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# ТЕМАТИЧЕСКИЙ РЕФЕРАТИВНЫЙ СБОРНИК № 34-2

## “Radar Scattering Matrix”
## («РЛ матрица рассеяния»)

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## "POLSAR Image Classification Based on Polarimetric Decomposition and Generalized Discriminant Analysis"

In this paper, a new classification scheme of fully polarimetric SAR images is proposed. This is based on the joint use of the Freeman-Durden decomposition and generalized discriminant analysis, a new method for Feature extraction. After getting the powers of the three scattering mechanism components through Freeman-Durden decomposition, the Feature extraction algorithm is introduced to well exploit the information available in the full polarimetric coherency matrix. The experimental results show that using this exploited information as new features of Fisher classification, can provides fine performance and good compactness. [C1]

## "Photonic structures in the microwave band and their applications"

The possibility to utilize microwave photonic structures for measurement parameters of nanometer films and for creating on their base functional devices of microwave electronics has been shown. A wideband waveguide matched load on the base of waveguide photonic crystal has been described. Microwave filers with transmittance controlled from -1.5 dB to-25 dB by changing the PIN-diodes bias voltage from 0 to 700 mV have been constructed. [C2]

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

The article describes the IRCTR PARSAX radar system. It is an S-band high-resolution Doppler polarimetric FMCW radar utilizing dual-orthogonal sounding signals. The signals allow for measuring in one sweep all elements of the radar targets polarization scattering matrix simultaneously. PARSAX characteristics are: modular system set-up, highly-optimised linearity and sensitivity of the RF front-end receiver, use of a flexible multi-channel arbitrary waveform generator as sounding waveforms source, high-resolution analogue to digital conversion of the received signals at sufficiently high intermediate frequency and FPGA-based programmable digital multi-channel receiver. The paper shows that PARSAX is a unique radar research platform for studying arbitrary sounding waveforms with bandwidth up to 50 MHz and processing algorithms in Doppler-polarimetric radar. [C3]

## "FPGA based IF digital receiver for the PARSAX-Polarimetric agile radar"

An FPGA-based digital receiver has been developed to perform real-time processing for the PARSAX radar. It is a fully polarimetric FMCW radar with dual-orthogonal sounding signals, which has the possibility to measure all elements of the radar targets polarization scattering matrix simultaneously, in one sweep. This paper presents the design principles including the range profile interpretation, optimal parameters selection and processing gain analysis. A novel parallel deramping processing architecture suitable for FPGA implementation is introduced; the overall digital de-ramping processing has been implemented in one chip of FPGA and verified by experimental results. [C4]

## "Application of hybrid approach to the analysis of resonators loaded with axially symmetrical posts"

In this paper a new hybrid method is applied to the analysis of circular cavity resonators loaded with arbitrary configuration of axially-symmetrical posts. The method is based on a combination of finite difference frequency domain method and mode matching technique. In our approach each scatterer is treated as an effective circular cylinder represented by impedance matrix defined in its local coordinate system. In order to obtain the scattering parameters of an arbitrary configuration of objects in global coordinate system an analytical iterative scattering procedure (ISP) is utilized. The proposed technique is applied to determine the resonant frequencies of three different configurations of resonators. The validity of the proposed approach is verified with the analytical approach and commercial software. [C5]

## "Acceleration of Time-Domain Finite-Element Method in electromagnetic analysis with OpenMP"

Paralleled Time-Domain Finite-Element Method (TDFEM) is developed based on OpenMP for 2-D electromagnetic scattering analysis in this paper. The matrix-vector multiplication in conjugate gradient (CG) solver is parallelized with OpenMP. As a result, the efficiency of TDFEM algorithm is accelerated dramatically with multi-processor PC. The bistatic radar cross sections (RCSs) of some typical 2-D objects are computed with paralleled TDFEM. High speedup ratio and high parallel efficiency are obtained, which provides a practical and effective acceleration method for TDFEM analysis on multi-CPU computers. [C6]

## "Scattering characteristic of soot aggregation particles randomly distributed"

The generation multiple Mie theory (GMMT) is introduced to investigate the scattering characteristic of a soot aggregation particles randomly distributed. Computes of the Muller matrix elements are carried out at two wavelengths (0.6328μm and 1.06μm). Some selected results are given by the equivalent medium method (EMM) and compared the results given by GMMT. The results are expected to provide useful insights into the formation mechanism and structural characteristics of randomly distributed cluster agglomerates. [C7]

## "Application of VSIE method to scattering problem involving conducting and anisotropic bodies"

Evaluation of electromagnetic scattering by anisotropic media may be of interest in many military and civil applications. This paper presents the hybrid volume and surface integral equation(VSIE) based scheme to analyze scattering from conducting and/or inhomogeneous dielectric bodies with anisotropic electromagnetic properties. The Rao-Wilton-Glisson (RWG) basis functions are used to discretize those unknowns of the matrix equations. The method of moments(MOM) technique is augmented with the fast multipole which enable large scale analysis. Finally, several numerical results are presented to demonstrate the stability and accuracy of the proposed method. [C8]

## "Inter-period compensation of the unambiguity range degradation in polarimetric FMCW radar with time-shifted dual-orthogonal signals"

This paper describes a new type of sounding signals for polarimetric FMCW radar and the corresponding signal processing technique. This technique coordinates continuous transmission of two bi-cyclic LFM-signals on orthogonal polarizations and applies an advanced de-ramping processing on receive. The first signal consists of two identical LFM-signals; the second one has time shift relatively first and is composed by the same LFM-signal and its copy having negative sign. The time between the components of sounding signal prevents the frequency overlap between polarimetric components of scattered signal in the branches of every polarimetric radar channel. Thanks to this frequency gap between the signals in every time instant, a high-isolation level in polarimetric FMCW radar channels can be provided. However, the use of two LFM-signals having the same form but a relative time shift can decrease the unambiguity range, because the delayed signals scattered by far-located objects (interfering signals) can be determined as useful signals scattered by close-located objects in a cross branch in a polarimetric radar channel. The use of the proposed bi-cyclic LFM-signals and the additional summation units in the de-ramping filter allows the suppression of these interfering signals due to the phase sign change of the beat signals. As result, the developed de-ramping processing technique can be used in polarimetric FMCW radar receiver providing high-level cross-channels isolation without unambiguity range degradation for estimation of all elements of the radar target scattering matrix. [C9]

## "An ultrawideband time reversal-based RADAR for microwave-range imaging in cluttered media"

This work presents a new RADAR prototype built for the purpose of imaging targets located in a cluttered environment. The system is capable of performing Phase Conjugation experiments in the ultrawideband [2-4] GHz. In addition, applying the D.O.R.T. method to the inter-element matrix allows us to selectively focus onto targets, hence reducing the clutter contribution. We aim to experimentally explore the use of this focusing wave into an inversion algorithm, in order to improve its robustness against noise. Before testing this idea, we show here the first results validating the prototype separately in the frame of selective focusing via the DORT method and of multistatic-multifrequency inversion. [C10]

## "Enhanced detection of planar retro-reflective arrays using polarization properties"

This paper presents a design concept to aid in the detection and tracking of objects in a cluttered environment at 26 GHz. Target tracking can generally be accomplished with the use of retro-reflectors which are able to return an incident signal back in the same direction with a radar cross section (RCS) that is independent of angle of arrival for a large range of incidence angles. [C11]

## "EM techniques for the detection of breast cancer"

Radar based microwave imaging technique has great potential for breast cancer detection. It has been demonstrated by recent experiments that the data adaptive radar microwave imaging reveals good image resolution. However, purely scattered energy based image reconstruction methods can face major challenges in differentiation since the fibroconnective and glandular tissues which could have similar dielectric properties as that of malignant tissues. It has been proposed that the morphological features of the tissue can differentiate the benign from malignant tissues due to their irregular, spiculated shapes. Thus to efficiently differentiate the healthy, benign and breast tissues, this paper proposes a method that combines a novel data-independent beamformer called MWDAS method with Matrix Pencil (MP) method to first localize the suspicious region and then extract the resonant frequency and damping factor of complex natural resonance (CNR) of the malignant tissues. We employ FD-TD based computational 2D and 3D breast models for testing our method. [C12]

## "Mutual coupling compensation applied to a uniform circular array"

In this paper, two approaches for compensation of mutual coupling and phase shifts in a passive radar system based on a circular array are compared. The first method is based on the measurement of the antenna scattering parameters and of further relative phase and amplitude variations between the channels introduced by the receiver analog front-end and by the analog-to-digital converter. The second method derives a total coupling matrix, which contains both the antenna and the front-end contributions, by measuring the signals transmitted from known positions. The two procedures have been applied to an FM-based passive radar that uses an 8-element circular array. It appears that for the considered geometry the antenna mutual coupling does not significantly affect the radiation pattern, while the major contribution is due to phase shifts introduced by the receiver front-end. [C13]

## "Microwaves reflection of centimeter wavelength range of two-dimensional square symmetry plasma photonic crystals"

In this paper, an exact approach, uniting several modern methods, to the theory of multiple scattering of wave fields in two dimensional inhomogeneous media, the so called transfer relations' method with the technique of matrix Riccati equation, is applied in a quantitative analysis with given accuracy of reflection spectra of plasma photonic crystals with square lattice symmetry. [C14]

## "Moving multy-scatterer target parametric identification using radar image"

The wideband coherent pulse radar provides high resolution image of the target. A model of this image is composed of the complex envelope superposition of signals diffracted by the point scatterers. The values of complex envelope are distributed over the radar image coordinate plane in accordance with the point scatterer's positions and their reflection coefficients. The radar image model is combining of the range and Doppler profiles. The parameters of the target point scatterers are processed using one dimensional data extracted from the complex discrete Fourier transform of the radar image. The Matrix Pencil algorithm is used for the parametrical target identification. [C15]

## "Analysis of helical systems containing periodical inhomogeneities"

Properties of helical systems containing periodical inhomogeneities are considered. The multiconductor line method is applied for modeling of the systems and calculations of retardation factor and input impedance. ABCD matrices are used to reveal rejection properties of lines containing periodical inhomogeneities. The method based on multiple reflection diagrams is used to determine transient responses. Possibilities to improve characteristics of helical systems containing periodical inhomogeneities are discovered. [C16]

## "PMCHW-AMCBFM for analysis of electromagnetic scattering by 3-D homogenous dielectric objects"

In this article, we present a novel approach based on PMCHW integral equation formulation in conjunction with the adaptively modified characteristic basis function method (AMCBFM) to solve the scattering from homogenous dielectric bodies. In the new method, equivalent electric and magnetic currents on the surface of object are needed and expanded using RWG basis functions. AMCFBM is subsequently used into the former matrix equation. The studied object is partitioned into distinct blocks with some overlapped-domains between neighboring ones. The matrix equation is solved by direct solution instead of iterative methods. The compatibility, accuracy and efficiency of this novel approach are demonstrated by a variety of scattering problems. [C17]

## "Spectral-domain analysis of a resistive patch antenna with uniaxial substrate"

The moment method technique has been developed to examine the scattering properties of a rectangular microstrip patch antenna with a surface resistance. Entire domain sinusoid basis functions without edge condition and roof top sub-domain basis functions are introduced to expand the unknown current on the metal patches. The boundary condition for the electric field was used to derive an integral equation for the electric current. The necessary terms for representing the surface resistance on the patch were derived and were included in the equation in the form of a resistance matrix. Effects of uniaxial anisotropy in the substrate on the complex resonant frequency, the half band width, the radar cross section and the radiation of the microstrip patch antenna are also investigated. Comparative study between our results and those available in the literature is done and showed a very good agreement. [C18]

## "Modified Range-Doppler imaging method for the high squint SAR"

In this paper, a modified Range-Doppler (RD) algorithm with the Keystone Transform and the rank-deficient Capon is proposed for the shorter Synthetic Aperture Radar (SAR) imaging in the high squint mode. With the decrease of the aperture time under the squint mode, the linear range-walk becomes the dominant part of the range migration. The Keystone Transform is well suitable for removal of the range walk. In order to achieve higher resolution in the azimuth domain with the shorter SAR, the rank-deficient Capon which is an efficient non-diagonal loading spectral estimation based on rank-deficient sample covariance matrix is adopted. Simulation results can obtain the finer SAR images of the proposed approaches. [C19]

## "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. [C20]

## "Scattering of 3-D objects with a new total-and scattered-field decomposition technique for FEM"

Finite element method (FEM) is combined with volumetric plane-wave excitation method (VPWE) and total-and scattered-field decomposition(TSFD)technique is used to analyze some electromagnetic scattering of typical 3-D objects in this paper. The whole computational area is decomposed into total-field and scattered-field. And then, the incident wave is impressed in the whole total-field region. The detailed algorithms of VPWE-TSFD/FEM are presented. Radar cross sections (RCS) of some typical objects are computed, which demonstrate that the given method is effective for electromagnetic scattering analysis of 3-D objects. [C21]

## "Hybrid array for the detection and imaging of termites"

This paper describes a 24 GHz radar receiver array, designed to detect and image termite activity, behind a wall, floor or ceiling. This hybrid array is composed of two sub-arrays. A Direction of Arrival (DOA) sub-array for wide area detection of termites, and a 3D high resolution imaging sub-array for imaging individual termites. Here, we introduce an enhanced DOA algorithm, to resolve arbitrary numbers of targets, and compare simulation results with video of actual termites. [C22]

## "SAR Image Segmentation Based on SWT and Improved AFSA"

In order to speed up the segmentation procedure and solve the problem of noise-sensibility in image segmentation, the paper suggests a fast SAR (Synthetic Aperture Radar image) image segmentation method, which integrates SWT (Stationary Wavelet Transform) and AFSA (Artificial Fish Swarm Algorithm). In the method, an original image is decomposed by multilevel SWT firstly. And then, approximation coefficients at the highest level are used to reconstruct the original image. Next, two-dimensional histogram of the reconstructed image and its mean-filtered image is produced, whose trace of the between-class scatter matrix is taken as the fitness function of our improved AFSA. Additionally, the method gets a faster convergence successfully by adjusting the strategy of keeping the best fish. Experimental results indicate that the proposed method has obvious improvement on segmenting speed and segmented effect. [C23]

## "MIMO radar target detection with parametric scattering correlation model"

Multiple-input multiple-output (MIMO) radars utilize various sources of diversity to improve the performance of

the radar. A MIMO radar in which angular diversity is achieved by using widely distributed antennas has been proposed to reduce the impact of the fluctuations of the target radar cross-section. This type of system is also known as the statistical MIMO radar. Typically, it has been assumed that the signals received by different antennas are either fully correlated or independent depending on the configuration. In this paper, we assume more realistically that the scattering from the target is correlated. We show that taking the correlation of the scattered signals into account can improve the probability of detecting the target. This is achieved by using a parametric model for the scattering which allows one to efficiently estimate the scattering covariance matrix. The numerical examples demonstrate that the probability of detection remains good even when parameters of the model are inaccurate. [C24]

## "SAR imaging of forest structure at longer wavelengths"

This paper is focused on the recovery of the vertical structure of forested areas from multi-baseline and multi-polarimetric SAR surveys at P-Band and L-Band. Baseline diversity provides sensitivity to the vertical structure of the vegetation layer, resulting in the possibility to yield Tomographic reconstructions of forested areas. Yet, far more information can be inferred basing on the joint exploitation of baseline and polarization diversity, which allows the decomposition of the SAR signal into ground-only and volume-only contributions. Ground-only contributions provide an easy and viable way to phase calibrate the data stack. Volume-only contributions, if correctly identified, allow a direct imaging of the vegetation layer. Results are shown basing on both P-Band and L-Band airborne data collected in the framework of the ESA campaign BioSAR 2008. The spaceborne case is also considered, basing on simulated BioMass data. [C25]

## "Calibration of a Digital phased Array for polarimetric Radar"

When an active phased array is used for polarimetric radar applications, the system must be calibrated to reflect the fact that polarization of the transmitted and received fields is dependent on the scan angle. This paper discusses the challenges of polarimetric phased array calibration, and demonstrates these techniques using a linear array of eight S-band dual-polarized antennas connected to an active Digital Array Radar (DAR) pro-totype system. The ability to accurately measure polarimetric scattering matrices is demonstrated after using direct far-field measurements to compensate for polarization errors on receive and target reflection measurements to compensate for transmit polarization errors. [C26]

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## "A target polarization recognition method for radar echoes"

This paper distinguishes ship target from chaff by their difference in depolarization characteristics using fully polarized dual-channel radar which transmits vertical and horizontal polarization wave alternately and receives co-polarization and cross-polarization components simultaneously with two channels. It recognize the target by taking advantage of the difference of the vertical and horizontal depolarization characteristic parameters of the target and chaff in radar echoes, after enlarging the difference between the cross-polarization component and co-polarization component of the radar echoes involving both target and chaff. furthermore, non-linear polarization transformation is adopted to increase the chaff and targets separability and to improve the recognition rate in result. In the end, the recognition result is proved to be more desirable by processing information in polarization domain than in time and frequency domain. [C28]

## "Robust waveform design for MIMO radars"

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

and the approximation of the detection probability in the high- and low-signal regimes. [C29]

## "RELAX based estimation of signal and clutter echoes modeled as discrete point scatterers"

We consider the radar signal return to be originating from discrete point scatterers, and utilize this to estimate clutter echoes and calibrate a multi-channel array. The point scatterers are parameterized with a specific Doppler and spatial frequency (u and v direction). Previous work considering this formulation of clutter is the SCHISM approach. Their estimation is based on the radar version of CLEAN. For many cases where the scatterers are well separated, the CLEAN algorithm is fast and accurate. However, for closely spaced scatterers (in either Doppler or space), the CLEAN method suffers. Thus, to enhance the ability to resolve such scatterers we instead employ a new estimator (RESCUE) that uses the approach introduced in RELAX. As for SCHISM, range gates are processed individually and independently from each other and sample covariance matrices are avoided. Real world multi-channel data are used to demonstrate the proposed method. The results are very promising and indicate that this approach can indeed be used as an alternative to traditional STAP. [C30]

## "Scattering analysis of flat electric dipoles on multilayer chiral structures"

Identification of natural targets out of polarimetric SAR data can be made from their scattering matrices, once they are determined. The methodology outlined here permits the spectral domain analysis of a confined chiral layer stacked up between free space and ground, containing flat electric and magnetic elements at any layer interface, and illuminated by an elliptically polarized plane wave at oblique incidence. From the closed-form field expressions so obtained, scattering parameters, including the scattering matrix, of an electric dipole atop the chiral layer are readily determined and analyzed. [C31]

## "ICA-based information extraction method for PolSAR images"

Identifying and characterizing objects in PolSAR images rely on proper backscattered signal models, correct segmentation algorithms and on exploiting the connections between the physical structure of the considered objects and their radar echos. The paper presents an ICA-based approach for characterizing physical properties of the objects on the Earth surface. Segmentation of PolSAR image is based on stochastic models. Each segment is assimilated to an object or surface type and pixels of the segment are treated like realizations of the underlying target scattering mechanism. This scattering mechanism is characterized through ICA-based approach, thus providing information about the corresponding target. The TSVM decomposition is used to analyze the mixing matrix issued from ICA and to link its values to physical properties of the target. [C32]

## "PolSAR images characterization through Blind Sources Separation techniques"

Since the backscattered signal in PolSAR images is intrinsically linked with the physical characteristics of the objects in the image, valuable information may be extracted therefrom. The paper focus is to propose a new physical characterization of the scattering target, inspired by the Blind Sources Separation techniques. [C33]

## "Polarimetric SAR tomography of natural environments using hybrid spectral estimators"

SAR tomography is the extension of conventional two dimensional SAR imaging principle to three dimensions. In order to improve the vertical resolution with respect to classical Fourier-based methods, high resolution approaches are used in this paper to perform SAR tomography. Both nonparametric spectral estimators, like beamforming and Capon and parametric ones, like MUSIC, maximum likelihood, are applied to real data sets and compared in terms of scatterer location accuracy and resolution. This paper addresses the discrimination of coherent scatterers presented in the natural environment and a joint approach of estimation and detection is proposed. [C34]

## "Target decomposition for fully polarimetric wideband radar system"

For fully polarimetric wideband radar system, a novel method of radar target recognition using polarimetric feature is proposed. First, polarimetric scattering matrix is obtained from fully polarimetric high resolution range profiles(HRRPs). Then, two different kinds of polarimetric features are extracted by polarimetric target decomposition theorem. At last, K-Nearest Neighbors(KNN) classifier is applied to verify the recognition performance of these two features. The simulation experiments indicate target recognition via polarimetric features can reach a higher recognition performance in different experimental scenarios. [C35]

## "Roll invariant target detection based on PolSAR clutter models"

Based on the Kennaugh-Huynen decomposition, the Target Scattering Vector Model (TSVM) allows to extract

four roll-invariant parameters. Those parameters are necessary for an unambiguous description of the target scattering mechanism. The proposed method consists in applying the TSVM prior to the GLRT-LQ detector for the detection of any oriented target. [C36]

## "Monitoring grasslands with radarsat 2 quad-pol imagery"

Radarsat 2 quad polarization imagery has been used to study the effectiveness of polarimetric radar to monitor the extent and health of prairie grasslands in southern Alberta, Canada. In this report of preliminary findings, the imagery is shown to be effective in the separation of cropped lands from rangelands, and in the separation of native grasslands and improved pastures. Classification was more accurate using Freeman-Durden decomposition parameters than using Cloude-Pottier parameters. Incidence angle differeces were noted and use of multiple angles in classification improved accuracy. In a second part of the study, it was shown that polarimetric imagery was capable of identifying weeds and brush growing in native rangland, and in separating different kinds of brush and weeds. Validated sample sets were too small to allow proper accuracy assessment, but a `performance metric' showed that accuracy would be improved by use of multiple incidence angles, and by the use of Freeman-Durden or coherency matrix parameters. [C37]

## "Forest structure from longer wavelength SARS"

In this paper we address three topics related to SAR Tomography of forest scenarios at P-Band. In first place we discuss the role of pulse bandwidth, which is shown to play a critical role as for the capability of the Tomographic system to separate ground and canopy contributions. Accordingly, vertical resolution depends not only on baseline aperture, but also on pulse bandwidth. Another factor to be accounted for is phase calibration, as the quality of the vertical focusing carried out by SAR Tomography is strictly related to the condition that phase contributions due to platform motion or atmospheric propagation are properly compensated for. Finally, multiple scattering phenomena are likely to occur at longer wavelengths, resulting in Tomographic techniques not being suffice for the aim of discriminating ground and volume scattering. The three points above are here discussed in light of the results achieved in the framework of the ESA campaign BioSAR 2008. The analysis has been carried out by exploiting the Algebraic Synthesis technique, which provides a theoretical framework to decompose the SAR signal into ground-only and volume-only contributions. Ground-only contributions provide an easy and viable way to phase calibrate the data stack. Volume-only contributions, if correctly identified, allow a direct Tomographic imaging of the vegetation layer. The impact of pulse bandwidth is tackled by assuming a Common Band Filtering approach, which results in a vertical resolution improvement by a factor 2. [C38]

## "Extension of the Target Scattering Vector Model to the bistatic case"

The polarimetric information has been widely used to interpret the Synthetic Aperture Radar (SAR) scene. Hence, many decompositions have been introduced to extract polarimetric parameters with a physical meaning. Nevertheless, for most of them, the reciprocity assumption is assumed. For a bistatic PolSAR sensor, the cross-polarization terms of the scattering matrix are not equal. This paper presents a generalization of the Target Scattering Vector Model (TSVM) to the bistatic case. [C39]

## "Spinning targets imaging based on OMP algorithm with radial basis function"

A new radar imaging method is proposed for spinning targets in space. The rapid spin motion of the target induces multi-period sinusoidal modulation of the radar echoes in both range and doppler domain, which causes Range-Doppler (R-D) algorithm invalid in conventional radar imaging. The presented method analyzes the echo model of the target spinning around an arbitrary axis. An exponential radial basis function (RBF) is then constructed from the scatters' range profile based on a distance-weighted criterion, and the image is rebuilt by recovering the projection of the target base on orthogonal matching pursuit (OMP) algorithm with the radial basis matrix. The simulation results show that the proposed method can obtain the radar image more effectively for the target with a uniform speed spin motion. [C40]

## "Full polarimetric SAR classification based on Yamaguchi decomposition model and scattering parameters"

The full polarimetric information of the target from polarized Synthetic Aperture Radar (POLSAR) enables us to implement recognition and classification of remote sensing images more effectively. Based on the analysis of typical polarized target decomposition and classification, the issue proposes a new scheme for iterative classification of polarimetric SAR image, which blends the outcomes of Yamaguchi decomposition and H/α decomposition. This technique extracts four decomposition coefficients of four scattering mechanism components through Yamaguchi decomposition, the scattering entropy and angle through H/α decomposition first; then the initial classification of the POLSAR images is done by the combination of the 6 parameters mentioned above.

The final result is obtained by iterative classification due to coherence scattering matrix following wishart distribution. The effectiveness of this method plus less computation required is demonstrated by the experimental results of polarimetric SAR data. [C41]

## "1-D superresolution ISAR imaging algorithm"

A novel 1-D scattering centers extraction algorithm of radar target based on conjugate unitary Root-MUSIC was introduced in this paper. To improve the resolution of 1-D scattering centers, the information of conjugated data was used availably by combining the observation data matrix with its conjugated data matrix. Centro-Hermitian data matrices with hermitian property was constructed by forward-backward(FB) averaging, Unitary transform was applied which convert the FB covariance matrix to a real matrix, and the computational efficiency is improved by real-valued eigendecomposition. Theory analysis and simulation result show that the new approach can improve the resolution and reduce significantly computational complexity. [C42]

## "Electromagnetic imaging using compressive sensing"

We develop a near-field compressive sensing (CS) estimation scheme for localizing scattering objects in vacuum. The potential of CS for localizing sparse targets was demonstrated in previous work. We extend the standard far-field approach to near-field scenarios by employing the electric field integral equation to capture the mutual interference among targets. We show that the advanced modeling improves the capability to resolve closely spaced targets. We compare the performance of our algorithm with the performances of CS applied to point targets and beamforming. In this paper, we consider two-dimensional (2D) scatterers. However, the results and conclusions can be extended to three-dimensional (3D) problems. [C43]

## "Microwave backscatter of ship signatures on SAR imagery"

Speckle characteristics was analyzed by computing the ENL (Equivalent Number of Looks) for sub images of 30 by 30 pixels from four RADARSAT-2 dual polarization products, two single look complex (SLC) products acquired in wide swath single beam mode with dual polarization of HH+HV and two ScanSAR Wide (SCW) products acquired in ScanSAR Wide beam mode with dual polarization of HH+HV, which lie in the sea area around Iberian Peninsula. The speckle analysis indicates that ENL value combined with the intensity value of the SAR image should be a feasible short cut to find ship signatures out of SAR image. Based on the ENL analysis of speckle characteristics, a data set for ship signature has been derived, from which the ship signature was measured by polarimetric synthesis since the polarimetric SAR signature is an effective way of utilizing the amplitude and phase information to characterize the polarization properties of microwave backscatter. Driven by the need for a realistic microwave backscatter of ship signature model, the detailed behavior of a single ship in different polarizations and different incidence angles will be investigated by the Ray-Optical method which was developed by Burkholder et al. The purpose of this paper is to pave the way for a further improved scatter matrix model. [C44]

## "Two methods of 3-D scattering center extraction for targets with micro-motion"

Aiming at the problem of three-dimensional scattering center extraction based on high resolution range profile (HRRP) sequence, two methods based on projection equation solving and spherical fitting were presented in this paper. Equation solving method was to solve the matrix equation based on the algebraic relations between the 1-D radial distance and 3-D position. Spherical fitting method was to extract scattering centers from the mapping graph according to the spherical distribution of 1-D projection data. In addition, a way of turning precession parameters into angle parameters indirectly was proposed for the difficulty of getting the look angle of the radar, Two methods were all verified by experiments developed with simulated and measured data. Finally, the features and performance of two methods were compared in the paper. The result indicates that the spherical fitting method is better than the equation solving method by 15dB under the same SNR. [C45]

## "Estimation of UWB radar scattering center with GTD-based 2D state-space method"

A GTD-based 2D state-space method is presented in this paper for estimating the parameters of the scattering centers on a moving target under the ultra-wideband conditions. Firstly, this method constructs the GTD-based impulse response from the moving target in the state space equation, and then arranges the impulse response of different frequency at different time into a Hankel matrix. Next, the range and the range rate are estimated by using the Hankel matrix singular value decomposition (SVD), which effectively solves the range aliasing problem when the ranges of different scattering centers are overlapped. It occurs in the ID state space when the range is estimated only. At last, the type parameter and intensity of the scattering center are solved out by this method. The effectiveness of the method is verified by comparing the result of processing the echo data from the rotating conical target with the CRB on parameters estimation. [C46]

## "Unsupervised classification of PolInSAR image based on Shannon Entropy Characterization"

In this paper, we propose a new method for unsupervised classification of polarimetric synthetic aperture radar interferometry (PolInSAR) images based on Shannon Entropy Characterization. Firstly, we use polarimetric H (entropy) and a parameters to classify the image initially. Then, we reclassify the image according to the span of Shannon Entropy Characterization. Finally, we fuse the results of the two previous steps and merge them to the specified number of clusters. The effectiveness of this method is demonstrated on CETC38 PolInSAR data and E-SAR PolInSAR data. [C47]

## "Radar retrieval of subsurface parameters for layered media with nonsmooth interfaces"

The solution to the inverse problem for a three-layer medium representing a large class of natural subsurface structures is developed in this paper using radar data. The retrieval of the layered medium parameters is accomplished as a sequential nonlinear optimization starting from the top layer and progressively characterizing the layers below. The optimization process is accomplished by an efficient iterative technique built around the solution of the forward scattering problem. The forward scattering process is formulated by using the Extended Boundary Condition Method (EBCM) and constructing reflection and transmission matrices for each interface. These matrices are then combined into the generalized scattering matrix for the entire system, from which radar scattering coefficients are then computed. To be efficiently utilized in the inverse problem, the forward scattering model is simulated over a wide range of unknowns to obtain a complete set of subspace-based equivalent closed form models that relate radar cross section coefficients to the sought-for parameters including dielectric constants of each layer and separation of the layers. The inversion algorithm is implemented as a modified conjugate-gradient-based nonlinear optimization. It is assumed that multifrequency radar measurements are available from tower-mounted or airborne platforms, for example at typical radar frequencies of L-band and P-band (UHF). It is shown that this technique results in accurate retrieval of surface and subsurface parameters, even in the presence of noise. [C48]

## "Target detection and positioning in correlated scattering using widely distributed MIMO radar"

Multiple-input multiple-output (MIMO) radars use different sources of diversity to improve the performance of the radar. A MIMO radar in which angular diversity is achieved by using widely distributed antennas has been proposed to reduce the impact of the fluctuations of the target radar cross-section. This type of system is also known as the statistical MIMO radar. Typically, it has been assumed that the scattering amplitudes of the signals received by different antennas are either fully correlated or independent depending on the configuration. However, the antennas may see similar aspects of the target in some situations leading to correlation in the scattering. In this paper, we show how the correlation of the scattering can be exploited to improve the probability of detection and positioning. This is achieved by using a parametric model for the correlation of the scattering. We also investigate how the correlation can be used for estimating the direction of arrival with an uncalibrated MIMO radar system. [C49]

## "The Equivalence Analysis for SDH Decomposition and Cameron Decomposition Based on a Unified Three-Component Scattering Model"

In 1996, Cameron proposed an approach to decompose an arbitrary polarization scattering matrix into three orthogonal components, including nonreciprocal scattering component, maximum symmetric scattering component, and minimum symmetric scattering component. In this paper, based on the analysis of the characteristics of the maximum symmetric scattering component and the minimum symmetric scattering component in Cameron decomposition, a unified three-component scattering model for polarimetric coherent target decomposition is proposed. Pauli decomposition, SDH decomposition and Cameron decomposition can be expressed as a simplified form of the unified model with some certain restriction respectively. In addition, we can prove that SDH decomposition and Cameron decomposition to be equivalent by verification of restrictions consistency. [C50]

## "Inverse scattering using a Time Reversal RADAR"

This work presents a new RADAR prototype built for the purpose of imaging targets located in a cluttered environment. The system is capable of performing Phase Conjugation experiments in the ultrawideband GHz. In addition, applying the D.O.R.T. method to the inter-element matrix allows us to selectively focus onto targets, hence reducing the clutter contribution. We aim to experimentally explore the use of this focusing wave into an inversion algorithm, in order to improve its robustness against noise. [C51]

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

The article describes specific aspects of the radar polarimetry using sounding signals with dual-orthogonality. Such signals provide the unique opportunity to measure all elements of the polarization back-scattering matrix simultaneously, during one sweep/pulse period of radar signal. This approach has been implemented in the IRCTR PARSAX radar system, the fully polarimetric high-resolution Doppler FMCW radar. The digital architecture of the radar starts from intermediate frequency and makes the radar fully reconfigurable in terms of sounding waveforms and processing algorithms. [C52]

## "Wetland mapping by using multi-band and multitemporal SAR images: A case study of Hong he National Natural Reserve"

Wetland ecosystems have many important functions as the regional environment stabilization, natural species protection and ecological resources facility. Investigation and monitoring on wetland urgently need the application of remote sensing. The optional remote sensing technology is sometimes difficult to receive the data due to the bad weather, or in specific light conditions. However, radar remote sensing has a great potential for technical application in wetland mapping with its all-weather, all-time capabilities. And SAR scattering intensity is sensitive to the soil moisture of land cover and land change, therefore it is also helpful to the wetland research. In this paper, multi-band, multi-temporal SAR technique was used for wetland mapping. Unifies the SAR polarization characteristic, the backscattering characteristic of multi-temporal ENVISAT ASAR HH, HV, VV polarization data and ALOS PALSAR HH polarization data of different land use type and different vegetation type in Honghe National Natural Reserve (HNNR) were analyzed. The multi-temporal SAR data was used for vegetation classification research in decision tree classification method. And the authors use actual samples to do accuracy assessment in the way of computing confusion matrix. The result from this study shows that the improvement of water and marsh classification accuracy owes to the summer data, and the classification accuracy can be improved when we used the multitemporal data, HV polarization data in winter is more advantageous for forest map. The recognition rate of water, marsh and forest was relatively high. The classification of grass and bush had confusion. The classification accuracy of multitemporal SAR reached 79.55%. [C53]

## "Classification of Polarimetric SAR Images Using Evolutionary RBF Networks"

This paper proposes an evolutionary RBF network classifier for polar metric synthetic aperture radar ( SAR) images. The proposed feature extraction process utilizes the full covariance matrix, the gray level co-occurrence matrix (GLCM) based texture features, and the backscattering power (Span) combined with the H/α/A decomposition, which are projected onto a lower dimensional feature space using principal component analysis. An experimental study is performed using the fully polar metric San Francisco Bay data set acquired by the NASA/Jet Propulsion Laboratory Airborne SAR (AIRSAR) at L-band to evaluate the performance of the proposed classifier. Classification results (in terms of confusion matrix, overall accuracy and classification map) compared to the Wish art and a recent NN-based classifiers demonstrate the effectiveness of the proposed algorithm. [C54]

## "A unique calibration method testified by X-band polarimetric radar"

This paper explores a unique calibration method for polarimetric radar without requiring any calibration targets. The error of the polarimetric scattering matrix measurement is modeled as antenna distortion matrices and channel distortion matrices. These distortion matrices can be determined using a signal generator in anechoic chamber. The performance of the calibration method is analyzed by simulation. Its validity is verified through the experiment of an X-band polarimetric radar system. [C55]

## "Polarimetric sar image visualization and interpretation with covariance matrix invariants"

In this study we give short overview of polarimetric SAR image visualization with colors. By studying the color models and polarization visualization models we propose basic principles which should be followed when presenting polarimetric information in color. We show that for different polarimetric parameters, different color models should be used, and give guidelines for color model selection. We present also two visualization schemes which are suitable for interpretation and browsing of large polarimetric SAR images. [C56]

## "Esprit-based scattering power decomposition by using modified volume scattering model"

The scattering power decomposition for POLSAR data is one of the powerful tools in the radar polarimetry. There are several model-based decomposition techniques. However, since the number of independent observables in POLSAR images is limited, these techniques require several assumptions to obtain unique solution. The authors have proposed an alternative technique with POL-InSAR dataset. By using the POL-

InSAR dataset, we can increase the number of observables. However, selection of volume scattering component was still a problem. Recently, Dr. Arii et. al., proposed a generalized volume scattering model, and applied it to the POLSAR dataset with the adaptive non-negative eigenvalue decomposition technique. In this report, we appy the model to the ESPRIT-based POL-InSAR decomposition technique and verify the estimation performance experimentally. [C57]

## "Polarimetric and structural properties of forest scenarios as imaged by longer wavelength SARS"

SAR data gathered from forested areas collect contributions coming from the vegetation layer, from the ground below and from other scattering mechanisms (SMs). Multi-baseline data allow a tomographic analysis thus retrieving information about the vertical structure of the target. Multi-polarimetric acquisitions enrich the data, providing ways to identify the targets basing on their electromagnetic properties. The joint exploitation of multi-polarimetric and multi-baseline data suggests the possibility of linking the estimation of the vertical structure of different SMs with their polarimetric signature. A formal framework in which this task can be accomplished is provided by the Algebraic Synthesis (AS) technique, which extends the concepts within PolInSAR through the assumption of the Sum of Kronecker Products (SKP) structure. By assuming the presence of two SMs (for example ground and volume scattering), the SKP assumption leads to a cross dependence between the polarimetric and interferometric coherences, in that ground structure is shown to be related to volume polarimetry, and dually volume structure is shown to be related to ground polarimetry. The aim of this paper is to investigate the implications of this cross relation. Experimental results will be shown basing on a data-set of multi-polarimetric and multi-baseline SAR images at P-band acquired by DLR's E-SAR over the Krycklan catchment, in northern Sweden, in the framework of the ESA campaign BioSAR 2008. [C58]

## "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. [C59]

## "Four-component scattering power decomposition with rotation of coherency matrix"

In this presentation, a new decomposition scheme of first using a rotation of the coherency matrix followed by the four-component decomposition is presented. It is shown using airborne Pi-SAR data sets that oriented urban areas are clearly distinguished from volume scattering as double bounce objects by the rotation of coherency matrix. [C60]

## "Polarimetric scattering analysis for accurate observation of stricken man-made targets using a rotated coherency matrix"

This paper investigates polarimetric scattering features generated from man-made targets for accurately observing stricken residential area by making full use of quad. polarimetric SAR data set. First, we propose a simple improvement of the scattering power decomposition method by introducing a unitary rotation of the coherency matrix. It is found from the results of the POLSAR image analysis for a mountainous region including some stricken residential areas that by carrying out the rotation procedure, double-bounce scattering contribution can be enhanced even when the targets are oriented and/or set on small inclined ground plane. This peculiar scattering feature is utilized as a useful marker for precisely detecting man-made targets. To verify the generating and enhancing mechanism of the double-bounce scattering, we also carry out the Finite-Difference Time-Domain (FDTD) polarimetric scattering analysis for a simplified man-made target model. The dependency of the polarimetric scattering feature on the variation of squint angle is investigated. It is confirmed from the FDTD analysis for oblique squint angular range that by applying the rotation procedure before the scattering power decomposition, the double-bounce scattering contribution tends to be enhanced, and the volume scattering becomes small. [C61]

## "Fully polarimetric ALOS PALSAR data applications for snow and ice studies"

In this study, the capability assessment of fully polarimetric L-band ALOS PALSAR data has been carried out for snow discrimination from other targets. Eigenvaluve based polarization fraction value has been determined for assessing the capability of PALSAR data for snow discrimination. Radar snow index has been developed using polarization fraction and normalized third eigenvalue of coherency matrix. It has been found that radar snow index is more robust and simple to implement that supervised classification. [C62]

## "A polarimetric two-scale model for soil moisture retrieval"

A polarimetric two-scale surface scattering model employed to retrieve the surface parameters of bare soils from polarimetric SAR data is proposed. The scattering surface is considered as composed of slightly rough randomly tilted facets, for which the Small Perturbation Method holds. The facet random tilt causes a random variation of the local incidence angle, and a random rotation of the local incidence plane around the line of sight, which in turn causes a random rotation of the facet scattering matrix. Unlike other similar already existing approaches, our method considers both these effects. The proposed scattering model is then used to retrieve bare soil moisture and (large-scale) roughness from the co-polarized and cross-polarized ratios. The performances of the resulting retrieval algorithm is finally assessed by comparing obtained results to "in situ" measurements. To this aim, data from Little Washita campaign available in literature is employed. [C63]

## "Effects of frequency-dependent attenuation on time delay estimation techniques applied to ground penetrating radar data"

