressive (AR) modeling of the clutter spectrum has been proposed to unmask targets from clutter using shorter coherent integration times (CITs). We compare the performance of three methods using AR parameters to maximize signal-to-clutter-to-noise ratio (SCNR) with shorter CITs. In particular, we consider AR-based data extrapolation (DATEX), minimum variance clutter pre-whitening (MV-CPW), and a method called HOPPLER, which consists of pre-whitening, conventional Doppler processing, and re-insertion of the clutter spectrum. We compare the methods using real data from a mid-latitude OTHR with a target beacon embedded in sea-clutter. [C393]

"Calculations of surface clutter interference with precipitation measurement from space by 35.5 GHz radar for Global Precipitation Measurement Mission"

Surface clutter interference with precipitation measurement from space using 35.5 GHz radar was evaluated for the Global Precipitation Measurement (GPM) Mission. The GPM Mission is unique in that it consists of a core satellite with dual-frequency precipitation radar (13.6 GHz and 35.5 GHz) and eight small companion satellites that are equipped with microwave radiometers. The 35.5 GHz precipitation radar has very high sensitivity; its designed minimum detectable rain rate at the rain top is 0.3 mm/h. In this study, a Taylor distribution with random errors in the excitation current is considered in calculating the radiation pattern of a 35.5 GHz slotted waveguide planar phased array antenna. The signal-to-clutter power ratio (S/C) was evaluated for the antenna pattern given by the Taylor distribution (peak side lobe level=-35dB, n=6; the same values as for the TRMM PR), where S is the received power from the rain scattering volume and C is the backscattered power from sea surface. Uniform rain rates of 0.3 and 1.0 mm/h were assumed in the calculation of S. We show that the interference of surface clutter with precipitation measurement can be suppressed more at 35.5 GHz than at 13.6 GHz because of the short wavelength. The calculated S/C ratio distribution showed that the effect of the side lobe clutter is not negligible, especially for low rain rates (less than 1.0 mm/h), but it is negligible for heavier rain (over 1.0 mm/h). The calculations also show that the effect of the main lobe clutter is severe and not negligible for either light or heavy rain. The conclusion is that 35.5 GHz precipitation radar can accurately observe rain with a planar phased array antenna fed with a Taylor distribution (n=6, peak side lobe level=-35 dB). [C394]

"Global mapping of attenuation at RF frequencies; application to spaceborne communication and RF systems"

The propagation of radio waves for Earth-space slant path at C-band and higher frequencies are dominated by precipitation in the atmosphere. At a given frequency, attenuation depends on the length of the radio path, the size distribution and the phase state of the hydrometeor profile. Using the observations from the Tropical Rainfall Measuring Mission (TRMM) space-borne Ku-band (13.8GHz) radar at Low Earth Orbit of 350km above earth, global attenuation maps are produced at the Ku-band frequency. A simple microphysical model for precipitation developed using hydrometeor size distributions and thermodynamic phase state is used to estimate attenuation and reflectivity observations at Ka-band (35GHz) where numerous high bandwidth satellite applications are being planned including the next generation space-based radar for the Global Precipitation Mission (GPM). Differences in the microphysical structure in convective and stratiform precipitation are also incorporated in the model. The results show substantial attenuation variation in a 12-month period at both Ku- and Ka-bands over the various regions of the globe, including the contrast between land and ocean. The estimates of attenuation made at Ku- and Ka-band will be useful in the design and development of space-borne communications and RF systems. [C395]

"Analysis and simulation of sea clutter at high range resolution and low grazing angles"

Sea clutter data provided by Thales Naval France are analyzed in order to determine their statistical and correlation properties. The K-compound distribution is found to match the best the amplitude pdf of the data. A new method is proposed for estimating the associated scale and shape parameters. Two innovative approaches are also described for simulating the sea clutter. The first one is based on the K-compound pdf model, while the second one is a 2D MA kernel based generating procedure. [C396]

"Modeling radar backscatter from breaking waves on the surface"

A model for describing radar sea clutter is proposed. It consists of two parts, an oceanographic and an electromagnetic one. The former contains swell, small capillary and gravity waves as well as breaking wave events. The latter combines ray tracing, Bragg scattering and the Method of Moments. It is shown that the combination of the two models is capable of well reproducing several key aspects of radar sea clutter. [C397]

"An optimal threshold for sidelobe control in adaptive beamforming using second-order cone programming"

In high-frequency radar systems, it is difficult to directly apply conventional adaptive beamforming Io localize source signals due to the high sidelobes from the non-Gaussian distributed sea clutter. Suppressing the high sidelobe level is necessary to enhance the detection performance. There are several sidelobe control approaches formerly proposed, however, there performances all depend on an arbitrary preset threshold. In this paper we propose a new algorithm to obtain the optimal threshold (loading factor) and low sidelobes simultaneously and automatically. We also derive the inter-relationship among those sidelobe control approaches under the second-order cone formulation structure theory. [C398]

"Investigations with SECAR-a bistatic HF surface wave radar"

This paper describes a bistatic HF surface wave radar, designated SECAR, which was deployed near Darwin, Australia, and used to conduct a variety of scientific investigations related to radar design, siting and target detection, as well as providing a test-bed for evaluating the operational utility of HFSWR as an element of a national surveillance network. The scientific results are significant because of their implications for improved radar design and effective deployment. [C399]

"An estimation and verification of vessel radar-cross-sections for HF surface wave radar"

The radar cross sections (RCS) of both small and large ships for High Frequency Surface Wave Radar (HFSWR) were studied by using Numerical Electromagnetics Code and by using measurements from a HFSWR system at Cape Race, Newfoundland, Canada. The results of the study indicate that Teleost, a 2405-ton Canadian Coast Guard ship, and large cargo-container vessels (36000 ton) have comparable RCS values at 3.1 and 4.1 MHz. This was verified by comparing Teleost signals with the reflections of seven cargo-container vessels identified during an operational evaluation of the HFSWR. The conclusion of the study is that Teleost and the large cargo-container vessels have an angle-averaged RCS of 40dBm2, while small vessels (1000 tons) could reasonably be characterized by an angle-averaged RCS of 30 dBm2, in the lower end of the HF band (3-5 MHz). [C400]

"L-band VV clutter analysis for natural land"

Land clutter is statistical by nature, and its values vary in many dimensions. This paper analyzes L-band VV polarized land clutter characteristics acquired by the NASA JPL AirSAR system. In particular, this paper mainly concentrates on the distribution of clutter values with respect to grazing angle for typical vegetation communities in the Northern Territory region in Australia. [C401]

"Statistical analysis of real sea clutter data measured by a high resolution radar at low grazing angles"

Summary form only given. The exact knowledge of the sea clutter properties is of great importance for a modern maritime surveillance radar because they are directly involved in the optimization of the detection process, mainly through the CFAR processor design. Although sea clutter has been investigated by many authors for many years, a generally accepted model still does not exist. [C402]

"Detection of small targets in ocean wave clutter using panchromatic time series imagery"

Visual detection of small objects on or near the ocean surface from an aircraft is important for search and rescue, and detection of stealthy boats and other militarily important targets. This is made difficult by a combination of the rapidly moving sensor platform and the typically high level of modulations in scattered light at the surface. To achieve reasonable search rates, the observer must scan through modest grazing angles (i.e., look towards the horizon) where the ocean clutter that limits detection performance is varying light from wave facets and white caps. This paper describes a technique for significantly improving the signal-to-clutter ratio. A time series of images is mapped to a common reference frame at the level of the mean ocean surface, separating time and space variations, and the temporal dwell is utilized. For moored targets, the signal may be simply integrated up in time, while for drifting and powered targets, it must be integrated along the appropriate target velocity vector. Specific examples are provided for navigation buoys, small surface floats and slowly moving boats, most of which are difficult if not impossible to find in any single image frame. Achieved gain using panchromatic images is shown to approach 20 dB in cases where the velocity vector is known or can be calculated from the data. [C403]

"Posteriori estimation of low altitude propagation loss from radar sea clutter data"

This paper describes the estimation of propagation loss and it statistical properties based on observations of radar sea clutter data. This problem is solved by first finding an ensemble (about 105models) of relevant refractivity model parameters and then using all these models to map into the propagation loss domain. In this mapping each refractivity model is weighted according to its data likelihood function. [C404]

"Two methods for simulating non-Gaussian highly correlated sea clutter maps"

Sea clutter features change significantly when measured by high resolution radars, at low grazing angles. The recorded data may be highly correlated and are characterized by long tail probability density functions, which are in the most cases very different compared to the classical Rayleigh distribution. In this paper we propose two

methods for simulating this type of clutter. The former is based on the statistical model of the sea clutter, which can be seen as a combination of two random processes, which are Gamma and Rayleigh distributed. The second makes use of the 2D MA analysis of real sea clutter maps to generate synthetic data having very similar statistic and correlation properties. [C405]

"Multiple sea spike definitions: reducing the clutter"

Multiple definitions of sea spikes have been developed and presented in the literature. This study shows the characteristics of spike populations where absolute cross section ratios are not critical to the spike definition. [C406]

"Power budget study for passive target detection and imaging using secondary applications of GPS signals in bistatic radar systems"

Signals from satellite systems like GPS, IRIDUM and Globalstar that are reflected from moving or stationary objects are utilised for their detection in a synthetic aperture bistatic radar system (SAR). The movements of the satellite and its position at different coordinates with respect to time can serve as a base for a synthetic aperture. This paper focuses on the development of a system based on the analysis of indirect signals, in particular GPS signals. The main concern in this study is the low power of the GPS signal at the earth's surface (typically about -160 dB). Due to the nature of the reflector/target, some power will be absorbed, and hence result in a further reduction in signal strength reflected by the target. However, the other equally important concern here is the ground and sea clutter, which is 18-22 dB stronger than the direct signal level. Here we present theoretical results of both the maximum detection range and land clutter contributions of the air target detection by bistatic SAR that utilizes the existing GPS satellite as the transmitting signal source. [C407]

"Polarimetric mapping of ship wakes"

This paper addresses the problem of ship wake detection and analysis at low grazing angles. specifically, we examine the spatial distribution of the characteristic polarimetric signatures of the sea surface in and around the wakes of a pilot boat. The received signals were range-processed and polarimetrically decomposed to yield the characteristic polarisation states. Inspection of the locations of these states revealed that the polarisation signatures were highly non-uniformly distributed in the spatial domain, as expected, with interesting features attributable to nonlinear effects. Focusing on the cross-polar s, we found that the corresponding eigenvector distribution made a strong transition as one moved from the wake region to the surrounding sea. By defining appropriate scalar quantities we were able to identify wake and clutter regions. The results suggest that exploitation of the coherent polarisation domain may significantly enhance wake feature extraction and discrimination. [C408]

"Modelling of the littoral environment for real-time radar performance assessment"

The role of the Royal Navy has changed dramatically since the end of the Cold War. Ships and personnel are now expected to fulfil a wider range of possible missions in theatres all over the world. Consequently ship's radar systems are now expected to give a high level of performance in regions that include the Middle East and the Eastern Mediterranean, despite being originally designed to operate predominately in the North Atlantic. The problem is that the local scenario and environmental conditions can dramatically affect radar system performance in two important ways. Firstly the environment can change the way that energy propagates outwards from the radar leading to large variations in target and clutter strength between different locations. Secondly these variations are often hidden by automatic threshold changes that reduce sensitivity to prevent the radar picture from becoming cluttered. This can give the false impression that the radar is operating optimally and could prevent ship's personnel from adapting their tactics to fit to the local situation. This paper outlines an updated model that is compared to real data in ducting conditions. The model is used to examine radar performance in littoral scenarios and to estimate sea state and duct strength from real radar data. The ultimate aim is to combine information collected by the ship's surveillance radar with modelling to allow ship's personnel to monitor the effect of the local environment on radar performance. [C409]

"Simulation on the extraction of ships' images embedded in speckle using cross-correlation of multilook SAR images and applications to Radarsat data"

Preliminary results are reported on the simulation of ship detection and applications to Radarsat data using coherence images computed from cross-correlating multilook SAR images. The traditional techniques of ship detection by radars such as CFAR (Constant False Alarm Rate) rely on the amplitude data, and therefore the detection tends to become difficult when the amplitudes of ships images are at similar level as the mean

amplitude of surrounding sea clutter. The proposed method utilizes the property that the multilook images of ships are correlated, while those of sea surface are covered by uncorrelated speckle. Thus, cross-correlation of multilook images yields the different degrees of coherence between the images of ships and water. The ability of the technique has been illustrated in the previous reports using Radarsat data, where the images of ships are clearly visible. In the present article, we examine the technique when the ships' images are embedded in the surrounding sea clutter. [C410]

"RADARSAT-1 synthetic aperture radar iceberg detection performance ADRO-2 A223"

Since the initial Canadian Space Agency (CSA) ADRO-1 program in 1997, C-CORE has been investigating the capabilities of the RADARSAT synthetic aperture radar (SAR) satellite for the detection of icebergs. This multiyear program has received support from a variety of sources including the CSA's ADRO-1 and ADRO-2 programs, the Canadian Ice Service, and a consortium of oil and gas companies operating on the east coast of Newfoundland. During this program, various RADARSAT modes, including Wide2, Wide3 and ScanSAR Narrow-B have been validated. Threshold and probability of detection curves were generated for small, medium and large sized icebergs in various wind conditions. For these curves, the radar cross-section values from ocean clutter were modeled using the CMOD4 wind model and verified with point source wind measurements. The performance curves show a reasonable success rate for detecting icebergs whose size is on the order of the resolution cell, despite the significant effect of wind speed on detection. [C411]

"Maritime target and sea clutter measurements with a coherent Doppler polarimetric surveillance radar"