In this paper, the effects of frequency-dependent attenuation on the performance of some time delay estimation techniques applied to ground penetrating radar (GPR) data are investigated. Being based on a complex power law of frequency for dielectric permittivity, the adopted signal model deviates from the damped exponential model and it is this mismatch that is likely to deteriorate the performance of the employed techniques. At first, we carry out a sensitivity study by determining the variations of the relative root mean square error of the time delay estimates as a function of the SNR and the quality factor Q for three algorithms, namely, root-MUSIC, ESPRIT and the matrix pencil method (MPM). These variations reveal a systematic error which is quantified by means of a first-order approximation and is found to be the ratio of the phase delay to the group delay. Then, this error is used to compensate for the bias introduced by the model mismatch with the aim of improving the estimates. [C64]

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

This paper presents a new type of sounding signals for polarimetric FM-CW radar and corresponding de-ramping technique for processing, which provide the possibility for simultaneous measurement of all backscattering matrix elements and have high-level isolation between branches of the polarimetric receiver. The radar transmitter forms sounding signal, which has orthogonally-polarized components with orthogonal waveforms. The radar receiver is splitting orthogonally-polarized components of the scattered signals in two parallel receiver channels. Every such channel includes two parallel independent branches, which use wave-form orthogonality of the orthogonally-polarized components of sounding signal to split further signal components for simultaneous estimation of all four complex elements of the polarization backscattering matrix of radar object. The isolation between pairs of such branches in one receiver channel strongly depends on the time interval when scattered signals with orthogonal waveforms occupy the same frequency band. In this paper we propose to use a pair of LFM-signals as orthogonally-polarized components of the sounding radar signal. Both have the same form but are shifted in time relatively to each other. Our analysis shows that such time shift between the components of sounding signal prevent the frequency overlap between polarimetric components of scattered signal. As result, standard de-ramping processing technique can be used in the receiver, providing high level isolation between receiver's branches that simultaneously estimate all elements of the radar target backscattering matrix. [C65]

## "Statistical MIMO radar under non-Gaussian target scattering"

We consider a multiple-input multiple-output (MIMO) detection problem with M widely-spaced transmit antennas and L widely-spaced receive antennas, and we optimize the signal waveforms transmitted by each source node. Two figures of merit are investigated for space-time code optimization under a semi-definite rank constraint and a received signal-to-clutter ratio constraint: (1) the lower Chernoff bound (LCB) to the detection probability for fixed probability of false alarm, and (2) the mutual information (MI) between the observations and the target scattering matrix. If the scattering distribution possesses some properties of exchangeability and unitary invariance, we show that MI-optimal and LCB-optimal space-time coding admit a simple closed-form solution. As an application, the detection of a compound-Gaussian target is examined. The robustness of code design under Gaussian scattering is also investigated. [C66]

## "Basics and first experiments demonstrating isolation improvements in the agile polarimetric FM-CW radar-PARSAX"

The article describes the IRCTR PARSAX radar system, the fully polarimetric FM-CW radar with dualorthogonal sounding signals, which has the possibility to measure all elements of the radar targets polarization scattering

matrix simultaneously, in one sweep. [C67]

## "Extended Small Perturbation Method and retrieval of natural surface parameters"

The extended Bragg (X-Bragg), or extended small perturbation method (X-SPM), has been recently introduced to widen the SPM range of validity in terms of surface roughness, and to account for cross-polarisation and depolarisation effects. This is obtained by modelling the scattering surface as composed by slightly rough randomly tilted facets. The facet random tilt causes a random variation of the local incidence angle and a random rotation of the local incidence plane around the line of sight, which in turn causes a random rotation of the facet scattering matrix. In, the random incident angle variation Deltathetav is ignored, and the incidence plane angle of rotation b is assumed to be uniformly distributed in an interval (-beta1, beta1). In this paper, we remove both these simplifying assumptions, in order to assess their validity and to improve them. In particular, we derive more realistic distributions of beta and Deltathetav by assuming that the facet slope (i.e., the slope of the large-scale surface roughness) is a Gaussian random variable, in agreement with both classical and fractal surface models. Finally, we show that, if the X-SPM is used, the same information about a bare soil surface that can be retrieved from the coherency matrix entropy and scattering angle (H, alpha) can be also retrieved from the co-pol and cross-pol ratios. [C68]

## "Extracting Residential Area Information from Dual-SAR Image Based on Object-Oriented Technique"

Quick and accurate extracting residential area information has important practical significance to plantation protection, city planning, and reasonable land use. Hence the paper introduces an innovative method about extracting residential area from dual polarization SAR image. First of All, create area object using region grow algorithm, secondly select residential area samples artificially and compute average covariance matrix of each type, then extract residential area objects based on Wishart distance. According to the above theory, design the corresponding procedure, and do experiment on dual polarization SAR image of a region, the result indicates that the method for residential area information extraction has higher precision, less calculations, faster speed than the existing ones. [C69]

## "Full polarimetric time domain calibration for UWB Radar systems"

In this paper a full polarimetric calibration for Ultra-Wideband Radar systems is presented. The proposed calibration method is completely performed in the time domain. Conducting the UWB Radar calibration in the time domain has several advantages compared to classical frequency domain calibration procedures. First of all, the possibility to perform a lower number of measurements than in the classical frequency domain calibration, and second that it is by far faster. A complete mathematical description by scattering and impulse response matrices is derived. Proper calibration targets and procedures are discussed and evaluated. [C70]

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

New scalable and flexible waveforms offer a great number of new opportunities for object- or environment-tailored signal processing. The paper will discuss two classes of such flexible waveforms, i.e. single carrier waveforms with orthogonal modulations and multiple carrier coded waveforms. These waveforms may for instance be used for the benefit of scalable resolution, fast unambiguous Doppler assessment, two-channel code-orthogonality supporting to measure the full back scatter matrix in radar polarimetry, and message transfer in a network by radar. [C71]

## "Analysing the elements of SAR polarimetry matrixes"

The various applications have been promised by the new generation of the spacecraft SAR data (i.e. Radarsat2 and TerraSAR-X), as the classification, the decomposition, and the modelling of the polarimetric synthetic aperture radar (SAR) data has been improved in recent years. This work is based on the fact that in order to extract the various patterns in distinctive field of studies, all the scattering matrix components are informative source of data. Different cross products of the complex scattering matrix channels (HH, HV, VH, and VV) that are involved in the phase and amplitude information are joined together to build instructive features. In the vector space, Fisher class separability algorithm will be tested, and the features with the best class separability, large distance between classes, and small within-class variances will be selected. As we measured the classification effectiveness of the individual features, we needed to choose a subset of the informative features from the nine originally available features. Finally, we combined all the educational information contents in order to classify desired images with the best overall accuracy. [C72]

## "Equivalent dipole-moment method for electromagnetic scattering by dielectric bodies"

This paper presents an efficient method for the generation of MoM matrix based on the equivalent dipole-moment method for electromagnetic scattering by dielectric bodies. Based on the RWG basis function, the surface of the dielectric object is discretized into several triangular patches. Each RWG common edge element containing two triangular patches is regarded as a pair. The impedance matrix elements are calculated by conventional MoM when the pair of triangular patches of source point are not so far away from the field point, otherwise the electric and magnetic surface currents on the pair of triangular patches of source point can be equivalence as electric and magnetic dipole-moment, respectively, and all the rest impedance matrix elements are calculated by the equivalent dipole-moment method. Considering the boundary condition and PMCHW equation, the formula of impedance matrix elements is expressed. The equivalent dipole-moment method avoids the double integrates of the gradient of Green function and speeds up the forming of MoM matrix significantly. Numerical results show that it has less computation cost and high accuracy compared with MoM. [C73]

## "Ultra wideband impulse radar calibration"

Sensing and locating with Ultra Wideband is a quickly evolving technology in automation and disaster monitoring. Features are the high resolution, extremely fast measurements and the moderate cost. For target and object classification these UWB impulse Radars require a full polarimetric calibration. Only by this, the correct target features can be assigned. A complete mathematical description by scattering and transfer matrices is derived. Proper calibration targets and procedures are discussed and evaluated. [C74]

## "Instantaneous polarimetric radar PSM measurement for moving target"

This paper proposes the instantaneous polarization radar measurement method of the PSM (polarimetric scattering matrix) using the up and down chirps for the motive target with a uniform acceleration; it defines a new ambiguity function matrix considering Doppler frequency shift and acceleration in order to get the PSM of target. This paper also gives the signal processing and the expression of the PSM for a target moving at a uniform acceleration. The simulation results of missile-defence radar prove the feasibility of the presented method, which enhances the precision in measurement of the PSM compared to the traditional method. [C75]

## "Unsupervised classification of PolSAR data using Freeman decomposition and fuzzy clustering"

An unsupervised classification method using Freeman decomposition and fuzzy clustering is proposed to solve the ambiguity problem among surface, volume and double-bounce scattering dominated region. A fuzzy clustering method of PolSAR data making use of scattering power entropy and anisotropy parameters is proposed to partition different scattering mechanisms dominated region. The proposed method is applied to full polarimetric synthetic aperture radar data of Oberpfaffenhofen acquired by ESAR. Experiment result confirms the validity of this method. [C76]

## "Study on Polarimetric measurement and radar target identification in instantaneous polarization radar system"

Instantaneous polarization radar can obtain radar target polarization scattering matrix (PSM) by taking advantage of single pulse echo signal. The Polarimetric measurement properties and weak target detection of this system is verified by external field experiment. The actual measured data is used to target classification by applying polarization statistical properties and transformation of target polarization scattering matrix or decomposition. Two different radar target identification subject to its polarization properties has been demonstrates the effectiveness of using Polarimetric data and motivates the use of polarimetry for target detection in clutter and interference environment. The back-scattering power and optimized transmission polarization of the system is also involved. [C77]

## "Fast computation of RCS of 3D electrically large structure by modified multilevel fast multipole algorithm"

In this paper, two novel strategies are proposed to determine the multipole number of multilevel fast multipole algorithm (MLFMA). With the modified multipole number, the computation of RCS of 3D electrically large structures is realized. Compared with traditional MLFMA, The proposed methods in this paper can reduce the multipole number, CPU time and the memory requirement. Numerical results show that the modified methods have the complexity of O(NlogN) both for the computation of matrix-vector multiplication and the memory requirement, thus yields more efficiency for scattering problems of 3D electrically large structures. [C78]

## "Application of ESPRIT method to stepped frequency radar for scattering centre extraction"

In this paper, we deduce the math expression of stepped frequency radar echo signal, and transform the formulations into matrix form according to the standard method of ESPRIT. We apply ESPRIT to estimate the target positions in different SNR comparing with conventional IFFT algorithm and analyze the effect factors of the evaluation performance. We do the simulation of moving targets to see the effect of velocity on the estimation. Finally, we conclude the advantages and disadvantages of this method. [C79]

## "A Novel Visual Combining Classifier Based on a Two-dimensional Graphical Representation of the Attribute Data"

A novel visual combining classifier (VCC), which integrates two-dimensional graphical representation of the attribute data, image processing and pattern recognition techniques together, has been proposed. The basic principle of the VCC is mapping attribute data of a data matrix to the two-dimensional graphs, transforming these graphs to sub classifiers by pixel graphs, and combining the sub classifiers by decision rules. By interactive approaches, the optimum graphs for classification could be chosen and then pattern recognition could be realized automatically. The two experiments of the scatter and pole graphical representations based on Iris database have been made and classification precisions are 98.67% and 97.33% by LOOCV respectively. [C80]

## "Applications of kernel methods to polarization radar target recognition using polarizationscattering matrix"

In this paper, we propose novel methods of polarization radar target recognition based on kernel methods using polarization scattering matrix (PSM), in which feature extraction from PSM is avoided. Firstly two kinds of kernel function based on PSM are defined, then, they are employed to the kernel principal component analysis (KPCA) respectively. Finally the nearest neighbor (1NN) classifier and the support vector machine (SVM) classifier are used for classifying targets. Experimental results based on simulated data show that the proposed methods achieve good recognition performance. Several forms of kernel function are used to prove the generalization of the proposed kernel methods. In order to validate its effectiveness, radar target recognitions of high resolution radar profiles (HRRP) are done, and the results show that the proposed methods are feasible. [C81]

## "Instantaneous polarization measurement method based on frequency-shift-pulse-vector waveform"

Instantaneous polarization measurement radars adopt "simultaneous transmitting, simultaneous receiving" operation scheme, so they can obtain target polarization scattering matrix (PSM) based on only one pair of target echoes. Frequency-shift-pulse-vector waveform is one of narrow band instantaneous polarization measurement waveforms. Based on its transmitted and received signal models, one estimation algorithm in spectral domain of PSM is developed in this paper. Outdoor experiments have been taken with polarization radar system developed by National University of Defense Technology (NUDT), China, and following conclusions can be drawn from experimental results: Compared with the results obtained by time division operation scheme, the difference of amplitude relative measurement results is smaller than 2dB, while that of phase relative measurement results is smaller than 10 degree, which prove the validity of this estimation algorithm here. [C82]

## "A broadband MLFMA using pseudospherical harmonics"

The Multilevel Fast Multipole Algorithm (MLFMA) is widely used for the acceleration of matrix-vector products in the iterative solution of scattering problems. The MLFMA, however, suffers from a low-frequency (LF) breakdown. This breakdown is usually avoided by hybridizing the MLFMA with a method that does not fail at LF. For example, the Green function can be decomposed using the spectral representation or multipoles. Recently, a novel decomposition was presented, which uses so-called pseudospherical harmonics in the translation operator. In this contribution, the coupling of this method and the MLFMA will be investigated in detail. [C83]

## "On the design of spaceborne polarimetric SARs"

To date, spaceborne polarimetric SARs have predominantly been implemented as experimental add-on modes to existing designs for single-pol or dual-pol systems. As a result, current and planned spaceborne SARs have polarimetric (or quad-pol) modes that are severely limited in swath width, are restricted in the range of look angles, suffer from low SNR and ambiguity problems, and are difficult to calibrate. The consequence of this is that the high potential science return expected from polarimetric SAR data has not and will not be realized. In this paper, the design of polarimetric SAR systems is revisited. Design principles are established, and recent advances will be described that allow wider swath polarimetry over a wide range of incidence angles, and simplified calibration of the final data product. [C84]

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

## applications"

A parallel and pipelined Fast Fourier Transform (FFT) processor for use in the Direction of Arrival (DOA) estimation of a wideband waveform is presented. The selected DOA algorithm follows the Coherent Signal Subspace Method (CSSM). The target device for implementation is a Xilinx Virtex-5 Field Programmable Gate Array (FPGA). The FFT processor was developed in MATLAB Simulink using the Xilinx System Generator block-set to auto-generate VHDL code. Although the parallel and pipelined architecture uses a large portion of the available FPGA resources, the architecture does yield a high throughput. [C85]

## "Utilization of compact range collimator for Radar Cross-Section measurements"

This paper describes the applications of a large compact range collimator used for radar cross-section measurements. Because the collimator surface is analytically describable, the field distribution in the test zone can be readily predicted for various feed radiation patterns and locations. Several unique applications of the collimating system are presented that benefit from these features. [C86]

## "Spatial characterization and downscaling of rain attenuation fields from Numerical Weather Prediction Models"

The development of a stochastic spatial downscaling algorithm, able to enhance the spatial resolution of rain or attenuation fields considered as input, is illustrated. The proposed algorithm takes advantages from the spatial characterization of the rain fields derived from numerical weather prediction models (NWPM) simulations at coarse spatial resolution. The associated attenuation field at frequencies higher than X band are derived from a numerical scattering simulator based on the T-matrix approach. The stochastic spatial downscaling technique will be described and used to provide an ensemble of possible realizations at a spatial resolution higher than that available at the output of the MM5 simulations which has been taken, for our purpose, as the reference NWPM. The developed methodology will be applied and discussed for some case studies where MM5 outputs, rain-gauge data and ground-based radar observations were available. [C87]

## "An approach to ground moving target indication (GMTI) using multiple resolutions of the clutter covariance matrix"

This paper presents an approach to simultaneous ground moving target indication (GMTI) and synthetic aperture radar (SAR) imaging that promises to outperform current space-time adaptive processing (STAP) GMTI techniques when jamming is not present. An inherent weakness in STAP is its inability to directly estimate the scattering statistics from nonmoving objects in the region under test. A SAR image is a measure of the scattering intensity from an illuminated area on Earth assuming everything in the scene is stationary; therefore, it provides the estimate of scattering from nonmoving targets required for GMTI. Since the homogeneity of the scattering statistics over the scene are unknown, using multiple spatial resolutions of the SAR image to estimate the scattering statistics results in more confidence in the final detection decision. [C88]

## "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. [C89]

## "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. [C90]

## "Application of AdaBoost in polarimetric SAR image classification"

In this paper, a method of polarimetric SAR image classification based on polarimetric decomposition and

AdaBoost algorithm is proposed. The proposed method improves classification accuracy and speed. AdaBoost algorithm, as a robust learner with high accuracy, can fully utilize the polarimetric features to achieve image classification. In simulated tests, the proposed method is observed to produce improved classification accuracy and speed, compared with H /alphamacr classification algorithm. [C91]

## "Resolution-fusion for LASAR based on DWT"

This paper introduces a new resolution-fusion method for linear array 3-D imaging SAR (LASAR). The cross-track (CT) resolution of LASAR is often coarser than that in the along-track (AT) direction, limited by the length of the linear array. To overcome this limitation, we assume that there are two LASAR systems whose trajectories are orthogonal to each other. Thus, we obtain a row-coarse-resolution image and a column-coarse-resolution image of the same scene. According to the multi-resolution theory, we could fuse the row/column-coarse-resolution images into a quasi-fine-resolution image using the discrete wavelet transform. There are two types of distortions in the process of fusion. One distortion is caused by the missing of diagonal high frequency coefficient matrix, and it is unrecoverable. As the coefficient matrix contains the high frequency information, the distortion will increase along with the increase of high frequency component. The other distortion is caused by the difference of scaling functions, and this distortion can be reduced by selecting fitted wavelet basis. [C92]

## "Time-Reversal UWB imaging with a single antenna in multi-path environments"

Electromagnetic inverse scattering with TR (Time-Reversal) imaging has been studied with great interest in a variety of applications. In this study, we propose a UWB radar system with a single antenna that utilizes multi-path scattering. The proposed imaging method is an extension of the conventional DORT method, and uses a frequency-frequency matrix that is suitable for a system with a single antenna. The performance of the proposed method is investigated by means of a numerical simulation and an experiment. [C93]

## "Three-dimensional electromagnetic scattering from flat plates by using sinc-type basis functions in method of moments"

Sinc functions are used in the basis and testing procedures in the conventional method of moments (MoM) formulation. But unlike conventional MoM, simple pointwise meshing is enough and no integral computation is required due to the mathematical properties of the sinc function. The simulation results of surface current densities and radar cross section for a few wavelength square flat plate are obtained by using our own codes. The results are compared with those of the rooftop basis functions. The CPU-time decreases by half of the time of the conventional method. The error that occurs from the approximated integral of the sinc function in the computation of main matrix elements is very small and decreases while the bandwidth of the sinc function increases. [C94]

## "Radar Target Scattering Center Extraction Based on the Full-Polarization GTD Model"

To accurately describe the high frequency electromagnetic scattering of the radar objects, the full-polarization GTD model is established based on the combination of the full-polarization information and the geometric theory of diffraction model. Meanwhile, A novel method, MUSIC based on polarization linear variation method (PL-MUSIC) is proposed. The estimation accuracy is improved and the computational load is greatly decreased compared with the method extracting the parameters from every polarization channel. Compared with the parallel polarization MUSIC method (PP-MUSIC), the proposed method decreases the computational complexity of the smoothing process and has the close accuracy. Moreover, the spatial spectrum estimation method based on eigenspace is utilized to establish the spectrum function. Simulations and computational load comparison show the validity of the full-polarization GTD model and the advantage of the MUSIC based on polarization linear variation method. [C95]

## "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. [C96]

## "Study of the characteristic on the one-dimensional rough sea surface"

In this paper, an introduction of chaos is firstly present. The subject matter selected for this part of the paper is given with emphasis on analysis of chaotic characteristic of radar echoes from the one dimensional rough sea surface. Based on the time series of radar echoes, the problems which are involved in the reconstruction of chaotic dynamics, calculation of correlation dimension and the largest Lyapunov exponent are discussed, and the numerical results indicates radar echoes shows the chaotic characteristic obviously. [C97]

## "Learning averages over the lie group of unitary matrices"

In the present paper, we treat the problem of learning averages out of a set of unitary matrices. We discuss a possible learning technique based on the differential geometrical properties of the Lie group of unitary matrices. We first recall some relevant notions from differential geometry, mainly related to Lie group theory, and then we propose a scheme for learning averages. Some numerical experiments will illustrate the features of the learnt averages. [C98]

## "LMS based arrays with compressed sensing"

This paper examines the potential of reducing the computational complexity of adaptive antenna-array systems by reducing the number of measurements per antenna using compressive sensing techniques. Compressive sensing is particularly suited for signals that are K sparse on some basis Psi. These types of signals are common in radar systems, multipath propagation, terrain scattered interference, etc. The idea is to take M observations (with M ~ O(K log(N))) instead of the standard N observations dictated by the Nyquist sampling criterion and desired frequency resolution, thereby reducing the size of the covariance matrix, hence expediting the adaptive process and reducing the computational demand of the antenna-array system. The least mean squared (LMS) algorithm is thus applied to the reduced-size observation vector, and the original signal is reconstructed at the output of the array. This reduction in complexity is counterbalanced by the error incurred in reconstructing the array output from few observations. [C99]

## "The application of the matrix pencil and beamforming to determine the presence of termites in situ EUROCON 2009"

The detection and location of termites in building structures involves near field sensing with RADAR arrays, where the plane wave assumption does not apply. In this paper, we explore a number of enhancements to the matrix pencil direction of arrival (DOA) algorithm, including augmentation with beamforming methods, which allow it to operate in the Fresnel Region, using a hybrid array which combines random and uniform planar array geometry. The results from simulations show that such a hybrid array can operate in the near field, even when there are coherent, interfering signals from other sources. [C100]

## "An efficient algorithm for large finite periodic arrays of microstrip patches using sub-entire domain basis functions"

In this paper, another efficient spatial-domain MoM solver based on the mixed potential integral equation (MPIE) is proposed for the analysis of scattering from large-scale finite periodic arrays of microstrip patches that employs sub-entire domain (SED) basis functions, which were first introduced for the free space case in W.B. Lu et al.(1991). The required spatial- domain Green's functions (GFs) are calculated efficiently by the discrete complex- imaging method (DCIM). The accuracy and efficiency of the developed techniques are demonstrated numerically for large finite periodic microstrip patch arrays having a rectangular or non-rectangular configuration. [C101]

## "Electromagnetic scattering from large cylindrically-shaped reflectors by using the characteristic basis function method with analytical basis functions"

A new procedure for an efficient solution of the problem of scattering from large cylindrically- shaped reflectors has been proposed in this paper. It utilizes the CBFs that are obtained by applying the SVD (singular value decomposition) procedure to analytically-derived basis functions. These bases, which are constructed by totally bypassing any conventional MoM-type computation, can be used for all angles of incidence and their application leads to a matrix whose dimensions are relatively small. [C102]

## "Methods for the rotation of ISAR images"

Image rotation plays an important role in image understanding. The rotation of inverse synthetic aperture radar

images can be done either in the image forming process or after. Also, when the image is rotated in the imaging forming process, it can be performed both in the time-domain and the frequency-domain. This paper introduces three methods for the rotation of ISAR images. Experimental results are presented to demonstrate the effectiveness of these methods. [C103]

## "Sea surface simulation for SAR remote sensing based on the fractal model"

Based on the fractal ocean surface model, electromagnetic scattering model under Kirchhoff Approximation and the raw signal simulation procedure of dynamic scene based on time domain, the sea surface of the SAR remote sensing has been simulated. The images of the wave and complex fractal sea surface are in accordance with the hydrodynamic modulation, the tilt modulation and the velocity bunching modulation. The simulation has been developed in the Matlab programming language. [C104]

## "A unified polarimetric approach for SAR sea oil slick observation"

In this study, a novel unified theoretical framework to describe the polarimetric sea surface scattering with and without surface slicks, entirely based on the Mueller scattering matrix, is proposed. Dealing with slick-free or weak-damping-slick-covered sea surface a Bragg scattering mechanism is expected, while, a non-Bragg scattering mechanism is expected in case of oil-covered sea surface. Following this rationale, the Mueller scattering matrix is physically read in terms of slick-free and slick-covered sea surface scattering mechanisms, through the analysis of some Mueller based polarimetric descriptors, i.e. the degree of polarization, the statistics of the phase difference and the pedestal height. Experiments accomplished on Level 1.1 full polarimetric L-band ALOS PalSAR data confirm the effectiveness of the proposed approach. [C105]

## "3-D characterization of buildings in a dense urban environment using L-band Pol-InSAR data with irregular baselines"

Diverse spectral estimations methods, i.e. MUSIC, Maximum Likelihood (ML), Weighted Subspace fitting (WSF), are proposed and applied to the estimation of building height dense urban environments and to the retrieval of scatterers' physical properties. Compared to other estimators, the polarimetric WSF estimator is optimally model adaptive and results in reduced sidelobes induced by irregularly sampled baselines. [C106]

## "Polarization plane rotation effects on SAR polarimetric attributes"

The polarization plane rotation effects on SAR polarimetric attributes are analyzed. This analysis is carried out by simulating a polarimetric SAR image containing four regions with different electric characteristic. The simulation process is based on an electromagnetic scattering model. Employing a rotation model is generated a image set having 361 images, where each image has it polarization plane rotated by a different angle. From all images of the set are computed the covariance matrix and six polarimetric attributes of each image region and compared with their correspondent parameter in the image without rotation. From this evaluation it could be seen that the rotation angle influences differently all polarimetric attributes. The effects of rotation angle can lead to a misunderstanding of the target scattering mechanism. [C107]

## "Comparison with CLPX II airborne data using DMRT model"

In this paper, we considered a physical-based model which use numerical solution of Maxwell Equations in three-dimensional simulations and apply into Dense Media Radiative Theory (DMRT). The model is validated in two specific dataset from the second Cold Land Processes Experiment (CLPX II) at Alaska and Colorado. The data were all obtain by the Ku-band (13.95 GHz) observations using airborne imaging polarimetric scatterometer (POLSCAT). Snow is a densely packed media. To take into account the collective scattering and incoherent scattering, analytical Quasi-Crystalline Approximation (QCA) and Numerical Maxwell Equation Method of 3-D simulation (NMM3D) are used to calculate the extinction coefficient and phase matrix. DMRT equations were solved by iterative solution up to 2ndorder for the case of small optical thickness and full multiple scattering solution by decomposing the diffuse intensities into Fourier series was used when optical thickness exceed unity. It was shown that the model predictions agree with the field experiment not only co-polarization but also cross-polarization. For Alaska region, the input snow structure data was obtain by the in situ ground observations, while for Colorado region, we combined the VIC model to get the snow profile. [C108]

## "Multi-baseline POL-inSAR statistical techniques for the characterization of distributed media"

This paper presents principles and robust techniques to estimate physical parameters of natural environments using Multi-Baseline Polarimetric and Interferometric SAR (MB-POL-inSAR) data. The first part of this paper concerns the abstract topic of MB-POL-inSAR coherence optimization The second part is dedicated to the

general estimation of the coherence line model parameters [1]. It is demonstrated that the line parameters can be estimated in an analytical and robust way by using the whole available POL-inSAR information. [C109]

## "An algebraic approach to ground-volume decomposition from multi-baseline PolInSAR data"

In this paper, an algebraic methodology is described for the separation of ground and volume contributions basing on multi-baseline and multi-polarimetric acquisitions. As a result, a new general procedure is defined that encompasses single-baseline PolInSAR as a special case, and allows to proceed to ground/volume separation not only through model based approaches, but also through model free and hybrid approaches. Furthermore, it will be shown that such a methodology yields the best solution in the Least Square sense. [C110]

## "A fast numerical method for scattering from dielectric rough surfaces"

In this paper we propose a fast numerical method for EM scattering from one-dimensional dielectric rough surfaces. we first employ a new impedance matrix splitting scheme for the associated iterative system. We further develop a block operation method to accelerate computation, which transform a 2N ГґВ— 2N problem to a N ГґВ— N one. Due to block operation, run time can be saved about 1/3. Through extensive numerical simulation, our proposed method has demonstrated much improved speed over FBM, and considerably improved convergence behavior over FBM-SA. [C111]

## "Hybrid of the method of moments/ Monte Carlo technique and a surface scattering model for estimating the radar backscatters OF harvested farm fields"

The method of moments/Monte Carlo technique is used to numerically compute the Mueller matrix for radar backscattering from stem-cut cluster sections of a harvested farm field, and a semi-empirical surface scattering model is employed for estimating the radar backscatter of a rough soil surface. The full-wave numerical technique and the surface scattering model are combined to compute the Mueller matrix and consequently the backscattering coefficients of a harvest farm field. This hybrid technique is verified comparing the numerical computations with the experimental measurements for the backscattering coefficients of harvested rice fields. [C112]

## "Hierarchical segmentation of Polarimetric SAR images using heterogeneous clutter models"

In this paper, heterogeneous clutter models are introduced to describe Polarimetric Synthetic Aperture Radar (PolSAR) data. Based on the Spherically Invariant Random Vectors (SIRV) estimation scheme, the scalar texture parameter and the normalized covariance matrix are extracted. If the texture parameter is modeled by a Fisher PDF, the observed target scattering vector follows a KummerU PDF. Then, this PDF is implemented in a hierarchical segmentation algorithm. Segmentation results are shown on high resolution PolSAR data at L and X band. [C113]

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

We consider a multiple-input multiple-output (MIMO) detection problem with M widely-spaced transmit antennas and L widely-spaced receive antennas (not necessarily co-located), and we study the problem of designing the signal waveforms transmitted by each source node under non-Gaussian target scattering and temporally-correlated Gaussian clutter. Two figures of merit are investigated for space-time code optimization under a semi-definite rank constraint and a received signal-to-clutter ratio constraint: 1) the lower Chernoff bound (LCB) to the detection probability for fixed probability of false alarm, and 2) the mutual information (MI) between the observations available at the receive nodes and the MГґВ—L Г‚Вїchannel matrixГ‚Вї generated by a target, assumed present tout court. If the scattering distribution possesses some suitably defined properties of exchangeability and unitary invariance, we show that MI-optimal and LCB-optimal space-time coding admit a simple closed-form solution. Finally, a case study of relevant practical interest is examined in depth so as to compare the proposed design criteria and to assess the impact of signal non-Gaussianity on the detection performances. [C114]

## "The use of SAR-ATI for maritime surveillance and difficult target detection"

This paper discusses the detection of low scatter cross-section maritime targets in a high clutter background using SAR multi-channel along track interferometry. Statistical arguments are presented based on the covariance matrix which enable the determination of the channel weights required to achieve maximum attenuation of false alarms produced by breaking waves. An example is shown of a target (a buoy) with scatter cross-section comparable with the false alarms. A false alarm attenuation of up to 16.1 dB relative to the target is demonstrated for a three-beam interferometer with no a priori knowledge of the target or false alarms.

Applications include detection of small stealthy boats and other difficult maritime targets. [C115]

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

Multiple-input multiple-output (MIMO) radars utilize multiple waveforms simultaneously to improve performance. A MIMO radar in which angular diversity is achieved by using widely distributed antennas has been proposed before. This type of system is also known as the statistical MIMO radar. Typically, it has been assumed that the signals received by different antennas are either fully correlated or independent depending on the configuration. We make a more realistic assumption of partially correlated scattering from the target. In this paper, we show that taking the correlation of the scattered signals into account can improve the probability of detecting the target. It is shown that the scattering statistics do not need to be known, but can be estimated reliably from the received signal if a certain type of scattering model is assumed. In this paper, the GLRT using the maximum likelihood estimates of the unknown parameters is proposed for target detection. [C116]

## "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). [C117]

## "Detection performance of MIMO radar with realistic target models"

We simulate a multiple-input multiple-output (MIMO) radar system involving a realistic target, which is a life-size land vehicle modeled using a EM simulator FEKO. Numerical results showing the detection performance of a MIMO radar are provided, which is measured based on multiple realizations of the channel matrix generated using the available FEKO data. The results validate in a practical setting the improvements in detection performance available from MIMO radar configurations. [C118]

## "Statistics of SDH target decomposition theorems in radar polarimetry"

The comparisons between different decompositions show that the SDH (sphere, deplane, helix) target decomposition gives the best overall performance with other automatic classification algorithms. In this paper, we emphasize that the different decompositions include the equal information while they decompose the information to different sub-scattering matrices indeed. The statistics of the SDH target decomposition theorems in radar polarimetry is given for the stochastic target fluctuation. Many classification algorithms almost ignore the important decomposed phases, therefore they make some useful information lost, which lead to the worse performance of classification. The results of this work are helpful to enhance the performance of classification. [C119]

## "Selectable target detector using the polarization fork"

A new target detection methodology is described that makes novel use of the polarization fork of the target. The mathematical formulation is general and can be applied to any kind of single target as long as its expression in the target space is known. Aim of this paper is to present a standard procedure to set the detector parameters for any target of interest. The algorithm makes use of the Gram-Schmidt ortho-normalization in order to set the appropriate basis for the polarimetric space. Validation against real data shows significant agreement with the expected results based on the theoretical description. [C120]

## "Compensation of clutter spectrum for airborne forward-looking radar based on the clutter subspace transformation"

Space-Time Adaptive Processing (STAP) is a powerful two-dimensional filtering algorithm for clutter suppression. However, most previous studies of STAP theory have focused on side-looking array radar (SLAR). This paper addresses the issue of forward-looking radar from a STAP. The clutter distribution of airborne forward-looking radar is analyzed and investigated, and a new clutter suppression approach to airborne radar with forward-looking array based on clutter subspace is proposed. This method is referred to as clutter subspace

transformation (CST) matrices, use clutter subspace transformation matrices are shown to eliminate ground clutter heterogeneous and generate a sufficient data to construct the new covariance matrix. Finally, the conventional STAP could be applied to the clutter suppression. Simulation results show a good improvement in processor performance. [C121]

## "Recent advances in SAR remote sensing: "Multimodal POLinSAR imaging with applications to remote sensing of the terrestrial covers and the monitoring of environmental stress changes""

Land cover monitoring is one of the most potential applications of Polarimetric Synthetic Aperture Radar (POLSAR) sensing and so is Repeat-Pass Polarimetric-Interferometric SAR (RP-DIFF-POL-IN-SAR) stress-change assessment by air/high-altitude/space-borne SAR sensor deployment. Provided fully polarimetric SAR information can be made available, a plethora of novel POLSAR matrix decomposition methods can be implemented for recovering rather precise scattering contributions from isolated and distributed scattering scenarios, and so can rather exact environmental changes from consecutive repeat-pass observations at 1 m resolution from air and from space. With the recent launches of the fully polarimetric satellites JAXA-ALOS (PAL-SAR-L-Band), the DLR TerraSAR-X (X-Band) and of RADASAT-2 (C-Band), a new era in space imaging of the terrestrial terrain and ocean surfaces has arrived providing unforeseen advantages. [C122]

## "PolSAR and PolInSAR model based information estimation"

Speckle for multidimensional SAR data may be modeled as the combination of multiplicative and additive noise sources. As demonstrated, the use of this noise model does not corrupt the estimation of physical information from PolInSAR data. The definition of a model based PolInSAR filter allows also the computation of relative errors for estimated heights of forested areas from PolInSAR data. [C123]

## "Independent component analysis of polarimetric SAR data for separating ground and vegetation components"

In this study, the use of independent component analysis (ICA) to separate the ground and vegetation scattering components from polarimetric, synthetic aperture radar (SAR) data is presented. In vegetation covered terrain, the backscattered signal is a composite of both a ground scattering component and a vegetation scattering component. The FastICA algorithm is customized and applied to both simulated and field data. The improved customized algorithm is found to work better than the standard FastICA algorithm. It is also shown that noise and depolarization limit the ability of ICA to separate the different scattering components. The technique is applied to field data from the Glen Afric region in Scotland and produces results consistent with other radar metrics obtained from that region. [C124]

## "A polarimetric vegetation model to retrieve particle and orientation distribution characteristics"

A simple vegetation model for polarimetric covariance and coherency matrix elements is presented. The model aims to represent vegetation characteristics which are observable by radar polarimetry, including the average particle scattering anisotropy, the main orientation of the volume, the degree of orientation randomness in the volume, and the terrain slopes. The goal of this approach is to quantify these parameters and to enable their estimation in a remote sensing parameter inversion framework. The retrieval of parameters related to effective particle shapes in the polarization plane and the orientation distribution characteristics is evaluated on real SAR data acquired by DLR's E-SAR system at L-band. [C125]

## "A preliminary study of target contour extraction based on scattering mechanism using polarimetric SAR images"

Finding the target contour information from a remote sensing image is one of the fundamental steps for image analysis. Conventional target contour extraction methods are usually based on the statistics information of the image. In this paper, using the maximum return value of the normalized scattering matrix derived from full-polarized Synthetic Aperture Radar (PolSAR), the relationship between the contour of targets and their corresponding dominate scattering type is preliminary researched. Then a novel target contour information extraction method based on the physical scattering mechanism of terrain targets is proposed, which is more effective and adaptable due to the scattering mechanism of terrain targets do not depend on the radar backscattering intensity, but its proportion among different polarizations. After applying to E-SAR airborne data, the results show that this method has a good capability to extract the target contour information. [C126]

## "An evaluation of PolSAR speckle filters"

Speckle suppression in PolSAR images is an important step for the extraction of meaningful information from

PolSAR images, especially for homogeneous extended targets. It has been shown that insufficient noise filtering resulting in low equivalent number of look (ENL) values will increase bias on incoherent polarimetric parameters such as the Cloude-Pottier parameters. In addition, meaningful high-frequency information, such as edges and point targets must be preserved. Adaptive filters have been the most successful in reaching a good compromise between noise suppression and detail preservation. A large set of artificial PolSAR images, which ground truth are realizations of Markov random fields, has been generated. Performance metrics are focusing on speckle suppression (ENL), edge preservation, relative errors on polarimetric parameters and point target preservation. [C127]

## "ALOS-PALSAR polarimetric SAR data to observe sea oil slicks"

In this study an electromagnetic approach is proposed for exploiting polarimetric information for sea oil slick observation in L-band ALOS PALSAR full polarimetric SAR data. The problem is tackled form an electromagnetic viewpoint by describing the sea surface scattering mechanism with and without oil slicks. Following this rationale, a filtering technique, based on the Mueller scattering matrix, is applied to detect oil slicks in full polarimetric SAR data. Successively, the filtering results are verified by the analysis of the slick-free and slick-covered pedestal height and polarimetric entropy (H). Experiments, accomplished on a meaningful set of Level 1.1 L-Band ALOS PALSAR full polarimetric data, demonstrate the effectiveness of the proposed approach. [C128]

## "ALOS-PALSAR Quad. Pol. images and their applications"

The four-component scattering power decomposition is applied to ALOS-PALSAR Quad. Pol. Data sets. PALSAR is Phased Array type L-band Synthetic Aperture Radar onboard ALOS (Advanced Land Observing Satellite) launched by JAXA, Japan, in 2006. It has acquired more than 10000 fully polarimetric scenes although the polarimetric mode is experimental one. This paper presents some of scenes in Sichuan earthquake area to see how polarimetric data works and to show the effectiveness and usefulness of fully polarimetric data. [C129]

## "Polarimetric sscattering for information retrieval of SAR imagery"

This paper presents an overview of recent research progress in WSRS on theoretical modeling of the terrain surface for polarimetric scattering simulation and Mueller matrix solution, mono-static and bistatic SAR image simulation, new parameters for unsupervised surface classification based on de-orientation approach, DEM inversion, change detection from multi-temporal SAR images, and reconstructions of buildings from multi-aspect SAR images etc. [C130]

## "Unsupervised classification for compact polarimetric SAR data using m-δ decomposition, SPAN and the Wishart classifier"

This paper studies the polarimetric decomposition and unsupervised classification of compact polarimetric data. Compact polarimetric data have been synthesized from AirSAR L-band fully polarimetric data by matrix transformations. Polarimetric decomposition for compact polarimetric data have been introduced and analyzed. Decomposition result of relevant fully polarimetric data has been used for comparison. An unsupervised classification method is proposed for compact polarimetric data using polarimtric decomposition. Degree of polarization m and relative H-V phase Γ‚Вї combined with the total backscattering power SPAN have been used to initialize the compact polarimetric data into 15 classes. Then the Wishart classifier is applied. The result of this algorithm is illustrated and compared with the classification result of full polarimetric data. [C131]

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

A multi-frame, multiple-input, multiple-output radar detection problem is considered here. Different waveform design strategies are inspected for both fixed-sample size and sequential test. The unified treatment of the two cases is a direct consequence of the divergence-based merit function used in the optimization process. It is proved that no strategy is uniformly optimal, and that the diversity order is limited by the available energy budget. [C132]

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

We present a new approach to radar imaging that exploits sparsity in the matched filter domain to enable high resolution imaging of targets in delay and Doppler. We show that the vector of radar cross-ambiguity values at any fixed test delay cell has a sparse representation in a Vandermonde frame that is obtained by discretizing the Doppler axis. The expansion coefficients are given by the auto-correlation functions of the transmitted waveforms. We show that the orthogonal matching pursuit (OMP) algorithm can then be easily used to identify

the locations of the radar targets in delay and Doppler. Unambiguous imaging in delay is enabled by alternating between a Golay pair of phase coded waveforms at the transmission to eliminate delay sidelobe effects. We then extend our work to multi-channel radar, by developing a sparse recovery approach for dually-polarimetric radar. We exploit sparsity in a bank of matched filters, each of which is matched to an entry of an Alamouti matrix of Golay waveforms to recover a co-polar or cross-polar polarization scattering component. [C133]

## "Accuracy improvement of maximum likelihood inversion of forest height with PolInSAR"

Polarimetric synthetic aperture radar interferometry (PolInSAR) technique has been intensively used for extracting forest heights. Among the forest height inversion algorithms, maximum-likelihood estimate computes the maximum-likelihood estimate of the vegetation parameters based directly on the sample coherency matrix. The estimation of the sample coherency matrix is of great importance in this inversion process. A coherency matrix estimation method with adaptive averaging window derived from coherence region shape parameters is presented. Then the estimated coherency matrices are applied in the maximum likelihood inversion algorithm. In order to confirm the validity of the proposed method, simulated L-band PolInSAR data provided by ESA is used. Experiment results suggest that this method can help improve the accuracy of maximum likelihood inversion of forest heights. [C134]

## "Fusion of ALOS Palsar and Landsat ETM data for land cover classification and biomass modeling using non-linear methods"

This work demonstrates the utility of reduced resolution ALOS PALSAR data for biomass mapping and land cover classification over the tropical forests of Indonesia. This study is important because we processed the ALOS PALSAR mosaic, which is made freely available within K&C initiatives project and will be updated regularly. We first used 38 sample plots collected on the ground during dry season in September 2004, to develop a tree diameter (dbh)-biomass model. The HH, HV, HV/HH and HH-HV backscatters of ALOS PALSAR data allowed the empirical estimation of forest above ground biomass (AGB). Each band of PALSAR data was separately used to estimate the biomass, and we found HV band resulted in better correlation with the AGB compared to other SAR bands. Validation of the prediction results was carried out by comparing the biomass estimates with those predicted from an existing allometric equation. Optical data are sensitive to the physical properties of the reflectors whereas SAR data are more influenced by the geometric properties of the scatterers. Therefore, the second part of this study concerned the integration of mosaic SAR textures and ETM data for land cover classification. The classification was conducted using ETM data and variations of ETM, SAR bands, and SAR textures calculated using GLC Matrix. The image classifications were carried out using a Machine Learning based classifier, so-called Support Vector Machine (SVM), and a conventional Maximum Likelihood method. An ensemble of neural networks method using Kalman filter and scaled conjugate gradient algorithm was applied. The classification accuracy was assessed using confusion matrices and Kappa statistics. We show that the introduction of SAR textures significantly enhanced the classification accuracies. This study showed that the joint processing of SAR and multispectral data increased the accuracies of biomass estimation and landuse classifications. The efficiency of the method at medium spatial r- esolutions allows its application of global datasets. [C135]

## "Polarimetric signatures and classification of tropical land covers"

Polarimetric signatures for different tropical land covers were extracted from RADARSAT-2 data. Subsequently, the data were classified. The objective of this work was to assess the potential of RADARSAT-2 polarimetric C band data on land cover mapping. RADARSAT-2 data were acquired over Tapajos National Forest, a tropical forest reserve in Brazil, and surroundings, in September 2008. A field campaign was conducted during the same week of the SAR data recording. Polarimetric signatures for the different land covers were extracted for co- and cross-polarised bands and results indicated the variety of scattering mechanisms in the study area. Following that, the coherence and covariance matrices were used for the Freeman-Durden target decomposition, which decomposed the image targets in new bands representing the main scattering mechanism in the resolution cells-corner reflection, volumetric and superficial. Data were later classified by a k-means-Wishart classifier. The bands representing volumetric and superficial scattering helped discriminating vegetated and non-vegetated areas. Classification accuracy reached around 80% for forest and pasture/bare soil classes. For the remaining classes, the classification accuracy results did not reach 50%. [C136]

## "Model-based statistical analysis of PolSAR data"

In this paper, we consider statistical analysis of PolSAR data in the framework of the multivariate product model. The complex scattering vector is here considered as a double stochastic circular Gaussian variable, in which the variance is linearly scaled by a common stochastic scaling factor z. The scaling factor is associated with texture.

We discuss various parametric probability density functions for z, and indicate how model parameters can be estimated from data by a simple moment based method. Experimental analysis shows that for some surface covers, certain texture distributions fit better than others. Then, polarimetric covariance matrix data analysis is addressed in the framework of product models, and we propose a processing scheme which perform image segmentation using a stochastic EM approach. [C137]

## "Polarimetric scattering feature estimation for accurate vegetation area classification"

This paper proposes an accuracy improvement of the vegetation area classification based on the POLSAR image analysis, when vegetation and man-made areas are both included in the radar target region. Here we introduce a simple compensate polarimetric marker, T13or T31, to accurately distinguish the unexpected scattering from the obliquely oriented man-made targets and the complex volume scattering generated from vegetation area. T13or T31is the (1, 3) or (3, 1) elements of the 3Гґ—3 averaged coherency matrix ([T]), and has not been effectively utilized in the general scattering power decomposition scheme. By appropriately utilizing T13(T31), one can extract only the vegetation area from the mixed target region. It is verified from the detailed analysis that the proposed marker T13(T31) works well not only for Pi-SAR data but also for ALOS/PALSAR data. [C138]

## "Three-component decomposition for polarimetric SAR"

An improved three-component decomposition for polarimetric SAR data is proposed in this paper. The reasons of the emergence of negative powers in the Freeman decomposition have been analyzed, and two improvements are included. Firstly, the deorientation process is applied to the coherency matrix before it is decomposed into three scattering components. Then, the coherency matrix with the maximal polarimetric entropy, i.e, the unit matrix is used as the new volume scattering model instead of the original one adopted in the Freeman decomposition. The E-SAR polarimetric data acquired over the Oberpfaffenhofen area in Germany are applied for experiment to demonstrate the effectiveness of the new model. [C139]

## "The effect of orientation angle compensation on polarimetric target decompositions"

The orientation angle of scattering media affects the polarimetric radar signatures. This paper investigates the effect of orientation compensation on polarimetric target decompositions including Pauli decomposition, Freeman and Durden decomposition and Yamaguchi decomposition. The Cloude and Pottier decomposition is excluded, because entropy, anisotropy and alpha angle are rotational invariant. We will show that after the orientation compensation, the volume scattering power is consistently decreased, while the double bounce power has increased. The surface scattering power is relatively unchanged, and the helicity power is rotational invariant. All these characteristics can be explained by the compensation effect on the nine elements of the coherency matrix. This analysis reveals that, contrary to the general perception, the 4-component component decomposition by Yamaguichi et al. does not use complete information of the coherency matrix. Only six quantities are included-one more than the Freeman/Durden decomposition under the assumption of refection symmetry. [C140]

## "Multi-resolution target scattering decomposition for urban feature characterization using polarimetric SARs"

Urban areas include features (buildings) of coherent scattering as well as areas such as parks that manifest partially coherent scattering due to the significant natural variability in the scattering properties. While high-resolution coherent target decomposition(CTD) can be used for characterization of buildings, incoherent target scattering decomposition (ICTD) is more suitable for analysis of partially coherent targets [11]. In contrast to CTD, ICTD preserves the polarimetric information of the latter at the expanse of the requirement for use of coarse-resolution for unbiased estimation of ICTD parameters [9]. The Touzi decomposition [10], [15] permits a unified roll invariant decomposition of both coherent and partially coherent scattering. In this paper, a multi-resolution technique is introduced to adapt the Touzi decomposition to the coherence nature of target scattering. The multi- resolution mixture CTD-ICTD decomposition is validated using polarimetric Convair 580 SAR data collected over Ottawa city. Implications on the use of the new multi-resolution decomposition for the unified analysis of coherent and partially coherent target scattering are discussed. [C141]

## "Scattering component decomposition for POL-InSAR dataset and its applications"

The three-component scattering model decomposition based on the scattering mechanisms corresponding to single-bounce, double-bounce, and volume scattering, is one of the powerful tools to classify terrain for fully polarimetric SAR data. However, the conventional scattering component decomposition technique with POLSAR image requires several assumptions to obtain a unique solution. This paper presents scattering component decomposition technique with Pol-InSAR image pair. The proposed technique based on the ESPRIT can

decompose without any assumptions when a suitable set of candidates for volume scattering covariance matrix is prepared. In this report, we show the concept of the proposed method with the POL-InSAR image pair and the role of the ESPRIT in the volume scattering estimation. Experimental results of SIR-C/X-SAR are also provided as an example. [C142]

## "A new scattering matrix of multiport antenna array"

This paper deals with the mathematical model and properties of a new scattering matrix of given antenna array normalized to complex multiport impedance matrix of generators. The introduced scattering matrix is described a matching problem for a connection of array with multiport beamformer. The scattering parameters are based on eigenvalues and eigenvectors of the antenna multiport matrices. As shown there are an infinite number of the scattering matrices for given antenna array and multiport beamformer. The extremum properties of the Rayleigh ratio for the power maximization for multiport networks are used. The particular array and excitation network (signal divider) and results of computer frequency characteristic simulations are described. [C143]

## "Parameters determination of symmetrical microwave two-ports"

Matching conditions for passive symmetrical microwave two-ports with an arbitrary connect structure and component types have been determined. A classification of such two-ports with regard of the matching conditions has been validated. For parametric mismatched two-ports a relation between input admittances of the proper one-ports has been determined. The admittance values have been found for given transmission and reflection coefficients. A method for definition of parameters of mismatched two-ports with a predetermined structure, belonging to the subset of parametric mismatched two-ports has been proposed. The application of the proposed method is illustrated by examples of parameter calculations for circuits with different component bases as well experiments conducted with the circuits. [C144]

## "Microwave study of ferroelectrics in waveguide"

Peculiar feature of ferroelectrics is high dielectric permittivity epsiv which sometimes is accompanied by very big loss tangent tandelta. This is a reason of difficulties to obtain accurate characterization despite of variety of techniques available. This report is devoted to the selection of proper waveguide method for specific cases of bulk or film materials investigation to obtain reliable data of their epsiv and tandelta. [C145]

## "RCB-based imaging method for 3-D target via curvilinear SAR"

The curvilinear synthetic aperture radar (SAR) is considered as a more practicable three-dimensional (3-D) SAR imaging system. Its received data, however, are the sparse data in 3-D frequency space. Therefore, the core problem in image formation is removing the influence of the severe high sidelobes on azimuth-height plane. Robust Capon beamforming (RCB) is a non-parametric adaptive method, which can dramatically suppress the sidelobes. In this paper, the curvilinear SAR data with same range frequency are regarded as snapshots. To eliminate the coupling between the range parameter and azimuth/height parameters, the point of interest is shifted to the zeros in the directions of azimuth and height by phase compensation. With these preparations, the RCB can be utilized to estimate the amplitude of the corresponding point. The image of 3-D target is obtained when all point in the scene have been estimated. Simulation results show that the proposed method can dramatically suppress the influence of sidelobes in curvilinear SAR image formation, and the more better 3-D target images are obtained. [C146]

## "Performance characterization of two adaptive range-spread target detectors for unwanted signal"

The adaptive detection of range-spread targets in non-Gaussian clutter is addressed. The clutter is modeled as spherically invariant random vector. After the sample covariance matrix based on secondary data, is inserted, in place of the true normalized covariance matrix, into the test, two adaptive detectors are derived, which are called as ANSDD-GLRT and ASDD-GLRT. The constant false alarm rate property for both detectors is proved. The experimental results show that the ANSDD-GLRT converges faster than the ASDD-GLRT, while the latter can reject the unwanted signal more effectively. [C147]

## "High Resolution Radar Automatic Target Recognition Based on an Improved LDA Method"

A novel improved linear discriminant analysis (ILDA) method is presented. Comparing with LDA, under the condition of d < c -1, d and c are the dimensionality of feature subspace and the number of classes respectively, ILDA uniformly preserves the class distances of classpairs by rearranging the contribution of each class-pair to the generalized between-class scatter matrix after whitening within-class scatter matrix. Experiment results based on simulating data and measured radar data both show that, under the condition of d < c -1, the features

extracted by ILDA are more efficient for multi-class classification than those extracted by LDA. [C148]

## "Scattering matrix description of analog fibre optical links"

In this paper, we describe model of an analog fibre optical link. In the result of above we received of the scattering matrix of an analog fibre optical link. We have present the basic parameters of an analog fibre optical link. [C149]

## "Tunneling properties of multilayered periodic structures"

This paper presents the analysis of electromagnetic wave scattering by multilayered periodic structure composed of cylindrical posts which constitutes a two-dimensional (2-D) electromagnetic band gap (EBG) structure. The presented procedure combines several efficient numerical techniques, such as the iterative scattering procedure (ISP), the orthogonal expansion method, the T-matrix approach and the lattice sums technique. A simple and accurate cascading procedure is utilized to calculate the scattering parameters of the entire EBG structure. The effect of complete wave tunneling through the proposed structure and the procedure of controlling the tunnelled wave are discussed here. [C150]

## "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. [C151]

## "On the fidelity of CEM techniques for estimation of the Sinclair matrix"

Numerous studies have examined the accuracy of computational electromagnetics (CEM) techniques for estimating the radar cross section (RCS) of targets, and the associated trade-offs between fidelity and computational load. Surprisingly, there appears to be no corresponding literature for the estimation of the polarisation scattering matrix, usually formulated in the backscatter alignment convention as the Sinclair matrix. In this paper we report an investigation of the fidelity of estimation of the Sinclair matrix for the case of two integral equation methods, namely, MOM and MLFMM. [C152]

## "Optimum two-pulse UWB detector for different target fluctuation models"

Single pulse UWB detectors do not have good performance as two-pulse or multi-pulse detectors. The more signals we use the better performance we have if we use optimum detectors. In this paper, we derive two-pulse optimum detectors for different target fluctuation models and extend them to multiple pulses. In each section of fluctuation model, suboptimum detectors are proposed to have good performance for targets with different number of bright points. [C153]

## "Space-time ODN suppressing reverberation method"

Reverberation of active sonar that resemble clutter of airborne radar has space-time coupling characteristic. Based on which, a method of space-time ODN reverberation is presented in this paper. Project matrix method is utilized to design time and space ODN filters. The time ODN filter is used to suppress the mainlobe reverberation with the same direction as the target. The space ODN filter is used to the sidelobe reverberation with the same Doppler frequency as the target. Compared with other space-time adaptive processing approaches, this method involves smaller computation and makes real-time processing possible, while the system performance is close to optimal. [C154]

## "Amplitude and phase distributions for bistatic scattering from Pierson-Moskowitz sea surfaces"

In this paper we study the statistical distributions of bistatic scattering from Pierson-Moskowitz sea surfaces. The Monte Carlo simulation method is applied and the Maxwellpsilas equations are solved numerically using the Banded Matrix Iterative Approach. By assuming normal-distributed and correlated real and imaginary scattering components, we derive analytical probability density functions (pdfs) for the amplitude and phase. The amplitude pdf is in the form of an infinite sum of modified Bessel functions while the phase pdf is expressed in terms of the error function. Results show that the amplitude and phase pdfs vary with wind speed, observation angle, and

polarization. TM wave has a wider amplitude distribution than the TE wave. The phase of scattered field from sea surface is not uniformly distributed, especially at low wind speed. The analytical pdf models are in good agreement with empirical distributions. [C155]

## "Radar target recognition method with MUSIC algorithm: Application to aircraft targets with measured scattered data"

This paper demonstrates the usefulness of an ultra wideband target recognition method in the case of realistic and complicated target geometries at resonance region. The method utilizes the MUSIC algorithm to extract the natural resonance-related scattering features of targets. The resulting features give the power distribution maps of targets. These maps are called as fused MUSIC spectrum matrices and used as the main target recognition feature in the method. The fusion process is needed to reduce the aspect dependency of target features, which increases the accuracy rate of the classifier. In this paper, the method is applied to classify three small-scale aircraft targets. It is demonstrated that the method provides high accurate classification rates although the target geometries are highly complex, the measured scattered data is incomplete and only a few different reference aspects are used in recognition design process. [C156]

## "Scattering Center Estimation of UWB Radar Target with Improved MP Method"

Successful target discrimination using the ultra wideband (UWB) radar hinges on an accurate understanding of the scattering behavior of complex radar targets. In the present study, a mathematical model of the UWB radar target is developed based on the analysis of its impulse response. Then an improved matrix pencil (MP) method with adaptive selection of the frequency sampling interval is proposed to extract the target scattering centers. Simulation experiments show that with the present method, the estimated scattering centers of the given UWB radar target are accurate and reliable even at the low signal noise ratio of 6 dB. [C157]

## "Fast analysis of wideband electromagnetic scattering from multi-objects based on characteristic basis function method"

The asymptotic waveform evaluation (AWE) is an efficient method for analyzing wideband electromagnetic scattering problems. As the number of unknowns increases, the size of MOM impedance matrix grows very rapidly, so it is a prohibitive task for the computation of wideband radar cross section (RCS) from electrically large objects or multi-objects using the traditional AWE technique. The characteristic basis function method (CBFM) is a novel efficient approach for reducing the matrix size to a manageable size for direct matrix inversion. In this paper, the AWE technique based on the CBFM for analyzing electromagnetic scattering from multi-objects over a given frequency band is proposed. Numerical examples are given to illustrate the accuracy and computational efficiency of the proposed method. [C158]

## "Two-dimensional clustering-based discriminant analysis for SAR ATR"

This paper gives a new image feature extraction technique coined two-dimensional clustering-based discriminant analysis (2DCDA), which is based on 2D image matrices for constructing the scatter matrices and assumes that the data obeys the multimodal distribution. The detailed procedure of 2DCDA is to first partition each class of the data into multiple clusters via fast 2D global k-means clustering algorithm, and then try to find some directions such that the projections of every pair of clusters from different classes are well separated while the within-cluster scatter is minimized. Therefore, it fully exploits the cluster information and alleviates the linearly unseparable problem to some extent. According to the projection fashion, we divide 2DCDA into two versions, the right 2DCDA (R-2DCDA) and the left 2DCDA (L-2DCDA). They compress the image row or column only, so they need more features. To solve this problem, two-directional 2DCDA ((2D)2CDA) is developed, which compresses the image row and column simultaneously. Experiments have been carried out for recognition of three types of ground vehicles in the Moving and Stationary Target Acquisition and Recognition (MSTAR) public database to evaluate and compare the performances of the proposed algorithms with other methods. Results demonstrate that 2DCDA and (2D)2CDA are effective. And, the highest recognition rate is up to 97.89%, which is the best ever reported in the literatures. [C159]

## "A parametric adaptive radar detector"

In this paper, we propose and assess an adaptive radar detector that can adjust its ldquodirectivityrdquo through a real scalar parameter. Proper choices of such a parameter return, as special cases, the well-known Kellypsilas GLRT and the recently introduced W-ABORT detector. More important, through the tuning of the above parameter one can control the level to which sidelobe signals are rejected. Such functionality is particularly important to contain the number of false alarms in presence of mismatched signals. At the analysis stage we

assume a homogeneous Gaussian environment and derive analytical expressions for the probability of false alarm and the probability of detection for matched and mismatched signals. Remarkably, the proposed detector possesses the CFAR property with respect to the noise covariance matrix and the considered examples have highlighted that it can ensure better rejection capabilities than the ACE at the price of an acceptable detection loss for matched signals with respect to Kellypsilas GLRT. [C160]

## "Fully polarimetric analysis of weather radar signatures"

In this work the concept of depolarization response, namely the degree of polarization as a function of transmit polarization state, is investigated. Application examples are shown in the field of radar meteorology, namely for hydrometeor identification with fully polarimetric weather radar signatures. Data are from POLDIRAD, DLR research weather radar. [C161]

## "Design of mismatched filters for long binary codes"

Several approaches for sidelobe suppression of pulse compression radar using mismatched filters were proposed for more than 30 years. Barker code of length 13 was invariably used for the performance comparison of these methods. Present day pulse compression radars with large time-bandwidth products use binary code lengths much greater than 13. Very few results of mismatched filter performance were shown for binary codes of length greater than 100. One of the reasons why the results were limited to shorter code lengths was the computational complexity involved in mismatched filter optimization. For example, to apply one of the earlier methods to reduce peak sidelobes, repeated inversion of 1000-by-1000 matrix would be needed for 1000-tap mismatched filter. In this paper, a simple iterative processing algorithm coupled with minimax optimization to reduce peak sidelobe level is proposed that demonstrates mismatched filter performance for code lengths far greater than 1000. The performance of the proposed mismatched filters approaches that of Wiener filtering techniques but with much less complexity and therefore could be applied for designing longer mismatched filters. Furthermore, with this approach mismatched filter iteration could be stopped to stay within the mismatch loss budget. [C162]

## "Knowledge-aided covariance matrix estimation: A MAXDET approach"

In this paper, we consider the problem of knowledge-aided covariance matrix estimation and its application to adaptive radar detection. We assume that an a-priori (knowledge-based) estimate of the disturbance covariance M, derived from a physical scattering model of the terrain and/or of the environment, is available. Hence, starting from a set of secondary data, we evaluate the maximum likelihood (ML) estimate of M assuming that it lies in a suitable neighborhood of the a-priori estimate. We formulate this ML estimation in terms of a convex optimization problem which falls within the class of MAXDET problems. Both the cases of unstructured and structured disturbance covariance are considered. At the analysis stage, we assess the performance of the new knowledge-aided covariance estimators in terms of detection probability achievable by a class of adaptive detectors. The results highlight that, if the a-priori knowledge is reliable, satisfactory levels of performance can be achieved with considerably less training data than those exploited by conventional algorithms. [C163]

## "A radar target for calibration and for codes validation"

The electromagnetic scattering of a plane wave by a penetrable (e.g., dielectric) or impenetrable (e.g., metallic) sphere concentric with a thin metallic disk is considered, in the frequency domain. At low and intermediate frequencies, either separation of variables and mode matching with matrix truncation or a direct numerical approach such as the MoM is adopted, while at high frequencies a combination of GTD and physical optics is employed. The analytical and numerical results are compared to measurements made in an anechoic chamber. [C164]

## "Descriptive experiment design unified with worst-case performance optimization-adapted regularization for high-resolution radar/SAR imaging"

This paper considers the problem of high-resolution imaging of the environment formalized in terms of a nonlinear ill-posed inverse problem of nonparametric estimation of the power spatial spectrum pattern (SSP) of the wavefield scattered from an extended remotely sensed scene (referred to as the scene image) via processing the discrete measurements of a finite number of independent realizations of the observed degraded radar data signals (one realization of the trajectory signal in the case of SAR). The model-level uncertainties are associated with unknown statistics of perturbations of the signal formation operator (SFO) in turbulent environment. The system-level uncertainties are attributed to the imperfect array calibration, finite dimensionality of measurements, uncontrolled antenna vibrations and random carrier trajectory deviations in the case of SAR. An effective method for SSP reconstruction is therefore proposed by incorporating into the minimum risk (MR) nonparametric spectral

estimation strategy the experiment design-motivated constraints of SSP observability/identifiability for the finite-dimensional range continuous-to-discrete SFO algorithmically coupled with descriptive experiment design regularization (DEDR) and unified with worst-case statistical performance optimization approach. The MR objective functional is constrained by this information, and the robust DEDR reconstruction operator applicable to the scenarios with the low-rank uncertain estimated data correlation matrices is found. We also show how this algorithm may be considered generalization of the robust MVDR and the regularized inverse spatial filtering techniques. The efficiency of the developed technique is illustrated via numerical simulations. [C165]

## "Radar HRRP Target Recognition Based on Optimal Transformation of Kernel Space and Cluster Centers"

How to extract effective discriminant features of high-resolution range profile (HRRP) is one of the issues for radar automatic target recognition (RATR). In this paper, a novel method for extracting discriminant features is proposed by using kernel optimal transformation and cluster centers techniques (KOT-CC). In addition, to alleviate the effect of independent noises on the discrimination, we propose a general algorithm for dealing with the singular cases of total scatter matrix, which are often encountered in various kernel methods, such as kernel fisher discriminant analysis (KFDA). Finally, experiment results on the measured radar data are compared and analyzed, which verify that KOT-CC is a powerful technique for extracting nonlinear discriminant features and improving recognition rate. [C166]

## "Detection of buried objects using GPR change detection in polarimetric Huynen spaces"

Change detection is a useful method for detecting new events in a scene such as the placement of mines, and/or the movement of people, vehicles and structures. The basis of the approach is to examine an area via radar several times. Once, before there were targets planted there, and the other (or others) after. The change detection algorithm will notice if there are any changes after the first view was made. False alarm, that is a critical issue in this approach, can be reduced in a number of ways: exploiting additional information such as phase and polarization, and 2) exploiting critical attributes by computing changes in focused sub-spaces. In this paper we present anew approach for polarimetric change detection, whereby the target is represented not in terms of the complex scattering elements but in terms of phenomenologically-based Huynen parameters. Each element of the Huynen parameter set conveys useful physical and geometrical attributes about the scatterers thus augmenting the potential for significant false alarm mitigation. Results of the application of this approach on fully polarimetric signatures of simulated buried targets are provided. These results indicate that Huynen parameters are more effective for change detection than the scattering matrix elements in generating higher unambiguous autocorrelation peaks and less prominent cross-correlation peaks. [C167]

## "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. [C168]

## "Polarimetric calibration-a comparison of different approaches"

Polarimetric calibration is performed by applying distortion matrices acting on transmit and receive. Two different approaches to determine these distortion matrices are compared to each other, a statistical one, and an approach that uses radar reflectors. The effect of polarimetric calibration is demonstrated by means of two examples pertaining to polarimetric detection, and to feature based target recognition. [C169]

## "Point scatterers target identification using frequency domain signal processing"

The coherent short pulse radar provides high resolution image of the target. A model of this image is composed in the superposition form by complex envelope of signals returned from point-scatterers. In accordance with their positions and reflection coefficients the values of complex envelope are distributed over radar image coordinate plane. Radar image model is based on known radar pulse envelope and pattern of the antenna. The parameters of the target point scatterers are processed in the frequency domain using one dimensional data extracted from

the complex discrete Fourier transformed image. Matrix pencil algorithm is used for the parametrical target identification. This approach is characterized by the ambiguity of the point scatterers positioning in the coordinate plane. Rotation of the image axes is used to provide a disambiguation. [C170]

## "A polarimetric scattering research of ocean surface based on the matrix of scattering facet"

A. new method of simulating polarimetric scatter coefficient of sea rough surface is given. Based on normal line matrix of scattering facets which is derived from a three dimensional sea model, an expression of scattered field with elliptic polarized incidence wave is deduced in Cartesian coordinate system. Finally fully polarized RCS are numerically calculated and compared in different conditions. [C171]

## "Polarization optimization for scattering estimation in heavy clutter"

Controlling the polarization information in transmitted waveforms enables improving the performance of radar systems. We consider the design of optimal polarization for the estimation of target scattering embedded in heavy clutter. The goal is to minimize the mean squared error of the scattering estimation subject to an average radar pulse power constraint. We show that such a problem is equivalent to the optimal design of a radar sensing matrix that contains the polarization information. We formulate the optimal design as a nonlinear optimization problem which can be recast it in a convex form and is thus efficiently solvable by semi-definite programming (SDP). We compare the sensing performance of the optimally selected polarization over the conventional approaches. Our numerical results indicate that a significant amount of power gain is achieved in the target scattering estimation through such an optimal design. [C172]

## "Simulation of Doubly-Selective Compound K Fading Channels for Mobile-to-Mobile Communications"

A computer simulation model is proposed for discrete-time doubly-selective compound-K fading channel. It first generates multiple independent mobile-to-mobile Rayleigh fading Channel Impulse Response (CIR) using the non-isotropic scattering model, then generates the cross- and auto-correlated gamma shadowing matrix using the combination of the memoryless nonlinear transformation (MNLT) method and the decomposition methods. It then combines the complex Rayleigh CIR with the gamma shadowing matrix to yield the doubly-selective fading channel CIR whose envelop follows the compound K distribution. Simulation examples demonstrate that the proposed method can effectively produce compound K fading channel responses with satisfactory statistical properties. [C173]

## "A two-stage detector with improved acceptance/rejection capabilities"

We propose a two-stage detector consisting of a subspace detector followed by the whitened adaptive beamformer orthogonal rejection test. The performance analysis shows that it possesses the constant false alarm rate property with respect to the unknown co-variance matrix of the noise and that it guarantees a wider range of directivity values with respect to previously proposed two-stage detectors. The probability of false alarm and the probability of detection (for both matched and mismatched signals) have been evaluated by means of numerical integration techniques. [C174]

## "Radar target recognition based on a kernel double discriminant subspaces method"

Kernel Fisher discriminant analysis (KFDA) is a very effective tool used for dimensionality reduction and feature extraction in pattern recognition. However, KFDA also suffers from the so-called small sample size problem (SSS) which often exists in high-dimensional pattern recognition data. In this paper, we present a complete KFDA method, namely kernel double discriminant subspaces (KDDS). The new algorithm views the optimal discriminant vectors as a global transform in the feature space to some extent, and it makes full use of the discriminative information within both null and non-null subspace of the within-class scatter matrix, which makes KDDS a more powerful dicriminator. Experiments based on the measured airplanes database are conducted to evaluate the effectiveness of the proposed method, and the results show that it can obtain better classification performance. [C175]

## "Modified MEMP method for 2D scattering center measurement based on GTD model"

To accurately measure scattering centers of the stealthy object whose main scattering centers are formed by the edge diffraction, a modified matrix enhancement and matrix pencil (modified MEMP) method is utilized based on the geometric theory of diffraction (GTD) model. Traditional MEMP method needs plenty of eigenvalue decomposition computation and an additional pairing step. When two or more distance parameters are equal or close, the MEMP may produce incorrect paired results. The modified MEMP method can avoid these drawbacks.

Simulations show it is accurate and has a good resolution; moreover, this method can estimate the types of scatterers. [C176]

## "Computed torque control with nonparametric regression models"

Computed torque control allows the design of considerably more precise, energy-efficient and compliant controls for robots. However, the major obstacle is the requirement of an accurate model for torque generation, which cannot be obtained in some cases using rigid-body formulations due to unmodeled nonlinearities, such as complex friction or actuator dynamics. In such cases, models approximated from robot data present an appealing alternative. In this paper, we compare two non- parametric regression methods for model approximation, i.e., locally weighted projection regression (LWPR) and Gaussian process regression (GPR). While locally weighted regression was employed for real-time model estimation in learning adaptive control, Gaussian process regression has not been used in control to-date due to high computational requirements. The comparison includes the assessment of model approximation for both regression methods using data originated from SARCOS robot arm, as well as an evaluation of the robot tracking performance in computed torque control employing the approximated models. Our results show that GPR can be applied for realtime control achieving higher accuracy. However, for the online learning LWPR is superior by reason of lower computational requirements. [C177]

## "Scattering performance of a composed ferrite-dielectric rotary- field phase shifter section"

The simulated scattering characteristics are presented for a section of circular waveguide filled with a rod consisting of a number of alternating ferrite and dielectric discs which are magnetized through a four pole magnetic field. The advantage of this waveguide structure is reduction of size to a fraction of the diameters needed for ferrite filled waveguide section. The simulated performance indicates application of this configuration as phase shifters and polarizers. [C178]

## "Fast multiplexer CAD using surrogate models for channel filters synthesis"

This paper presents a fast approach to CAD of microwave manifold multiplexers using accurate surrogate models for channels synthesis. An example of three-channel multiplexer with dual-mode filters is presented showing remarkable performance of the approach. [C179]

## "Point scatterers target identification using frequency domain signal processing"

The coherent ultra short pulse radar provides high resolution image of the target. A model of this image is composed in the superposition form by complex envelope of signals returned from point scatterers. In accordance with their positions and reflection coefficients the values of complex envelope are distributed over radar image coordinate plane. Radar image model is based on the known radar pulse envelope and a pattern of the antenna. The parameters of the target point scatterers are processed in the frequency domain using one dimensional data extracted from the complex discrete Fourier transform of the radar image. The Matrix pencil algorithm is used for the parametrical target identification. This approach is characterized by the ambiguity of the point scatterers positioning in the coordinate plane. Rotation of the image axes is used to provide a disambiguation. [C180]

## "Performance of 2Ч2 MIMO system utilizing various omnidirectional antennas"

Present paper concerns performance of 2times2 MIMO system utilizing various omnidirectional antennas. Performed computer simulations have shown that symbol error rate of MIMO system utilizing simple monopole antenna is close to symbol error rate of MIMO system utilizing planar antenna with circular slot. This implies that in some applications monopole can be replaced by planar antenna, which is easier to manufacture, easier to integrate with microwave circuit, and resistant to mechanical damage. [C181]

## "Wideband correlation processing in polarimetric radar with compound signals and simultaneous measurement of scattering matrix elements"

In this paper wideband correlation processing is proposed for use in polarimetric radar with compound signals and simultaneous capabilities for measuring the scattering matrix elements. The processing technique does not affect the range and velocity characteristics of radar objects. [C182]

## "Polarimetric signature for oil spill observation"

Synthetic aperture radar (SAR) oil spill observation is not at all an easy task since the presence of many natural

phenomena and surfactants call for complex and time-consuming classification techniques, generally based on the use of ancillary external data. In this study, polarization diversity is employed to assist oil spill observation techniques. The polarization signature, commonly used for land application, is firstly read in terms of a sea surface scattering mechanism with and without surface slicks. Experiments, accomplished over multilook complex (MLC) C-band SIR-C/X-SAR data, show that the polarization signature can be useful both for observing oil spills and for distinguishing between oil spills and biogenic look-alikes. [C183]

## "Polarization filtering enhancement of buried landmine"

Here the optimum polarization of antenna for buried landmines detection in soil surface clutter is investigated theoretically to enhance radar target back scattered power. An expression of the Mueller matrix from this fractal surface is obtained. The optimum polarization to reduce clutter is given. Then, the variations are found of power density of buried landmines with polarization state, and the optimum polarization is given to increase power density. In the end, the paper researches the polarization filtering enhancement of buried landmines in soil surface clutter. [C184]

## "Unsupervised classification of PolSAR images using eigenvector analysis, Krogager decomposition and the Wishart classifier"

In this paper, a new scheme for unsupervised classification of polarimetric synthetic aperture radar (PolSAR) images is presented. The method mainly consists of four parts: eigenvector analysis of the coherency (or covariance) matrix, Krogager decomposition, unsupervised classification using Krogager coefficients and scattering entropy, and iterative classification based on the Wishart distance measure. The method can classify the pixels into nine classes, and its effectiveness is demonstrated using the Jet Propulsion Laboratorypsilas AIRSAR and SIR-C/X-SAR L-band PolSAR data. [C185]

## "Error associated with the direction of arrival estimation in the presence of material bodies"

In many adaptive signal processing applications, it is assumed that the direction of arrival of (DOA) of the signals is known. For a radar problem, this is true as we know along which direction we transmitted the beam, and therefore, we expect the radar return to be arriving from that direction. However, this assumption is questionable when there are material bodies near or along its path. Here, we address the question as to what happens to the direction of propagation when the electromagnetic wave encounters a material body near or along its path for the noise free case. Thus, the objective is to calculate the error associated with the prediction of DOA when the free space is not empty. We illustrate the error associated with the estimation of the DOA when there is a perfect electric conducting (PEC) sphere and a dielectric sphere along/near the path of propagation. A PEC and dielectric will diffract the incident electromagnetic energy. We evaluate the scattered far fields at a few points away from the obstacle. From the measured field points, we predict the DOA of the signal of interest. The simulations have been carried out using an electromagnetic simulator and a DOA estimation algorithm using the Matrix Pencil method. The examples deal with the case of both one- and two-dimensional antenna arrays and how they interpret the diffracted signals. [C186]

## "Coverage prediction in large scenarios based on the TLM method"

This paper introduces a method to model scenes with considerably larger cell size. The method is based on neglecting interference phenomena at the wavelength scale. It can thus be considered a method based on power flow since it essentially drops the information about the phase of the local field.The relation between time-domain simulation and frequency domain averaging is given by Parseval's theorem which will be shown in the paper. [C187]

## "Shape optimization of total radar cross section for antenna struts"

In this article, we consider a perfect electric conducting (PEC) cylinder and reduce the blockage for a TE wave by shape optimization, i.e. by changing the shape of the cylinder boundary. To calculate the blockage caused by the strut we use the optical theorem, which gives the total scattering cross section of the cylinder as a function of the scattering in the forward direction. This means that we only have to calculate the scattered field in the forward direction to obtain the total scattering. For the optimization we use an adjoint problem to obtain the gradient of the goal function as continuous integrals over the boundaries of the PEC. The field solver used in the problem is a stable hybrid FEM-FDTD time-domain solver in 2D. The solver combines the body-conforming capabilities of the FEM with the efficiency of the FDTD method in large homogeneous domains. [C188]

## "Analysis of H-T junction in rectangular waveguide using the MPSTD algorithm"

In this paper, the MPSTD algorithm is applied to model the H-T junction in rectangular waveguide. The S parameters of the H-T junction are analyzed by MPSTD. The numerical results indicate that the MPSTD algorithm is accurate and efficient to analyze the H-T junction. [C189]

## "Small Perturbation Method for Scattering From Rough Multilayers"

In this paper, we present an elegant closed form solution obtained applying perturbation theory to three-dimensional layered structures with an arbitrary number of rough interfaces. A general method has been developed to treat layered structures that can be described by small changes with respect to an idealized (unperturbed) structure, whose associated problem is exactly solvable. The final expression, beyond the compactness, allows us to directly prove that our formulation satisfies the reciprocity principle. [C190]

## "Land Cover Characterization and Classification using Polarimetric ALOS PALSAR"

In this study, the Touzi and Cloude-Pottier decompositions are compared for land cover characterization using ALOS/PALSAR polarimetric data collected at September, 4, 2006, over the Weinan region of Shanxi Province in China, the most useful parameters are combined for land cover classification. The classification results are assessed and validated using Landsat TM image of Weinan area acquired at August, 9, 2006. [C191]

## "Segmentation of Polarimetric SAR Data based on the Fisher Distribution for Texture Modeling"

The Polarimetric Synthetic Aperture Radar (PolSAR) covariance matrix is generally modeled by a complex Wishart distribution. For textured scenes, the product model is used and the texture component is often modeled by a Gamma distribution. In this paper, authors propose to use the Fisher distribution for texture modeling. From a Fisher distributed texture component, we derive the distribution of the complex covariance matrix and we propose to implement the KummerU distribution in a hierarchical segmentation and a hierarchical clustering algorithm. Segmentation and classification results are shown on synthetic images and on ESAR L-band PolSAR data over the Oberpfaffenhofen test-site. [C192]

## "Comparison of Polarimetric Change Detection Methods on ALOS PALSAR Images over Finland"

Six polarimetric change detection indices were tested on L band ALOS PALSAR data over Kuortane, Finland. Tests included quantitative evaluation of change indices compared to reference change maps, and qualitative evaluation by visual inspection. Results suggest an additional accuracy using fully polarimetric data in change detection. Contrast Ratio and the Wishart test gave the best results among the tested indices. [C193]

## "Classification of Polarimetric SAR Images using the Degree of Polarization and the Co-Polarized Phase Difference"

A new polarimetric SAR image classification technique based on the degree of polarization (DoP) and the co-polarized phase-difference (CPD) is presented in this paper. Since the DoP and the CPD of a scattered wave provide information on the randomness of the scattering and the type of scattering mechanisms, at first, the statistics of the DoP and CPD are examined with measured polarimetric SAR image data. Then, a DoP-CPD diagram with appropriate boundaries between six different classes is developed based on the SAR image. The classification results are compared with the existing Entropy-alpha diagram as well as the JPL-AirSAR polarimetric data. The technique may have capability to classify an SAR image into six major classes; a bare surface, a village, a crown-layer short vegetation canopy, a trunk-layer short vegetation canopy, a crown-layer forest, and a trunk-dominated forest. [C194]

## "Automatic Target Recognition by Means of Polarimetric ISAR Images and Neural Networks"

Inverse Synthetic Aperture Radar (ISAR) images are often used for classifying and recognising targets. Moreover the use of a fully polarimentric ISAR image enhances classiication capabilities. In this paper, the authors propose a novel ATR technique based on the use of fully polarimetric ISAR images and Neural Networks. In order to reduce the amount of data processed by the classifier, the brightest scattering centres are first extracted by means of the Pol-CLEAN technique and then their scattering matrices are decomposed using Cameron's decomposition. The proposed ATR algorithm is finally tested on real data. [C195]