Doppler polarimetry in a surveillance radar for the maritime surface picture is considered. This radar must be able to detect low-RCS targets in littoral environments. Measurements on such targets have been conducted with a coherent polarimetric measurement radar in March 2001 and preliminary results from that campaign are presented. The system provides estimates of the scattering matrix per range-Doppler bin. Several physical quantities that can be exploited to discriminate target echoes from sea clutter responses are discussed and an impression is given on their effectiveness. [C412]

"Chaotic behaviour and non-linear prediction of airborne radar sea clutter data"

The potential to model sea clutter radar returns using chaos theory is examined. Chaotic systems display qualitative similarities to sea clutter returns such as broad flat spectra, boundedness and irregular temporal behaviour. In this report several key parameters of chaotic systems, namely correlation dimension, Lyapunov spectrum and Lyapunov dimension are calculated from real sea clutter returns and found to be consistent with a chaotic interpretation. The airborne high resolution data (less than one metre) produces a correlation coefficient with an average value of 4.63 and an embedding dimension of 6-7. Lyapunov dimensions are consistent with correlation values. A local linear technique and a radial basis function (RBF) are used to construct a one step non-linear predictor. A mean square error (MSE) of approximately 0.0032 between the predicted and normalized (i.e. maximum +/-1 range) real time series is measured. [C413]

"Multifractal features of sea clutter"

Sea clutter refers to the backscattered returns from a patch of the sea surface illuminated by a transmitted radar pulse. Since the complicated sea clutter signals depend on the complex wave motions an the sea surface, it is reasonable to study sea clutter from nonlinear dynamics, especially chaos, point of view, instead of simply based on random processes. In the past decade, Dr. Simon Haykin's (1997) group at the McMaster University of Canada carried out analysis of some sea clutter data using chaos theory, based on the the assumption that a chaotic attractor is fully characterized by a non-integer fractal dimension and a positive Lyapunov exponent. Thus, they concluded that sea clutter signals are chaotic. In other words, the complicated sea clutter waveforms are generated by nonlinear deterministic interactions of a few modes (i.e., number of degrees of freedom). However, a numerically estimated non-integral fractal dimension and a positive Lyapunov exponent may not be sufficient indication of chaos. Cowper and Mulgrew (see Proc. UCNN, vol.4, p.2633, July 1999), Noga (see Ph.D thesis, Cambridge University, 1998), and Davies (1994) separately have questioned the chaoticness of the radar sea clutter. We show, using the direct dynamical test for deterministic chaos developed by Gao and Zheng, which is one of the more stringent criteria for low-dimensional chaos, a two minute duration sea clutter data is not chaotic. We also carry out a multifractal analysis of this sea clutter data set, and find that the original sea clutter amplitude signal is approximately multifractal, while the envelope signal, formed by picking up the successive local maxima of the amplitude signal, thus measuring the energy of successive waves on the sea surface, is well modeled as multifractals. These behaviors determine that the amplitude signal follows approximately log-normal distribution while the envelope signal, and thus the energy of the successive waves of

the sea surface, is log-normally distributed. Approximate log-normal distributions for the amplitude signal has been observed earlier. However, by using the multiplicative multifractal theory, there is theoretical justification for the log-normal distribution of sea clutter, as discussed. The implications of the multifracta- l nature of sea clutter may have relevance for the detection of point targets on the sea surface. [C414]

"Characterization of symmetric scattering using polarimetric SARs"

Cameron's coherent target decomposition (CTD) and classification are discussed in the context of SAR, and the limitations of Cameron's classification are examined. It is shown that these methods may lead to a coarse and misleading scattering segmentation because of the large radiometric dispersion tolerated in each of the elemental scatterer classes, as well as the implicit assumption on the coherence nature of target scattering. A new method, named the symmetric scattering characterization method (SSCM), is introduced to better exploit the information provided by the largest target symmetric scattering component, under coherent conditions. The SSCM, which expressed the symmetric scattering in term of the Poincare sphere angles, permits a better characterization of target symmetric scattering and the generation of coherent scattering segmentation of much higher resolution, in comparison with Cameron's segmentation. [C415]

"Chaotic system reconstruction from noisy time series measurements using improved least squares genetic programming"

The problem of chaotic system reconstruction in the presence of measurement noise is not only an important one from the viewpoint of communication systems and radar signal processing, but also a challenging one if one has no a priori knowledge of the system structure. In this paper, we propose a novel algorithm based on genetic programming to reconstruct not only the structure of the underlying chaotic dynamical system but also the optimal parameters of the dynamical system using time series measurements that are corrupted by additive Gaussian noise. We show via computer simulations that the proposed algorithm called improved least squares genetic program (ILS-GP) is able to reconstruct different kinds of chaotic systems from their noisy time series measurements even at low SNRs. We finally show the improved ability of the ILS-GP algorithm by applying it to predict the time series of airborne radar sea clutter. [C416]

"ARIES: a high-resolution shipboard radar"

This paper introduces the new ARIES radar, a high-resolution surveillance system designed for operation at sea. Its main characteristics are described, together with some remarkable experimental results regarding high-resolution observation of sea clutter and real targets. [C417]

"Some aspects of design and environmental management in HF surface wave radar"

With the current emphasis on the surveillance of coastal waters, particularly for economic exclusion zone (EEZ) applications, there has been an increased interest in the capability of HF surface wave radar (HFSWR) to detect targets beyond the conventional radar horizon. The surface wave mode is generated where a vertically polarised high frequency electromagnetic wave is launched over a saline water surface; this then behaves in a manner such that there is significant propagation of the field around the curvature of the Earth. As this propagation mode relies on the surface currents in the conducting media of the sea, the resulting additional propagation loss has a dependence on the water salinity, surface roughness and frequency. A comparison of two-way HFSW loss with frequency over a smooth surface is shown. As the operating frequency increases, the additional propagation losses increase; however many other system constraints ease as the wavelength grows smaller (e.g. antenna size and target Doppler shift). This paper highlighted and provided some analysis for the frequency management and impulse suppression techniques that should be implemented in an effective HFSWR. [C418]

"Statistical analysis of high resolution land clutter"

Results are described from land clutter analysis obtained from the fixed site BYSON radar at Malvern. Digital terrain elevation data is used to determine the imaged regions and the normalized log estimator, U, is measured to investigate the stability of the high resolution heavy-tailed clutter distribution. A numerical Laplace inversion scheme is described that can determine the distribution of an arbitrary sum of K-distributed variates within noise. However, without a priori knowledge of the clutter distribution, long-tailed distributions can only be accepted after rejecting the hypothesis of exponential clutter that may contain edges. A likelihood based discrimination test is proposed which can operate simultaneously at the same spatial level as a constant false alarm rate (CFAR) window. Results suggest that the majority of the scene is in fact closer to edge-corrupted speckle and many 'spiky' areas are related to man-made structures. [C419]

"A comparison of radar sea clutter models"