## "Estimation of the Equivalent Number of Looks in Polarimetric SAR Imagery"

We present two new estimators for the equivalent number number of looks (ENL) designed for polarimetric synthetic aperture radar data. These are the first known estimators to utilise the full multilook polarimetric covariance matrix, and both are derived from moments of the Wishart distribution. The first estimator is obtained

from the second-order trace moment, which provides a multivariate generalisation of the conventional ENL definition. The second estimator is found from the log-determinant moment, and is also shown to be the maximum likelihood estimator. The latter estimator proves to have superior statistical properties to any other known ENL estimator. These properties are decisive for the good performance obtained with a proposed procedure for unsupervised estimation. We demonstrate on airborne AIRSAR data how a robust ENL estimate can be extracted from the distribution of small sample estimates collected over the whole scene. [C196]

## "Radar Polar Decomposition for Natural Surfaces Cartography"

Illustrations of parameters obtained from polar decomposition derived from fully polarimetric data acquired by ALOS-PALSAR over the Mai-Ndombo lake, in the Democratic Republic of Congo are presented. Results show their complementarity to usual polarimetric indices, such as the entropy or the alpha parameters [C197]

## "The H/A/Alpha Polarimetric Decomposition Theorem and Complex Wishart Distribution for Snow Cover Monitoring"

This study discusses the capability of full polarimetric L-band ALOS PALSAR data for snow classification. In this study, Polarimetric decomposition and the complex Wishart classifier are applied on ALOS-PALSAR data. Optical (ALOS-AVNIR) data within six days difference was used for visual interpretation of snow and non-snow classes. Application of Entropy-Anistropy-Alpha-Wishart classifier for training samples gives better classification results. To reduce speckle effects and to improve classification results, the refined Lee filter was applied on the covariance matrix several times, each time increasing the size of the moving window. Over all classification accuracy were observed 75.61%, 91.46%, 94.91%, 96.19%, 97.16% and 98.37% using different window sizes 1times1 (without filtered image), 3times3, 5times5, 7times7, 9times9 and 11times11 respectively for refined lee speckle filter. It is observed that classification accuracy increases as size of the filter window increases for speckle reduction. Polarization signatures of various features have also been generated using polarization synthesis techniques and signatures are represented in 3-D plot. [C198]

## "Microwave Subsurface Crosswell Imaging using Finite Difference Frequency Domain Modeling"

We have developed a new algorithm for electromagnetic inverse scattering problem in inhomogeneous media using finite difference frequency domain (FDFD) forward modeling, referred as FDFD-based inversion method. The key issue of this method is to build a linear expression for the inverse problem from the FDFD forward modeling by using the Born approximation. An important advantage of this matrix-based method is that there is no need to specify a Green's function. This inversion algorithm is applied to microwave subsurface object detection using cross well radar. The new method is compared with the conventional inversion using Green function-based Born Approximation (GFBA). This EM scattering inverse algorithm is easily implemented and is robust to the heterogeneity of background. Numerical experiments are presented for a two dimensional borehole geometry for buried object detection in soil. [C199]

## "Decomposition of Polarimetirc Scattering of Paddy Rice"

This paper reports the effects of the probability distribution of the target shape to the results of four-component decomposition. The four-component decomposition method decomposes polarimetric microwave data into four components, i.e. surface scattering, double bounce scattering, volume scattering and helix scattering. Prior to the present research, three dimensional structure of the rice was measured and modeled. The model was used to calculate the probability density function of the rice leaves at a viewpoint of arbitrary zenith and azimuth angles. With this probability density function, a covariance matrix of volume scattering for the rice was developed. This covariance matrix was embedded in the four-component decomposition, and it was applied for the polarimetric X-band scattering data of rice, measured in an anechoic radio wave chamber in Niigata Univ. during September 25 to 26, 2007. It was found that the proposed four-component decomposition produced more volume scattering and less surface scattering than the results produced by the standard four-component analysis. As a result, it is concluded that the probability distribution to the target shape should be considered. [C200]

## "Requirements for Model-based Polarimetric Decompositions"

Several authors have proposed decompositions of measured polarimetric covariance matrices into the weighted sums of individual covariance matrices that represent known scattering models. In this paper we critically examine some minimum requirements that these model-based polarimetric scattering decompositions must satisfy. Starting with the definition of the covariance matrix, we show that a necessary requirement for these decompositions is that the eigenvalues of the individual covariance matrices must be non-negative. We then show with examples that this is not guaranteed for some of the proposed decompositions. Finally, we propose a method of decomposition that would ensure that the eigenvalues of the individual covariance matrices would be

non-negative. [C201]

## "The efficient technique for extracting two-dimensional SCs of a target using the SSOC and the MSSP"

This paper proposes technique for extracting 2D scattering centers (SC) of a target. The proposed technique is very efficient to estimate SCs. Given the fast and accurate estimation of SCs, the suggested approach is an excellent candidate for ATR. [C202]

## "A new iterative physical optics method based on MFIE for computing the RCS (radar cross-section) of electrically large cavities"

In this paper, magnetic field integral equations (MFIE) are applied to simplify the complex computation caused by the calculation of shadowing effect in the common iterative physical optics method (IPO). Furthermore, in order to avoid the inverse operation of large matrix in the discretization of MFIE, three-dimensional point functions are applied as the weighting functions while RWG (Rao-Wilton-Glisson) functions act as the basis functions. The whole algorithm of the new method is presented and its validity is convinced by the numerical results, which agree well with the experimental value. [C203]

## "Improving PWF Method of Despeckle in Polarimetric SAR Image by Fusion Based on Nonsubsampled Contourlet Transform"

A novel and efficient improving PWF method of speckle reduction in polarimetric SAR image by fusion based on nonsubsampled contourlet transform is proposed. First, the three complex elements (HH, HV, and VV) of the polarimetric scattering matrix were decorrelated to form a new elements matrix. Then we show that the sub-band decompositions of the three elements using nonsubsampled contourlet transform, and fusion factor is applied to the decomposed directional high-frequency coefficients to create new sub-band coefficients. Finally, we process and reconstruct multi-resolution contourlet coefficients according to the PWF method. Experimental results show that compared with PWF de-speckling algorithm, the proposed algorithm can achieve an excellent balance between suppresses speckle effectively and preserves image details, and the significant information of original image like textures and contour details is well maintained. [C204]

## "Reduced-rank STAP algorithm for adaptive radar based on joint iterative optimization of adaptive filters"

In this paper, we develop a novel reduced-rank space-time adaptive processing (STAP) algorithm based on joint iterative optimization of filters for adaptive radar applications. The proposed algorithm consists of a joint iterative optimization of a bank of full-rank adaptive filters that forms the projection matrix and an adaptive reduced-rank filter that operates at the output of the bank of filters. We describe constrained minimum variance (CMV) expressions for the design of the projection matrix and the reduced-rank filter. Adaptive algorithms including normalized least-mean-squares (NLMS) and recursive least square (RLS) are derived for its efficient implementation. Simulations for a clutter-plus-jamming suppression application show that the proposed STAP algorithm outperforms the state-of-the-art reduced-rank schemes in convergence and tracking at significantly lower complexity. [C205]

## "Quad Polarimetry SAR Target Recognition Based on Parametric Statistics and Multidimensional Analysis"

Diverse parameters decomposed from quad-polarimetric SAR could become the important basis in target recognition, classification and other applications.During the target recognition, due to the sidedness of single parameter or two parameters decomposed by same algorithm, obvious differences exist among the results extracted by different parameters. In this paper, a parametric statistics and multidimensional analysis algorithm will be applied in target recognition from quad-polarimetric SAR image. The proposed algorithm looked the backscattering characters of land cover targets as the basis of analysis. Through parametric statistics, the dominant scattering mechanisms of every decomposing algorithm would be picked out such as volume scattering and sphere scattering of paddy. They become the data of multi dimensional analysis. In the multi-dimensional analysis, the targetpsilas location of parametric space will be the basis of target recognition. The application on land cover and land use by the proposed algorithm improved the monitoring capability of quad polarimetric SAR. [C206]

## "An improved SAI preconditioning for higher Order FMM implementation"

In this paper, an improved SAI preconditioner is proposed to efficiently solve the EFIE system based on a new set of higher order hierarchical basis functions, which is accelerated by MLFMM. Numerical experiments with a few electromagnetic scattering problems for open structures are given to show the validity and efficiency of the proposed SAI preconditioner. [C207]

## "Understanding of the interaction of the radar response with the river ice cover"

The development of a theoretical model to describe the scattering mechanisms involved in the interaction of the radar signal with the fresh water ice is important, as it helps in river ice monitoring. The model used in this study is based on radiative transfer theory which is solved by Doubling Matrix Methods". This numerical method accounts for scattering effects due to the volume, boundaries, boundary-volume interactions and coupling between layers. Three ice types were formed on this river (Columnar ice, snow ice and frazil ice). This study focused mainly on two objectives. First, the understanding of the interaction of the radar signal with the different ice types formed in the river. Second, the determining the dominant scattering mechanism for the different ice types and radar configurations (frequencies and angles of incidence). [C208]

## "Phased Array Radar Polarimetry for Weather Sensing: Challenges and Opportunities"

It is becoming widely accepted that radar polarimetry provides accurate and informative weather measurements, while phased array technology can shorten data updating time. In this paper, a theory of phased array radar polarimetry is developed, and the relationship between the wave field at the radar antenna coordinate and that at the hydrometeors is established, along with the correction matrix to the scattering matrix. The challenges and opportunities for the weather sensing are discussed. [C209]

## "Improvement of Earthquake Prediction by using Global Signal Elimination from Environmental Electromagnetic Signals"

Anomalous environmental electromagnetic (EM) radiation waves have been reported as the portents of earthquakes. We have been measuring the Extremely Low Frequency (ELF) range all over Japan. Our goal is to predict earthquakes using EM radiation waves. Previously, we proposed a method of detecting anomalous signals by focusing on linear prediction errors. However, this method also sensitively responds to earthquake-unrelated anomaly. For accurate earthquake-prediction, we should eliminate earthquake-unrelated signals. In this paper, we try to reduce false detection rate by global signal elimination using Non-negative Matrix Factorization (NMF) and evaluate the effectiveness of this method. [C210]

## "A modified 2D ESPRIT method for scattering centers measurements"

The JSVD is introduced to the 2D ESPRIT method. And the means and standard deviations of the estimation errors are reduced effectively compared to the initial method. The estimated results of the real data show that the modified 2D ESPRIT provides increased resolution and precision over the FFT method. [C211]

## "Effectiveness of global signal elimination from environmental electromagnetic signals for earthquake prediction"

Anomalous environmental electromagnetic (EM) radiation waves have been reported as the portents of earthquakes. We have been measuring the extremely low frequency (ELF) range all over Japan. Our goal is to predict earthquakes using EM radiation waves. Previously, we proposed a method of detecting anomalous signals by focusing on linear prediction errors. However, this method also sensitively responds to earthquake-unrelated anomaly. For accurate earthquake-prediction, we should eliminate earthquake-unrelated signals. In this paper, we try to reduce false detection rate by global signal elimination using non-negative matrix factorization (NMF) and evaluate the effectiveness of this method. [C212]

## "Critical analysis of polarimetric PALSAR data for landcover classification"

Polarimetric SAR provides a substantial source of information over conventional imaging radars. Fully polarimetric PALSAR data has been used for land cover classification. Co and Cross Polarization signatures for different classes are obtained in linear (h,v) and circular (l.r) basis. Different combinations from both basis have been extracted for the (principal component analysis) PCA. Supervised minimum distance classifier is used on principal components of various bases combinations for classification. HH-HV-VV feature set gives a better estimate of urban and vegetation class but water bodies are estimated with higher accuracy from LL-LR-RR feature set. [C213]

## "Recent advances of POL-SAR, POL-IN-SAR & RP-POL-IN-SAR imagery for remotely sensing natural habitats: Desert and wetlands remote sensing"

Land cover monitoring is one of the most potential applications of Polarimetric Synthetic Aperture Radar (POLSAR) sensing and so is Repeat-Pass Polarimetric-Interferometric SAR (RP-DIFF-POL-IN-SAR) stress-change assessment for air/high-altitude/spaceborne SAR sensor deployment. Provided fully polarimetric SAR information can be made available, a plethora of novel POLSAR matrix decomposition methods can be implemented for recovering rather precise scattering contributions from isolated and distributed scattering scenarios, and so can rather exact environmental changes from consecutive repeat-pass observations. With the recent launches of the fully polarimetric satellites JAXA-ALOS (PAL-SAR-L), the DLR TerraSAR-X and RADASAT-2 (C), a new era in space imaging of the terrestrial terrain and ocean surfaces has arrived providing unforeseen advantages. Whereas in the past, POLSAR applications were focused mainly on information product gathering for agriculture, forestry and the fisheries, little emphasis was placed on demonstrating its full capacity also for the assessment of natural habitats and especially wetlands. Therefore, it is essential to demonstrate how seasonal changes and features of vegetation in natural habitats, shallow vegetated lakes and wetlands can be recovered, provided fully polarimetric SAR image data takes can be made available for full polarimetric scattering matrix acquisition for which the standard symmetry condition HV=VH may not necessarily be sufficient. [C214]

## "LOS PALSAR data analysis of snow cover area in Himalayan region using four component scattering decomposition technique"

Snow cover is the important parameter for hydrological modeling and climate change modeling. Land use/cover classification is one of the most important applications of polarimetric synthetic aperture radar (POLSAR) sensing. Hence, the application of radar polarimetry is one of the best remote sensing techniques to classify snow cover terrain. In this paper, PALSAR data have been analyzed of snow cover area in Himalayan region based on three and four component scattering mechanism model. This study shows the implementation problem of four-component decomposition model in Himalayan terrain. Finally, supervised Wishart classifier has been used for snow cover and other land feature classification. The over all accuracy was measured to be 74.12 % without speckle noise reduction. [C215]

## "Recent advances in microwave multi-modal SAR remote sensing of the terrestrial covers"

Land cover monitoring is one of the most potential applications of Polarimetric Synthetic Aperture Radar (POLSAR) sensing and so is Repeat-Pass Polarimetric-Interferometric SAR (RP-DIFF-POL-INSAR) stress-change assessment by air/high-altitude/space-borne SAR sensor deployment. Provided fully polarimetric SAR information can be made available, a plethora of novel POLSAR matrix decomposition methods can be implemented for recovering rather precise scattering contributions from isolated and distributed scattering scenarios, and so can rather exact environmental changes from consecutive repeat-pass observations at 1 m resolution from air and from space. With the recent launches of the fully polarimetric satellites JAXA-ALOS (PAL-SAR-L-Band), the DLR TerraSAR-X (X-Band) and of RADASAT-2 (C-Band), a new era in space imaging of the terrestrial terrain and ocean surfaces has arrived providing unforeseen advantages. Whereas in the past, POLSAR applications were focused mainly on information product gathering for agriculture, forestry and the fisheries, little emphasis was placed on demonstrating its full capacity also for the assessment of natural habitats and especially wetlands and desert regions. Specifically, we are now able to demonstrate how seasonal changes and features of vegetation in natural habitats, shallow vegetated lakes and wetlands & deserts can be recovered under worst weather conditions and at day and during night at most distant and often inaccessible hidden sites, where for example migrant birds rest. Land cover monitoring is one of the most potential applications of Polarimetric Synthetic Aperture Radar (POLSAR) sensing and so is Repeat-Pass Polarimetric-Interferometric SAR (RP-DIFF-POL-IN-SAR) stress-change assessment by air/high-altitude/space-borne SAR sensor deployment. Provided fully polarimetric SAR information can be made available, a plethora of novel POLSAR matrix decomposition methods can be implemented for recovering rather precise scatte--ring contributions from isolated and distributed scattering scenarios, and so can rather exact environmental changes from consecutive repeat-pass observations at 1 m resolution from air and from space. It is essential to emphasize that fully polarimetric SAR image data sets are strictly required for optimal information extraction and compacted or hybrid quasi-polarimetric SAR imaging will fail to discover intricate detailed feature characteristics and parameters. [C216]

## "Classification of polarimetric synthetic aperture radar images from SIR-C and ALOS PALSAR"

SIR-C quad-pol MLC data and ALOS PALSAR quad-pol and dual pol SLC data over Indian sites have been processed using PolSARpro software for classification of various land features. The land features include ocean, clear water, settlements, agriculture fields, arid lands, grown and young forest, hilly terrain, mangrove forest, etc. The test sites used are SIR-C L-band and C-band Kolkata city and its surroundings, ALOS PALSAR data over

West Bengal, Haryana, Rajasthan, Uttar Pradesh, and Mumbai. For Kolkata city we observed that classification results for L- and C-bands are slightly different. For Mumbai dual pol data classification accuracy is poor due to overlap of backscattering values for bare ground and mangrove vegetation with ocean backscattering values. [C217]

## "Wideband ambiguity matrix of LFM-signals used in polarimetric radar allowing simultaneous measurement of scattering matrix elements"

A pair of concurrent up- and down-going Linear Frequency Modulated (LFM) wideband signals is used in a polarimetric radar allowing simultaneous measurement of all scattering matrix elements. In wideband LFM radar the ambiguity function for a selected polarization at transmit and receive and presented in the delay time versus Doppler frequency coordinate system shows a skewness. This skewness affects the accuracies in object range and velocity. The ambiguity matrix in wideband multi-polarization LFM radar can be used to study for the different orthogonal polarization states the impact of this shortcoming connected to this skewness. In this paper the wideband ambiguity matrix is generalized. We define the time scaling so that in the ambiguity matrix the consequences of skewness are minimized. We show simulation results to demonstrate the improved potentials of this newly-defined wideband ambiguity matrix approach. The error in range (time delay) measurements for fast moving radar target becomes minimal. [C218]

## "Waveform design for MIMO radar using Kronecker structured matrix estimation"

The multiple-input multiple-output (MIMO) radar system is a new kind of radar technology. It can choose flexibly the probing signals transmitted via its antennas or increase the inter-element distance to reduce the cross-correlation of the signals, so that the spatial diversity gain can be obtained. Waveform design is one of the important topics of the MIMO radar. We discuss here the waveform design method for extended radar targets using Kronecker structured matrix estimation. Simulation results are provided to validate the proposed solutions. [C219]

## "Scattering center estimation of UWB radar target with improved MP method"

Successful target discrimination using the ultra wideband (UWB) radar hinges on an accurate understanding of the scattering behavior of complex radar targets. In the present study, a mathematical model of the UWB radar target is developed based on the analysis of its impulse response. Then an improved matrix pencil (MP) method with adaptive selection of the frequency sampling interval is employed to extract the target scattering centers. Simulation experiments show that with the proposed method, the estimated scattering centers of the given UWB radar target are accurate and reliable even at the low signal noise ratio of 6 dB. [C220]

## "Modular modeling and optimization for large antenna arrays"

In the next-generation phased-array systems, a closely packed system of RF functions and electronics is expected. This creates a need for both accurate and flexible design tools. We employ the generalized scattering matrix (GSM) formalism to arrive at a flexible tool with modest computational costs to enable a computer-aided design trajectory. We employ an integral equation technique to generate the scattering matrices and discuss some optimization strategies that seem appropriate for the type design problem that is obtained via the GSM formalism. [C221]

## "The PARSAX-full polarimetric FMCW radar with dual-orthogonal signals"

The article describes the IRCTR PARSAX radar system-fully polarimetric FMCW radar with dual-orthogonal sounding signals, which has the possibility to measure all elements of the radar targets polarization scattering matrix simultaneously, in one sweep. [C222]

## "Incoherent Polarimetric ISAR Decomposition for target classification"

The incoherent target decomposition theorem (ICTD) has been largely used when dealing with the problem of classifying distributed targets by using polarimetric synthetic aperture radar (PolSAR) images. In this paper, a method based on the use of the ICTD and the nearest neighbour classifier is proposed and applied to man made point-like targets in an ISAR-like scenario. the algorithm is tested by using real data in several signal to noise ratio (SNR) scenarios. [C223]

## "Basics of microwave radar & SAR polarimetry and its applications"

The development of radar polarimetry and radar interferometry is advancing rapidly, and these novel radar

technologies are revamping "synthetic aperture radar imaging" decisively. In this exposition the successive advancements are sketched; beginning with the fundamental formulations and high-lighting the salient points of these diverse remote sensing techniques. Whereas with radar polarimetry the textural fine-structure, target-orientation and shape, symmetries and material constituents can be recovered with considerable improvements above that of standard 'amplitude-only polarization radar'; with radar interferometry the spatial (in depth) structure can be explored. In 'polarimetric-interferometric synthetic aperture radar (POL-IN-SAR) imaging' it is possible to recover such co-registered textural plus spatial properties simultaneously. This includes the extraction of 'digital elevation maps (DEM)" from either 'fully polarimetric (scattering matrix)' or interferometric (dual antenna) SAR image data takes' with the additional benefit of obtaining co-registered threedimensional 'POL-IN-DEM' information. Extra-wide-band POL-IN-SAR imaging-when applied to 'repeat-pass image overlay interferometry'-provides differential background validation and measurement, stress assessment, and environmental stress-change monitoring capabilities with hitherto unattained accuracy, which are essential tools for improved global biomass estimation. More recently, by applying multiple parallel repeat-pass EWB-POL-D(RP)- IN-SAR imaging along stacked (altitudinal) or displaced (horizontal) flight-lines will result in 'tomographic (multi-interferometric) polarimetric SAR stereo- imaging', including foliage and ground penetrating capabilities. It is shown that the accelerated advancement of these modern 'EWB-POL-D(RP)-IN- SAR' imaging techniques is of direct relevance and of paramount priority to wide-area dynamic homeland security surveillance and local-to-global envi--ronmental groundtruth measurement and validation, stress assessment, and stress-change monitoring of the terrestrial and planetary covers. [C224]

## "Evaluating the Potential of L Band PolSAR Data to Discriminate Deforestation Increment Areas in Amazon Rain Forest"

The main objective of this work is to evaluate the potential of L band PolSAR data to discriminate deforestation increment. In order to achieve this purpose, it was performed a coherent attributes exploratory analysis and a Maximum Likelihood-ICM (Iterated Conditional Modes) classification of R99B sensor L band PolSAR data. The PolSAR data classification obtained good agreement with PRODES Digital project reference map (k=0,71). This result might indicate that R99B L band PolSAR data have good potential to discriminate deforestation increment areas in Amazon Forest. [C225]

## "Speckle Filtering of Dual-Polarization and Polarimetric SAR Data based on Improved Sigma Filter"

The advancement of SAR technology with high resolution and multiple polarization data demands better and efficient speckle filtering algorithms. In this paper, we developed an effective speckle filtering algorithm for dual-pol and fully polarimetric high resolution data. The proposed algorithm is effective and computational efficient based on the improved sigma filter ALOS/PALSAR and JPL AIRSAR data were used for demonstration. [C226]

## "Coherent Decomposition of Fully Polarimetric Radar Data"

This paper presents a coherent decomposition scheme for a few scattering matrix data. A simple model-fitting decomposition method is applied to retrieve scattering mechanism or identify scatterers based on the coherency matrix. The decomposition results are compared with some experimental data obtained by fully polarimetric FM-CW radar. It is shown the scattering mechanisms are well recovered and the orientation angles of wire scatterer are precisely measured. [C227]

## "Polarimetric Scattering Model Decomposition for Pol-InSAR Data"

This paper presents scattering model decomposition technique with Pol-InSAR datasets. The target model decomposition based on the scattering mechanisms corresponding to surface, double, and volume scattering, is one of the powerful tools to analyze and classify the ground surface conditions with fully polarimetric SAR data. However, we sometimes meet difficulty that the power of the decomposed component(s) becomes negative. This is caused by assumptions in the decomposition technique. When a Pol-InSAR dataset is available, additional observables can be obtained. These new observables will be available to resolve the difficulty of negative power in the conventional decomposition technique. In this paper, we consider the scattering model decomposition technique with Pol-InSAR data, and propose some modifications for the decomposition. [C228]

## "Polarimetric Deformation Maps Retrieval of Urban Areas using Ground-Based SAR Acquisitions"

A one-year subsidence monitoring activity has been carried out by the Remote Sensing Laboratory (RSLab) of the Universitat Politecnica de Catalunya (UPC) using an X-band ground-based SAR sensor. The project aimed at studying the subsidence phenomenon induced by salt mining extraction of the past years in the village of Sallent (Spain). The polarimetric capability of the system allowed to gather zero-baseline POL-SAR data in the single-pass mode in 9 different days, from June 2006 to April 2007. The estimation of the linear component of

deformation process obtained using each polarization channel separately is here compared with the result of a new approach exploiting the full knowledge of the scattering matrix at once. For this purpose, a coherence-based approach is employed. The higher amount information carried by polarimetric data is finally pointed out both in terms of number of reliable pixels selected within the scene and higher quality of the retrieved subsidence map. [C229]

## "Super-Resolution of Polarimetric SAR Images Based on Target Decomposition and Polarimetric Spatial Correlation"

Polarimetric SAR (PolSAR) is becoming more and more popular in remote sensing research area. Super-resolution processing of PolSAR image is usually desired for PolSAR image applications, such as image interpretation and target detection. Usually in a PolSAR image, each resolution contains several different scattering mechanisms. If these mechanisms can be allocated to different parts in one resolution cell, the details of the images can be enhanced, which means the resolution of the images is improved. In this paper, a new super-resolution algorithm for PolSAR image processing is proposed, in which target decomposition and polarimetric spatial correlation are both taken into consideration. Results of ESAR L-band full polarized images have validated the effectiveness of the proposed method. [C230]

## "Scattering type phase for wetland classification using C-band polarimetric SAR"

The Touzi decomposition is investigated for wetland characterization. Like the Cloude alpha scattering type, the magnitude alphasof the symmetric scattering is not effective for vegetation type discrimination. The phase Phialphasof the symmetric scattering type has to be used for enhanced characterization of wetland vegetation species. A new tool is introduced for assessment of the scattering type phase coherence, and the phase of the dominant scattering type is shown to be very promising for wetland target classification. The unique information provided by Phialphasfor enhanced wetland class discrimination is demonstrated using Convair-580 polarimetric C-band SAR data collected over the Mer Bleue wetland in the East of Ottawa, Canada. The use of Phialphasmakes possible the discrimination of shrub bog from sedges fen, and permits even the discrimination between conifer dominated treed bog from upland deciduous forest under leafy conditions. [C231]

## "Synthetic Digital Correlation for Combined Polarimetric Microwave Remote Sensing"

Combined passive and active microwave remote sensing can provide complementary information and enhance performance of the retrieval of parameters. In consideration of the combination of passive and active microwave polarimeters in an identical system, an active polarimetric matrix consisting of six parameters is combined with the format of the passive polarimetric parameters matrix which is known as the Stokes vector. A synthetic digital correlation method is designed to perform combined measurements of the two types of parameter matrixes, and to achieve cost saving using shared subsystems and hardware. Performances of the design are analyzed including measurement sensitivities, relative errors, and dynamic range. [C232]

## "Recent Advances in POL-SAR & POL-IN-SAR Imaging of Natural Habitats and Wetland Remote Sensing"

Land cover monitoring is one of the most potential applications of Polarimetric Synthetic Aperture Radar (POLSAR) sensing and so is Repeat-Pass Polarimetric-Interferometric SAR (RP-DIFF-POL-IN-SAR) stress-change assessment for air/high-altitude/space-borne SAR sensor deployment. Provided fully polarimetric SAR information can be made available, a plethora of novel POLSAR matrixde composition methods can be implemented for recovering rather precise scattering contributions from isolated and distributed scattering scenarios, and so can rather exact environmental changes from consecutive repeat-pass observations. With the recent launches of the fully polarimetric satellites JAXA-ALOS (PAL-SAR-L), the DLR TerraSAR-X and RADASAT-2 (C), a new era in space imaging of the terrestrial terrain and ocean surfaces has arrived providing unforeseen advantages. Whereas in the past, POLSAR applications were focused mainly on information product gathering for agriculture, forestry and the fisheries, little emphasis was placed on demonstrating its full capacity also for the assessment of natural habitats and especially wetlands. Therefore, it is essential to demonstrate how seasonal changes and features of vegetation in natural habitats, shallow vegetated lakes and wetlands can be recovered, provided fully polarimetric SAR image data takes can be made available for full polarimetric scattering matrix acquisition for which the standard symmetry condition HV=VH may not necessarily be sufficient. [C233]

## "Robust vegetation height Extraction using maximum likelihood estimation for Dual-baseline PolInSAR"

Polarimetric SAR interferometry technique has been widely used for parameters extraction of the earth's surface

vegetation. In this paper, based on the two layers Random Volume over Ground model, we present a vegetation height inversion algorithm for dual-baseline PolInSAR data. The method obtained the ground and volume scattering component respectively by using the theory of Freeman polarimetric decomposition. Then the maximum likelihood estimation of the covariance matrix was used to construct the vegetation height for dual-baseline PolInSAR. The proposed algorithm overcomes the restriction of traditional maximum likelihood estimation method which required the parameters of ground scattering to be known. Finally, the experimental results of L-band PolInSAR simulated data show that the algorithm improves the effect of height estimation compare to the coherence method. [C234]

## "Model Based SAR Tomography of Forested Areas"

In this paper a technique is described for the tomographic characterization of forested areas through multiple SAR observations. This technique is based on a model of the second order statistics of the multi baseline, multi polarimetric, data which accounts for the presence of multiple distributed targets within the system resolution cell. The results of an experiment performed on a real P-band, multi-baseline, fully polarimetric data set relative to the forested site of Remningstorp, Sweden, are reported. Such results show the feasibility of performing a model based tomographic analysis of forests, resulting in a characterization of both the ground and the canopy in terms of elevation, spatial structure, and scattered power. [C235]

## "Effects of mutual coupling in smart antenna arrays"

The radiation pattern in the H-plane of smart antenna arrays (SAA), which includes the effects of mutual coupling (MC) is examined. In an SAA the effects of MC and nonuniform spacing between the array elements are compensated with the use of a transformation matrix T. The weight vector of the array is updated by way of the least-mean-square (LMS) algorithm. A MatLab program was developed to verify the MC for a smart antenna array. [C236]

## "Estimation of 2D-DOAs and angular spreads for coherently distributed sources using cumulants"

In this paper, a new 2D-DOAs and angular spreads estimation algorithm is proposed for coherently distributed (CD) sources. Based on the newly designed array geometry, multiple CD sources model is developed. The respectively azimuth DOAs, elevation DOAs and their angular spreads of CD sources can be estimated by the proposed LS-VESPA-based algorithm, which first compute the cumulants using the specially designed guiding sensors, then estimate the invariance structured matrix by LS-VESPA algorithm, and finally obtain the parameters from the phase information and the module information of the approximation closed form of the steering vectors. The efficiency of the algorithm is validated by computer simulations. [C237]

## "Statistical distribution for scattering mechanism of targets based on eigenvector decomposition in polarimetric radars"

In this paper a decomposition scheme for analysis and classification of statistical radar targets is presented. For this purpose eigenvector target decomposition (ETD) analysis method is used for calculating coherency eigenvalues. Also a simulation scheme is developed for calculating Entropy, Scattering mechanism for discrimination of several surface scattering objects within distributed targets. As results, radar image data set have been used for compare. [C238]

## "Fully polarized radar target scattering center extraction"

A new method for fully polarized radar target scattering center extraction is proposed using Coherent Polarization Geometrical Theory of Diffraction (CP-GTD) model. Unlike the traditional single fixed-polarization GTD method, the new method can overleap the step of scattering centers association and can estimate coherent scattering matrices of scattering centers accurately. It also provides a better performance and a reduced computation burden because the full-polarization information is used. The superiority of the CP-GTD is verified by experiment results based on simulated data. The method can also be easily extended for SAR/ISAR. [C239]

## "Statistical distribution for scattering mechanism of targets based on eigenvector decomposition in Polarimetric Radars"

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## "Electromagnetic scattering by "tree-shaped" open cylinders"

In M. Lucido et al. (2004) and M. Lucido et al. (2006) a new approach has been introduced, based on the method of analytical regularization (MAR):: it is shown that the use of a Galerkin scheme with expansion functions ensuring the correct edge behaviour and continuity conditions of the current allows for an efficient solution of the electric and magnetic field integral equations (EFIE and MFIE) describing the problem, achieving a quick convergence, and therefore small matrices to be numerically computed, and an effective control of the truncation error, which is quite difficult by using other conventional numerical methods. In M. Lucido et al. (2006) the method has been extended to the analysis of open polygonal cylinders, for which the MFIE cannot be used. A further generalization is presented in the present contribution, in order to analyze a "tree-shaped" open structure, which is useful, for instance, in radio propagation modeling. [C241]

## "Image Processing in Polarimetric SAR Images Using a Hybrid Entropy Decomposition and Maximum Likelihood (EDML)"

This paper presents a hybrid entropy decomposition and maximum likelihood (EDML) for synthetic aperture radar (SAR) image analysis and classification with the application of land use management. Entropy decomposition is an effective technique to obtain valuable decomposed parameters for image interpretation with analysis of the underlying scattering mechanisms. However, the main disadvantage of entropy decomposition is that the decision boundaries of the analysis plane are arbitrary. To overcome this problem, maximum likelihood technique is taken into consideration to help to determine the decision boundaries based upon Gaussian probability model. Hence, the hybrid EDML is developed to provide alternative way to improve the classification accuracy. The objective of this paper is to assess the use of polarimetric data for the image analysis and classification of land use management. It is illustrated using a well-known polarimetric AIRSAR data of San Francisco. In this paper, EDML technique is shown to have a superior result compared to other techniques. [C242]

## "Footprint Adjustment On SFCW-GPR With Modified Dipole Array"

Antennas footprint is an important parameter for good detection result in ground penetrating radar (GPR) survey. The various condition of soil under which a target is buried may change the footprint of an antenna. An antenna with a capacity to adapt with different soil condition is therefore needed. This type of antenna is capable of keeping the footprint constant in different soil condition. The footprint of an antenna is related to the antennas dimension. In this paper, modified dipole array is proposed as an adaptive antenna for GPR. With RF switch circuit, we choose the element on the antenna that will be fed considering to footprint that will be produced. Resistive loading is used to reduce coupling level between elements in the array. The simulation results show that different active element produce different near field area. The size of near field area is proportional to the dimension of the element. [C243]

## "Recent Advancements of Multi-modal Radar & SAR Imaging"

Radar polarimetry radar interferometry and polarimetric SAR interferometry represent the current culmination in 'microwave remote sensing' technology. Whereas with radar polarimetry, the textural fine-structure, target orientation, symmetries and material constituents can be recovered with considerable improvement above that of standard 'amplitude-only' radar, by implementing 'radar interferometry', the spatial (in depth) structure can be explored. With polarimetric interferometric synthetic aperture, radar (POL-IN-SAR) imaging it is possible to recover such co-registered textural and spatial information from POL-IN-SAR digital image data sets simultaneously, including the extraction of digital elevation maps (DEM) from either polarimetric (scattering matrix) or interferometric (dual antenna) SAR systems. [C244]

## "Electromagnetic scattering from multilayer rough surfaces with arbitrary dielectric profiles for remote sensing of subsurface soil moisture"

Radar remote sensing of soil moisture content at low frequencies requires an accurate scattering model of realistic soils, which often involves multilayer rough surfaces and inhomogeneous dielectric profiles. In this paper, a hybrid analytical/numerical solution to two- dimensional scattering from multilayer rough surfaces separated by arbitrary dielectric profiles based on the extended boundary condition method (EBCM) and scattering matrix technique is presented. The reflection and transmission matrices of a rough interface are constructed using EBCM. The inhomogeneous dielectric profile is modeled as a stack of piecewise homogeneous dielectric thin layers. The scattering matrices of an inhomogeneous dielectric profile are computed by recursively cascading reflection and transmission matrices of individual dielectric interfaces. The interactions between the rough interfaces and the inhomogeneous dielectric profile are accounted for by applying the generalized scattering

matrix technique. The solution presented in this paper is for the two-dimensional scenario of multilayer rough surfaces. The technique can also be applied in three dimensions. In numerical simulations, the actual field-collected soil moisture data are used. In particular, the dielectric profiles during both dry and wet ground conditions are examined. The numerical simulations are performed to investigate both backscattering scattering coefficients and co- polarized phase difference due to different subsurface roughness parameters and ground conditions. The results show that both backscattering coefficients and co-polarized phase difference at low frequencies are sensitive to the roughness of subsurface interfaces and deep soil moisture. Also, much larger depth sensitivity can be achieved using co-polarized phase difference than scattering coefficients. [C245]

## "A near-field bistatic radar cross section calibration method"

The PW scattering-matrix theory, originally introduced by Kerns and Dinallo, enables to evaluate the far-field scattering matrix of a target from a near-field illumination and near-field measurements of the scattered field. It compensates the near-field effects as well as the own characteristics of the near-field setup. The mathematical processing, which is used to evaluate the far-field scattering matrix, has been developed step by step. This mathematical extraction requires planar near-field measurements of the field scattered by the target. It also requires the near-field setup to be calibrated. Two different calibration methods have been developed. The first one is based on a two or three-antenna technique and requires a limited number of measurements. The second one uses bistatic RCS measurements. The PW scattering-matrix theory will now be experimented. [C246]

## "Simulation research of parametric methods for multi-baseline SAR tomography"

Multi-baseline SAR tomography is an extension of SAR interferometry. It uses multi-baseline data to obtain the distribution of scatterers along the height direction and realize three-dimensional imaging of the investigated scene. The parametric method can be used to realize SAR tomography. Super-resolution method based on modern spectrum analysis and inverse processing with singular values decomposition (SVD) are the main algorithms of parametric method. We analyze the principle of multi-baseline SAR tomography. The steps of the two algorithms are introduced, and the imaging results and efficiencies of the two algorithms are compared. We simulate the two algorithms with spaceborne SAR parameters, and get the tomographic images of the investigated targets. [C247]

## "Polarimetric temporal information for urban deformation map retrieval"

In this work, a preliminary study on the use of polarimetric persistent scatterers for differential interferometric applications within an urban environmental is presented. The PolSAR measurements campaign that the RSLab of UPC is carrying on in the village of Salient using an X-Band ground- based SAR sensor is first described. The work is then focused on the additional information the knowledge of full scattering matrix [S] may provide with respect to the single polarization approach. The problem of instability of the polarimetric signature of urban targets is also analyzed. Finally, a solution based on the search of repeated patterns in the long-temporal profile of pixels' polarimetric signature is briefly introduced. [C248]

## "Review of existing monographs and books on radar polarimetry and polariemtric SAR with the aim of justifying the need of updates"

Radar Polarimetry, Radar Interferometry and Polarimetric SAR Interferometry represent the current culmination in active 'Microwave Remote Sensing' technology, but we still need to progress considerably more in order to reach the limits of physical realizability. Whereas with radar polarimetry the textural fine-structure, target orientation, symmetries and material constituents can be recovered with considerable improvement above that of standard 'amplitude-only radar', by implementing 'radar interferometry' the spatial (in depth) structure can be explored. With Polarimetric Interferometric Synthetic Aperture Radar (POL-IN-SAR) imaging, it is possible to recover such co-registered textural and spatial information from POL-IN-SAR digital image data sets simultaneously, including the extraction of Digital Elevation Maps (DEM) from either Polarimetric (scattering matrix) or Interferometric (dual antenna) SAR systems. However, in order to further advance this promising technology, we require pertinent basic educational and advanced research texts plus application oriented books for the practicing engineering scientists and users. Hitherto there are not available satisfactory updated sets of basic books or application oriented handbooks. Therefore, in this paper a succinct review of the existing pertinent monographs, books and guides will be presented with the aim of identifying particular topics that still need to be covered. We do now require these urgently associated sets of revised and updated multi-lingual (English, Japanese, Korean, Chinese) books. [C249]

## "Pol-dinSAR: polarimetric SAR differential interferometry using coherent scatterers"

We investigate the impact of polarimetry and polarimetric effects on the Differential Interferometry (DinSAR)

technique for the coherent backscattering reciprocal case, with the aim to obtain better accuracy and to extract additional information about the scatterer. Emphasis is given to the effects of Faraday and scatterer line-of-sight (LOS) rotations, and to the determination of the intrinsic scatterer scattering mechanism. [C250]

## "Closed form expressions for scattering matrix of simple targets in multilayer structures"

Scattering matrix of a simple target embedded in multilayer planar structure is derived. The structure is excited by an elliptically polarized plane wave incident at an oblique angle. The calculation of the electromagnetic fields is performed in spectral domain. The scattering matrix of a planar electric dipole printed on upper interface and surrounding by free-space is evaluated. The obtained results agree with those existing on the literature for normal incidence case. [C251]

## "The equivalence of Cameron's unit disc and Poincarй's sphere for symmetric scattering characterisation and classification"

Cameron's coherent target decomposition and classification is able to represent a symmetric scatterer onto a unit disc in the complex plane, and assign it to one of the six symmetrical elemental scatterer classes. Recently, Touzi et al. proposed a variation of Cameron's method by introducing a coherent analysis. Moreover the Poincare's sphere, was used instead of the unit disc for representing symmetric scattering because it was considered a more suitable domain. The aim of this work is to demonstrate the equivalence of using Poincare's sphere domain and Cameron's unit disc, in term of characterisation and classification of symmetric scattering types. [C252]

## "Evaluation and bias removal of multi-look effect on entropy/alpha/anisotropy"

Entropy, alpha and anisotropy (H/alpha/A) of the polarimetric target decomposition has been an effective and popular tool for polarimetric SAR image analysis and geophysical parameter estimation. However, multi-look processing can severely affects the values of these parameters. In this paper, we evaluate the bias problem in H/alpha/A due to insufficient averaging. We found that the estimated bias is radar frequency dependent. A procedure for bias compensation is proposed. Data from L-band DLR/E-SAR and L-band JPL/AIRSAR, and X-band PI-SAR data are used for demonstration in this study. [C253]

## "Iterative classification of polarimetric SAR image based on the freeman decomposition and scattering entropy"

In this paper, a new scheme for iterative classification of polarimetric SAR image based on the Freeman decomposition and scattering entropy is proposed. This technique extracts three decomposition coefficients of three scattering mechanism components through the Freeman decomposition and the scattering entropy through the H/Alpha decomposition first; then classifies the polarimetric SAR image into nine initial classes using the four parameters, and obtains the final result by iterative classification with Wishart classifier. This method, utilizing polarimetric scattering information of terrain, can acquire good effect of classification and requires less computation. The effectiveness of this method is demonstrated by the experimental results of polarimetric SAR data acquired practically. [C254]

## "ESPRIT super-resolution imaging algorithm based on external illuminators"

Passive radar imaging algorithm based on external illuminator requires large accumulated rotating angle of target. But in an actual circumstance, large rotating angle demands long time, which is hard to satisfy the request of real time, on the other hand, target reflectivity function differs at various aspect angles, moreover, when rotating angle increases, target reflectivity function differs seriously. In this paper, an ESPRIT based high resolution passive radar imaging algorithm is proposed to solve the problem which is that how to form a good image at the instant of small rotating angle. In the method self-correlation matrix of the returned echoes is estimated firstly, then corresponding sine wave frequencies of the scattering-centers with the object is determined through eigenvalue decomposition, target location is deduced by the sine wave frequency, hence the reflectivity of the scattering-centers are computed. Computer simulation confirms the feasibility of the algorithm. [C255]

## "Algorithm of target classification based on target decomposition and support vector machine"

Since Huynen's original work, there have been many other proposed target decomposition theorems. In this paper, we provide a review of the different approaches used for target decomposition theory in radar polarimetry and classify three main types of theorems: those based on Mueller matrix, those using an eigenvector analysis of the coherency matrix, and those employing coherent decomposition of the scattering matrix. Support vector

machine (SVM), as a novel approach in pattern recognition, has demonstrated a success in many fields. Here we first extract scattering mechanisms of radar targets by target decomposition and color composite. Then we propose a new algorithm of target classification by combining target decomposition and support vector machine. We conduct the experiment on the polarimetric synthetic aperture radar data. Experimental results show that: it is feasible and efficient to target classification by designing SVM classifiers using target decomposition, and the effects of kernel functions and its parameters on the classification efficiency are significant. [C256]

## "Analysis of non-Gaussian POLSAR data"

In this paper we present a generalised Wishart classifier derived from a non-Gaussian model for polarimetric synthetic aperture radar (POLSAR) data. Our starting point is to demonstrate that the scale mixture of Gaussian (SMoG) distribution model is suitable for modelling POLSAR data. We show that the distribution of the sample covariance matrix for the SMoG model is given as a generalisation of the Wishart distribution, and present this expression in integral form. We then derive the closed form solution for one particular SMoG distribution, known as the multivariate K-distribution. Based on this new distribution, termed the K-Wishart distribution, we propose a Bayesian classification scheme, which can be used in both supervised and unsupervised mode. Modelling and classification is tested on airborne EMISAR data. [C257]

## "Improvement of 3D radar backscatter model by matrix-doubling methods"

Radiative transfer models have been widely used to simulate the radar backscatter from forested areas. Most of these models are two dimensional. In order to take full account of spatial position of trees in a forest stand, a three-dimensional radar backscatter model of forest canopy was constructed by Guoqing Sun and Ranson in 1995[1]. The model takes into account only first-order scattering within tree crown and the double scattering between tree trunk (crown) and ground surface. The model predictions agree well with copolarized backscatter measurements, while it tends to underestimates the backscattering coefficients for cross-polarization, when there is strong volume scattering. In order to produce good estimations for cross-polarized component, the matrix-doubling method is employed in this paper to compute multiple-scattering within the crown. The comparison between the results of original model and that of modified model shows that the method is effective. The cross-polarization can be improved in different degrees according to the size and density of scatters within crown cell. [C258]

## "Simultaneous Extraction of Temporal, Spatial, and Spectral Information from Multi-Wavelength Lidar Data"

Analysis of lidar data is generally done through parametric analysis where the lidar range dependent backscattering and extinction are deduced from the analytical lidar equation, and the range dependent concentration is deduced from the backscattering (or extinction). In previous work we have treated lidar measurements as a hyperspectral vector and applied traditional anomaly detection to determine (from one wavelength) the presence of a cloud of interest. Multi-wavelength lidar data, however, is not a matrix (range-by-time), but instead is a tensor: a multidimensional w-way array (range-by-time-by-wavelength). Matrix analysis techniques such as anomaly detection will not extract all the information available within this array. This work describes the use of n-way analysis techniques to simultaneously extract temporal, spatial, and spectral information from multi-wavelength lidar data. [C259]

## "Space-Time Adaptive Processing for Non-Sidelooking Airborne Radar with HPRF"

The primary differences in airborne radar clutter spectrum between non-sidelooking and sidelooking arrays are that its Doppler frequency of the clutter spectrum varies with the range and its clutter degrees of freedom (DOFs) are increased. In this paper, firstly a new clutter suppression approach for non-sidelooking airborne radar based on covariance matrix taper (CMT) is proposed at low pulse repetition frequency (LPRF) mode. Secondly a range ambiguous clutter suppression preprocessing method based on orthogonal projection technique is presented for non-sidelooking airborne radar with high pulse repetition frequency (HPRF). Finally the experimental simulation results indicate their correctness. [C260]

## "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. [C261]

## "Tracking High-Speed Targets Using a Pulse Doppler Stepped-Frequency Waveform"

This paper develops a computationally efficient processing technique using fast Fourier transforms (FFT), averaging, and weighted least squares fits to track high-speed targets with a pulse Doppler waveform that is stepped in frequency. The measurements will be unambiguous in Doppler for high-speed targets of interest, but highly ambiguous in range before tracking. First, a range-Doppler matrix is formed using motion compensated data. Then, the effect of the range, radial velocity, and radial acceleration of the target on the processed data is approximated by a polynomial series, and the parameters are estimated using a weighted least squares fit. Monte Carlo simulations of the algorithm when four or more cpis of data are processed are in reasonable agreement with the theoretical predictions. [C262]

## "A Target Recognition Method Based on Non-Linear Polarization Transformation"

This paper proposed a target recognition method to distinguish ships from chaff by polarization information for the fully polarized dual-channel radars with low resolution. The method expands the original single polarization radar system to dual polarization radar system with both left and right circular polarizations by receiving and processing the foil polarization information of radar echoes. It recognizes the target by taking advantage of the difference of the left and right circular depolarization characteristic parameters of the target and chaff in radar echoes. The recognition rate were improved in results by enlarging the difference between the cross-polarization component and co-polarization component of the radar echoes involving target and chaff employing non-linear polarization transformation. In the end, the recognition results were proved to be more desirable by processing information in polarization domain than in time and frequency domain. [C263]

## "Clustering Polarimetric SAR Image Under Deorientation Theory"

In natural complex terrain surfaces, scattering targets with random orientations produce random fluctuating echoes which lead to confused classifications by directly using target decomposition on polarimetric SAR (PolSAR) image. In order to reduce the influence, the target vector is transformed into the state with minimization of cross-polarization. Then a set of new parameters u/v/w are used to characterize scattering mechanisms under the deorientation theory, and the fuzzy membership is adopted instead of "hard" division of parameter plan. Characterizing the sample coherency matrices as complex Wishart distribution, the PolSAR image is clustered based on Bayes maximum likelihood (ML) criteria. Experiment is carried out on an L-band NASA/JPL SIR-C PolSAR image over Danshui town, Guangdong, China. Comparison results with the popular used methods show that the proposed method provides a significant improvement in classification and the associated scattering mechanism of class is more accurate and beneficial for automatic terrain recognition. [C264]

## "Estimation of Near-Field Parameters using Spatial Time-Frequency Distributions"

This work deals with the estimation of near-field parameters using passive sensor arrays. A transformation of the array data is proposed which allows the extraction of near-field time-frequency signatures from data containing a mixture of far- and near-field sources. Spatial time-frequency distribution matrices are then used as a means for solving the near-field parameter estimation problem. The estimation accuracy of the proposed approach is compared to existing methods via simulation analysis. An experimental validation of theoretical ideas is also presented [C265]

## "Full Wave Analysis of a Ferrite Cross-Patch Antenna"

This paper describes the analysis of cross -patch antennas on ferrite substrates and compares its radar cross section (RCS) with respect to the full -patch antenna. The direction of the dc magnetization of the ferrite is assumed arbitrarily in thetas and phi. The analysis is based on a 3-D full wave analysis using method of moments. The Greens function and the excitation vector are formulated in a closed form using the transmission matrix approach. The linearly-varying basis function is used. In general, we notice that the first resonance is almost at the same frequency for both patches, the cross and the full. However, the RCS level is reduced. The cross patch excites less number of modes than the case of full patch. [C266]

## "Adaptive Polarized Waveform Design for Target Tracking using Electromagnetic Vector Sensors"

We develop an adaptive waveform design method for target tracking. In our method, at each time step, we optimally select the parameters, including the polarization of the transmitted signal waveform to improve the tracking accuracy. An array of electromagnetic vector sensors is employed to fully recover the polarimetric

information from the reflected signals. We derive our approach under a framework of sequential Bayesian filtering. We apply a sequential Monte Carlo method to manipulate the nonlinear and non-Gaussian state and measurement models. We design a criterion for the waveform optimization based on a posterior Cramer-Rao bound [C267]

## "SAR Processor based on a CFAR Signal or Interference Subspace Detector Matched to Man Made Target Detection in a Forest"

This paper deals with two new SAR processors based on CFAR subspaces detector. These two algorithms aim at improving man made target detection performances in a forest clutter by using electromagnetic scattering models. The implementation of the two detectors is described. An application on simulated data shows the interest of the two methods [C268]

## "Maximum Likelihood Range Dependence Compensation for STAP"

We present a new method to estimate the clutter-plus-noise covariance matrix used to compute an adaptive filter in space-time adaptive processing (STAP). The method computes a ML estimate of the clutter scattering coefficients using a Bayesian framework and knowledge on the structure of the covariance matrix. A priori information on the clutter statistics is used to regularize the estimation method. Other estimation methods based on the computation of the power spectrum using for instance the periodogram are compared to our method. The result in terms of SINR loss shows that the proposed method outperforms the other ones. [C269]

## "New Solution to the Range-Dependence Problem in STAP Radar with HPRF"

The primary differences in airborne radar clutter spectrum between non-sidelooking and sidelooking arrays are that its Doppler frequency of the clutter spectrum varies with the range and its clutter degrees of freedom (DOFs) are increased, so that the conventional STAP methods are not feasible. In this paper, the clutter distribution of airborne non-sidelooking arrays radar is analyzed and investigated in detail, then a new approach to non-sidelooking airborne radar with low pulse repetition frequency (LPRF) based on covariance matrix taper (CMT) is proposed, finally a novel ambiguous clutter suppression preprocessing method based on orthogonal projection technique is presented for non-sidelooking airborne radar with high pulse repetition frequency (HPRF). Using the preprocessing technique, clutter suppression improvement of 10 dB is achieved. [C270]

## "Characterizing Railroad Ballast Using GPR: Recent Experiences in the United States"

Recent work has been conducted in the United States with 2 GHz horn antennas to characterize railroad ballast. There were a number observations made during the course of the project that derive from gaining a more thorough understanding of ballast and the interaction of GPR with the ballast matrix. The major observations from over 238 km of track data at four different geographical locations include: (1) it cannot be assumed that there will be a reflection from the bottom of clean ballast or that there will be a reflection from the ballast-subballast interface; (2) the presence of a strong reflection in the data generally, but not always, infers moderately-fouled to clean ballast above the reflecting boundary; and (3) no observable ballast-subballast interface reflections are generally, but not always, associated with gradational fouling or a fully-fouled ballast section. [C271]

## "Data Interpolation in Time and Frequency Domains Using Coupled Matrix Pencil Method"

Data interpolation using early-time response in time domain and low-frequency response in frequency domain is a very interesting problem for RCS rapid estimation. As the early-time and low-frequency data are complementary and contain all the desired information, a new solution to interpolate the intermediate time information with the available early-time and low-frequency data is proposed in this paper. The late-time information converting from low-frequency data is obtained by the inverse- discrete-Fourier-transform (IDFT). Then the details of data interpolation based on the coupled matrix pencil method(COMPM), is discussed. The simulation results show that the new method proposed here is efficiency. It is also important to note that the key of the method is not to create new information, but to extract the information in an efficient and accurate manner. [C272]

## "Sub-wavelength Microwave Radar Imaging for Detection of Breast Cancer Tumors"

This paper presents a novel approach to the detection of tumors of size well below a centimeter using a sub-wavelength ultrawide band (UWB) microwave radar imaging technique. Our approach exploits the principle of phase-shifting mask (PSM) and is implemented using a time-reversal (TR) algorithm based on the transmission-line matrix (TLM) method. A 0.5-mm diameter tumor was detected and located using a 200-ps UWB pulse in a

realistic inhomogeneous two dimensional breast model. The breast model was derived from magnetic resonance imaging data and simulated using the TLM method. [C273]

## "Polarimetric Monopulse Radar Intelligent Emulator"

For debugging polarimetric monopulse radar and testing polarization algorithms, a new polarimetric monopulse radar intelligent emulator is proposed and designed in this paper. The polarization information, as a basic character of the target echo, plays an important role in modern radar detection nowadays. The polarization algorithms are developed with rapid speed. It is not realistic to test all algorithms on real radar in research stage. Therefore, the polarimetric radar emulator is required. The functions of radar emulator are as follows: recording the valuable experiment data for researching, playing the experiment data as a radar receiver for radar signal processor debugging, running some polarization programs with real experiment data to test the programs. In the paper, the polarimetric monopulse radar intelligent emulator is introduced in detail. Firstly, the index of emulator is given; secondly, the emulator is divided into 3 modules to be introduced; thirdly, the system architecture and key techniques are analyzed; finally, the performance of emulator is given. [C274]

## "On the Phase Centers of the Scattering of Compound Shape Bodies in SHF and Short-Wave Ranges"

In this paper the results of the experimental study of the polarization features of the backscattering from the compound shape bodies are presented that could be used for their recognition and their course determination as well. The investigations were carried out using the polarimetric coherent systems of the pulse as well as CW transmitting modes of the millimeter wave band. For the study of the phase parity between the elements of the scattering polarization matrix for the polarimeters utilizing the CW mode transmitting the polarization selectors were developed that provides not only orthogonally polarized component expansion of the received signal and the heterodyne signal injection to the working channel having equal phases as well. In the pulse radar polarimeters we used the pulse-by-pulse switching of the receiving signal polarization and alignment of the electrical length of the signal injection and heterodyne ducts in the channels having orthogonally polarized components. [C275]

## "A recognition method depended on enlarge the difference between target and chaff"

This paper proposed a target recognition method to distinguish ships from chaff by polarization information, aiming at fully polarized dual-channel radars with low resolution. The method expands the original single polarization radar system to dual polarization radar system with both left and right circular polarizations by receiving and processing the full polarization information of radar echoes. It recognize the target by taking advantage of the difference of the left and right circular depolarization characteristic parameters of the target and chaff in radar echoes, after enlarging the difference between the cross- polarization component and co-polarization component of the radar echoes involving both target and chaff, furthermore, non-linear polarization transformation is adopted to increase the chaff and targets respectively, and to improve the recognition rate in result. In the end, the recognition result is proved to be more desirable by processing information in polarization domain than in time and frequency domain. [C276]

## "Adaptive IIR Filtering via a Recursive Total Instrumental Variable Algorithm"

Adaptive IIR filtering in the case where noise exists in both the input and output of the system amounts to solving over-determined normal equations. In this paper a recursive total instrumental-variable (RTIV) algorithm is proposed for tracking the total least-squares (TLS) solution of the normal equations in the over-determined instrumental-variable methods. It is shown that the weight vector in the RTIV algorithm converges to the direction parallel to the singular vector associated with the smallest singular value of the augmented cross-correlation matrix. Moreover, the estimated parameters of the adaptive IIR filter are optimal in the TLS sense and its noise rejection capability is superior to that of the least-squares based algorithms. The appealing behavior of the RTIV algorithm for noisy adaptive IIR filtering is substantiated by simulation results. [C277]

## "Automatic Detection of Power Transmission Series in Full Polarimetric SAR Imagery"

An automatic extraction scheme of power transmission tower series in full polarimetric synthetic aperture radar is presented. Through analyzing the amplitude of four scattering powers in terms of scattering matrix elements based on four-component decomposition model, point-like targets including the power transmission towers are detected in the helix scattering component using the multi-resolution statistic energy level method. Due to the geometrical properties of power transmission tower series, radon transform is used for extraction by applying it to the graph structure which constructed by linking all the isolated power transmission towers. Using L-band Pi-SAR images, the effectiveness of the extraction method is validated. [C278]

## "A New ESPRIT Algorithm for Coherently Distributed Source DOA Estimation"

A new rotation structure formulation of the popular ESPRIT for the central direction-of-arrival (DOA) estimation technique is considered. The steering vector of coherently distributed source is expressed as Schur-Hadamard product composed of point source steering vector and a real matrix. And then the new rotation structure is deduced to exist. So the TLS- ESPRIT can be used to estimate the central DOA of Gaussian coherently distributed sources. The so-obtained DOA estimate does not depend on any assumption on angular signal intensity of the source and is hence robust to mismodeling. Simulations clearly demonstrate that the proposed method is not only effective, but also has better estimation accuracy. [C279]

## "Simulation of ISAR Imaging for a Missile"

In this paper, physical optical (PO) method is introduced and applied to calculate the echo data from a missile illuminated by plane waves with arbitrary aspects and different frequencies for inverse synthetic aperture radar (ISAR) imaging. The missile is approximated by component disassembly method (CMD) and concept of scattering matrix is introduced in order to simplify complexity of the numerical calculation. Generated images of several incidence angles are analyzed by signal processing theory and can precisely represent the mirror scattering region and the rotation of the target. The results of the simulation indicate that PO method is simple and effective to calculate the radar echo of a missile for ISAR imaging. [C280]

## "Recognition of Radar Target Based on Kernel Projection Subspace using Range Profiles"

A novel subspace method of radar target recognition, which is named as kernel projection subspace (KPS) method, is proposed in this paper, in which geometric relations are preserved according to prior class-label information and nonlinear variations of range profiles are represented by nonlinear mapping. So, the KPS can be used to extract target feature for enhancing local within-class relations. The experimental results of four kinds of planes demonstrate the efficiency of approach proposed in this paper. [C281]

## "Characterization of scatterers by their anisotropic and dispersive behavior"

Synthetic Aperture Radar (SAR) images built from received signals are high-resolution maps of the spatial distribution of the reflectivity function of targets. Conventional radar imaging assumes that all the scatterers are considered as bright points (isotropic for all observation angles and white in the frequency band) [1]. Recent studies based on multidimensional Time-Frequency Analysis describe the angular and frequency behavior of scatterers and show that they are anisotropic and dispersive [2]. Another useful information source in radar imaging is the polarimetry Studies based on multidimensional wavelet and coherent decompositions allow to represent the angular and frequency polarimetric behavior and show the non-stationarity of this behavior. The aim is to characterize scatterers by time-frequency analysis and polarimetry. [C282]

## "Techniques for Measurement of Radar Signatures"

The radar signature measurement facilities operated by the Thales signature management group are described. The different options for target support are compared, and processing methods in use for mitigating residual target- support interaction are discussed. A brief description of calibration methods is given, with particular reference to bistatic scattering matrix measurements. [C283]

## "Compression of the Fast Multipole Method using the Singular Value Decomposition"

In this work a new matrix compression algorithm to improve the efficiency of the fast multipole method (FMM) is presented. The method is based on the application of the singular value decomposition (SVD) to the plane wave FMM aggregation matrices. These matrices are low-ranked, which is exploited to provide alternative sets of orthonormal singular basis functions. By choosing only the most relevant singular functions, a much more compact representation is obtained. The new formulation provides a reduction close to one order of magnitude both in computational cost and memory requirements without compromising at all the accuracy of the solution. [C284]

## "Some polarimetric aspects of processing sea surface M-ATI SAR data"

A brief review is presented of published work on detection and imaging techniques based on matrix group theory for the scalar non-polarimetric two channel along track interferometer and the vector polarimetric two channel across track interferometer. The relevance to ATI of the vector theory for the across track interferometer is discussed as is the problem of extending the theory to the case of the ATI with N beams. Difficulties in

developing detection and imaging methods for the general case of N beams have lead to attempts to develop an alternative approach based on linear filtering. It is assumed that image modulations are a result of local fluctuations in mean intensity which can be described by a spherically invariant statistical process with a compound distribution. The unmodulated background consists of Gaussian scatterers. These scatterers and the modulated ones have different Doppler spectra and maximising the normalised standard deviation of the filtered image maximises the visibility of the image modulations. Polarimetric aspects of this approach are discussed and experimental results obtained with an airborne four beam M-ATI are presented illustrating aspects of the discussion. [C285]

## "Degree of polarization for weather radars"

Future operational weather radars are likely to implement hybrid polarization, an operating mode that involves transmitting 45deg slant polarization and receiving the horizontal and vertical components of the backscattered field. In this work, the degree of polarization at slant send is theoretically considered and experimentally evaluated from fully polarimetric signatures in order to assess its potential for use in next generation operational weather radars. [C286]

## "Polarimetric optical tools and decompositions applied to SAR images"

Radar polarimetry aims to determine the scattering properties of a target or scatterer. For this purpose, the scattering matrix can be analyzed and represented in several ways using various techniques to extract information about the scattering mechanisms. Polarimetry and ellipsometry are techniques which both study the properties of the polarization of the scattered waves but traditionally refer to different wavelengths: optical wavelengths for ellipsometry, and high-frequencies radio waves for radar polarimetry. This paper deals with natural targets in the general bistatic case, for which the 16 parameters of the Mueller matrix are independent. We try to answer the following questions: how to deduce the radar polarimetric parameters from the optical measurements of a Mueller ellipsometer? What are the polarimetric parameters traditionally devoted to optical images, and in which extent is it possible to apply and interpret them in the case of SAR images? [C287]

## "Dynamic persistent scatterers interferometry"

This paper presents the concept of Dynamic Persistent Scatterers Interferometry (PSI) processing, which enables the sequential estimation of parameters. The method is based on the Integer Least Squares (ILSQ) PSI concept and makes use of the estimation vector and corresponding variance-covariance matrix of the initial estimation epoch. In addition, the concept of multi-modal adaptive estimation and testing is applied. The algorithm systematically adds a new acquisition or set of acquisitions to an existing stack, updates the solution of the previous run, and analyzes whether the behavior of the (pre-) selected points fits the expected one. [C288]

## "Estimating Three-Dimensional Scattering Centers of a Target using High Resolution Techniques"

In this paper, we present high resolution techniques for application in three-dimensional (3D) scattering center extraction for a radar backscattered signal. We propose a 3D pairing procedure, a new approach to estimate 3D scattering centers. This pairing procedure is more accurate and robust than the general criterion. 3D MEMP with the 3D pairing procedure first creates an autocorrelation matrix from radar backscattered field data samples. A matrix pencil method is then used to extract 3D scattering centers from the principal eigenvectors of the autocorrelation matrix. An autocorrelation matrix is constructed by the MSSP (modified spatial smoothing preprocessing) method. The observation matrix required for estimation of 3D scattering center locations is built using the sparse scanning order conception. In order to demonstrate the performance of the proposed technique, we use backscattered field data generated by ideal point scatterers. [C289]

## "Recent Advancements of Radar Remote Sensing; Air- and Space-borne Multimodal SAR Remote Sensing in Forestry & Agriculture, Geology, Geophysics (Volcanology and Tectonology): Advances in P0L-SAR, IN-SAR, POLinSAR and POL-DIFF-IN-SAR Sensing and Imaging with Applications to Environmental and Geodynamic Stress-change Monitoring"

Radar Polarimetry Radar Interferometry and Polarimetric SAR Interferometry represent the current culmination in "Microwave Remote Sensing' technology, but we still need to progress very considerably in order to reach the limits of physical realizability. Whereas with radar polarimetry the textural fine-structure, target orientation, symmetries and material constituents can be recovered with considerable improvement above that of standard 'amplitude-only' radar; by implementing "radar interferometry' the spatial (in depth) structure can be explored. With Polarimetric Interferometric Synthetic Aperture Radar (POL-IN-SAR) imaging, it is possible to recover such co-registered textural and spatial information from POL-IN-SAR digital image data sets simultaneously, including

the extraction of Digital Elevation Maps (DEM) from either Polarimetric (scattering matrix) or Interferometric (dual antenna) SAR systems. Simultaneous Polarimetric plus Interferometric SAR Imaging offers the additional benefit of obtaining co-registered textural-plus-spatial three-dimensional POL-IN-DEM information, which when applied to Repeat-Pass Image-Overlay Interferometry provides differential background validation and environmental stress-change information with highly improved accuracy. Then, by either designing multiple dual polarization antenna POL-IN-SAR systems or by applying advanced POL-IN-SAR image compression techniques, will result in 'POLarimetric TOMOgraphic' (Multi-Interferometric) SAR or POL-TOMO-SAR imaging. By advancing these EWB-D-POL-IN/TOMO-SAR Imaging modes, we are slowly but steadily approaching the ultimate goal of eventually realizing air-borne and space-borne 'Geo-Environmental Background Validation, Stress Assessment, and Stress-Change Monitoring and Wide-area Military Surveillance of the Terrestrial and Planetary Covers'. [C290]

## "Radar cross section of a semi-elliptic channel in a ground plane loaded by multi -dielectric layerers"

An analytic solution to the problem of scattering of a plane electromagnetic wave by a lossy or lossless dielectric confocal elliptic shell loading a semi-elliptic channel is derived. The incident, scattered and transmitted fields in every region are expressed in terms of complex Mathieu functions. Applying the boundary conditions at various faces and interfaces along with the partial orthogonality properties of angular Mathieu functions, the unknown scattered and transmitted field coefficients are obtained and written in matrix form. The presented numerical results show a good agreement with the published data especially for the case of a lossless dielectric shell loading a semi-circular channel. [C291]

## "Fast RCS Computation Using Method of Moments along with Characteristic Modes and General Asymptotic Waveform Evaluation"

The technique to integrate the characteristic modes (CM) with the general asymptotic waveform evaluation (GAWE) is proposed for computing the radar cross section (RCS) of an arbitrarily shaped perfect electric conductor (PEC). In the analysis, a few CMs with smaller eigenvalue are chosen to construct the subspace of the solution of a matrix equation. Hence, the solution of the equation can be obtained by combining the based-vectors of the subspace with a set of coefficients, which is determined by GAWE at a given frequency. In addition, the criterion of the spectral radius is found in order that the subspace can be adaptively constructed. The comparison of the two kinds of methods of asymptotic waveform evaluation (AWE) is also given. Finally, the RCS for different PEC objects are computed. The numerical results prove that the novel technique with CM and GAWE (CMGAWE) is effective in widening the extrapolation range. [C292]

## "PO-MLFMA Hybrid Technique for the Solution of Electromagnetic Scattering Problems Involving Complex Targets"

The multilevel fast multipole algorithm (MLFMA) is a powerful tool for efficient and accurate solutions of electromagnetic scattering problems involving large and complicated structures. On the other hand, it is still desirable to increase the efficiency of the solutions further by combining the MLFMA implementations with the high- frequency techniques such as the physical optics (PO). In this paper, we present our efforts in order to reduce the computational cost of the MLFMA solutions by introducing PO currents appropriately on the scatterer. Since PO is valid only on smooth and large surfaces that are illuminated strongly by the incident fields, accurate solutions require careful choices of the PO and MLFMA regions. Our hybrid technique is useful especially when multiple solutions are required for different frequencies, illuminations, and scenarios, so that the direct solutions with MLFMA become expensive. For these problems, we easily accelerate the MLFMA solutions by systematically introducing the PO currents and reducing the matrix dimensions without sacrificing the accuracy. [C293]

## "Plane-of-Scattering Bistatic Scattering Matrix of Simply Shaped Targets"

We study polarization properties of radar scattering from canonical targets in the bistatic case. Components of the scattering matrix are defined with respect to the plane of scattering (PoS), which allows a physically justifiable definition of co- and cross polarization in the bistatic radar scattering. We describe transformation rules that transform the scattering matrix from the conventional bases of the spherical coordinate system to the PoS bases. We show that this transformation makes the scattering matrix of a perfectly conducting sphere diagonal, regardless of the sphere radius, the wavelength, the incidence and scattering aspects. Numerical examples for several basic targets (faceted spheres, thin cylinder (wire), thin disc, dihedral) are presented. [C294]

## "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. [C295]

## "Retrieval of fully polarimetric mueller matrix under Faraday rotation effect at P band in space-borne polarimetric SAR observation"

Spaceborne microwave observation of subcanopy and subsurface requires the SAR (polarimetric synthetic aperture radar) technology at lower microwave frequencies, such as P band. However, SAR observation at P band is remarkably influenced by Faraday rotation (FR) effect through ionosphere. An example in this paper illustrates why the measured polarimetric data with FR at P band cannot be directly applied to terrain surface classification. We further present that the parameters u, v, H, a, A for terrain surface classification derived from the polarimetric data without FR, which are recovered from the data with FR, can be applied to the surface classification, even there is a plusmn pi/2 ambiguity error unresolved. Based on gradual change of FR degree along geographical location, a method to eliminate the plusmn pi/2 ambiguity error is designed. Thus, the polarimetric scattering vector and Mueller matrix without FR and plusmn pi/2 ambiguity can be fully inverted from the measured polarimetric data with FR. [C296]

## "Persistent scatterer density improvement using adaptive deformation models"

Because the quality assessment of Persistent Scatterers (PS) is dependent on the deformation model chosen, PS may be falsely rejected due to model imperfections. To accept these PS, more advanced deformation models should be used. Two methods applying adaptive deformation models are proposed. The first is based on a sequential scheme of alternative hypothesis testing of extended deformation models within the integer least-squares framework. The second uses a iterative scheme of global deformation modeling based on previous PS results. Application of the techniques to a salt mining area in The Netherlands confirms the increase in the number of detected PS. [C297]

## "Ortho-rectification and terrain correction of polarimetric SAR data applied in the ALOS/Palsar context"

Methods for terrain correction of polarimetric SAR data were studied and developed. Ortho-rectification resampling and amplitude correction utilized Stokes matrix data. The Stokes matrix of thermal noise was subtracted before amplitude normalization. Application of an azimuth-slope correction algorithm resulted in slightly narrower distribution of orientation angles compared to input data. [C298]

## "Application of bootstrap techniques for the estimation of Target Decomposition parameters in RADAR polarimetry"

The precise estimation of the eigenvalues of PolSAR reponses is essential in the derivation of Target Decomposition parameters such as the Cloude-Pottier parameters (Entropy, Anisotropy and average angle Alpha). However, sample eigenvalues are strongly biased for small sample sizes leading to underestimated Entropy and overestimated Anisotropy values. In this paper, we investigate the use of a particular bootstrap technique for the correction of the bias. Bootstrap techniques are attractive because they can deal with very small sample sizes under minimal assumptions on the signal distribution. Here, we are using the jackknife bias correction technique which has been successfully applied to various signal processing problems. Monte-Carlo simulations reveal that the jackknife bias correction directly applied on the Cloude-Pottier parameters lead to better bias reduction. [C299]

## "New polarimetric calibration proposal and its evaluation using ALOS PALSAR calibration campaign measurements"

We propose new polarimetric calibration algorithms using two reference targets: a polarization-preserving reflector and a polarization rotating one. In this method, iteration procedure is adopted for accuracy improvement in deriving transfer matrices of radar transmitting and receiving antennas, FR(Faraday rotation) matrix and actual scattering matrix of observed target. Availability of this method was evaluated by measured results obtained in calibration campaign of PALSAR(phased array type L-band synthetic aperture radar) boarded on ALOS(advanced land observing satellite). It is proved that the proposed method can derive each matrix component separately. [C300]

## "Validation of a backscatter model of a river ice covers using Radarsat-1 images"

Simultaneous microwave radar data and measurements field at some study sites on river ice were collected over the Athabasca River during winter 2006. These data will be employed to validate an electromagnetic model developed to simulate the backscatter of river ice cover. This model is based on radiative transfer theory which is solved by doubling matrix methods". This numerical method accounts for scattering effects due to the volume, boundaries, boundary-volume interactions and coupling between layers. Three ice types were formed on this river (columnar ice, snow ice and frazil ice). The measurements collected from the extracted ice cores included the ice thickness, ice type, ice densities, and size and form of the scatters embedded in the ice cover. These measurements will be used as inputs data for the model developed to its validation with the Radarsat-1 images and to understand the interaction of radar signal with the different ice types formed on the river. [C301]

## "Multibaseline POL-InSAR analysis of urban scenes for 3D modeling and physical feature retrieval at L-band"

This paper generalizes a multibaseline interferometric SAR signal model taking polarization diversity into account. Based on this formulation, two high-performance spectral analysis techniques are extended to the multibaseline POL-InSAR configuration. These new algorithms enhance the height estimation of scatterers by calculating optimal polarization combinations and allow to determine their physical characteristics. Applying the methods to urban scenes, experimental results show the retrieval of building height and polarimetric properties by means of single-baseline polarimetric datasets. Dual-baseline observations permit the solution of the layover problem by separating two contributions within one resolution cell. The algorithms are tested using multibaseline Pol-InSAR data acquired by DLR's E-SAR system over Dresden city. [C302]

## "A multi-scattering and multi-layer snow model and its validation"

Microwave scattering from snow is difficult to model due to the complexity and heterogeneity of natural snow. In this paper, we developed a multi-layer, multi-scattering model based on recent theoretical advances in snow and surface modeling. In the proposed multi-layer model, Matrix Doubling method is used to account for scattering from each snow layer; and Advanced Integral Equation Model (AIEM) is incorporated into the model to describe surface scattering. Comparisons were made between the model predictions and field observations from truck-mounted L- and Ku-band scatterometers (frequencies are 1.25 GHz and 15.5 GHz) at Local-Scale Observation Site (LSOS) of NASA Cold- land Processes Field Experiment (CLPX) during Third Intensive Observation Period (IOP3). It was found that model predictions were in good agreement with field observations with proper particle size selected. Analysis on scatterer shape, multiple scattering and snow stratification effects were also made based on model simulations. [C303]

## "Stochastic models of SLC HR SAR images"

The paper presents two algorithms for texture primitive feature extraction on Single Look Complex (SLC) and Polarimetric Synthetic Aperture Radar (PolSAR) SLC data. We assume the data to be modeled by a Gauss-Markov Random Field (GMRF): a complex GMRF model for characterizing the spatial correlation in SLC data and an extension of the model for inter-band correlation characterization. The complex GMRF characterizes the spatial relationship of a two-dimensional complex signal, i.e. SLC SAR data. The extended model characterizes the spatial interaction and the inter-band pixels correlation between the polarimetric complex channels. The Bayesian approach permits to deal with model fitting and selection in a direct way. The results are presented on a polarimetric E-SAR L band scene of Mannheim, Germany. [C304]

## "Multi-look polar decomposition of polarimetric SAR images"

This paper focuses an the multi-look polar decomposition of SAR images. Standard polar decomposition is generally used in single look polarimetry to decompose a bi-static or mono-static polarimetric scattering matrix into a product of an Hermitian matrix (boost) and a unitary matrix (rotation). An extension of this use in the framework of multi-looked polarimetry is proposed here. This new approach consists in decomposing the scattering matrix into boost and rotation components before vectorisation, then in averaging to generate boost and rotation coherency matrices separately, with new inferred parameters; the boost and rotation entropies, and concurrent dominant scattering mechanisms (alpha boost and alpha rotation). Tins multi-look extension of polar decomposition may allow for the definition of a new classification strategy for remote sensing data. [C305]

## "The dependence of polarimetric decomposition parameters on biophysical forest parameters, frequency and methodology"

The increasing availability of fully polarimetric SAR data provides a large potential for the assessment of biophysical forest parameters. Aiming at an inversion of polarimetric parameters into forest parameters, this study shows the sensitivity of polarimetric decomposition theorems (Pauli- and H-Ialpha decompositions) to biophysical forest parameters, especially forest density. Effects of non-biophysical parameters on the estimation of decomposition parameters are also shown. The investigations were carried out on fully polarimetric data at L-band (1.3 GHz) and P-band (350 MHz) acquired in 2003 in a preAlpine region in Switzerland with the German E-SAR (Experimental SAR) platform. [C306]

## "Waveform coding for dual polarization weather radars"

Polarimetric variables are an essential part of algorithms for improved rainfall rate estimation, attenuation correction and hydrometeor identification. In such systems the transmit polarization state changes according to some fixed pattern that is repeated. The simultaneous mode and alternating mode waveforms are commonly used in weather radars. In the simultaneous mode of operation the horizontal and vertical polarization states are transmitted simultaneously and samples of both horizontal and vertical co-polar return are obtained A drawback of the current implementation of simultaneous mode is its inability to measure cross-polar parameters such as linear depolarization ratio. In this paper a technique to estimate cross- polar signals with a simultaneous mode waveform is presented. In this method, the horizontally and vertically polarized transmit waveforms are coded with orthogonal phase sequences. The performance of the phase coded waveform is determined by the properties of the phase codes. This paper presents the performance of the cross-polar and co-polar parameter estimation based on the simulation as well as data collected from CSU- CHILL radar. [C307]

## "The use of multidimensional copulas to describe amplitude distribution of polarimetric SAR data"

The paper focuses on a flexible model of multidimensional probability density function (pdf) dedicated to describe amplitude distribution of polarimetric SAR data. The model is based on the copula theory for characterizing the dependency between polarimetric channels (HH, VV, HV/VH or the target vector components). The benefit in using copula theory is to extend correlation concept to a wider dependence one, which may not be linear. From this point of view, the model is more flexible than the classical Wishart distribution. But it may include it. The other benefit in using the copula model is to separate the dependence concept from the shape of the marginal pdfs. Hence, this multidimensional characterization may be linked to classical 1D gamma pdf, or to a more flexible Pearson system of distributions. In the case of high resolution data, pdf shapes are becoming of heavy tailed and the Fisher system of distributions seems to be an interesting alternative for such a model. Any parametric 1D model may be used. The paper mainly focuses on the model itself and more precisely on the technique required to construct such multidimensional dependence function. The difficulties arise for copula on 3D in which the dependency is not homogeneous between the components (the link between HH and VV may not be of the same behavior as the one between HH and HV). Illustrations are given on classification and despeckling. Classification will be performed by a stochastic estimation maximisation (SEM). Despeckling will be achieved by a maximum A posteriori technique. [C308]

## "Need for developing repeat-pass differential POLSAR interferometry"

Radar Polarimetry, Radar Interferometry and Polarimetric SAR Interferometry represent the current culmination in active 'Microwave Remote Sensing' technology, but we still need to progress very considerably in order to reach the limits of physical realizability. Whereas with radar polarimetry the textural fine-structure, target orientation, symmetries and material constituents can be recovered with considerable improvement above that of standard 'amplitude-only' radar; by implementing 'radar interferometry' the spatial (in depth) structure can be explored. With Polarimetric Interferometric Synthetic Aperture Radar (POL-IN-SAR) imaging, it is possible to recover such co-registered textural and spatial information from POL-IN-SAR digital image data sets simultaneously, including the extraction of Digital Elevation Maps (DEM) from either Polarimetric (scattering matrix) or Interferometric (dual antenna) SAR systems. Simultaneous Polarimetric-plus- Interferometric SAR Imaging offers the additional benefit of obtaining co-registered textural-plus-spatial three-dimensional POL-IN-DEM information, which when applied to Repeat-Pass Image-Overlay Interferometry provides differential background validation and environmental stress-change information with highly improved accuracy. However, hitherto only single-polarization-channel repeat-pass IN-SAR was developed and considered; and therefore the aim of this paper is to scrutinize and determine why and for what specific problems fully polarimetric differential RP-POL-IN-SAR imaging is required. [C309]