Radar performance prediction has always been an important part of the design and development of radar systems. Performance prediction offers a way of extending limited trials results obtained for the environmental conditions on the day to the full envelope of desired operation. The analysis of radar performance in free space is well documented and understood but the modelling of the radar target in a clutter environment is still an area of active research. This paper concentrates on airborne maritime radar. The key to obtaining realistic predictions of the probability of detecting a target on the sea surface is governed by the spatial and temporal statistics and correlation properties of the sea clutter. Radar detection is governed by the combination of the mean radar cross-section of the clutter and the temporal fluctuations of the pulse-by-pulse radar returns about the mean. Here, two models for the mean radar cross-section of the clutter are compared. [C420]

"Comparison of Doppler clutter cancellation techniques for naval multi-function radars"

We describe a comparison of fixed and adaptive clutter cancellation processes applied to measured multi-function radar (MFR) data in a littoral environment. The adaptive filters require estimates of the clutter covariance and comparisons of different strategies for obtaining this are made. The results for the adaptive filters generally show substantially improved target detection over the non-adaptive filters. [C421]

"Analysis of spectrum variability in sea clutter"

Naval radar systems commonly employ Doppler processing to separate targets from clutter. A widely used system is the moving target detector or MTD system (Skolnik 1981) which performs a frequency analysis of a sequence of returns in each range gate. A threshold is then determined by some form of constant false alarm rate (CFAR) algorithm for the contents of each Doppler channel based on the returns in neighbouring range gates. It is normally assumed that the clutter spectrum is the same in each range gate; however, if this is not the case, it will clearly affect the threshold-setting process. It has been shown previously by Miller (2000) that there may be considerable variation in spectra for sea clutter observed at low grazing angles. In the above paper, an initial attempt was made to model this variability. The current paper applies this model to data collected by QinetiQ, Portsdown West and discusses enhancements to the original model. [C422]

"Small ship detection with high frequency radar using an adaptive ocean clutter pre-whitened subspace method"

We propose a novel scheme for using high frequency ocean surveillance radar (HFOSR) to detect slow weak target echoes embedded in temporally correlated sea clutter having a continuous spectrum. General Doppler processing CFAR detection of ships in ocean surveillance radar is usually inhibited by the continuous high order sea clutter. Conventional subspace methods can be utilized to enhance the detection, but they deteriorate dramatically in the presence of correlated sea clutter. In our paper an adaptive sea clutter filtering is introduced which improves the threshold and accuracy of the subspace detection method. Both simulated and real ship targets are used to verify the effectiveness of our proposed method. [C423]

"A comparison of EM scattering results and radar sea clutter"

The characteristics of radar sea clutter have been studied for many years, mostly to develop empirical models for the average back-scattered energy, the amplitude statistics and the Doppler spectrum. These models have been successful at describing the variations of behaviour with sea-state and viewing geometry, but have not been able to establish the link between specific features on the sea surface and the radar backscatter. This paper describes a programme of work where carefully controlled radar and surface measurements in a wavetank are compared with real radar sea clutter and electromagnetic scattering calculations. The results show that a direct link can be made, thus allowing a causal relationship to be established between specific features on the sea surface and remotely gathered radar sea clutter. The EM scattering calculations provide the means for the results to be extended over a wide range of radar frequencies, resolutions, and grazing angles. Also the effect of modifying the sea surface wave spectrum may be calculated. [C424]

"Joint estimation of target number and DOA using reversible jump MCMC in sea clutter"

We address the problem of detection of a small target in high frequency ocean surveillance radar using the method of reversible jump Monte Carlo Markov chain. The number and the directions of arrival of targets are estimated simultaneously. However, the existence of sea clutter makes the traditional RJMCMC inefficient, and an adaptive preprocessing is preferred in combination with the original RJMCMC to achieve better detection. The performance of the proposed method is analyzed through several experiments with real data. [C425]

"Improvement of high frequency ocean surveillance radar using subspace methods based on sea clutter suppression"

We present a new direction finding scheme for slow targets embedded in sea clutter that combines subspace methods (MUSIC and Root-MUSIC) and time domain sea clutter and noise suppression. The ocean surface behaves as a distributed source in contrast to ships that are point sources. By mapping data to eigenspaces, the sea clutter level decreases due to its non-deterministic behavior while point targets' levels remain unchanged while enhancing estimation performance. Since subspace methods have a higher threshold and are degraded heavily by the correlated sea clutter, clutter and noise suppression is introduced to enhance algorithm performance. Both simulated and real ship targets are used to show the lower threshold and higher estimation performance of the proposed algorithm. [C426]

"Dependence of HF surface wave radar sea clutter on sea state"

An empirical relationship between the power of the second-order sea clutter in HF surface wave radar (HFSWR) and the average ocean wave height is derived from the data measured from a trial using the HFSWR at Cape Race, Newfoundland and a TriAxys wave buoy. The power of the second-order sea clutter between Bragg lines, measured at the radio frequency of 3.1 MHz, is found to depend linearly, in logarithmic scale, on average ocean wave height. Significant ocean wave height could be used as an indicator for sea state. The linear relationship therefore provides a gauge of the radar performance in ship detection with respect to sea state. [C427]

"Radar detection performance in sea clutter with discrete spikes"

Previous work on radar scattering from the ocean surface has led to the identification of three distinct scattering mechanisms. These are: (1) resonant scattering from small ripples riding on top of longer ocean waves; (2) scattering from the very rough whitecaps of broken waves; and (3) specular scattering from the crest of a wave, just before it spills. We consider the implications of these components on the statistical distribution of sea clutter and the consequential effects on radar detection performance. [C428]

"Wavelet detection of low observable targets within sea clutter"

We observe scattering events in the Doppler domain via a continuous wavelet transform (CWT). By minimising the uncertainty in velocity and time, the dominant event in the non-stationary instantaneous Doppler spectrum can be isolated. Considering the returns to be discrete in nature leads to a physically motivated detection statistic termed 'persistence' that measures the observed lifetime of the scatterers. A Doppler detection scheme is formulated at low velocities within the clutter spectrum, an area neglected by current Doppler filtering. When operated on real data containing an oil drum target, results appear to be complementary to simple intensity thresholding; this suggests detection is made on secondary effects such as wake disturbance. [C429]

"Surface modelling using 2D FFENN"

This paper is concerned with the development of a two-dimensional feed-forward functionally expanded neural network (2D FFENN) surface modeller. New nonlinear surface basis functions are proposed for the network's functional expansion. A network optimization technique based on an iterative function selection strategy is also described. Comparative simulation results for surface mappings generated by the 2D FFENN, multi-layered perceptron (MLP) and radial basis function (RBF) architectures are presented. The main purpose of this work is the development of a two-dimensional system, able to produce surface data mappings. The main application area of interest for the proposed system is sea surface modelling and target detection by sea clutter suppression. [C430]

"Enhanced OTHR ship detection via dual frequency operation"