## "Coherent lidar modulated with frequency stepped pulse trains for unambiguous high duty cycle range and velocity sensing in the atmosphere"

Range unambiguous high duty cycle coherent lidars can be constructed based on frequency stepped pulse train

modulation, even continuously emitting systems could be envisioned. Such systems are suitable for velocity sensing of dispersed targets, like the atmosphere, at fast acquisition rates. The lightwave synthesized frequency sweeper is a suitable generator yielding fast pulse repetition rates and stable equidistant frequency steps. Theoretical range resolution profiles of modulated lidars are presented. [C310]

## "Polar Decomposition and Polarimetric SAR Analysis: A Quaternion Approach"

We assess here the use of polar decomposition in SAR polarimetry, based on the quaternion formalism. Quaternions are helpful to obtain compact and original expressions of polar decomposition parameters, with straightforward extensions in bi-static polarimetry. Once the formalism of quaternions has been presented, both coherent and incoherent polarimetry approaches are discussed in this joint framework of polar decomposition and quaternions. Preliminary tests and comparisons with Cloude-Pottier parameters are conducted on ONERA/Ramses SAR data takes. [C311]

## "Consideration of the Correlation between Beta-angle and Lineament Patterns by Using Polarimetric SAR Images"

This paper describes the relationship between a polarimetric parameter, the beta-angle, and the lineament features based on the eigenvalues and eigenvectors of the coherency matrix of the polarimetric SAR (POLSAR) data. First, coherency matrix was calculated from the Pauli vector of the POLSAR image set. Then, eigenvalues and corresponding eigenvectors of the coherency matrix were calculated. Subsequently, beta-angle, derived from the eigenvalue and the corresponding eigenvectors. However, the beta-angle has the potential to represent the orientation of the scatterer about the radar line of sight. In addition, alpha-angle has been obtained using the same eigenvector above. We validate them using fully polarimetric L-band SAR data. The relationship between these two angles is also discussed, and a two-dimensional feature space is constructed (beta-alpha space). We then show initial results of applying the beta-alpha space to the Japanese airborne polarimetric and interferometric SAR (Pi-SAR) to extract features of lineaments as one of the geological features of the land surface. The results demonstrate that the effectiveness of the proposed extraction algorithm. [C312]

## "Polarimetric Covariance Matrix Least Squares Estimation for Weather Radar Applications"

First Page of the Article [C313]

## "Speckle Filtering of PolSAR and PolInSAR Images using Trace-based Partial Differential Equations"

First Page of the Article [C314]

## "Estimation of Built-up Area Characteristics from Polarimetric Interferometric Multiple Track L-Band SAR Data"

First Page of the Article [C315]

## "Determination of SAR System Parameters Constraints from a Soil Moisture Retrieval Scheme"

First Page of the Article [C316]

## "Single-Snapshot Beamformer Performance using Large Arrays with Faulty Sensors"

Large sensor arrays are prone to element failures which can seriously degrade their performance. In the event of sensor failures, conventional non-adaptive re-design of array weights for the resulting non-uniform or even sparse array often leads to undesirable mainlobe-versus-sidelobe level trade-offs. Alternatively, adaptive array processing techniques can be employed but for large arrays it can be compromised by lack of snapshot support in dynamic environments. Recently, an approach called beamspace adaptive channel compensation (BACC) was introduced based on the idea of reconstructing the filled array data from the receive beams in which the sidelobe leakage of strong interferers from adjacent beams is minimized. In this paper, BACC and various alternatives are evaluated using actual radar data with both injected and real scatterers. Results of four methods, BACC, MV adaptive beamforming using an augmented Toeplitz covariance matrix (Toeplitz-MV), principal solution beamforming, and conventional beamforming in the presence of faulty sensors are compared in terms of ROC performance, probability of detection versus SINR, and the unmasking of targets in estimated range-Doppler spectra [C317]

## "Radar Waveform Design using Minimum Mean-Square Error and Mutual Information"

This paper addresses the problem of radar waveform design for target identification and classification. Both the ordinary radar with a single transmitter and receiver and the recently proposed multiple-input multiple-output (MIMO) radar are considered. A random target impulse response is used to model the scattering characteristics of the extended (nonpoint) target, and two radar waveform design problems with constraints on waveform power have been investigated. The first one is to design waveforms that maximize the conditional mutual information (MI) between the random target impulse response and the reflected waveforms given the knowledge of transmitted waveforms. The second one is to find transmitted waveforms that minimize the mean-square error (MSE) in estimating the target impulse response. Our analysis indicates that under the same total power constraint, these two criteria lead to the same solution for a matrix which specifies the essential part of the optimum waveform design. The solution employs water-filling to allocate the limited power appropriately. We also present an asymptotic formulation which requires less knowledge of the statistical model of the target [C318]

## "Spatially Variant Restoration for Polarimetric Synthetic Aperture Radar Imagery"

A. spatially variant speckle filter is proposed for multi-look polarimetric synthetic aperture radar (POLSAR) imagery. The central idea is that the filtering is applied only to homogeneous areas based on the scattering properties, while for detected edges, lines and point-like textural features, the original complex covariance matrix of these features is restored in order to preserve the actual features. The capabilities of the proposed filter were examined using nine-look NASA/JPL POLSAR C-band data. Based on the obtained results, the proposed filter showed a promising performance in speckle removal and radiometric preservation. Moreover, the point-like textural features as well as structural features (i.e. edges and lines) were well-retained in the filtered outputs. [C319]

## "Comparison of PolSAR Speckle Filtering Techniques"

The objective of this paper is to compare the most widely used and the most recent speckle polarimetric synthetic aperture radar (PolSAR) filters. Two new conceptual approaches in PolSAR filtering are evaluated on simulated PolSAR images. The criteria of comparison includes indicator of speckle reduction capability, edge sharpness and preservation of scattering properties. Results indicate better performances with the partial differential equation (PDE) -based filters. [C320]

## "Resonance behavior of a dielectric target in a half-space using the CNR (complex natural resonance) method"

The primary objective of this research work is to detect and identify a dielectric target buried below a homogeneous half-space from the backscattered time domain signature. It is well known that the transient scattering of electromagnetic waves from a conducting or dielectric target contains information about the resonance behavior of the target itself as quantified by the complex poles or complex natural resonances (CNR) of the target. This paper describes an approach to model the impulse response of a dielectric target in a half-space using a time domain deconvolution technique. A finite difference time domain code is used to calculate the time domain responses. A singular value decomposition algorithm is used to estimate the impulse response of target and a robust algorithm such as matrix pencil of functions (MPOF) algorithm is used to calculate the CNR's of the scatterer. The extracted poles are compared with the poles scattered by the target in free space [C321]

## "RCS frequency response of printed-circuit-boards in a GTEM cell using the method of moments"

First Page of the Article [C322]

## "An Optimal Baseline Design and Performance Analysis in Distributed Spaceborne SAR System"

This paper discusses the capability of distributed spaceborne SAR, and presents a novel honeycomb configuration of satellite constellations with 6 micro-satellites. And a further analysis of five functional models about this configuration is done. The reliability determination test shows dependability in different working status of this 6-satellite system. Basing on the performance of this constellation, the optional baseline design was given. Furthermore, the relationship between multi-baseline and the range resolution, the accuracy of height measurement, the velocity accuracy, etc, are discussed. Then some simulations were accomplished to analysis the effects of the height measurement error, the accuracy of velocity and the flat land effect. It demonstrated that 6 micro satellites SAR system with the optimal baseline performs perfectly [C323]

## "Fast analysis of FSS radome for antenna RCS reduction"

This work presents a method for the analysis of large frequency selective radomes relying on the combination of a high frequency approach, based on a locally planar approximation, and the PRM method for an efficient characterization of the planar selective structure. The proposed approach combines efficiency and conceptual simplicity with a reasonable accuracy, thus providing a tool for a fast analysis of antennas enclosed by large arbitrarily shaped frequency selective radomes [C324]

## "Polarimetric Characteristics of Radar Echoes from the Sea Surface as a Function of Incidence Angle"

This paper presents some initial results of polarimetric radar measurements made over a range of look-down angles using the DSTO high resolution multi-band radar. Specifically, X-band polarimetric measurements of the sea were made from 95 m high cliffs along the Great Australian Bight, for look-down angles of 3deg, 4deg, 5deg, 10deg, 15deg, 20deg, 25deg and 30deg. The analysis is addressing scattering matrix element statistics, entropy-alpha space distributions and correlation with visible spectrum imagery. [C325]

## "An Effective Deconvolution Algorithm for Time-Domain Near-Field ISAR Imaging"

In this paper, we present a deconvolution algorithm for time-domain near-field ISAR imaging. Due to its impulse-like waveform, the backscattering waveform from an electrically large conducting sphere is adopted as the system response to restore the impulse response, and to reconstruct the images. The deconvolution is discretized into a matrix equation, and the least-squares solution is implemented by the conjugate gradient method. Furthermore, the Coifman wavelet (Coiflets) of the 6th order is employed to replace the system function of the 1st and 3rd derivatives of a Gaussian function. The resulting images are clean with most smearing removed. Owing to the orthogonality and compact support of the Coiflets, the deconvolution process is accelerated 22 times without sacrificing the image quality [C326]

## "The application of the iterative near-zone preconditioning method to accelerate multilevel fast multipole method"

In this paper, the iterative near-zone preconditioning method with MLFMM technique is introduced for the iterative solution of CFIE formulations. The preconditioner is derived from the strongest matrix elements of the coupling matrix and its iteration avoids the typical fill-in problem associated with direct factorization methods. It is found that the iterative near-zone preconditioning method can considerably speed up the convergence for the CFIE system. In the future, the more suitable preconditioning technique is proposed to accelerate their convergence [C327]

## "Building Extraction Using C Band Pol-SAR Image"

This paper introduces a method for building location information extraction using airborne C-band polarimetric SAR data. The method is based on the analysis of building feature. The method decomposes the scattering covariance matrix into three simple mechanism, i.e., odd-bounce; even-bounce; cross-bounce. Taking into account that the typical strong T-shaped echoes from quite large buildings are visible, a method is introduced to extract the location of the buildings. [C328]

## "Two Novel Polarimetric Indices and Their Application on the Target Enhancement in POLSAR Images"

In this paper we introduce two new parameters for polarimetric SAR (POLSAR) images. For this purpose, the eigenvalues and corresponding eigenvectors of the coherence matrix is calculated. It can be assumed that there are different land cover features, and they are represented by different or slightly different coherence matrix so that eigenvalues and corresponding eigenvectors. However, the condition number and perturbation in the solution of the coherence matrix are calculated for each pixel in the POLSAR image. The results indicate that different scatterer properties so that the scattering mechanisms could be represented with these parameters. [C329]

## "A New Unified Approach to Channel Imbalance and Cross-Talk Calibration of Polarimetric Data"

A new unified approach to channel imbalance and cross-talk calibration of polarimetric data is described. This approach is applied during the SAR image formation, employing the multilook SAR processing technique and the covariance matrix of observed data. This method makes no assumptions about the reciprocity of the distortion model and noise system, and about the presence of dominating target with azimuthal symmetry. The standard linear and nonreciprocal distortion model for the received signal is assumed for each polarimetric image obtained

from three looks without overlapping. This leads to a set of equations that relate the observed covariance matrix and the distortion system parameters. The non-linear solution of the calibration parameters is solved by iterative approach based on numerical methods. Fully polarimetric SAR L-band data, acquired by CENSIPAM Airborne R99-SAR on the Tapajos Forest (Brazilian Amazon), was used to evaluate the method as well the polarization signature response of some trihedral corner reflectors deployed in the area. [C330]

## "Assessing Vegetation Scattering Mechanisms of L-band AIRSAR Data on Sloping Forest Area"

In this paper an improvement of radiative transfer models that accounts for the depolarizing ground scattering and tilted scattering surface is presented to model vegetation scattering mechanisms. This study is implemented with the real L-band NASA (JPL) AIRSAR data in Jeju volcanic island. The vegetation scattering model in sloping surface is adequate to assess slight changes in microwave scattering mechanisms and to interpret the physical characteristics of eigen-parameters of the coherency matrix in sloping vegetated area. [C331]

## "The Application of Polarimetric Calibration using Polarimetric Scattering Characteristics of Urban Areas to ALOS PALSAR"

This paper discusses an ambiguity resolution of polarimetric calibration parameter. Since ALOS was successfully launched on January 24, 2006, the utilization of polarimetric data observed by PALSAR is expected for various remote sensing applications. Thus, polarimetric calibration becomes important issue. However, there is a possibility that calibration algorithm has a 180deg sign ambiguity with respect to cross-polarized components of a calibrated scattering matrix. The reason is that two polarimetric calibration parameter sets are derived. On the other hand, we found that a 180deg phase shift of cross-polarized component occurred due to the change of an angle between a direction parallel to a building wall and a radar line of sight in azimuth plane. Thus, we examined that this scattering property was applied for selecting a correct polarimetric calibration parameter set. The experimental result shows that urban structures can be used for polarimetric calibration. [C332]

## "Electromagnetic Scattering from Multilayer Rough Surfaces Separated by Arbitrary Dielectric Profiles"

Radar remote sensing of soil moisture content at low frequencies requires an accurate scattering model of realistic soils, which often involves multilayer rough surfaces and inhomogeneous dielectric profiles. In this paper, a hybrid analytical/numerical solution to two- dimensional scattering from multilayer rough surfaces separated by arbitrary dielectric profiles based on the extended boundary condition method (EBCM) and scattering matrix technique is presented. The reflection and transmission matrices of a rough interface are constructed using EBCM. The inhomogeneous dielectric profile is modeled as a stack of piecewise homogeneous dielectric thin layers. The scattering matrices of an inhomogeneous dielectric profile are computed by recursively cascading reflection and transmission matrices of individual dielectric interfaces from the bottom dielectric interface to the top interface. The interactions between the rough interfaces and the inhomogeneous dielectric profile are taken into account by applying the generalized scattering matrix technique, hi numerical simulations, the actual field-collected soil moisture data are used, hi particular, the dielectric profiles during both dry and wet ground conditions are examined. The numerical simulations are performed to investigate both bistatic scattering coefficients and copolarized phase difference due to different subsurface roughness parameters and ground conditions. Simulation results show that the bistatic scattering coefficients at low frequencies are sensitive to subsurface roughness parameters and copolarized phase difference strongly depends on soil moisture contents. [C333]

## "Polarimetric SAR Detection of Man-Made Structures Using Normalized Circular-pol Correlation Coefficients"

Polarimetric synthetic aperture radar (SAR) backscatter from man-made structures is often quite different than scatter from predominantly natural areas. Backscatter from natural areas is often characterized by near zero values for linear-basis covariance matrix off- diagonal terms of the form <SHVS*HH> and <SHVS*VV>. A new approach is proposed to detect man-made structures using circular-pol RR-LL correlation coefficients. This method uses a normalization term, which enhances the return from man-made structures and eliminates most of the unnecessary details of the backscatter from natural areas. [C334]

## "Efficient Method for Obtaining Derivatives of Current Vector for AWE Techniques"

In this paper, the improved asymptotic waveform evaluation (AWE) are outlined as the efficient, based on method-of-moments, technique for obtaining broad-band response of the radiators/scatterers. The proposed approach allows to make conventional AWE techniques more effective with respect to time of analysis and

memory requirements. The technique consists in fast algorithm for evaluation of impedance matrix derivatives and current vector derivatives, i.e. the most important elements for AWE technique. [C335]

## "A New Approach for Polarimetric Calibration"

This paper presents a new calibration approach for polarimetric SAR using distributed targets with known scattering matrixes. A genetic algorithm based on complex-valued encoding is used to solve the polarimetric calibration problem, which has multiple variables and over-determined non-linear equations. This paper also describes the genetic algorithm in detail, and validates the algorithm by simulations. [C336]

## "Decomposition of a Partially Depolarizing Kennaugh Matrix into Sum of Two Nondepolarizing Matrices"

Consideration of the simplest model of the partially depolarizing rain leads to the partially depolarizing Kennaugh symmetric matrix of the monostatic scattering which can be decomposed into two nondepolarizing matrices. [C337]

## "An Adaptive Polarimetric SAR Speckle Filtering Algorithm Based on Unsupervised Classification"

In this paper, a new approach is proposed for speckle reduction in full polarimetric SAR images. Being different from others, it adopts an enhanced unsupervised classification method to estimate the parameters of the speckle filter and thus an adaptive moving window is formed to better speckle reduction and preservation of texture information. . Experimental results demonstrate the effectiveness of this new filtering algorithm. Comparisons with other methods are also made. [C338]

## "A New Numerical Method for Zakharov-Shabat'S Inverse Scattering Problem Solution"

A numerical aspect of inverse scattering problem solution for plane wave normal incidence on an absorbing medium is considered in the paper. The electromagnetic field equations are reduced to the Zakharov-Shabat's one. A new numerical scheme is developed taking into account peculiarities of the integral equation method for this inverse scattering problem solution. The proposed method has a high accuracy and what is more, it requires neither time consumed iterative approximation nor direct matrix inversion. [C339]

## "Comparison of Theoretically Simulated and Experimental Scattering Matrix Parameters in a Five Port Transmission Line Frequency Multiplexer for Solid State Nuclear Magnetic Resonance Techniques"

Radio frequency (abbr.: RF) techniques constitute a very useful tool in studies on biologic and chemical systems, therefore it is employed in Nuclear Magnetic Resonance (abbr.: NMR) techniques. In order to make use of it, there is a need of designing and modelling of NMR probes. These NMR probes exemplify single-or multi-port radio frequency multiplexers. The NMR probe undergoing analysis is comprised of an impedance tuned and matched coaxial transmission line network terminated with a single sample coil, and multiple RF input-output connections adapted to 50 Ohm standard by means of tuning and matching capacitors. The comparison of scattering matrix elements S(i,i) (reflection coefficients) of both theoretically simulated and constructed a five channel transmission line frequency multiplexer probe of J.Schaefer & R.McKay type is presented. The S-matrix transmission coefficients: S(i,j), ine j, are presented for a "real" multiplexer only, due to the importance of the real NMR probe performance. So called calibration spectra obtained with the multiplexer probe are shown as well. [C340]

## "TLM Modelling of Electromagnetic Structures Using Static Sub-Griddings"

In transmission line matrix modelling the space discretization of the electromagnetic structures is related to the wavelength. Usually it is assumed that the spatial discretization interval should not be larger than 5 percent of the shortest wavelength occurring in the signal spectrum. However, if the electromagnetic structure exhibits fine details, strong field variations may occur within much smaller spatial distances. However, within this short distances the field variations are determined by the electrostatic and magnetostatic field solutions. Therefore the computational effort may be reduced considerably by introducing a static sub-gridding. In this case, with the static sub-grid, the electrostatic and magnetostatic field solutions are computed and are used to compute correction factors for the larger cells used in the TLM electrodynamic simulation. The method is applied to a MS-stub on a Silicon on Insulator wafer in the frequency range of 90 to 140 GHz. Simulation results are compared with measurements. [C341]

## "Passive Spice Networks from Non-Passive Data"

A new approach to passive SPICE network construction from disturbed and/or non-passive scattering parameters of general multiport device is presented. The passivity of the macromodel is restored using a mini-max optimization procedure with a goal function based on eigenvalues of Hamiltonian matrix of macromodel and nonlinear constrains. To illustrate its usefulness, the technique is applied to enforce passivity of multivariate surrogate models. The surrogates with passivity enforcement may become a powerful tool dedicated to design and optimization of RFIC devices, mixed digital-analog circuits and signal integrity analysis. [C342]

## "A New Method for Array Pattern Correction"

Mutual coupling causes in small antenna arrays distorted and correlated element patterns. To have more identical and ideal element patterns the array can be corrected computationally with a correction matrix. For microstrip arrays a new method to find a reference plane for pattern correction which uses the measured scattering matrix is presented. The method determines an optimum reference plane for which the imaginary part of the mean pattern correlation has a minimum. The computation is completed over a frequency band. The method is evaluated using several microstrip arrays with element spacings 0.3lambda ... 0.9lambda. [C343]

## "Alternative Decompositions of the Partially Depolarizing Symmetric Kennaugh Matrix into Two Nondepolarizing Constituents"

The simplest model of rain backscatterer considered as the incoherent couple of point scatterers of equal effective crossection has been described elsewhere [1]. Here, two other decompositions of the partially depolarizing Kennaugh matrix are presented: into two mutually orthogonal matrices, or matrices producing cross- and co-polarized returns when incident polarization has been chosen for minimum total received power. [C344]

## "Characteristics of Lumped Element Branch Line Couplers"

Lumped element orthogonal couplers are analyzed using the eigenvalue approach. A wide range of different designs is compared and tabulated. Parallel branch and series branch circuits are shown to fall into four classes with different output phase characteristics. Within each class, three different kinds of amplitude behavior exist. Experimental results are given as examples and compared with theory. The eigenvalue approach is also helpful in the explanation of the measurements. Special features in the application of the couplers are discussed and "orthogonal baluns" are suggested as special cases of some of the series branch couplers. [C345]

## "Experimental Investigations of Ferrite Phase Shifter Magnetized with Rotary Four-Pole Magnetic Fields"

The practical ferrite rotary field phase changer is designed and fabricated for low frequency by using a composite ferrite dielectric rod that allows to reduce diameter of a circular waveguide of phase shift section. Experimental results at 1.3 GHz agree well with ones predicted theoretically confirming the developed design procedure. [C346]

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

In this paper we propose decision schemes to distinguish between the H0hypothesis that range cells under test contain disturbance only (i.e., noise plus interference) and the H1hypothesis that they also contain signal components along a direction which is a priori unknown, but constrained to belong to a given subspace (H) of the observables. The disturbance is modeled in terms of complex normal noise vectors plus deterministic interference assumed to belong to a known subspace (J) of the observables. At the design stage we resort to either the plain generalized likelihood ratio test (GLRT) or the two-step GLRT-based design procedure. Moreover, we assume that a set of noise only (secondary) data is available. A preliminary performance analysis, conducted by resorting to simulated data, shows that the one-step GLRT performs better than the two-step GLRT-based design procedure [C347]

## "Higher order clutter mitigation in bistatic space-based radar systems using a knowledge-aided STAP approach"

Bistatic space-based radar (SBR) systems offer several advantages for performing wide area ground moving target indication (GMTI) surveillance. However, in bistatic systems there is inherent non-stationarity of the clutter covariance matrix due to the bistatic geometry. This non-stationarity presents challenges for performing space-time adaptive processing (STAP) to separate ground targets from the clutter returns. Various approaches for mitigating the clutter non-stationarity in bistatic systems have been presented in the literature by different

authors. In realistic bistatic SBR GMTI scenarios, there are higher order effects, in addition to the first order effect of ground clutter non-stationarity, that can present significant additional challenges for performing STAP. [C348]

## "Resonance effects in electromagnetic propagation using a modified J.W.K.B. approach"

We consider the propagation of electromagnetic waves through a medium of arbitrarily varying density that can give rise to evanescent behavior. We solve the Helmholtz equation using a phase integral approximation and show that this leads to the J.W.K.B. method. However, the conventional J.W.K.B. approach for the transmission of electromagnetic waves deals with evanescent characteristics only and does not consider the medium beyond the turning points or caustics that give rise to resonance/interference effects. By the use of two-dimensional matrix propagators, we modify the conventional J.W.K.B. formulation to include a correction term that allows us to calculate all regions of interest. The modified J.W.K.B. method we present is used to calculate the transmission probability (τ) and reflection probability (ρ) exactly and without the need to use the 'connectivity' property of the waves across the turning points which can otherwise give rise to singularities in the solutions. [C349]

## "Multifrequency Full Polarimetric SAR Classification with Multiple Sources of Statistical Evidence"

First Page of the Article [C350]

## "Cramer-Rao Bound Analysis on Multiple Scattering in Multistatic Point Scatterer Estimation"

The resolution improvements of time reversal methods through exploiting nonhomogeneous media have attracted much interest recently with broad applications, including the destruction of kidney stones, underwater acoustics, radar, detection of defects in metals, communications, and mine detection. In this paper, we analyze the effect of inhomogeneity generated by multiple scattering among point scatterers under a multistatic sensing setup. We derive the Cramer-Rao bounds (CRBs) on parameters of the scatterers and compare the CRBs for multiple scattering using the Foldy-Lax model with the reference case without multiple scattering using the Born approximation. We find that multiple scattering could significantly improve the estimation performance of the system. For the case where multiple scattering is not possible, e.g., where only a single target scatterer exists in the illuminated scenario, we propose the use of artificial scatterers, which could effectively improve the estimation performance of the target despite a decrease in the degrees of freedom of the estimation problem due to the introduced unknown parameters of the artificial scatterers. Numerical examples demonstrate the advantage of the artificial scatterer [C351]

## "Performance Analysis of 1D Scattering Center Extraction From Wideband Radar Measurements"

Performance bounds on the estimates of position, intensity and geometry parameter of scattering centers based on wideband radar measurements are presented in analytic forms. The resolution limit for wideband radar and the SNR threshold for identifying scatterer's geometry are further deduced. Though the results are obtained from the Cramer-Rao bound (CRB) matrix for damped exponentials (DE) after simplification, their validity and adaptability for geometric theory of diffraction (GTD) based scattering data have been verified by simulations [C352]

## "Fast monostatic RCS computation in FEM based solvers using QR decomposition"

A technique to reduce computational time in problems involving monostatic RCS computation using the finite element method is presented. In scattering problems, the excitation vectors for different angle of incidence are highly linearly dependent. Using this fact, the excitation matrix assembled over all incident angles can be approximated with a specified tolerance by QR decomposition with column rank that is much less than the number of incident angles of interest. The number of matrix solutions required is reduced to the effective column rank, resulting in significant reduction in computational time. Numerical examples highlighting the effectiveness of the proposed acceleration technique is presented. [C353]

## "Reduced Rank Fast-time STAP using the Multistage Wiener Filter in Multichannel SAR"

Large regions of a synthetic aperture radar (SAR) image can potentially be destroyed by an airborne broadband jammer. Jammer components include both the direct-path and multipath reflections from the ground, known as hot-clutter (HC) or terrain scattered interference. Using multiple antennas on a SAR provides spatial degrees of freedom and allows for beamforming to partially reject the interference components. Previous studies have shown that derivative constraints when combined with fast-time taps can provide improved HC suppression while maintaining a reasonable SAR image. This approach however requires an expensive matrix inverse and may not

be implementable in real time. This paper therefore presents a fast-time space time adaptive processing (STAP) algorithm using a constrained multistage Wiener filter (MWF). [C354]

## "A review and significance of bases used in polarimetric equations and different forms of change of basis matrices"

Precise bases are very important in presentation of polarimetric quantities. Several different kinds of bases are in use. The paper lists and defines those bases, justifies their use and presents the change of basis equations. [C355]

## "Classifying dielectric mine-like objects using the Huynen-Fork polarization parameters"

We present a polarimetric approach that can be used to characterize subsurface targets by means of ground-penetrating radar. Several quantities related to the Huynen-Fork parameters are basic to the study. These quantities are all expressible in terms of the elements of Sinclair matrix S, which in turn, can be determined as functions of frequency by an application of the method-of-moment (MoM). The method is applied to a mine-like object buried at various depths in a soil of specified dielectric and moisture properties. The quantities in question are the Stokes parameters, the elevation, azimuth, and polarizability angles, as well as the polarization ratios and the scattering eigenvalues which optimize the backscattered power. Some of these quantities are studied here and displayed in various graphs. These frequency dependent graphs exhibit useful symmetry properties. The plots of the polarizability angle (β) vs. frequency seem to remain invariant with target depth, and exhibit resonance features that are later shown to agree well with other standard methods to estimate resonances such as Prony method. A simple analysis of the early-time resonances thus estimated is used to obtain acceptable mine dimensions. The agreement found implies that polarimetric techniques, such as present one, can also be used in the arsenal of techniques yielding target-ID clues. [C356]

## "An approximation for bistatic scattering matrix of a target above a ground plane"

The paper derives a high-frequency approximation for the scattering matrix of a target placed above an infinite ground plane which can be either perfectly electrically conducting (p.e.c.) or non-metallic. The approximation accounts for electromagnetic interactions between the target and the ground plane, which involves a single reflection from the target and up to two reflections from the ground. It provides the correction for amplitude, phase, and polarization of the scattered signal for both mono- and bistatic configurations. The approximation is validated by application to a test configuration (a p.e.c. sphere over a dielectric half space), for which independent results obtained with the Method of Moments are available. [C357]

## "Fast and accurate modelling of large plane array antenna"

This paper presents a new way of modelling very large planar array antennas included in tridimensional structure. The aim is to match a rigorous method to a Floquet mode expansion. The first method is in fact a multi domain one (a domain decomposition method) based on electrical field integral equation -EFIE- and partial differential equation -FEM-. It describes electromagnetic behaviour of a single radiating element of the array. The description requires the use of generalised scattering matrices. Fields in radiation space are expressed by an Floquet modes combination with usual hypothesis. The array's environment is finally taken into account by asymptotic methods (PO and PTD) or rigorous method (EFIE). The accuracy and efficiency of our technique is illustrated by RCS diagram of a patch antenna placed in a canonical metallic box. [C358]

## "Monte Carlo Evaluation of Multi-Look Effect on Entropy/Alpha /Anisotropy Parameters of Polarimetric Target Decomposition"

Entropy, alpha and anisotropy (H/alpha/A) of the polarimetric target decomposition of Cloude and Pettier has been an effective and popular tool for polarimetric SAR image analysis and geophysical parameter estimation. However, multi-look processing can severely affect the values of these parameters. In this paper, a Monte Carlo method is used to evaluate the multi- look effect on these parameters for various media of grass, forest and urban. The effect of pixel correlation due to over sampling, and the mixed pixel effects will also be investigated. DLR/E-SAR and JPL/AIRSAR L-band data are used in this study. [C359]

## "Joint Estimation of the Central Direction of Arrival and Angular Spread for Distributed Source Based on Beamspace Propagator"

Beamspace propagator method is suggested to estimate the central direction of arrival and angular spread for distributed source jointly. Especially for coherently distributed source, when the deterministic angular signal density is uniform, the nominal steering vector is deduced to subject to Vandermonde matrix. The proposed

method is a possible alternative to conventional propagator method to estimate the parameters for distributed source, which enhances estimate accuracy with lower computational complexity. Simulation results clearly demonstrate that the proposed method is not only effective, but also enjoys better SNR performance compared with conventional propagator method [C360]

## "An ESPRIT-like Algorithm for the Central DOA Estimation of Distributed Source"

In antenna array application, the propagation environment is often more complicated than the ordinarily assumed model of plane wavefronts. Here, an ESPRIT-like algorithm is suggested for estimating the central direction-of-arrival (DOA) of a source subject to local scattering, using a uniform linear array. The ESPRIT-like rotation matrix between the two subarrays is showed to exist based on the approximate closed form of the steering vector. So the DOA estimate can be obtained from the relationship between the two subarrays. The so-obtained DOA estimate does not depend on any assumption on the spatial distribution of the source and is hence robust to mismodeling. Simulations clearly demonstrate that the proposed method is not only effective, but also increases estimation accuracy compared with TLS-ESPRIT based on Taylor series expansion and DSPE algorithm. [C361]

## "On Bayesian Tracking of Extended Objects"

In tracking and sensor data fusion targets of interest are usually considered as point source objects; i.e. compared to the sensor resolution their extension is neglected. Due to the increasing resolution capabilities of modern sensors, however, this assumption is often no longer valid: different scattering centers of an object can cause distinct detections. Examples of extended targets are found in short-range applications (littoral surveillance, autonomous weapons, or robotics). As an extended target also a collectively moving, loosely structured group can be considered. This point of view is all the more appropriate, the smaller the mutual distances between the individual targets are. Due to the resulting data association and resolution conflicts any attempt of tracking the individual objects is no longer reasonable. With reference to simulated radar data produced by a partly resolvable aircraft formation a Bayesian solution to the resulting tracking problem is proposed. Ellipsoidal object extensions are modeled by random matrices and treated as additional state variables to be estimated or 'tracked'. We expect that the resulting tracking algorithms are relevant also for tracking large, collectively moving target swarms [C362]

## "Study on Ultra-wideband Scattering Characteristics of Targets Based on UPML-FDTD"

The ultra-wideband (UWB) scattering characteristics of targets are computed by the method of FDTD with unsplit-field perfectly matched layer (UPML) boundary condition. The scattering waveform and RCS of targets are presented. The computation results of sphere are compared with the Mie series solutions and both are accorded with well. It proves that the method is very efficient. The ultra-wideband scattering characteristics of targets are valuable to targets identification and stealthy technique [C363]

## "Robust Adaptive Beamforming Based on Generalized Sidelobe Cancellation"

If the desired signal is present in training snapshots, conventional adaptive beamformer is quite sensitive even to slight mismatches between the presumed and actual signal steering vectors (spatial signatures). Such mismatches can occur as a result of environmental nonstationarities, look direction errors, imperfect array calibration, distorted antenna shape, as well as distortions caused by near-far mismatch, source spreading, and local scattering. It induces signal cancellation in the traditional adaptive beamforming and severely degrades the beamforming performance. In this paper, we develop a new approach to robust GSC (generalized sidelobe cancellation)-based adaptive beamforming in the presence of an arbitrary unknown signal steering vector mismatch. The proposed method involves two steps: the first step is to use a nulling broadened blocking matrix to exclude the desired signal component from the auxiliary channels, and the second step is to obtain optimal weight by sidelobe cancellation method. Finally, simulation results demonstrate that the proposed structure can considerably enhance the overall performance. It has greatly improved robustness as compared with existing adaptive beamforming-algorithms, and enjoys simple implementation [C364]

## "Analysis on Rank of Channel Matrix for Monostatic MIMO Radar System"

Multiple-input multiple-output (MIMO) radar has shown its great potential on. combating with target fades by averaging the target RCSs on many decorrelated channels, and hence significantly improves the system performance. The amount of decorrelated channels is mathematically represented by the rank of channel matrix. In this paper, an analysis on the rank of channel matrix for monostatic MIMO radar is given. It is found that the rank can be approximated by the bandwidth-aperture product. The sufficient condition to obtain a full-rank channel matrix is presented. As well, the effect of array structure on the rank is investigated. Sequentially, some

suggestions are proposed to keep a large rank while using relatively small inter-sensor spacing. Finally, some simulations are given to verify the analysis [C365]

## "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 [C366]

## "On multivariate matrix Pade-type approximants"

Following naturally the same ways as Brezinski developed in the scalar case and Draux in the matrix scale, the author constructs a kind of generalized multivariate rectangular matrix Pade-type approximants on a rectangular grid, choosing an arbitrary monic bivariate polynomial as the generating one of the approximant, discusses their several typical important properties and studies the connection between generalized bivariate rectangular matrix Pade-type approximants and Pade approximants. The arguments given in detail in two variables can extend directly to the case of d variables (d>2) [C367]

## "DOA Estimation of Currents Based on Toeplitzization With HF Ground Wave Radar"

Echoes scattered from ocean waves with the same velocity of flow and in the same range bin are partially correlated in ocean current detection with HF ground wave radar, therefore decorrelation is needed before estimating the direction of arrival (DOA) of ocean currents by MUSIC method. In this paper the conventional MUSIC method is modified by performing a Toeplitzization on the array covariance matrix before implementing MUSIC method. Theoretical analysis and simulation show that this process can reduce the correlation between signals, and can therefore improve the performance of MUSIC remarkably. Finally by analyzing the measured data, it is shown that the improved method can detect the currents more effectively [C368]

## "Target Detection and Characterization using H/alpha Decomposition and Polarimetric Signatures"

Recently, the characterization and classification of terrain-cover using polarimetric SAR data has been extensively investigated and reported on (J.S.Lee, 1994). In this paper we re-examine the entropy-alpha approach (J.S.Lee, 1999) to radar polarimetry and show how the basic method may be augmented by the addition of the polarimetric signature parameters (F.T. Ulaby and C. Elachi, 1990), the propagation and helicity phase angles and the backscattering cross section. The method has been tested using the full polarimetric airborne data sets acquired with DLR's experiment SAR (E-SAR). The test region is the area of Oberpfaffenhofen, Germany acquired in the P-band. The results agree with the accepted understanding of radar backscatter and show that the use of the polarimetric signatures deliver complementary information to the entropy/alpha decomposition [C369]

## "Subpixel Processing for Target Scattering Center Extraction from SAR Images"

In high frequency region, the response of an extended target is well approximated as a sum of responses from individual scattering centers. This work presents two subpixel processing techniques for target scattering center extraction from synthetic aperture radar (SAR) or inverse SAR (ISAR) images. Using the proposed techniques, procedures for scattering center extraction are developed and used to characterize the electromagnetic (EM) scattering of complex targets. Typical results demonstrate the superior performance and usefulness of the current techniques [C370]

## "A Nonconformal Volume Integral Equation for Electromagnetic Scattering from Penetrable Objects"

A nonconformal volume integral equation is presented for electromagnetic scattering from penetrable objects with complex permittivity and permeability. The method of moments solution of the equation leads to a symmetric coefficient matrix for a reciprocal medium. The mesh that discretizes the object need not be conformal. Moreover, the numerical study proves that the formulation is well-posed [C371]

## "Waveform Design for MIMO Radar Based on Mutual Information and Minimum Mean-Square Error Estimation"

This paper addresses the problem of optimum radar waveform design for both radars employing a single

transmit and receive antenna and the recently proposed multiple-input multiple-output (MIMO) radar. A random target impulse response is used to model the scattering characteristics of the target, and both point and extended radar targets are considered. Assuming the constraint on waveform power, two radar waveform design problems have been investigated. The first one is to design waveforms that maximize the conditional mutual information (MI) between the random target impulse response and the reflected waveforms given the knowledge of the transmitted waveforms. The second one is to find transmitted waveforms that minimize the minimum mean-square error (MMSE) in estimating the target impulse response. Our analysis indicates that under the same total power constraint, these two criteria lead to the same solution for a matrix which specifies the essential part of the optimum waveform design. The solution employs water-filling to allocate the limited power appropriately. We also present an asymptotic formulation which requires less knowledge of the statistical model of the target. [C372]

## "A Modified State-space Method for Estimating Parameters of High Frequency Inverse Scattering"

Estimating parameters of inverse scattering is very important for studies of characteristics of radar targets. In this paper, a modified state-space method for estimating parameters is presented. Unlike the original algorithm, a new Hankel matrix is constructed and incorporated an iterative method to refine the estimates. The validity and effectiveness of the method are proven theoretically and experimentally [C373]

## "Similarity Parameter in Polarimetric SAR Interferometry"

The similarity parameter is used to measure the similarity between two different scattering matrixes. In this paper, the similarity parameter is introduced into polarimetric SAR Interferometry (Pol-In-SAR). For two scattering matrixes of every scattering cell, the similarity parameter can be used to register the pairs of images received by two flights and fuse the polarimetric information to enhance the coherence and reduce the phase noise. The quality of the interferometric phase is improved remarkably and the number of residues is reduced sufficiently. This is helpful in generating an accurate digital elevation model (DEM) [C374]

## "Pure Target Detection Based on Eigenvector Decomposition Using H-α Method in Radar Polarimetry"

In this paper a new decomposition scheme (H-α method) for analysis of pure targets echo around distributed targets (random targets) is presented. Pure targets have deterministic scattering matrix. In random targets scattering matrix, noise components is existed that must be omitted with applying ensemble averaging method. For this objective, eigenvector analysis technique in the H-α method is used for calculating eigenvector as well as probability of them from coherency or covariance matrix. Also a simulation scheme is developed for calculating entropy (H) and scattering mechanism ( α ) for spheroid targets. In this work drop size distribution (DSD) is considered for stochastic process of oblated or prolated spheroid rain droplet. Results of pure target simulation are presented and these results are compared with radar data set. [C375]

## "Scattering Centers Measurements Using a Modified Matrix Pencil Method"

A modified matrix pencil (MP) method is discussed with applications to the scattering centers measurements in step-frequency radar system. Comparison with the Kumaresan-Tufts (KT) method, a parameter estimation method belonging to the "polynomial" method, is given out, and it is shown the MP method is more robust than the KT method with respect to noise and to the pencil parameter changes. Also the MP method has the computational advantage over the KT method. Results compared with the IFFT method show that the resolution and precision of the MP method are both higher than those of the IFFT method. The MP method is more sensitive to noise than the IFFT method when the signal-to-noise ratio (SNR) is low. But the robustness can be significantly improved by using the mean of the estimates [C376]

## "Clutter Suppression Approach to Airborne Phased Radar with Non-sidelooking Array Based on CMT"

The non-sidelooking array is different from the sidelooking array in that its Doppler frequency of the clutter spectrum varies with the range and its clutter degree of freedom (DOF) is increased, so that the conventional STAP methods are not feasible. The clutter distribution of airborne non-sidelooking array radar is analyzed and investigated in detail, and a new clutter suppression approach to airborne phased radar with non-sidelooking array based on covariance matrix taper (CMT) is proposed. The simulation results verify the effectivity of the method [C377]

## "Polarimetric Radar Pulse Echoes from Lunar Regolith Layer with Scatter Inhomogeneity and

## Rough Interfaces"

To explore the potential utilities of lower frequency (L band) radar pulse for lunar exploration, a theoretical model of stratified lunar regolith media and numerical simulation of polarimetric radar pulse echoes are developed. The lunar regolith layer consists of the low lossy regolith layer with randomly rough top and bottom interfaces, and a layer of random stone-scatterers (spatially oriented oblate spheroids are assumed) is embedded and overlays the underlying rock media. The time domain Mueller matrix solution is derived to take account for scattering mechanisms of the stratified scatter media. Temporal characteristics and structure of the polarimetric echo profile as functional dependence on model parameters such as the layer thickness and the content of FeO+TiO2, are numerically simulated, and well display an image of regolith structures. It demonstrates a potential new way to explore moon surface in future. [C378]

## "Preconditioned Multilevel Fast Inhomogeneous Plane Wave Algorithm for Solving Electromagnetic Scattering Problems"

A mesh-neighbor preconditioner is implemented into the multilevel fast inhomogeneous plane wave algorithm (MLFIPWA), to solve three dimensional electromagnetic scattering problems more efficiently. The spectrum integration of the Green's function and grouping technique are used in FIPWA to translate the direct source and field interaction into aggregation, translation and disaggregation, to accelerate the matrix-vector multiplication. The computation complexity of this algorithm is O(N4/3). By applying a multilevel strategy, this complexity can be reduced to O(N log N) . To further speed up the solution process, a mesh-neighbor preconditioner is applied into this fast algorithm. Numerical results show the accuracy and efficiency of this algorithm. [C379]

## "A Novel Unsupervised Iteration Classification Method For Fully Polarimetric SAR Image"

Based on the theory of eigen-decomposition of fully polarimetric synthetic aperture radar (SAR) and scatter criterion clustering method, an unsupervised iteration classification method is proposed. It is simple, flexible and with high precision. Several schemes of the iteration classification method are given in this paper. The characteristic of each scheme is carefully analyzed according to the properties of eigen-decomposition and scatter criterion, and each scheme holds its own merit. Experiments are done on SIR-C/X-SAR data near Tien Mountains and perfect classification results are obtained. More importantly, this method is robust and has high adaptability. [C380]

## "The Effect of Channel Mismatch and Mutual Coupling on GPS Adaptive Antenna Array"

In order to design the receiving channel of the GPS adaptive antenna array, it is necessary to analyze the effect of channel mismatch and antenna mutual coupling on SINK (signal-to-interference-plus-noise ratio) and ICR (interference-to-cancellation ratio). In term of the signal environment of GPS, the expressions of SINR and ICR are conducted in existence of the deviation and the perturbation of the HF channel amplitude/phase (A/P), I/Q imbalance and the antenna mutual coupling by using the orthogonality of weight vector and the jammer space. It is proved that ICR is mainly determined by the HF channel A/P perturbation and the I/Q imbalance, but almost independent of the HF channel A/P deviation and the mutual coupling, and the calibrations for the deviation aren't always increase the SINR and the correction for mutual coupling can get the benefit of SINR just proportional to the maximal singular value of scattering matrix. The simulation results on the aspect of the above are given [C381]

## "Aspects of Statistical Radar Polarimetry"

A comparison between the Kennaugh matrix and the covariance matrix formulation of second-order moment radar polarimetry reveals fundamental relationships between power and variance aspects of bistatic and monostatic radar scattering from randomly distributed targets. [C382]

## "Analysis of Large-Scale EM Scattering Using the Parallel Characteristic Basis Function Method"

It is crucial to overcome the limitation of the computer capacity in analyzing the electromagnetic (EM) scattering from electrically large objects. The characteristic basis function method (CBFM) is a novel approach to solve this problem. In this paper, a more efficient method is presented by combining CBFM with the parallel technique. The matrix used in CBFM is rearranged to be suitable for parallel process. The parallel CBFM is applied to analyze the electromagnetic scattering feature of 3-D objects. The obtained results confirm the accuracy and efficiency of the proposed method in speeding up the RCS calculation of large scale objects. [C383]

## "Modeling and Design of Offset Parabolic Reflector Antennas using Physical Optics and Multilevel Fast Multipole Method Accelerated Method of Moments"

Modern radio, wireless and satellite communication and radar systems often involve electrically large and arbitrarily shaped metallic surfaces those span many wavelengths in three dimensions. High frequency asymptotic techniques e.g. current based physical optics (PO), ray based uniform theory of diffraction (UTD) represent approximate forms for solving radiation and scattering problems, and more accurate solutions are sometimes desired. Exact numerical results can be found by solving integral equations (IE's) using the method of moments (MoM). Application of the moment method to an integral equation yields full coupling matrices resulting in bad computational complexity and more importantly memory resources are fastly becoming insufficient for large objects. Recently a multilevel fast multipole method (MLFMM) accelerated MoM technique has been implemented for the efficient and yet accurate solution of radiation and scattering problems for arbitrarily shaped electrically large structures. The MLFMM-MOM scheme provides accurate solutions in the regions where asymptotic techniques do not produce good results. This approach is used for the numerical computation of radiated fields of offset parabolic reflector antennas. Excellent agreement of physical optics results in the main lobe and out to several lobes has been found with those of MLFMM accelerated MoM technique. Because of current singularities at edges of reflector and absence of feed coupling effects in physical optics formulations, significant deviations of PO results are observed in far side lobes. Review of the computational techniques is presented and numerical results for two reflector antennas are shown. [C384]

## "Recent Advances in Polarimetry and Polarimetric Interferometry"

Radar polarimetry radar Interferometry and polarimetric SAR interferometry represent the current culmination in 'microwave remote sensing' technology, but we still need to progress very considerably in order to reach the limits of physical realizability. Whereas with radar polarimetry the textural fine-structure, target orientation, symmetries and material constituents can be recovered with considerable improvement above that of standard 'amplitude-only' radar; by implementing 'radar interferometry' the spatial (in depth) structure can be explored. With polarimetric interferometric synthetic aperture radar (POL-IN-SAR) imaging, it is possible to recover such co-registered textural and spatial information from POL-IN-SAR digital image data sets simultaneously, including the extraction of digital elevation maps (DEM) from either polarimetric (scattering matrix) or interferometric (dual antenna) SAR systems. Simultaneous polarimetric-plus-interferometric SAR imaging offers the additional benefit of obtaining co-registered textural-plus-spatial three-dimensional POL-IN-DEM information, which when applied to repeat-pass image-overlay interferometry provides differential background validation and environmental stress-change information with highly improved accuracy. Then, by either designing multiple dual polarization antenna POL-IN-SAR systems or by applying advanced POL-IN-SAR image compression techniques, will result in 'POL-arimetric TOMO-graphic' (multi-interferometric) SAR or POL-TOMO-SAR imaging. By advancing these EWB-D-POL-IN/TOMO-SAR imaging modes, we are slowly but steadily approaching the ultimate goal of eventually realizing airborne and spaceborne 'geo-environmental background validation, stress assessment, and stress-change monitoring and wide-area military surveillance of the terrestrial and planetary covers'. [C385]

## "Analysis of Scattering and Radiation of Mixed Conducting/Dielectric Objects Using MLFMA"

A scheme is presented to apply multilevel fast multipole algorithm (MLFMA) to analyze the scattering and radiation for three dimensional (3D) objects comprising conducting and dielectric bodies. Applying equivalence principle, PMCHW formulations are used on the surface of the 3D dielectric bodies and EFIE is used on conducting surface. The far-field matrix-vector multiplication and the near-singular problems are analyzed. Application of MLFMA reduces the memory requirement and computational complexity of the MOM solution significantly, which renders us to analyze the electrically large objects. Numerical examples are presented to demonstrate the accuracy and high efficiency. [C386]

## "Scattering Centers Measurements by a 2-D ESPRIT Type Method"

A 2-D ESPRIT type method is presented for the scattering centers measurements in step-frequency radar. This method estimates the signal parameter pairs directly unlike the matrix enhancement and matrix pencil (MEMP) method which contains an additional step to pair the parameters related to each dimension. We use a forward-backward prediction data matrix to increase the estimation accuracy and the robustness to noise. Results compared with the Fourier transform method show that the resolution and precision of the 2-D ESPRIT type method are both higher than those of the Fourier method. [C387]

## "Analysis of EM scattering characteristics from 2D electrically large objects using characteristic basis function method"

Characteristic basis function method (CBFM) is a novel approach for the efficient solution of electromagnetic scattering problems. In this paper, CBFM combined with the domain decomposition technique is used to calculate the radar cross sections from 2D electrically large conducting cylinder and dielectric cylinder. It is

shown that the numerical results presented in this paper are in good agreement with that achieved by the traditional method of moments, while the computational efficiency is improved greatly. [C388]

## "Fast Implementation of H / α-Wishart Classification to Polarimetric SAR Images"

A method of fast implementation of H/α-Wishart iterative classification is proposed in this paper. The fast method not only convergence stability, but also need less computing. The application to AIRSAR image of San Francisco shows the method's effectiveness [C389]

## "Automatic Target Recognition Using Multiple Radar High Range Resolution Profiles"

Radar automatic target recognition (ATR) based on multiple high range resolution profiles (HRRPs) is concerned. To relax the target aspect sensitivity and use more statistical information of the HRRPs, in this paper we extract the average range profile and the variance range profile together as the feature vectors for both training data and test data representation. And a decision rule is established for ATR based on the minimum Kullback-Leibler distance (KLD) criterion. The recognition performance of the proposed method is comparable with that of adaptive Gaussian classifier (AGQ with multiple test HRRPs, but the proposed method is much more computational efficiently. Experimental results based on the measured data show the minimum KLD classifier is effective [C390]

## "GLRT Detection for Range and Doppler Distributed Targets in non-Gaussian Clutter"

A generalized likelihood ratio test (GLRT) is derived for adaptive detection of range and Doppler distributed targets. The clutter is modelled as a spherically invariant random process (SIRP) and its texture component is range dependent (heterogeneous clutter). We suppose here that the speckle component covariance matrix is known or estimated thanks to a secondary data set. Thus, unknown parameters to be estimated are local texture values, the complex amplitudes and frequencies of all scattering centers. The proposed detector assumes a priori knowledge on the spatial distribution of the target and has the precious property of constant false alarm rate (CFAR) with the assumption of a known speckle covariance matrix or by the use of frequency agility [C391]

## "Interferometric Phase Estimation in Polarimetric SAR Interferometry"

Polarimetric synthetic aperture radar (SAR) interferometry has been developed for the estimation of accurate terrain elevation and vegetation parameter. One of the important process steps is to estimate the interferometric phases of effective scattering centers which located in different height positions and represented different scattering mechanisms. The interferometric phases can be acquired by the fully polarimetric SAR scattering decomposition. The coherence optimization algorithm and the ESPRIT algorithm are analyzed for the interferometric phase decomposition. SIR-C/X-SAR L-band fully polarimetric data are used to estimate interferometric phase, experimental results verify the validity of the methods [C392]

## "A Novel Approach for RCS Feature Extraction Using Imaging Processing"

In this paper, a novel approach for RCS feature extraction using imaging processing is proposed firstly. We take the frequency-angle RCS data sets normalized for every observation angle as intensity images with 256 gray levels, and find that different targets have different textures. This implicates that the particular textures of each image can be used to recognize the corresponding targets. Here, we chose the gray level co-occurrence matrix for texture feature extraction by using of discrete wavelet transform (DWT) to further enhance the performance of target recognition. The simulation results show that the proposed approach is of great perspective for target discrimination. By properly choice of texture features, it can provide good feature vectors for further pattern recognition [C393]

## "Fully-Polarized Scattering Center Extraction and Parameter Estimation: P-SPRIT Algorithm"

In this paper, a novel method called P-ESPRIT algorithm is proposed for fully-polarized scattering center extraction and parameter estimation. The P-ESPRIT algorithm is a joint processing between polarization and super-resolution essentially. It is able to estimate the number, position, intensity and normalized scattering matrix of scattering centers instantaneously for each channel rather than the one which extracts parameters from each channel separately, and its performance is better than the latter because the fully-polarized information is used. It has computational advantage over other methods like MUSIC and ML because it needn't search. Its validity is proved by the experimental results based on simulated and real data [C394]

## "Target polarization recognition under rain and snow cluster"

This paper derived the polarization scattering matrix of both warship target and interferential chaff conditioned on the exit of rain and snow cluster, and furthermore, proposed a method to recognize chaff and warship by analyzing their corresponding polarization information. This method mainly aims to radar, which can receive both left and right circularly polarized wave, to catch the full polarization information of echoes, then, acquires the more accurate polarization characteristics of target and chaff after getting rid of the impacts of rain and snow cluster from the polarization scattering power matrix of echoes. In order to further improve the recognition probability, non-linear polarization transformation is introduced to make the separation of target and chaff more realizable. It indicates that the resulting performance is incredible for the traditional recognition in time and frequency domain [C395]

## "Nearest neighbor classifier based on Riemannian metric in radar target recognition"

A successful design for a nearest neighbor classifier based on Riemannian metric in radar target recognition is presented. In Riemannian space, obtaining feature coefficient using subspace methods can be regarded as an affine transformation, and the classifier can be deduced easily from the distance formula in Riemannian space. The classifier is compared with other classifiers and good performance is reported. This design for the classifier may serve as a guideline for dealing with the puzzle that how to combine feature extraction with classifiers reasonably in radar target recognition using range profiles. [C396]

## "Unsupervised classification of a central italy landscape by polarimetric L-band SAR data"

{no data available} [C397]

## "Speckle filtering of polarimetric SAR image and the enhancement for classification"

In this paper, a new approach to speckle filtering of synthetic aperture radar (SAR) data is presented. We define a parameter space consisting of two orthogonal subspaces-the signal subspace and the noise subspace. Then, the full polarimetric information from the signal subspace is obtained after speckle filtering. Moreover, edges of different kinds of targets are preserved. Using polarimetric SAR data, the effectiveness of the proposed method is not only validate by the standard-deviation-to mean ratio, but also by target classification [C398]

## "Scattering centre extraction for extended targets"

In this paper, we consider the estimation of scattering centre parameters for the case of extended targets. In general, models are tested on synthetic targets made up of few scatterers. This choice is imposed by the maximum model-order assumed by the method. It is limited by the rank of the observation matrix and by the noise which corrupts the signal subspace. However real-world systems have to deal with complex targets such as aircrafts. For this reason, we revisit the theory for the case of targets made up of a large number of scatterers. We present a novel method for selecting poles corresponding to true physical scatterers. Finally, we propose a technique for reducing the model order based on a modification to the ISAR technique. The resulting 2D-model results in lower noise compared to traditional techniques and can be used for pole selection, data compression, image enhancement and high resolution ISAR-imaging. [C399]

## "Characteristics of the melting layer in the mediterranean region from dual polarization radar measurements at vertical incidence"

{no data available} [C400]

## "Intensity-driven-adaptive-neighborhood technique for POLSAR parameters estimation"

{no data available} [C401]

## "A four-component decomposition of POLSAR image"

{no data available} [C402]

## "Polarimetric analysis of the disastorus environment by using Pi-SAR"

{no data available} [C403]

## "Quantitative assessment of physical information retrieved via multidimensional radar systems"

The advent of multidimensional synthetic aperture radar (SAR) systems in the last decade has made possible the quantitative retrieval of physical parameters to characterize the Earth's surface. As a result, nowadays, radar

technology has an important and leading role in remote sensing. Despite the clear advantages respect to other remote sensing techniques, the presence of speckle noise in SAR systems represents still an important drawback, which is even more critical for multidimensional systems. This paper is devoted to present a novel multidimensional speckle noise model which, as demonstrated, allows the characterization of multidimensional data and permits to identify and quantify the effects of speckle in the process to estimate physical information. Special attention is devoted to polarimetric systems [C404]

## "Space-time ambiguity matrices for synthetic aperture radar"

In the paper the concept of space-time ambiguity matrices of radar signals is introduced and investigated for polarimetric synthetic aperture radar. The results can be used for signal processing optimization in polarimetric SAR systems and their potential performance estimation [C405]

## "Electromagnetic waves scattering on slot systems in rectangular waveguides with arbitrary loads"

The work deals with investigation of electromagnetic waves scattering on the slot systems in rectangular waveguides with arbitrary end loads. The linear slotted-guide gratings with slot elements of different kinds, such as longitudinal slots, doubled ones and cross-like slots, are considered. The influence of inner and external mutual coupling and finite wall thickness are taken into account. The solution of the problem under consideration is based on improved and specially modified well-known method of successive approximations [C406]

## "Tracking algorithm for three-dimensional bistatic forward scattering radar with weighting of primary measurements"

The paper deals with iterative target tracking algorithm for three-dimensional bistatic forward scattering radar. The ability to use bistatic radar cross section variance in tracking algorithm is considered. It is shown estimation of covariance matrix of primary measurement errors using target return amplitude measurements provides improvement of tracking accuracy [C407]

## "Radar system concept for simultaneous BSM of complicated and non-stable targets measurements"

The algorithms of the signal processing and the functional scheme of the polarization radar with simultaneous back scattering matrices measurements are given in this paper. The radar is destined for low atmosphere remote sensing [C408]

## "Evaluating PolInSAR parameter estimation using tomographic imaging results"

This paper concentrates on the forest height and ground topography estimation by means of polarimetric SAR interferometry and tomography. In polarimetric SAR interferometry, one of the most important methods described in literature is the line-fitting approach in the complex unitary circle (S.R. Cloude and K.P. Papathanassiou, 2003). Although it has shown their principal potential, an open issue is still the precise validation of the estimated parameters, as ground-truth collection is an extremely complex task in the case of forest parameters. SAR tomography is an alternative technique, which generates a fully three-dimensional representation of the imaged scene through coherent combination of a greater number of tracks (A. Reigber and A. Moreira, 2000) (S. Guillaso and A. Reigber, 2005). Forest ground and canopy are directly visible in a tomographic image; a tomographic image can therefore be used as an ideal validation base for PolInSAR forest parameter estimation. This paper compares high-resolution polarimetric SAR tomograms with PolInSAR forest height estimations, both derived from the same data set. This allows to identify areas of good applicability, as well as principal deficiencies of the different PolInSAR approaches [C409]

## "New eigenvalue-based parameters for natural media characterization"

The aim of this paper is to present two novel polarimetric parameters, the eigenvalue relative difference (ERD) and the single bounce eigenvalue relative difference (SERD), to characterize natural media. These parameters are derived from the eigen-decomposition of the coherency matrix considering the reflection symmetry hypothesis. An analysis of these parameters is performed on multi-frequency polarimetric SAR data acquired on bare soils and forested areas [C410]

## "Polarimetric SAR with simultaneous backscattering matrix estimation"

In the paper the concept of a polarimetric SAR performing a simultaneous full target backscattering matrix estimation is proposed. The block diagram of the system and the signal processing algorithms are developed;

main characteristics of the system are defined. Simultaneous backscattering matrix estimation implemented in the system allows avoiding errors existing in other systems. SAR PHARUS (Hoogeboom et al., 1992), developed in FEL TNO, that performs pulse-to-pulse method of BSM estimation, and the project of radar COMESA jointly performed by IRCTR TUDelft and TUCSR (Project EWI 04 044, 2004) are used as prototypes. [C411]

## "A cross-entropy based parameter for ship detection from a polarimetric SAR image"

A cross-entropy based parameter is proposed to measure the difference between a river area and others. This parameter can be employed for ship detection from a polarimetric SAR image. After deciding the boundaries of the river area, ships are detected only in the river area instead of the whole site. Therefore, most of the false alarms are eliminated. Finally, the performance of this new approach is validated by the X-band full polarimetric SAR data in Niigata area of Japan [C412]

## "Cramer'r-Rao bounds for compound-Gaussian clutter and target parameters"

We compute Cramer'r-Rao bounds (CRBs) for the target and compound-Gaussian clutter parameters using radar array measurements. In particular, we compute CRBs for (i) complex target amplitudes, (ii) the spatial covariance matrix of the speckle component, (iii) texture distribution parameters. We first derive general CRB expressions under an arbitrary texture model and simplify them for gamma and inverse gamma texture distributions. We use the generalized Gauss-Laguerre quadrature to compute the CRBs for gamma texture, whereas the CRBs for inverse-gamma texture do not require numerical integration. We use numerical simulations to validate our results. [C413]

## "Solving scattering from 3D composite conducting and dielectric object by surface integral equation method"

Recently, scattering from 3D composite conducting and dielectric object receives much attention. Traditionally, FEM-BI method is applied to solve the problem. But absorption boundary condition (ABC) is needed in FEM-BI method. In this paper, we use two combinations of surface integral equation to solve the RCS of 3D composite conducting and dielectric object. Fast multipole method (FMM) is used. The problem is formulated in terms of a set of coupled integral equations involving equivalent electric and magnetic surface currents based on the equivalence theorem. The conducting structures and the dielectric materials are modeled by planar triangular patches, RWG basis and Galerkin method are used. The fast multipole method is applied to accelerate the computation of matrix-vector multiplication. The computational complexity and storage requirement is O(N1.5), respectively. Numerical results are given for various structures and compared with other available data. The numerical results show that the present method has satisfying accuracy. [C414]

## "Polarimetric SAR with simultaneous backscattering matrix estimation"

In the paper the concept of a polarimetric SAR performing a simultaneous full target backscattering matrix estimation is proposed. The block diagram of the system and the signal processing algorithms are developed; main characteristics of the system are defined. Simultaneous backscattering matrix estimation implemented in the system allows avoiding errors existing in other systems. SAR PHARUS (P. Hoogeboom et al., 1992), developed in FEL TNO, that performs pulse-to-pulse method of BSM estimation, and the project of radar COMESA jointly performed by IRCTR TUDelft and TUCSR (2004) are used as prototypes [C415]

## "Analyse the ultra-band electromagnetic scattering system by MoM-2MBPE"

The natural frequencies (poles) of a scattering object is one of the basic characteristics used to target recognition. Usually, an iterative method is used to find the solutions of the matrix equation coming from the MoM (Method of Moments). However, the method is very time-consuming. Whereas MBPE gives excellent results over a wide frequency band, and is much more efficient than the conventional point-by-point approach, in this paper the system function is constructed by using the MBPE twice. Finally, the poles of the scattering system are analyzed. [C416]

## "An automatic load-balanced parallel multilevel fast multipole method for large scale electromagnetic scattering problem"

A parallel multilevel fast multipole method for computing the large scale electromagnetic scattering problem is proposed and implemented in this paper. In recent years, multilevel fast multipole method (MLFMA) has been widely used for analyzing electromagnetic scattering problem of electric large object. In order to extend the range of problem that can be solved using this algorithm, we implement a parallel fast multipole method which can run on the distributed memory computer system. This parallel algorithm is based on the message-passing interface

(MPI). A compressed octree based parallel domain subdivision algorithm is used for efficiently avoiding the load balance problem between different CPUs which is caused by the irregular object shape. The parallel efficiency of this algorithm is demonstrated by different computing examples. We have solved electromagnetic scattering problem of many practicality military targets with more than 5,000,000 unknowns using our parallel multilevel fast multipole code on Drawing 4000A Super-Computer at Shanghai Super-Computing Center. [C417]

## "Analysis of finite phased arrays of printed dipoles using P-FFT algorithm"

This paper presents an accurate and efficient method of moments (MoM) for analyzing the characteristic of a large-scale phased dipole array. The precorrected fast Fourier transform (P-FFT) method is employed to accelerate the entire computational process to reduce significantly both the memory requirement and computational time for large arrays. Numerical results are presented to demonstrate the efficiency and accuracy of the presented method. [C418]

## "Advanced design of phased array beam-forming networks"

Recent fundamental results in the theory of linear, multi-port networks enable cost-effective, higher-reliability designs for electronically-steered phased arrays. The new results are based on a generalization of the classical concepts of scalar image impedance, and of a scalar image-transfer function for two-port networks, to the new concepts of multidimensional image-impedance matrix, and of multidimensional image-transfer function for linear multi-port networks. [C419]

## "Application of cross-polar optimal polarizations for precipitation sensing"

{no data available} [C420]

## "Analysis of the scattering characteristics of finite arrays on an infinite ground plane based on finite elements and generalized scattering matrix"

We achieve an efficient characterization of the scattering of electromagnetic plane waves from antennas and cavities on an infinite ground plane as well as finite arrays. For this purpose the generalized scattering matrix approach is applied as an intermediate step to compute the transition matrix (T-matrix) that provides the scattering characteristics of the scatterers or radiating structures. [C421]

## "Inner-outer GMRES algorithm for MLFMA implementation"

Method of moments (MoM) solutions of surface integral equations are among the most successful methods for solving scattering and radiation problems involving metallic objects. A simple and effective preconditioning technique is introduced for the iterative solution of multilevel fast multipole algorithm (MLFMA) equation systems from the combined field integral equation (CFIE). The preconditioner is derived from the near zone strong interaction matrix elements of the coupling matrix and its iteration avoids the typical fill-in problem associated with direct factorization methods. Using the preconditioner with an inner generalized minimum residual (GMRES) solver results in excellent convergence with fewer iterative steps. This keeps a low memory requirement and helps to alleviate the influence of the lost convergence information for the conventional restarted GMRES. [C422]

## "Analysis of scattering of composite cylinder structure using multilevel fast inhomogeneous plane wave algorithm"

Scattering of composite cylinder structures containing both conductor and dielectric material plays an important role in the analysis of the radar cross sections (RCS) of complex targets. A fast algorithm, namely the multilevel fast inhomogeneous plane wave algorithm (MLFIPWA) (Bin Hu et al., Radio Science, vol.34, no.4, p.759-72, 1999) is implemented to solve this problem. It is based on the volume-surface integral equation (VSIE). Traditionally, the integral equation is discretized by MoM, and O(N2) computational complexity is needed when an iterative method, such as conjugate gradient (CG), is used. The fast multipole method (FMM) (Lu, C.C. and Chew, W.C., IEE Proc.-H, vol.140, no.6, 1993) is applied to accelerate the matrix-vector multiplication, and achieves O(N32/). The FIPWA, based on a different expansion of Green's function compared to FMM, is also proposed for this purpose, and it achieves O(N43/); both attain O(NlogN) if a multilevel strategy is applied. Compared to MLFMM, the MLFIPWA can be easily expanded to solve the scattering of targets in an inhomogeneous environment. The method is accurate and efficient. [C423]

## "Single snapshot signal subspace method for target location"

A signal subspace approach is developed for the passive sensing problem of locating radiation-emitting point sources from a single statistical realization or snapshot of the superposed radiation as detected at a receiving antenna array, and for the active sensing problem of locating point scatterers or "targets" from the multistatic response matrix (MRM) of the targets as measured either by a coincident array of "same transmit/same receive" antennas or by a non-coincident array where different elements are used for transmit and receive. Two applications are emphasized: (1) passive location of M [C424]

## "Radar cross section computation of multi-layered dielectric and magnetic obstacles using an efficient wavelet-like method"

The scattering behaviour of multi-layered dielectric and magnetic obstacles is a complex problem of great practical interest. The bistatic radar cross section (RCS) of two dimensional scatterers composed of lossy magnetic and dielectric materials, including perfect conductor metals (PEC), is obtained following a surface formulation, the method of moments (MoM) and a wavelet-like matrix compression technique. [C425]

## "Fast and accurate algorithm for scattering from large-scale 2D dielectric ocean surfaces"

The paper presents a fast and accurate algorithm for the direct method-of-moment (MoM) numerical simulation of radar scattering from two-dimensional (2D) randomly finite-conducting (dielectric) ocean surfaces. The proposed algorithm consists of three major components: the multi-grid (MG) algorithm, the iterative generalized conjugate residual (GCR) method with a novel preconditioning strategy, and a variation of the spectral acceleration scheme devised by D. Torrungrueng and J.T. Johnson (see J. Electromagnetic Waves & App., vol.15, p.1337-62, 2001) featuring an alternative strong-weak region partitioning. While the strong field-source interaction is implemented as usual in the physical space in terms of matrix-vector dot product, the integral form of the weak field-source interaction region is carried out in the wavenumber space. The efficiency of the proposed two-layered algorithm facilitates scattering calculations from 2D finitely conducting surfaces with a total number of unknowns up to a few millions. Presented numerical simulations are typically performed at X-band frequencies with 7 m/s wind speed and 20° grazing angle. [C426]

## "A unified model for decomposition of coherent and partially coherent target scattering using polarimetric SARs"

{no data available} [C427]

## "Data classification based on PolInSAR coherence shapes"

{no data available} [C428]

## "New blind source separation technique for removing vegetation bias in polarimetric SAR interferometer measurements"

{no data available} [C429]

## "Mueller matrix modeling of atmospheric scattering medium through polarized laser beam"

The atmospheric scattering and absorption in turbid medium is characterized through Mueller matrix modeling of backscattered polarized laser radiation. The scattering medium is homogeneous and contains one kind of randomly distributed asymmetric particles. We used polarized He-Ne laser of specific wavelength focused on scattering medium. Different polarization components of backscattered light are obtained by varying the polarization state of incident laser light and the analyzer configuration. The calculation of the 16 element of the output Mueller matrix experimentally confirmed that theoretically only seven elements of backscattered light are independent and remaining nine can be calculated through symmetry relation. Matrix calculus concept for backscattered light fully characterized the material. Our results for turbid atmospheric system predict the absorption and scattering parameters closed to the parameters in literature. This study will be useful in remote sensing, aerospace technology, radar and lidar applications, weather predictions and upper and lower atmospheric observations [C430]

## "One-dimensional model-based approach for ISAR imaging"

In this paper, we extend the estimation of scattering centre parameters to the case of ISAR imaging. The representation of a target by a set of individual scattering centres has shown promising results for applications where high resolution is needed (high-resolution imaging, classification, NCTR). In practice, methods extract time-delay and amplitude parameters associated with strong scattering sources from complex-valued reflectivity

samples in the frequency domain. The principle has been successfully applied with samples from one or several segments. We show that a one-dimensional model can be used to create a two-dimensional ISAR image. After presenting the principle of ISAR matrix data collection and processing, we propose two methods for building the ISAR model matrix. We show that the technique processing the Doppler information first is more suitable for building ISAR-Model. As an example, we consider the case of a corrupted data matrix, which can be restored by coherently processing sparse sub-bands. Samples from a simulated Mig25 are used to illustrate the technique. [C431]

## "POLSAR speckle filtering with structural feature and scattering property preservation"

In this paper two speckle filters for multi-look polarimetric synthetic aperture radar (POLSAR) imagery are proposed, which preserve structural features, i.e. edges and line, as well as scattering properties. The filtering operations are performed spatially variant for the edges/lines along their orientation and for the homogeneous areas based on the scattering properties. The capabilities of both filters are demonstrated for the NASA/JPL nine-look POLSAR C-band data, whereby comparisons with the Boxcar, Lee refined and Annealing filters are provided. In summary, both proposed filters show a good performance in speckle removal, structural feature retention and radiometric preservation. [C432]

## "Application of principal component analysis in radar polarimetry"

{no data available} [C433]

## "A new classification method based on Cloude Pottier eigenvalue/eigenvector decomposition"

In this paper, a new polarimetric scattering parameter, the averaged intensity (I), is introduced to present the backscatter intensity of fully polarimetric SAR data. According to the particular analysis on the properties of I, α angle and entropy H, the mapping rule of I-α-H feature space onto the intensity-hue-saturation (I-H-S) color space is proposed. We use the IHS transform instead of segmentation algorithm to finish the classification. The important advantages of this method are that the information contained in the I-α-H feature space is preserved without any loss in the resulting image, and the execution time is saved since IHS transform is faster than most complicated segmentations. The result shows that I has the additional information which is not contained in α and H, and the classification result is more readable than that of H/α/A. [C434]

## "Estimation of forest height and forested area with polarimetric SAR interferometry"

{no data available} [C435]

## "New eigenvalue-based parameters for natural media characterization"

The aim of this paper is to present two novel polarimetric parameters, the eigenvalue relative difference (ERD) and the single bounce eigenvalue relative difference (SERD), to characterize natural media. These parameters are derived from the eigen-decomposition of the coherency matrix considering the reflection symmetry hypothesis. An analysis of these parameters is performed on multi-frequency polarimetric SAR data acquired on bare soils and forested areas. [C436]

## "Polarimetric SAR image classification employing subaperture polarimetric analysis"

Polarimetric SAR image classification remains an important research area. Various methods continue to be developed for specific applications. High-resolution polarimetric SAR systems and advances in computational and data storage capabilities have revived interest in novel polarimetric analysis techniques. Accordingly, subaperture analysis of polarimetric SAR data has received renewed attention. A central assumption of SAR image formation is that individual radar scatterers are stationary; they have no structure and provide a constant reflectivity during the imaging process. However, with increased resolution, and hence fewer scatterers per pixel, the nonstationary response from any given scatterer is more likely to influence total radar backscatter of a pixel. We present a method to assess the polarimetric variability across the full aperture. [C437]

## "On the status of bistatic polarimetry theory"

{no data available} [C438]

## "Comparison of methods for extracting and utilizing radar target characteristic parameters"

{no data available} [C439]

## "Polarimetric doppler measurements for weather radar applications"

{no data available} [C440]

## "Data fusion for a surveillance system: addressing some practical problems"

This paper presents solutions for some data fusion problems encountered in a real life command and control system and outlines the systems engineering approach used while addressing these problems. The systems engineering approach takes into account the functionality and the capabilities of the system, operational and user aspects, safety and security, subsystem interfaces, sustainability and design constraints. The system comprises several sensor points scattered around a vast region that collect radar plots and produce tracks and two central command points that receive these tracks and process them. The processing of tracks involve carrying the tracks obtained from geographically dispersed sensors onto a common reference point (e.g. coordinate conversion and registration), fusing the tracks originating from the same target provide full air picture of the surveillance region. Also, the proposed system reproduces the track states and corresponding covariance matrix from the track quality information. [C441]

## "Radar absorbing material (RAM) and shaping on radar cross section reduction of dihedral corners"

How far can a radar system detect an object depends the radar cross section (RCS) of the target. Corner reflectors are the major scattering centers in the radar signatures of vehicles. The monostatic return from such structures can be reduced by ensuring that surfaces never meet at right angles and by application of radar absorbing materials (RAM). This paper deals with the RCS reduction of dihedrals by shaping and by application of RAM. RCS from dihedrals were compared before and after the application of radar absorbing coating. RAM is based on conductive carbon black dispersed in rubber matrix. [C442]

## "Calibration of full-polarization radar"

A novel method of external calibration for polarization radar is proposed for accurate estimation of the backscattering matrix of radar objects. By using the reciprocity theorem for backscattering from a known reflector the calibration procedure can be simplified, the influence of background reflectors decreased and the requirements of passive reference reflectors lowered. [C443]

## "Full maximum likelihood inversion of polinsar scattering models"

We expand upon the maximum likelihood inversion approach presented in Flynn, Tabb, and Carande ["Direct estimation of vegetation parameters from covariance data in polarimetric SAR interferometry", IGARSS 2002], and show how to optimally combine the polarimetric channels to form a bare earth estimate for the case of single layer ground scattering. In addition, for the two layer randomly oriented volume over ground (RV+G) scattering model, we show how to optimally recover the canopy structural parameters (bare earth and tree height) as well as the ground and volume backscatter polarimetric covariance matrices. This approach outperforms other techniques in terms of both estimation accuracy and computational complexity [C444]

## "Statistical assessment of eigenvector-based target decomposition theorems in radar polarimetry"

This paper concerns the analytical study of the eigen decomposition of hermitian, positive semidefinite matrices applied to PolSAR data analysis. Based on the Gaussian scattering assumption for multidimensional SAR data, the joint distribution of the sample eigenvalues of the coherency, or covariance, matrices is derived for a general case. The distribution is particularized for PolSAR data, and the moments of the sample eigenvalues, the entropy (H), and the anisotropy (A) are analyzed [C445]

## "Determination of polarimetric calibration parameters of L band SAR using uniform forest data"

Proposes a new method to calibrate L band polarimetric SAR using the forest data. Model based covariance matrix containing the distortion matrices and the scattering components from the forest were solved using the Pi-SAR data over the Japan uniform forest of Tomakomai, Hokkaido. The result showed that the distortion matrices depend on the function of the incidence angle and the operation timings. [C446]

## "Geometric interpretation of the characteristic polarizations"

The scattering mechanism can be analyzed from the geometrical point of view using the polar decomposition which decomposes the normalized scattering matrix in a unitary matrix and in a Hermitian (positive definite) one. Each of them can be built using parameters (polar parameters) such as vectors, angles and scalars which have

geometrical meaning in the Stokes space. In this work it is shown the relation between them and some of the characteristic polarizations of a normalized, symmetric scattering matrix: the copolar and the copolar maxima. Moreover, the inverse relations are found: the parameters which characterize the unitary and the Hemitian matrices can be expressed as function of the copolar s only. Using these relations, the problem to find the polarizations such that the received voltage is maximized (or minimized) for a given S, is reduced to apply the polar decomposition and compute the polar parameters. Furthermore, the scattering matrix is parameterized by the characteristic polarization states. Since it exists a direct connection between a unitary matrix and a rotation and between a Hermitian matrix and a boost, the Mueller (or Kennaugh) matrix can be built using the same parameters. This is the first step towards the study of the characteristic polarization states in the more general case of received partially polarized waves, the stochastic case. [C447]

## "FEM/PO-PTD for evaluation of scattering by complex objects"

A hybrid technique is developed for the evaluation of electromagnetic scattering by electrically large conducting bodies with cavities on their surfaces. The edge-based finite-element method (FEM) is employed to compute the scattering from the cavities. Physical optics (PO) and physical theory of diffraction (PTD) are utilized to evaluate the scattering from the large bodies with the cavities filled with perfect conductors. These two methods are combined by an efficient coupling scheme. Some numerical results are presented. It is shown that the hybrid technique has some advantages over other methods in regard to saving computer memory units and CPU time. [C448]

## "Analysis of the time-reversal operator for planar dipole arrays"

Tortel et al. (1999) analyzed the electromagnetic time-reversal operator for sources and receivers in a ring surrounding a number of dielectric and conducting spheres and cylinders. We analyze the TRO for a planar array and show that for point scatterers there can be up to six eigenvalues and eigenvectors of the time-reversal operator associated with each scatterer. These are associated with various configurations of the induced dipole moments in the scatterer, and depend not only on the geometry but also the polarization capability of the array. [C449]

## "A comparative study of infinite elements for two-dimensional electromagnetic scattering analysis"

Recently, a new type of infinite element was proposed as an accurate and efficient mesh truncation method for the finite element analysis of open-region acoustic scattering (D.S. Burnett, J. Acoust. Soc. Am., vol. 96, no. 5, pp. 2798-2816, 1994; D.S. Burnett and R.L. Holford, Comput. Meth. Appl. Mech. Engrg., vol. 158, pp. 117-141, 1998; J. J. Shirron and I. Babuska, ibid., vol. 164, pp. 121-139, 1998; J. Shirron and S. Dey, ibid., vol. 191, pp. 4123-4139, 2002). These infinite elements are based on the radial expansion of the scattered field and are used to model the scattered field outside a separable surface characterized by a constant radial coordinate (such as a spherical or a spheroidal surface in three dimensions). In this paper, two-dimensional (2D) elliptic infinite elements are formulated and implemented for the finite element analysis of 2D time-harmonic electromagnetic scattering and their performance is studied by comparison with the finite element solution using conventional absorbing boundary conditions (ABCs). Numerical results are presented to demonstrate that the new type of infinite elements is indeed more accurate than both the first- and second-order ABCs. [C450]

## "STAP training through knowledge-aided predictive modeling [Cradar signal processing]"

In this paper, we investigate a spectral-domain approach to estimating the interference covariance matrix used in space-time adaptive processing. Traditionally, an estimate of the interference covariance matrix is obtained by averaging the space-time covariance matrices of multiple range bins. Unfortunately, the spectral content of these data snapshots usually varies, which corrupts the covariance estimate for the desired range. We propose to use knowledge sources to identify angle-Doppler spectral regions having the same underlying scattering statistics. Then, we use real-time data to form a synthetic aperture radar image, which is inherently an estimate of non-moving ground clutter. We then average the SAR pixels within each homogeneous region. The resulting clutter power map is used, along with knowledge of the radar system and scenario geometry, to compute the interference covariance matrix. Using simulated data, we demonstrate the potential performance of such a technique, demonstrate its dependence on accurate space-time steering vectors, and provide an example of using data to compensate for imperfect knowledge. [C451]