Ship detection by means of HF skywave radar is limited by: (i) sea clutter whose intrinsic Doppler spectrum extends over most of the relevant frequency band; (ii) signal distortion and contamination during ionospheric propagation. In this paper we present an analysis of a technique for enhancing detectability by means of dual frequency transmissions. Simulated sea clutter is convolved with measured ionospheric transfer functions to demonstrate the efficacy of this approach [C431]

"Refractivity-from-clutter using global environmental parameters"

This paper examines the sensitivity of radar clutter returns to variations in parameters used to describe the refractive environment that is associated with surface-based ducts. This supports determining efficient parameters so as to minimize the search space required in the inverse problem of inferring the refractivity

environment from observations of radar sea clutter. First, the sensitivity of replica fields to variations in range-independent parameters are considered. Next, variations in the parameters with range are modeled as a Markov processes. It is seen that either source of variation could explain variations in radar clutter observations obtained during a surface-based ducting event with the 3.0 GHz Space Range Radar (SPANDAR) at Wallops Island, VA. We then use the Simulated Annealing/Genetic Algorithm (SAGA) general purpose inversion code to infer refractivity parameters from observed clutter. SAGA is configured to use an embedded parabolic equation electromagnetic propagation model, a four-parameter model for atmospheric refractivity, and a linear least-squares objective function. The mismatch between (a) the optimal replica field and the observed clutter and (b) the inferred refractivity profile and the range-dependent refractivity structure obtained by in situ measurements, is discussed [C432]

"An approach to detecting the targets of aircraft and ship together by over-the-horizon radar"

The paper discusses the selection of over-the-horizon radar (OTHR) parameters for detecting aircraft and ship separately. Then, a method of detecting a high-flying target (i.e., aircraft) and a slow-speed target (i.e., ship) in parallel by OTHR is presented. The combination of range-Doppler 2-dimensional CFAR and superresolution techniques is the main problem in the process of detection. Simulation results of real (OTHR) data demonstrate the efficiency of the proposed method [C433]

"An automatic tracking system for marine navigation"

A fully automatic tracking system is discussed in this paper. Compared with conventional tracking systems, a new detection approach based on image recognition is proposed for rejecting ground clutter. The multiple hypothesis tracking (MHT) method is applied in sea or weather clutter background to keep tracks more reliable and more stable. Tracking performance is improved. Thus, the major problems of clutter interference that mainly prevents the realizing of automatic tracking are solved. Finally, track presentation logic is discussed in detail [C434]

"HF shipborne over-the-horizon surface wave radar background clutter statistics"

Sea clutter statistics are very important in designing target detection algorithms in both shore-based SWR (surface wave radar) and shipborne SWR. The sea clutter statistical characteristics in shore-based SWR have been discussed (see Barrick, D.E. and Bsnider, J., IEEE Trans. on Antennas and Propagation, p.19-28, 1997), but the statistics of sea echo in shipborne SWR radar have not been reported. The statistical models of first-order Bragg lines and the second order components of sea echoes, which include the effect of motion of the radar platform, are established for shipborne SWR. The effects of radar platform motion on the statistics of sea echoes are analyzed and the results are verified by measured data. This provides a theoretical basis for some Gaussian-based target detection techniques to be used in shipborne SWR [C435]

"Statistical properties of L-band sea clutter measured with a polarimetric synthetic aperture radar"

The limiting factor affecting the performance of most airborne radar systems in detecting targets on or near the surface of the sea is return echoes from the sea surface or sea clutter. The objective of this paper is to provide an analysis of the statistics of Australian sea clutter for an L-band VV-polarised airborne radar system from sampled measured values. Polarimetric synthetic aperture radar (POLSAR) image of the North-West region of Australia, acquired in 1996 by the Jet Propulsion Laboratory (JPL) was used to study, the backscattered statistics of the sea surface. Using this POLSAR image, a number of different candidate distribution functions have been investigated, and their goodness-of-fit have been carried out using the Kolmogorov Smirnov goodness-of-fit test. The log-normal, Weibull and K-distributions have been applied to model the statistical properties of multi-look polarimetric SAR sea clutter. The K-distribution has been found to have good agreement with the observed sea clutter intensity distributions [C436]

"Autofocus of multi-band, shallow-water synthetic aperture sonar imagery using shear-averaging"

A significant problem with Synthetic Aperture Sonar (SAS) imaging is the compensation of compensating for unknown errors in the sonar path trajectory. Unknown path errors in SAS have the effect of blurring and smearing the sea-floor image. Inertial navigation systems as used in Synthetic Aperture Radar (SAR), are not accurate enough for use in SAS. To deal with this problem, techniques for estimating and compensating the path errors from the gathered data (autofocus algorithms) have been developed. In this paper we present enhancements to an existing sonar autofocus algorithm presented in 1995 by Johnston et al. These enhancements help prevent the autofocus being biased by strong targets. Improvement in autofocus is significant and more apparent whenever an extended prominent target is far stronger than the surrounding seafloor clutter signal. We have tested both algorithms using and simulated data and the results are presented in

this paper. In addition, we demonstrate the advantage of using single pass multiband imagery to improve the autofocus result [C437]

"Detection of ships using cross-correlation of split-look SAR images"

One of the main problems in ship detection is the presence of sea clutter inherent to coherent imagery. A traditional approach to differentiate a target embedded in noise is to utilize the statistical property of the clutter with some success. In this paper, we propose a new technique of ship detection based on cross-correlating split-look SAR images. If the inter-look images consist of the correlated images of a ship and clutter, the degree of mutual correlation increases, and from the difference in correlation, the ship can be identified. Applying the present method to RADARSAT (Standard 1) images, we have found the minimum detectable size of ships is 62.6 m. The SAR data used in this application were acquired under fairly calm sea states, such that the ships can be identified by the naked eye. Thus, the method has not been tested in an extreme limit of high sea states, and remains as a further study [C438]

"CFAR detection of extended objects in high resolution SAR images"

Presents a processing scheme for the constant false alarm rate (CFAR) detection of extended objects embedded in non-Gaussian disturbance. The proposed receiver exploits some relevant properties of the location-scale distributions for ensuring constant false alarm against Weibull clutter. The system has been specifically conceived for operating on high-resolution SAR images where space processing (but not time processing) is allowed [C439]

"Fractal and multifractal analysis of sea SAR clutter data"

The goal of this work is to investigate on the fractality of the sea clutter collected by SAR systems like the existing ERS1-2 SAR. The analysis of data generated by simulation is performed by using two kind of techniques: 1) Multiscale fractal analysis; 2) Multifractal analysis. The results show that sea clutter retains a few fractal features of the sea. This study is very interesting for applications in the field of sea remote sensing like classification and target recognition [C440]

"Optimal design of clutter rejection filters for MTI system"

Transversal digital high-pass filters are considered for extracting moving target signals from clutter. A new approach is suggested for the analytical design of clutter rejection filters. Based on the required filter pass-band response, a procedure for selecting suitable PRI (pulse repetition interval) values has been used. According to the requirements of the filter rejection-band response, a kind of high pass filter has been suggested as the prototype for determining the optimal filter weighting coefficients [C441]

"The modelling of sea clutter and its application to the specification and measurement of radar performance"

This paper concentrates on the problem of specifying and measuring the performance of airborne maritime surveillance radars that are required to detect small targets against a background of sea clutter. In particular, the need is identified for the very careful specification of the clutter models used for predicting and comparing the performance of competing radars. It is also shown how the appropriate specification of modelling or simulation methods can address some of the dynamic performance measures that are not covered by traditional specifications. Finally, the role of models in assessing performance is discussed [C442]

"An approach to the correction of I and Q imbalance in time domain"

An approach to the correction of I and Q imbalance in the time domain is discussed. The correction coefficients are resolved in the time domain by injecting a standard sinusoidal test signal. Compared with the methods developed by Li (see Radar Engineering. The Sea Press, Beijing, 1999) and Churchill (1981), who obtained the correction coefficients in the frequency domain by the discrete Fourier transform (DFT), our method decreases the large amount of calculations. The formulas of residual deviations after correction, which depend on the ratio of signal energy- to-noise power density (2E / N0), are also discussed [C443]

"Adaptive power-managed FMCW emitter detection performance against low-RCS ships"

The design of a modern 9.3 GHz homodyne triangular-FMCW emitter for detection of low radar cross section (RCS) ships is described. Both searchand track-mode processing are described including a description of transmit and receive waveforms. Tradeoffs in emitter design are examined as a function of the modulation

bandwidth. To predict target detection capability, clutter and target models are developed as the emitter is flown at 300 m/s in a scenario that starts at a range of 15 nmi from the target. To evaluate the feasibility of detecting low RCS ships at the horizon, a low-RCS ship design is examined. Each sea state (0-4) is characterized by using a second-order polynomial that describes the normalized mean sea backscatter coefficient as a function of the grazing angle. The emitter transmit power is adapted in time to measure the target characteristics. The emitter transmit power level is consistent with the RCS and range to the target while keeping a target-to-clutter power ratio at 20 dB. For detection analysis, 50, 100 and 500 m2 RCS values are considered [C444]

"Chaotic characteristics of radar scattering from ground and sea"

Along with the development of nonlinear science, the chaotic dynamics of radar scattering are being paid more attention. The data of ground-based and airborne radar are analyzed with the chaos theory. The correlation dimension and Lyapunov exponent are calculated from space reconstruction, the chaotic characteristics for many types of scattering are revealed. It shows that radar scattering is produced by nonlinear chaotic systems with four to seven freedoms and the invariant of chaos are concerned with sea wave, terrain and relative movement between the airborne radar and the terrain or sea. [C445]

"The modification of intelligent target detection in nonstationary clutter"

In non-stationary background, like sea clutter, the intelligent detection method independent of the statistical model, has the obvious advantages. Based on the strategy by Haykin (1997), a new intelligent detection scheme is proposed to improve the detection performance, in which the Kohonen neural network (NN) and the modified fuzzy NN are used. A variety of comparison experiments have been done with both the simulated data and the real sea clutter data between our proposed scheme and Haykin's scheme, which show clearly our method has a higher detection ability and a lower false-alarm rate [C446]

"On the increasing importance of simulations in the conception of new naval radar systems"

The purpose of this paper is to explain the increasing importance of adequate simulation tools in the design of new high-resolution radar systems for defence purposes. Changing demands on radar performance imply the need for a new scale of representation in simulations. To meet these new demands, the classical macroscopic descriptions no longer provide enough information. The radar chains, as well as the targets and environments, have to be represented on a microscopic scale, allowing for more detail [C447]

"A new method for small target detection over chaotic background"

Based on the chaos of sea clutter, a nonlinear prediction method is used to transform the classic binary decision problem to the analysis of prediction error in radar target detection, and a fuzzy min-max neural network-based detection scheme is proposed. The simulation experiment results show that this method is effective even in very low signal to clutter ratio background [C448]

"A comparison of sea waves in open sea and coastal waters"

Detection of small targets in coastal waters is generally more difficult than in open waters. One reason for this might be the different behaviour of the sea waves as the sea waves are not fully developed in closed waters. The paper presents a comparison of measured sea clutter and wave rider buoy data in open sea and coastal waters [C449]

"An effective method of anti-impulsive-disturbance for ship-target detection in HF radar"

This paper presents an effective method against impulsive disturbances resulting in the spectral base wholly rising, which may cover the spectra of ship target returns. The first-order sea clutter in the time domain is always dominant in amplitude and the impulsive disturbances would usually be covered. In order to eliminate impulsive disturbances, the first-order sea clutter is first cancelled in the frequency domain and then those impulsive disturbances which are dominant in amplitude in the time domain can be eliminated. The remainder is basically the weaker background noise and ship target echoes and signal detection becomes possible, especially for weaker targets [C450]

"A relationship between external noise and the ocean clutter models for bistatic operation of a pulsed high-frequency radar"

Bistatic models of the ocean clutter in the context of pulsed high-frequency ground wave radar (HFGWR) operation have previously been developed. Several new features, distinct from earlier monostatic developments,

appear as products of the analysis. The question that must be addressed is “will the characteristics of the theoretical clutter models be visible in real-life data collected from the ocean surface?” One of the major considerations in answering this is the development of an appropriate noise model. Such a model for the noise spectral density as it relates to the pulsed HF radar operation is considered here. The analysis proceeds on the assumption of an ideal, externally noise limited, system. The aliasing due to noise undersampling is seen to be an integral part of the model. Statistical stationarity is assumed throughout [C451]

"MFR-IRST integration in the naval environment"

A low elevation threat can potentially exploit degradations in radar performance on naval platforms caused by multipath effects and sea clutter. Particularly in littoral environments and when electronic countermeasures are deployed, the use of radar with dissimilar (passive) sensors promises significant improvements in target detection and tracking capability. This paper provides an insight into a research project that has investigated the interactive integration of the Multifunction Electronically Scanned Adaptive Radar (MESAR2) and infrared search-and-track (IRST) sensor, based on the Air Defence Alerting Device, in a technology demonstrator trials programme. The sensor integration was achieved using the sensor fusion and tracking system known as TOTS (Target Oriented Tracking System) [C452]

"Determining the importance of learning the underlying dynamics of sea clutter for radar target detection"

Existing evidence for and against sea clutter being chaotic and nonlinearly predictable is briefly discussed. Despite the uncertainty surrounding the chaotic nature of sea clutter, and its nonlinear predictability, the purpose of this paper is to examine what the best design criterion is for a nonlinear predictor which is to be used to detect targets against clutter which is known to be chaotic: mean square error performance or capturing the chaotic clutter's underlying dynamics. Single pulse detection analysis using a Swerling I target and chaotic "clutter" is carried out using predictor-based detectors in an attempt to determine which criterion is most suitable. The predictor detectors are compared with standard detection strategies [C453]

"An application of nonlinear spatial filtration methods for improving the small ships observation on the sea clutter background"

In the process of synthesizing systems for temporal filtering of signals on a background of passive clutter, created by surface reflections, as a rule, one may use the differences in both distribution laws and spectra of clutter and useful signals, observed in a radar resolution element. The experimental research has allowed one to determine, that the signal, reflected from the sea, is characterized by the presence of a spatial periodic structure. At the same time the sizes of the majority of surface objects do not exceed the size of the radar resolution element and they can be considered as points. So, it is possible to use information about clutter spatial characteristics for improving the radar observation of small sized slow objects on a sea background by applying a spatial auto-compensator. For spatial compensator design it is possible to use the classic principle of matching the signals, separated by some time period. In this paper the possibility of using multiplicative signal multiplexing on the outputs of single-unit compensator channels, realizing different spatial delay, is discussed [C454]

"Refractivity estimation from radar clutter by sequential importance sampling with a Markov model for microwave propagation"

This paper addresses the problem of estimating range-varying parameters of the height-dependent index of refraction over the sea surface in order to predict ducted microwave propagation loss. Refractivity estimation is performed using a Markov model for microwave radar clutter returns from the sea surface. Specifically, the parabolic approximation for numerical solution of the wave equation is used to formulate the problem within a nonlinear recursive Bayesian state estimation framework. Solution for the conditional expectation of range-varying refractivity, given log-amplitude clutter versus range data, is achieved using a sequential importance sampling technique. Simulation results are presented which demonstrate the ability of this approach to synoptically estimate range-varying refractivity parameters by "through-the-sensor" remote sensing [C455]

"Texture modeling and validation using recorded high resolution sea clutter data"

We consider modeling and estimating the texture in high-resolution non-Gaussian sea clutter. The cyclostationarity of sea clutter is investigated and validated by processing measured high-resolution data. The clutter is modeled as a compound Gaussian process and the texture as the superposition of real cosines with unknown frequencies, amplitudes, and phases. We propose a method for estimating the model parameters and retrieving the texture component from the intensity data in the presence of multiplicative noise (the speckle) with

unknown power spectral density. The method exploits the clutter cyclostationarity and is based on a relaxation optimization approach. The ability of the proposed method to retrieve texture information is investigated by processing simulated and measured sea clutter data [C456]

"Fractal dimension as an indicator of track seduction"

A modern scanning radar is designed with sufficient sensitivity to detect small targets, and as a consequence will produce plot returns from many clutter objects. Much of the clutter, such as land clutter returns from large fixed objects, will produce a plot on almost every scan and algorithms may be designed to track and remove such clutter. However, many clutter sources such as sea or rain clutter produce plots having little or no correlation in position from scan to scan. If a track is seduced by such clutter plots, or if a false track starts within such an area of clutter, then the track may be maintained using random plots for some considerable time before failing to associate for sufficient scans to cause deletion. Indeed, the instability of the track will reduce the level of track smoothing, increase prediction error and open up association gates to make track maintenance more likely with each update. It is required to identify tracks that are maintained by random clutter; this paper shows that a measure of fractal dimension provides a suitable mechanism for identification. [C457]

"Adaptation to the clutter environment by airborne maritime surveillance radars"

Airborne maritime surveillance radars must detect small targets against a background of sea clutter whilst maintaining surveillance over a large area of sea. This task is very demanding and requires the radar to dynamically adapt to the local environment in order to obtain the best possible detection sensitivity. An aircraft flying at, say 3000 ft would be able to observe an area of sea of about 49,000 km, with a range to the horizon of about 124 km. Over this area, the clutter characteristics observed the radar will be continuously changing as a function of range and look direction. These characteristics will vary in a manner dependent on the prevailing conditions, the radar characteristics and the viewing geometry. In practice, the radar must cope with a very wide dynamic range of signal amplitude, with amplitude statistics varying from those of thermal noise to very spiky sea clutter and land. Continuous adaptation to this environment is required as a function of range and bearing. The dynamic behaviour of the radar as it adapts in this way is often a much more relevant measure of performance than more traditional static measures such as detection range. Methods used to adapt to the environment are surveyed in this paper, together with indications of how their dynamic behaviour can influence performance. [C458]

"Ship detection in SAR images: a segmentation-based approach"

This paper deals with the problem of detecting ship targets in medium- and high-resolution SAR images. Achieving a controlled false alarm rate is a major problem for the presence of a highly non-homogeneous sea clutter environment due to the highly variable environmental and weather conditions in closely spaced areas. After highlighting the problems of conventional techniques, a new approach is proposed based on cascading a segmentation stage and a local CFAR detection stage. The former estimates the homogeneous backscattering regions, while the latter detects the ship targets inside the fairly homogeneous identified regions [C459]

"Statistics of monopulse measurements of Rayleigh targets in the presence of specular and diffuse multipath"

In tracking of low-elevation targets with a monopulse radar, the presence of reflections from the sea surface causes severe errors in the direction-of-arrival (DOA) measurements of the target. Since the target echoes that are received directly and via the sea surface are unresolved in time and frequency, tracking targets in the presence of sea-surface induced multipath is a special case of tracking unresolved targets. The sea-surface reflection is modeled by a specular (coherent) component and a diffuse (noncoherent) component. The probability density function (pdf) of the measured amplitude of the sum signal and the amplitude-conditioned pdf of the in-phase and quadrature monopulse ratios are given for low-elevation, Rayleigh targets in the presence of sea-surface induced multipath. The means and variances of the monopulse ratios are used to illustrate the effects of diffuse multipath for a notional S-band radar [C460]

"Development of a digital array radar (DAR)"

Twenty-first century littoral and open-sea missions present USA Navy (USN) shipboard-radar systems with the challenge of detecting small targets in severe clutter and against multiple sources of interference. In fiscal year 2000 (FY00), the Office of Naval Research (ONR) sponsored a program to develop an active array radar that includes a digital beamforming (DBF) architecture. The DBF radar system has the potential for improved time-energy management, improved signal-to-clutter (S/C) ratios, improved reliability and reduced life-cycle costs. This paper summarizes the latest developments of the program during FY00 [C461]

"Tropical Rainfall Measuring Mission algorithm consistency studies"

Results are presented from analysis of the Tropical Rainfall Measuring Mission (TRMM) data from two perspectives: instrument/algorithm consistency checks and comparisons of precipitation retrievals between instruments. The instruments specific to this study are the Precipitation Radar (PR) and the TRMM Microwave Imager (TMI) [C462]

"Doppler polarimetry of high resolution radar sea clutter"

The non-stationary nature of high resolution grazing angle X-band radar backscatter of the sea surface is investigated. The temporal behavior is modeled as resulting from a fast and a slow process, and statistical parameters are derived for both processes separately. It is found that the fast process is consistent with an underlying complex Gaussian process, independent of polarization or range resolution, while the slow process is responsible for the spiky nature of the HH backscatter [C463]

"Island wake impact on evaporation duct height and sea clutter in the lee of Kauai"

Perturbed flow over and around an island can produce leeside vortices and a long wake region of reduced wind speed and altered thermodynamic structure that impacts the evaporation duct height field and directional wave spectra, both of which impact radar sea clutter returns. In this paper, predicted radar clutter is constructed by using evaporation duct height and wind fields from a mesoscale model along with appropriate sea clutter and electromagnetic propagation models. This predicted radar clutter is compared to shipboard observations of radar clutter taken off the leeward slide of Kauai, in December 1999 [C464]

"Maximum a posteriori refractivity estimation from radar clutter using a Markov model for microwave propagation"

This paper addresses the problem of estimating range-varying parameters of the height-dependent index of refraction over the sea surface in order to predict ducted microwave propagation loss. Refractivity estimation is performed using a Markov model for microwave radar clutter returns from the sea surface. Specifically, the parabolic approximation for numerical solution of the wave equation is used to formulate the problem within a non-linear recursive Bayesian state estimation framework. Solution for the maximum a posteriori (MAP) sequence of range-varying refractivity parameters, given log-amplitude clutter versus range data, is achieved using a technique based on the Viterbi algorithm. Simulation and real data results based on experiments performed off Wallops Island, Virginia are presented which quantify the technique's ability to predict propagation loss at 3 GHz [C465]

"Estimating refractivity from land clutter: another look at a simple approach"

In a previous report, two methods of estimating refractivity from land clutter were discussed where one of the methods used a parabolic equation (PE) algorithm combined with a least squares technique, and the other used a ray trace algorithm combined with a rank correlation scheme (Barrios 2000). Based on simulations alone, both of these methods were fairly successful in estimating a tri-linear representation of a radiosonde-measured refractivity profile over two mixed land-sea paths. However, each method appears to favor a certain type of land topography. The PE/least-squares method performed well over land paths characterized by steep peaks and valleys and the ray trace/correlation method performed well over land paths which were not sharply varying in elevation. This latter method offers a more attractive alternative to the conventional least-squares technique because of its execution speed and simplicity, therefore we take a more extensive look at this technique [C466]

"Estimation of sea-ice SAR clutter statistics from Pearson's system of distributions"

SAR images can be used to help ship routing in sea-ice conditions. In this study, we focus on the Antarctic region where no multi-year ice nor big ice floes are to be found. As a matter of fact, each clutter obeys a backscattering mechanism that induces a specific pixel distribution and our attempt is to identify automatically the correct distribution for each ice type. The problem is that of generalized mixture estimation and unsupervised image classification. In this work, we modelled the mixture with distributions from Pearson's system. Parameter estimation is realized according to the ICE algorithm in the context of hidden Markov chains. The results obtained from Pearson's system are compared to ones obtained with a classical mixture of Gaussian distributions [C467]

"Spike statistics features of the radar sea clutter in the millimeter wave band at extremely small

grazing angles"

Spikes of the scattered signal with specific statistical features are observed even for large grazing angles in addition to the range continuous signal. The strict physical model of the spikes is absent and this does not permit one to explain their statistics. It is noted only that the spike spatial statistics are associated with the breaking sea waves and foam presence on sea surface. In this paper the problems of the spike radar characteristics for frequency band of 10-140 GHz are considered [C468]

"Simulation of radar echo from a ship in ocean clutter using the GFBM/SAA method"

A hybrid approach of the generalized forward-backward method (GFBM) with the spectral accelerate algorithm (SAA) and Monte Carlo method is developed. It is applied to numerical simulation of angular radar echo from a rough sea surface with a ship presence as TE or TM tapered waves are incident upon it. Due to the high efficiency of the GFBM/SAA, radar echo at low grazing angle (LGA) can be also calculated. Numerical simulations show the functional dependence upon polarization, observation angle, sea surface wind speeds, ship location and other parameters [C469]

"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 [C470]

"Estimation of radio refractivity structure using radar clutter"

Describes the estimation of low-altitude atmospheric refractivity from observations of radar sea clutter. Both surface and evaporation ducts are considered. The intended use of the technique is to provide near-real-time estimation of ducting effects for naval forces, which is important for radar performance prediction. For surface duct inversions, the authors use the Simulated Annealing/Genetic Algorithm (SAGA) general purpose inversion code. SAGA is configured to use an embedded parabolic equation electromagnetic propagation model, a four-parameter model for atmospheric refractivity, and a linear least-squares objective function. The mismatch between (a) the optimal replica field and the observed clutter and (b) the inferred refractivity profile and the range-dependent refractivity structure obtained by in situmeasurements, is discussed. The inference of evaporation duct heights is simpler than the inference of surface duct parameters and has already been presented in the open literature. The material presented is an update on the performance of the algorithm based on at-sea testing [C471]

"Prediction of chaotic time series based on wavelet neural network"

Wavelet neural network possesses the best function approximation ability, that is to say it has the ability to identify the model. Because the constricting model algorithm is different from common artificial neural network BP algorithm, it can effectively overcome intrinsic defect of common artificial neural network. Therefore the better prediction effect can be reached effectively. The paper gives a method of prediction model of chaotic time series based on wavelet neural network that enables prediction model to have not only wavelet good approximation property, but also neural network self-learning adaptive quality. The authors make use the method to predict sea clutter data [C472]

"Suppression of the sea clutter in marine radar system"

The purpose of this paper is to analyze the radar echo signal data in a marine radar system, and we tackle the problem of the suppression of sea clutter on a marine radar display by using the wavelet transform, which gives optimum cut-off frequency with time (distance). Also, we propose a signal to clutter ratio (SCR) to evaluate our method and optimum cut-off wavelet coefficients. The experiment was carried out by using the X band radar (3 cm wave length) of the marine practice center of our school in Awaji Island. In short, the collection of the radar echo signal data reflected from floats, a test buoy and a ship was carried out in smooth and moderate sea conditions, and target distances 0.13, 0.24 and 1.17 nautical miles. The received signals are processed by an 8 bit, 120 MHz A/D converter and stored in the 8 Mbytes memory of our system. [C473]

"MAP sequence estimation of microwave refractivity from radar clutter via a particle filtering implementation of the Viterbi algorithm"

This paper addresses the problem of predicting microwave propagation loss under ducting conditions by means of estimating the range and height varying index of refraction from observations of radar sea clutter returns. Specifically, the Fourier split-step solution to the parabolic equation for wave propagation is used to formulate the problem into a nonlinear dynamic state-estimation framework. The solution for the maximum a posteriori (MAP) sequence estimate of the range-varying refractivity is achieved by extending notions of the particle filtering framework to the Viterbi algorithm for state estimation. Real data results based on experiments performed off Wallops Island, Virginia are presented which quantify the proposed method's ability to predict propagation loss at 3 GHz. [C474]

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