## "New implementation of the Billingsley clutter model for GMTI data cube generation"

Internal clutter motion (ICM) places significant limits on the effectiveness of STAP clutter suppression techniques, for example in achieving the smallest minimum detectable velocity in GMTI radar surveillance applications. To simulate this effect with maximum fidelity, the required correlation must be impressed on the returns from

individual scatterers during the construction of the data cube. Doing so can represent a substantial computational burden on the simulation process when a clutter scene is characterized by many millions of individual pixels. Such numbers are typical when using high fidelity SAR maps as the basis of the clutter model. The paper reports on a fast computational technique for wind-blown clutter simulation that works within a flexible data-generation system employing real high-fidelity IFSAR maps with co-registered elevation data as ground truth. [C452]

## "Parallel fast algorithm for large-scale electromagnetic scattering"

Electromagnetic scattering analysis for radar cross section (RCS) prediction and electromagnetic compatibility analysis have extensive military and civil applications. Meanwhile, it presents very large computational demands. Parallel multi-level fast multipole method (MLFMM), a powerful and efficient computational algorithm on solving large-scale RCS problems, is developed and implemented on massively parallel, distributed memory computer systems. Multilevel grouping structure is partitioned carefully to separate computational tasks and reduce data communication. Message passing interface (MPI) is employed to perform the data transfer among processors and support the matrix-vector product in parallel iterative procedure. The accuracy of code is verified by comparison with results of benchmark target. The computational complexity and efficiency of parallel MLFMM is discussed. The parallel code is validated on Unix and Linux platforms with different number of processors, and proven to be scalable, portable, and efficient. [C453]

## "Orthomode transducer for mm-wave range"

The orthogonal polarized signals are widely used in millimeter-wave applications such as in radar, communications, remote sensing and radiometry. The diplexing (i.e., combination or separation) of the orthogonal signals is imposed on the components, which are usually called as "orthomode transducers" (OMTs). In general, the OMT has three physical ports, though it exhibits properties of a four-port device, because the common port, usually with a square or circular cross section, provides two electrical ports that correspond to the independent orthogonal polarized signals. In modern systems, requirements to the OMT are a high cross-polarization discrimination between the orthogonal signals and a good match of all electrical ports. In the millimeter-wave range, it is a difficult problem to design and produce OMT meeting to the required specification, because of dimensions of the components are very small. Therefore, the development of a new OMTs design suitable for mm band is an important task. In the present report we consider a narrowband OMT design that suits most applications in radar and radio-relay link systems. [C454]

## "Mesh-free approach to Hemholtz equation based on radial basis functions"

Recently, a radial basis functions (RBFs) method, which was originally proposed for interpolation problems, has been developed and applied to solve partial differential equations and eigenproblems. Properties of that method (mesh-free algorithm) allows one to use it in many areas, including electromagnetics. In this paper the mesh-free RBF method for solving Helmholtz equation was applied and a new adaptive algorithm for defining the set of interpolation centers was proposed. Using the proposed approach the cutoff wavelengths and the field distribution in cylindrical waveguides of arbitrary cross-section were calculated with a high accuracy. [C455]

## "Efficient multimode mixed time-frequency domain analysis and optimization of waveguide structures"

Application of full-wave analysis and optimization method of waveguide structures having any desired topology is presented. Modeling of waveguide discontinuities by generalized scattering matrices are efficiently performed utilizing the modified FDTD-IBC method. Numerical optimization and model measurements of the 7-th order waveguide direct coupled cavity filter validate presented approach. [C456]

## "Bistatic canopy scattering simulation using modified MIMICS"

The Michigan microwave canopy scattering model (MIMICS) was developed to simulate microwave backscattering from tree canopies. It is a simulation solution of the radiative transfer equations. The tree canopy is modeled as two horizontal vegetation layers over a dielectric ground surface. We modify MIMICS to accommodate the simulation of bistatic canopy scattering. Two angle parameters are added to specify the scattered direction. More types of extinction, source, and phase matrices, and ground reflectivity matrices are calculated. We present and analyze the bistatic scattering simulation results of several canopy coverages. [C457]

## "Partly approximate iteration technique for accelerating CG-MLFMA solution"

To further expedite the solution of the conjugate gradient iteration multilevel fast multipole algorithm (CG-

MLFMA), we have developed a partly approximate iteration technique. When the iterative error is lower than the critical iteration error (CIE), the matrix-vector multiplication can be computed approximately by the interactions from the nearby region. The CIE is determined by the contributions of the nearby region and the accuracy required. Compared to the interactions from the non-nearby region, the interactions from the nearby region only possess a very small portion of the total complexity. Because the number of iterations needed in the presented method does not increase dramatically, total CPU time can be reduced greatly. Numerical results are given to demonstrate the validity and efficiency of the presented method. [C458]

## "Numerical study of planar GPR antenna measurements"

First Page of the Article [C459]

## "A study on extraction of urban areas from polarimetric Synthetic Aperture Radar image"

This paper discusses the polarimetric correlation coefficient to extract the urban areas from polarimetric Synthetic Aperture Radar (POLSAR) image. For classification of POLSAR image, several methods have been proposed to extract polarimetric feature, such as Polarimetric Entropy-Alpha, three-component scattering model, Huynen parameters and so on. However, there is a possibility that the polarimetric correlation coefficient has a potential for the objective of this paper, too. In order to verify the capability of polarimetric correlation coefficient, we examine the behavior of this coefficient between the urban areas and the natural distributed areas with respect to the several polarimetric scattering models and the difference of polarization basis. Moreover, we apply the polarimetric correlation coefficient to the actual polarimetric SAR data acquired by Pi-SAR/X-SAR. [C460]

## "A polarization radar channel: elements and singularities"

The factors, having a considerable influence to the radar signals polarization structure, are considered. An influence value of these factors to information obtained, is estimated. [C461]

## "The scattering matrix of radar object"

The decompositions of radar object scattering matrix are considered for the cases of linear and elliptical eigenpolarizations. The series of these matrixex parameter is considered. The parameters mentioned can be measured and displayed on the radar screen [C462]

## "One-channel polarization radar "polaris" using the polarization modulation of radiated signal"

The problems of polarization radar design are considered for the case of its functioning in real time. The functioning algorithm is established. The design results are shown. [C463]

## "Emergence principle for electromagnetic waves polarization parameters at the scattering by complex radar objects"

In this paper, systems analysis and the emergence principle are used for investigation of electromagnetic wave polarization of the scattering by complex radar objects. [C464]

## "Electromagnetic modeling of 3D PEC objects in a half-space environment"

In this paper, efficient methods are discussed to calculate radiation or scattering from three-dimensional perfectly electrically conducting objects located in the half-space environment. Firstly, optimization for impedance-matrix-filling is accomplished to avoid repeated evaluation of Green's functions or Sommerfeld integrals. Then the appropriate evaluation methods for Sommerfeld integrals, such as the method of integration along folded Sommerfeld integral path (FSIP), the method of integration along steepest descent path (SDP), the discrete complex image method (DCIM) and so on, are applied to the different regions with different observation-to-source distance. By these methods, the Sommerfeld integrals can be calculated accurately and fast. Finally, tabulation and interpolation for Green's functions are used to further accelerate the process of impedance-matrix-filling. Some examples are presented for validation. The numerical results have shown that these methods can be used to model the radiation and scattering from complex objects located in a half-space environment accurately and efficiently. [C465]

## "A method for characterizing a target in polarimetric radar remote sensing"

A method for characterizing a target is proposed in this paper, based on the eigenvalue decomposition of a scattering matrix. From this method, a set of parameters is derived. The parameters are not only independent of

the spans of the scattering matrices, but also independent of the target orientation angles. With these parameters, we enhance the contrast between the road and forest of a SAR image, demonstrating the effectiveness of the proposed parameters. [C466]

## "A solution for fast radar target detection with high detection probability using dynamic polarization method"

For every radar station location we can make a library of the elements of the radar target scattering matrix (CBEM1,2,3,...N) combinations, which have the ability to give a high detection probability (PD). In dynamic polarimetry mode, we have PDiwith each CBEMj, at the certain j polarimetry state (PSj) j=1,...,M. If M is a number of the PS, we have PDmaxj=max{PDi} then we can calculate max{PDmaxj}=PDmaxmax,. Here PDmaxmaxis the highest PDvalue for the selected CBEM. [C467]

## "Parallel multilevel fast multipole method for solving large scale electromagnetic problems [Cradar cross section problems]"

The parallel multilevel fast multipole method (MLFMM) is an efficient computational algorithm for solving large-scale radar cross section (RCS) problems. The code is developed and implemented on massively parallel, distributed memory computer systems. The multilevel grouping structure is partitioned carefully to separate computational tasks and reduce data communication. A message passing interface (MPI) is employed to perform the data transfer and support the matrix-vector product in the parallel iterative procedure. The accuracy of the code is verified by comparison with results of a benchmark target. The computational complexity and efficiency of the parallel MLFMM is discussed. [C468]

## "Analysis of impacts of various RAM on RCS of 3-D complex targets using the FEM-FMA [Cradar absorbing materials]"

The hybrid vector finite element method and fast multipole algorithm (FEM-FMA) are used to calculate the RCS of 3D complex targets coated with various radar absorbing materials (RAM). For a cone as an example, This work analyzes the impact of four canonical RAM coatings, including lossy isotropic, positive uniaxial anisotropic, negative uniaxial anisotropic and nanometer absorbing materials on the electromagnetic scattering characteristics of the objects. The effect on the RCS caused by different coating thickness is discussed and an optimal coating thickness is obtained to attain the best stealth response. Numerical results shows that the back scattering RCS can be reduced about 16.6 dB compared with the uncoated objects by using an optimal coating of RAM. [C469]

## "Robust AMF performance in non-Gaussian clutter using self-censoring"

This paper discusses the performance of the adaptive matched filter (AMF) in impulsive clutter backgrounds modelled as a spherically invariant random process. Three different techniques are used to determine the weights of the adaptive matched filter. It is shown that a self censoring reiterative approach for calculating the weights results in robust performance for a large class of clutter scenarios ranging from highly impulsive clutter to Gaussian clutter backgrounds. Performance analysis is presented in terms of the output signal-to-noise-ratio of the AMF. [C470]

## "Fast surface-search algorithm for adaptive FIR filtering"

This paper proposes a fast surface search (FSS) algorithm for adaptive FIR filtering. The proposed algorithm depends on the efficient calculation of the fast gain vector (FGA) defined in C. E. Davila (July 1993) and the rank-one updating formula of the correlation matrix of the input vector sequence. This algorithm is of computational complexity O(M), which is comparable with the fast recursive least squares transversal filters for adaptive FIR filtering. The global convergence of the proposed algorithm is studied by the Lyapunov indirect method. The performances of the relative algorithms are shown via computer simulations. [C471]

## "Polarization-doppler response function"

A possibility of complex radar object polarization parameters presentation is considered taking into account an object movement. [C472]

## "Polarization-doppler response function in the inverse synthesis problem"

A possibility of complex radar object polarization Doppler response function is considered for an aperture synthesis. [C473]

## "Radar signals polarization structure transformation in the medium with hidrometeors"

The problems of radar signals polarization structure transformation are considered for mediums with hidrometeors. Both analysis and experimental results are demonstrated. [C474]

## "Scattering mechanism identification based on the rotation and eccentric angles of polarimetric SAR data"

In this paper we introduce two novel parameters for polarimetric SAR (POLSAR) images. For this purpose, a 2times2 matrix is defined to take into account the independent elements of the covariance matrix. To understand the geometry of this new matrix, an equation of ellipse is defined. As a result, the geometry of the ellipse is completely tied up with the eigenvalues and eigenvectors. Two novel parameters, the rotation and eccentric angles of the ellipse which can directly be derived from the eigenvalues and eigenvectors, are presented. The results indicate that different scattering mechanisms can be represented with the rotation and eccentric angles. Results obtained from the proposed parameters, when compared with the results derived from existing features, were in agreement in terms of the scattering mechanisms, as well as terrain cover types present in the test site [C475]

## "A polarization-rotating Van Atta array reflector and its application to polarimetric radar calibration"

This paper presents the principle, design, and measured characteristics of a 90-degree polarization-rotating Van Atta array reflector with suppressed scattered field as a reference target for polarimetric radar calibration. A polarimetric calibration method that uses a trihedral and the present reflector needs no assumptions on scene characteristics and statistics and no independent phase calibration [C476]

## "Raw signal simulation for very high resolution SAR based on polarimetric scattering theory"

A method for raw signal simulation for extended SAR scenes with very high resolution is described. This simulator can handle resolution better than 1 m, squinted geometry, elliptical orbit motion and use a polarimetric reflectivity matrix. Classical polarimetric scattering theory is based on electromagnetic harmonic fields using Maxwell's equations, Green's function, Huygens' principle and Kirchhoff's approximation. Here, the scattering theory is modified for a chirp field. Calculated expressions for the scattered chirp field or the reflectivity matrix are presented. Such a reflectivity matrix can then be input to the inverse-EETF4 for raw data generation [C477]

## "The scattering fields of 2-D sea fractal surface with finite conductivity illuminated by ellipse polarization wave. Part two. Scattering matrix and numerical results"

The scattering fields of 2D sea fractal surface with finite conductivity illuminated by ellipse polarization wave in Cartesian coordinate system have been evaluated in part one. We derive here the relation expression between scattering fields and d illumination fields with 3Ч3 matrix in local coordinate system. The radar cross section (RCS) on different polarization is obtained and numerically simulated. It shows that the results of our scattering model are in agreement with those of other literatures for some special case. We get some conclusions: (1) valued of radar cross sections of cross polarization (VH and HV) are less than those of co-polarization (VV and HH) but cannot be neglected; (2) when the incidence angle θ1, and the scattering angle θ2are determined, the angle of the scattering plane out of the illuminating plane θ3varies from 0° to 180°, different relations among θ1, θ2and θ3in different relationships between σvs,vt0, σhδ,hi0and σvδ,hi0, σhδ,vi0are derived, we can use these inequalities to predict the critical angle θ3where the relation between RCS of VV and HH,VH and HV polarization will exchange, respectively; (3) the effects of depolarization can be neglected though we derived the expressions for them. [C478]

## "Physical interpretation on eigen-analysis of the polarimetric coherency matrix for microwave scattering from vegetation"

The potential of using the eigen-analysis of the coherency matrix is discussed for improved understanding of microwave interaction mechanism in vegetated areas. Using a nonsymmetric vegetation scattering model, a theoretical target matrix is generated to compare the eigen-parameters of the coherency matrix with vegetated scattering mechanisms. [C479]

## "Target scattering decomposition of one-look and multi-look SAR data using a new coherent scattering model: the TSVM"

A new model, the target scattering vector model (TSVM), is introduced for decomposition of coherent scattering.

The model that is inspired from Kennaugh and Huynen [1965] con-diagonalization method, Cameron and the SSCM coherent scattering decomposition [1996] represents coherent scattering of symmetric and non-symmetric targets in term of five independents parameters; the target orientation angle and four orientation invariant target parameters. The TSVM is integrated in Cloude's incoherent decomposition method to derive a general scattering decomposition method, the TSVM-coherency characteristic decomposition, which can be applied to both single and multi-look SAR data for characterization of point and distributed targets. The conditions requested for a successful application of the TSVM-coherency characteristic decomposition are discussed. [C480]

## "The scattering fields of 2-D sea fractal surface with finite conductivity illuminated by ellipse polarization wave. Part One. Scattering fields in Cartesian coordinates"

Recently, many analytical expressions of scattering fields of sea fractal surface with infinite conductivity were derived. In order to simulate multi-polarization SAR imaging of sea surface and consider the effects of polarization on remote sensing of sea surface, we derive the scattering fields from 2D sea fractal surface with finite conductivity illuminated by ellipse polarization wave at Kirchhoff approximation. Then we present the scattering matrix of this model and numerically simulate the bistatic radar cross section (RCS) of 2D sea fractal surface. It shows that the result of applying our model coincides with that of relevant literatures. Our work is divided into two parts. In the first part, we derive the scattering fields in Cartesian coordinates. And in the second part, we evaluate the scattering matrix of this model and then give the numerical results and discuss them. [C481]

## "Detection of objects with non-reciprocal properties by polarization radar"

First Page of the Article [C482]

## "Multi-rank Capon beamforming"

This paper presents a multi-rank extension of the Capon beamformer. By expanding the rank of the beamformer it is possible to fully exploit situations in which signals lie in multi-dimensional subspaces, as opposed to the standard point source case. Such situations are commonly caused by array mismatches and scattered or distributed sources. The extension involves the design of a constraint matrix which can be interpreted in terms of signal power. Three possible choices for the constraint are proposed. These correspond to one non-adaptive choice, one choice that is dependent on the signal covariance structure only, and one choice that is both signal and data adaptive. Simulation examples are presented that show the promise of the idea of multi-rank Capon beamforming. Especially the signal- and data adaptive constraint appears very promising. [C483]

## "Polarimetric EM scattering and information retrieval in SAR remote sensing"

The advance of polarimetric SAR imagery technology. such as SIR-C and RADARSAT-2 has promoted extensive study and applications for information retrieval from polarimetric scattering measurements. This paper briefly reports our research on three issues: (1) solutions of the Mueller matrix, the eigenvalues of the coherency matrix and information entropy to directly relate with measurements of the co-polarized and cross-polarized scattering in SAR imagery; (2) an inversion approach for digital elevation mapping (DEM) by using a single pass instead of two-pass or interferometric SAR (INSAR), of polarimetric SAR data; (3) an algorithm of two-threshold EM (expectation maximisation) and MRF (Markov random field) for automatic analysis of the context change detection in the urban area from multi-year SAR observations. [C484]

## "MM-wave rain scattering with regard to raindrop nonsphericity"

Angle dependences of MM-wave rain scattering have been numerically analyzed using the T-matrix technique with regard to both the raindrop nonsphericity and size distribution. Results of numerically calculating the angle dependence of rain scattering are presented. The differential scattering cross-section of a single raindrop has been studied. Angle dependence of scattering cross-sections for unit volume of rain have been analyzed. The available results may prove useful in the design of frequency reuse systems. [C485]

## "Potential of coherent decompositions in SAR polarimetry and interferometry"

A comparative study has indicated that coherent decompositions may have high potential in applications using fully polarimetric and interferometric SAR data, as an alternative or supplement to standard non-coherent techniques developed during the last decade. One important reason for this seems to be that the coherent techniques are better able to benefit from the coherent nature of the underlying data and scattering mechanisms. By avoiding averaging at the first processing stage, the coherent techniques can extract target features that may otherwise be lost in the early averaging process. On the other hand, averaging is indeed important in most

cases for obtaining stable and reliable end results. [C486]

## "Signal processing techniques at radar measurement of the UWB polarization characteristics"

In the report the principles of processing of the UWB signals for an estimation of frequency responses polarization matrices by results of measurements are discussed. The reviewed methods are introduced in a "TSUNAMI-3" collimating type radar measuring complex. The outcomes of obtaining 2D polarization object radar images on experimental data are resulted. [C487]

## "Natural resonance frequency extraction using an early-time and late-time responses combined technique"

In this paper, a pole extraction method using an early-time and late-time responses combined technique is presented. Without the determination of the beginning of the target transient response, the proposed method assumes an ARMA representation to approximate the complete target transient response, and a total least square method is applied to poles extraction. The proposed method is validated using a measured scattering data of a thin wire and a finite cylinder. The processing results show that the proposed method is superior to the KT method and matrix pencil method in an appropriate SNR [C488]

## "Solution of the inverse problems of subsurface radiolocation"

A common approach is stated to the solution of an inverse scattering problem from the results of an exploration of a subsurface radio-stage by ultrawideband short-pulse signals. At the first stage, with the help of multiple loggers, the time-space matrix of a scattered electromagnetic field is shaped. The second stage is bound to the definition of the physical properties of the subsurface area. At the third stage, the detection procedure is carried out by shaping a 2D or 3D image of the subsurface area. Examples of 2D images restored by a spectral method are reduced. At the fourth stage, the procedure for reconstructing the geometrical and physical properties of subsurface objects is carried out. The procedure is based on a method of computing diagnostics (MCD). [C489]

## "Ultra wideband double ridged horns with rectangular aperture"

A mode matching technique, that takes into account field singularities at the edges, an integral equation method and a generalized scattering matrix method were applied for the development of a mathematical model of double ridged horns with a rectangular aperture. During the modeling, the horn structure, which is inhomogeneous in the longitudinal direction, has been decomposed to the homogeneous H- and rectangular waveguides. We present the design of an ultra wideband doubled ridged horn with rectangular aperture, developed for the 1-10 GHz frequency band, and the results of its experimental investigation. [C490]

## "An accurate broadband method of moments using higher order basis functions and tree-loop decomposition"

The method of moments (MoM) has been one of the most popular computational methods for the solution of electromagnetic scattering problems. While many MoM formulations are possible, the electric field integral equation (EFIE) formulation is of great importance as it can be applied to either closed or open structures. Unfortunately, at very low frequencies, naive EFIE implementations become inaccurate due to severe cancellation in the computation of the scalar potential. This work presents a method to create a loop-tree decomposition for the divergence-conforming higher-order triangular patch bases so that a single mesh can be used to gather broadband information. The proposed method is completely general, and works for any basis function order. In addition, frequency scaling of the impedance matrix was used to further lower its condition number and the right hand side was reformulated to alleviate subtractive cancellation. [C491]

## "The evolution of UWB technology"

This talk will review the development of time domain electromagnetics by this writer and others over more than a 40-year period and show how the work contributed to the growth of ultra-wideband (UWB) radar and communications. It will also review some of the latest advancements made in the field of communications by investigators making presentations at this UWB session at RAWCON and attempt to put their work in perspective. Additionally, some remaining problem areas will be identified. [C492]

## "Evaluation of possibilities of solving the inverse scattering problem for multilayered structures in the case of plane wave"

Investigation of approaches to solving of one-dimensional inverse scattering problem of electromagnetic waves is

presented in the paper. Two approaches were analysed in detail as alternative ways of inverse scattering problem solving. One of them is based on analytical solution of Riccati equation and other realizes minimization of objective function defined by character of inverse problem. Efficiency of investigated methods was estimated at the solving of both profile reconstruction and multilayered structures synthesis starting from frequency dependence of reflection coefficients. [C493]

## "Robust antenna array processing using M-estimators of pseudo-covariance"

This paper addresses the problem of antenna array processing in nonGaussian noise and interference conditions. Such conditions arise due to man-made interference in indoor and outdoor mobile communication channels as well as in military communications. In this paper M-estimators of the array (pseudo-)covariance matrix based upon complex data set are introduced. Estimates of the noise and signal subspaces based on M-estimators are then used to robustify the subspace direction of arrival (DOA) estimation methods. In addition, eigenvalues based on M-estimators are used in MDL criterion, thus yielding a robust signal detection method. The reliable performance of the proposed methods are shown by simulations. [C494]

## "Algorithm of spatial selection of uncorrelated signals"

The opportunity of using supersolution algorithm in radar-location system to spatial selection of signals scattered from targets is considered in the paper. The analysis of rate of signals correlated in temporal and space parameters is given. The conditions, which signals are uncorrelated or rate of correlation is less than the given value, are defined. The algorithm of treatment of radar signals is proposed on the base of the given expressions and its efficiency is evaluated. The results of numerical simulations of spatial selection of signal reflected from various targets performed on the basis of both classical algorithm and suggested algorithm is carried out. [C495]

## "Target discrimination in the S.A.R. systems by using radar polarimetry"

For a SAR system that coherently transmits and receives both signals from an orthogonally polarized antenna pair, the elements of the resulting scattering [S] matrix can be measured. As a result, polarimetric processed imagery is visually much clearer than single-polarization channel imagery. In addition, fully polarimetric SAR imagery improves the performance of an ATR system, compared to the performance achieved by using single-polarization channel imagery. This paper gives a brief description of some polarimetric tools and techniques used to analyze and process polarimetric data. Several polarimetric discrimination results are displayed, demonstrating the potential capability of characteristic polarization imaging and the usefulness of polarimetric radar in the target discrimination process. [C496]

## "RCS computation over a frequency band using the characteristic basis and model order reduction method"

In many practical applications, it is desirable to analyze the radar scattering from an object over a wide frequency band. Earlier attempts to achieving a fast frequency sweep involved the computation of higher order moments of the MoM matrix, which requires considerable fill time for each frequency point when the number of unknowns is large. In this paper, we present an approach for constructing a set of universal basis functions that can be used over the entire frequency band of interest. The use of this universal basis set obviates the need to factorize the block sub-matrices at each frequency, and results in considerable time saving. The numerical accuracy and the computational advantage of the proposed technique are illustrated by studying the problem of plane wave scattering from a PEC plate over a wide frequency band. [C497]

## "Processing and analysis of polarimetric ground penetrating radar landmine signatures"

The paper presents an analysis of landmine signatures acquired with a polarimetric ground penetrating radar (GPR). First, preprocessing was applied to isolate the target signatures from other reflection events. This included a frequency-wavenumber (f-k) filter to remove unwanted side reflections, followed by background subtraction to remove the direct wave and the ground reflection. The obtained polarimetric signatures of the landmines indicated that these can contain significant cross-polar components, which is in contrast to expectation for a target with a cylindrical casing and most likely a result of internal structure. Making use of the reciprocity property of the scattering matrix, the polarimetric signatures were transformed into the target frame, yielding signatures that are independent of target orientation. From the transformed signatures target impulse responses were estimated using a newly developed deconvolution algorithm. The novelty of the deconvolution algorithm lies in the fact that it computes impulse responses, which adhere to a physical model. Accordingly, the computed impulse responses can be related to mine properties such as size and dielectric permittivity. An interesting application of this is the estimation of a mine's permittivity from its impulse response and the impulse response of a calibration target, of which an example is given. [C498]

## "The Kennaugh's concept of the inversion point inside the Poincare sphere model of the scattering matrix and further developments of his ideas"

Edward Morton Kennaugh (1920-1983), in his last paper (IEEE Trans. Antennas and Propag., vol.AP-29, no.2, p.412-13, 1981), recalled his geometrical interpretation of polarization dependence of the radar cross-section (RCS). That dependence had been discovered by him and announced for the first time in his two Ohio State University Antenna Laboratory reports of the years 1950 and 1951. Kennaugh noted that his results 'described 30 years earlier, seemed to have been generally overlooked'. Now we can observe that those results, so simple and so important for practical applications, have been 'generally overlooked' during the next 20 years also. The aim of this paper is to recall his original 'inversion point' concept as a corner-stone of the Poincare sphere model of the scattering matrix and to present some further developments of his ideas based on that concept. [C499]

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

We address the problem of detecting slow-moving targets using a non-sidelooking monostatic space-time adaptive processing (STAP) radar. The construction of optimum weights at each range implies the estimation of the clutter covariance matrix. This is typically done by straight averaging of neighboring data snapshots. The range-dependence of these snapshots generally results in poor performance. We present two new methods that handle the range-dependence by exploiting the geometry of the direction-Doppler curves. [C500]

## "Blind adaptive detection of distributed targets in compound-Gaussian clutter"

This paper considers the problem of detecting distributed targets in the presence of compound-Gaussian noise with unknown statistics. At the design stage, in order to cope with the a priori uncertainty, we model clutter returns as Gaussian vectors with the same structure of the covariance matrix, but possibly different power levels. Hence, resorting to the method of sieves, we devise a fully blind detector, which ensures the constant false alarm rate (CFAR) property with respect to the disturbance power levels. Moreover the performance analysis confirms the capability of the novel receiver to operate in scenarios of practical interest for radar systems. Finally the comparison with the plain modified generalized likelihood ratio test (MGLRT), devised assuming Gaussian disturbance, and shows that even in the presence of Gaussian clutter, the newly proposed detector achieves satisfactory performance. [C501]

## "Detection of targets above rough surfaces using millimeter-wave bistatic radars"

In this paper, we report on a new set of indoor measurements aimed at characterizing the bistatic radar return from rough surfaces at Ka-band. The polarimetric response over the entire upper hemisphere, at both low and high incidence and scattering angles, and at near forward and backward directions are reported. This first of a kind data reveals the angular dependence of various polarimetric quantities such as the copolarization ratio, the crossto copolarization ratio, and the correlation between various polarized radar returns. It can be used to validate existing or new surface scattering models and to identify and evaluate bistatic configurations for radar operation. The potential of bistatic radars in detecting the presence of targets embedded in clutter is also demonstrated experimentally using a simple target above a rough surface. [C502]

## "The minimum residual interpolation method applied to multiple scattering in MM-PO"

We developed the minimum residual interpolation method (MRI). MRI is efficient when the right hand sides depend smoothly on a parameter. The advantage of MRI is the independence of the underlying solution method and the ability to predict the residual without computing a matrix vector product. Once enough right hand sides axe solved, MRI can predict the solutions to the remaining right hand sides. In this paper the versatility of MRI is demonstrated. MRI is applied to the solution of the equations in the method of moment (MM), the physical optics method (PO) and the iterative method of moment-physical optics hybrid (MM-PO). The PO part is formulated as a Galerkin problem. The MM part is handled with an iterative method that uses MLFMM matrix vector multiplication. The coupling between the two regions is also handled with MLFMM. The iteration between MM and PO can be viewed as an iterative block Gauss-Seidel method. [C503]

## "Generalized optimization of polarimetric contrast enhancement"

The optimization of polarimetric contrast enhancement (OPCE) is one of important problems in radar polarimetry. The traditional OPCE is to choose optimal polarization states for enhancing a desired target versus an undesired target/clutter. The contrast enhancement enables us to discriminate or distinguish the desired target from background or from the undesired target. We propose a generalized OPCE (GOPCE). For the GOPCE problem,

we need to find not only three coefficients such that the ratio of two factors associated with the desired target and clutter is maximal, but also optimal polarization states such that the received power ratio of the target and clutter is maximal. Both the factors consist of three parameters, i.e., the Cloude entropy (Cloude, S.R. and Pottier, E., IEEE Trans. Geosci. Remote Sensing, vol.35, p.68-78, 1997) and two special similarity parameters (Yang, J. et al., Electron. Lett., vol.37, p.193-4, 2001). The optimal coefficients of the GOPCE are obtained by solving an eigenvalue problem. Using an example, we demonstrate that the GOPCE can be employed for detecting roads in a forest area by using polarimetric SAR data. [C504]

## "Numerical determination of ISAR images of objects modeled with NURBS surfaces"

An application to obtain ISAR images of real targets is presented. ISAR images are obtained by means of two different algorithms FFT and MUSIC. Targets are modeled using NURBS surfaces, which guarantee the use of geometrical realistic models to describe the bodies. [C505]

## "A hybridization technique for MLFMM for a large class of cavity backed aperture scattering problems"

An efficient technique for the analysis of electromagnetic problems involving large metallic bodies with arbitrary complex interior and a number of apertures is presented. Typical applications for this technique are the computation of EMC related transfer-functions of the electromagnetic field, describing the coupling of energy into complex systems as well as the computation of the RCS of complex cavities in large metallic scatterers. The proposed method is based on the combination of generalized admittance matrices (GAMs) for the apertures with MLFMM for the outer problem. The GAMs are first computed by the most appropriate technique for the complex interior problem (e.g. FDTD). In the second step of this technique, the admittance matrices are incorporated into the MLFMM-accelerated iterative MoM solution process. This technique is especially suited for coupling studies of complex systems requiring many different field incident angles, since the GAMs are to be computed only once. [C506]

## "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. [C507]

## "Examination of forest polarimetric backscattering with coherent cylinder model"

In this work a coherent backscattering model for cylinders has been employed to simulate L-band and C-band polarimetric backscattering form a pine forest. Scattering covariance matrix, entropy, alpha angle, polarimetric coherence and temporal coherence are calculated and compared with SAR measurements. The results show that direct backscattering from tree crowns is an important scattering mechanism. Realistic ground reflection modelling was shown to be very important. By simulating the tree growth, general agreement between the known biomass and backscattering parameters was achieved. [C508]

## "Optimal image classification employing "optimal" polarimetric variables"

Analysis of polarimetric SAR data often proceeds after first identifying important degrees of freedom in the data, thereby reducing the dimensionality of the problem. Various derived parameters (e.g. entropy, polarization fraction) and/or descriptions of polarimetric data (e.g. scattering matrix, covariance matrix, Stokes Parameters) are employed to effectively reduce the dimensionality of the data while at the same time preserving the relevant polarimetric information. The classification presented in this work involves two steps: first determine the reduced set of variables, from the data, that "optimally" represents the polarimetric information. Second, employ these newfound variables to segment (and classify) the polarimetric SAR image. Finally, the classification results are compared with standard statistical maximum likelihood techniques. [C509]

## "Coherence estimation and speckle filtering based on scattering properties"

In this paper, we propose a new speckle filter for polarimetric SAR that preserves pixels' scattering properties. The basic principle is to select pixels of the same scattering characteristics to be included in the average. To achieve this, the algorithm first applies the Freeman and Durden decomposition to separate pixels into three scattering categories: surface, double bounce and volume, and then unsupervised classification is applied. Speckle filtering is performed using the classification map masks. Pixels centered in a 9Ч9 window are filtered by including only pixels in the same and two neighboring classes from the same scattering category. This

algorithm is extended to the coherence estimation of polarimetric interferometry SAR data. The effectiveness of this new algorithm is demonstrated with JPL AIRSAR and E-SAR data. [C510]

## "Analysis of multi-frequency polarimetric data for assessment of bare soil roughness"

The aim of this study is to assess the bare soil surface roughness parameter, i.e. the root mean square height (hrms) when the moisture is constant, using anechoic chamber measurements based on fully polarimetric scatterometer data. An incidence angle based algorithm has been proposed to assess the bare soil height hrms. For this purpose, sets of experimental backscattering data have been evaluated on different types of rough surfaces (Rough Gaussian, hrms= 2.5 cm, Smooth Gaussian, hrms= 0.4 cm and Medium Mixed surface, hrms= 0.9 cm) with known geometrical and dielectric properties. The scattering matrix of those three surfaces under test was measured in monostatic mode vs. frequency ( 1-19 GHz) and incidence angles ( θ = 10° to 50° in steps of 10° for hrms= 2.5 cm and 0.9 cm and 5° for hrms= 0.4 cm) data. An empirical relationship has been developed between backscattering, hrmsand incidence angle independently for L-, C-, X- and Ka-band for all polarizations (i.e. HH, VV and HV). This relationship provides the calculated backscattering values, which is helpful in the inversion process. A good agreement has been obtained between the observed and calculated hrms. The analyses show the strong dependence of hrmson incidence angle, polarization and frequency. This type of work is also helpful in the near future to predict the optimum sensor parameters (i.e. incidence angle, polarization and frequency) for measuring the bare soil roughness. [C511]

## "Comparison of multipolarization SAR systems depending on the way of the full scattering matrix measurements"

A number techniques, providing simultaneous or quasi-simultaneous measurements of the co-polarized and cross-polarized components in each orthogonal polarization are discussed in the report. Among the techniques of the measurements separation are time separation (SIR-C case), spatial/temporal separation from the same orbit of a squint SAR, repeated orbits interferometry mode, carrier separation and orthogonal codes separation. Each of the techniques under discussion is characteristic by the required PRF or swath width, data rate, level of polarization coupling and ambiguities. The comparison of the distortions is being made as well as a comparison of the SAR parameters. [C512]

## "Targets classification of semi-arid region using polarimetric SAR data $an example in Xinjiang, China"

This paper develops a classification way using polarimetric synthetic aperture radar (SAR) data. Polarization of radar electromagnetic wave is a very important factor of backscattering theory and geosciences applications. However, polarimetric SAR images are still difficult to interpret and therefore there is a need to improve the classifier that can make use of the polarimetric information. Under the certain circumstance the present paper attempts to classify remotely sensed scenes by all the complete polarization response parameters, which are presented as data dimensions for classification arithmetic. The test site is located in Hetian of Xinjiang, China. SIR-C data were acquired in the test site in 1994. Fully polarimetric SAR data can be processed as multi-dimensions images. But the polarimetric information is related greatly with variable targets. Firstly, we decompose the backscattering matrix and get polarimetric ratios, polarimetric degree, and polarimetric entropy. These polarimetric parameters are considered as data dimensions in which elements change in terms of probability functions with variable targets. Training samples were then generated from the outputs of the unsupervised classification of K-means, to be used in subsequent supervised classifications of two frequencies (C- and L-band for SIR-C data) and various polarization combinations. The estimation of the classifier tallies with the local municipal statistics. The result shows that classification precision can be improved finely with the polarimetric technique. [C513]

## "Estimating vegetation bias in polarimetric SAR interferometry"

First Page of the Article [C514]

## "Classification of polarimetric synthetic aperture radar images using fuzzy clustering"

Clustering is a well known technique for classification in polarimetric synthetic aperture radar (POLSAR) images. Pixels are represented as complex covariance matrices, which demand dissimilarity measures that can capture the phase relationships between the polar components of the returns. Four dissimilarity measures are compared to judge their efficacy to separate complex covariances within the fuzzy clustering process. When these four measures are used to classify, a POLSAR image, the measures that are based upon the Wishart distribution outperform the standard metrics because they better represent the total information contained in the polarimetric

data. The Expectation Maximization (EM) algorithm is applied to a mixture of complex Wishart distributions to classify the image. Its performance matches the FCM clustering results yielding a tentative conclusion that the Wishart distribution model is more important than the clustering mechanism itself. [C515]

## "The SSCM for ship characterization using polarimetric SAR"

Ship characterization is investigated using the symmetric scattering characterization method (SSCM), which was introduced by Touzi and Charbonneau (2002). The SSCM method appears to be very promising for ship identification. Identification of ship targets with significant symmetric scattering is shown to lead to accurate pitch measurement, under certain conditions. [C516]

## "Unsupervised classification of polarimetric SAR images using neural networks"

We study two unsupervised algorithms for polarimetric SAR image classification. The first one is Cloude's decomposition algorithm. The main advantage of this unsupervised algorithm is to provide terrain identification information where the most important kinds of scattering medium can be discriminated. However, his main advantage is the arbitrary location of decision boundaries. To surmount this insufficiency, we present the second algorithm based on neural networks. We propose a new scheme of unsupervised classification that combine the most important kind of trained nets. [C517]

## "An entropy-based approach to wake echo analysis [Cship wake radar detection]"

This paper addresses the problem of ship wake detection and analysis at low grazing angles using eigenvalue analysis of the covariance matrix. Polarimetric measurements of the wake produced by a pilot boat operating in Port Phillip Bay were obtained using the Defence Science and Technology Organisation's (DSTO) high resolution radar system. By employing a polarimetric decomposition on the covariance matrix data, the polarimetric entropy, scattering alpha and anisotropy plots were obtained. Wake and clutter regions were then identified using suitable thresholds. These results were compared with previous results obtained using analysis of the S matrix data and the distribution of cross-polar states and showed good agreement. The ratio of the maximum and minimum eigenvalues of the covariance matrix was also determined as an upper bound on the processing gain that might be achieved by exploiting the polarization domain. [C518]

## "Analysis of the electromagnetic scattering of rivets on the conducting plate"

In this paper, the electric field integral equation (EFIE) in conjunction with the moment method is used to analyze the electromagnetic scattering problem of rivets on the conducting plate. The surfaces of the rivets and the plate are partitioned into triangular cells, the current distribution on the patches is represented by a subdomain-type basis function, the EFIE is translated into a matrix equation by the Galerkin method, then the current coefficient is obtained. Results show the properties of RCS varying with the incident angle when there are rivets on the plate. Furthermore, we can see the effect of rivets on RCS. [C519]

## "Nonreciprocal horn reflector"

The scattering properties of different bodies over radar wave bands can be studied providing the conditions of reciprocity theorem are present. Producing radar reflectors (RR) with clearly expressed nonreciprocal properties allows one to solve the problem of detecting a target by means of polarization signs on the background of underlying surface. Such reflectors can be used as navigation beacons in controlling air and sea transport, standard objects in satellite map-making Earth's surface as well as in army technique. [C520]

## "Evaluation of the scattering matrix for impedance sphere"

In this work, scattering matrix of the constant impedance sphere is investigated by using series expansion of the incident and the scattering field. Using impedance boundary condition, unknown coefficients in the scattering field were found. We consider the there dimensional case as, sphere is illuminated by plane wave that be along z direction. We obtained the general expressions of the scattered field. Then we sought for the scattering matrix for the y-z plane [C521]

## "Consolidation of a pixel-based classification using neighborhood information"

A two-step consolidation process is presented that reduces the effect of speckle in the classification result. The degree of consolidation or smoothing can be adjusted using a classification confidence measure and a threshold for the amount of neighborhood agreement needed. Results from AIRSAR ice data shown are compared to a classification result form pre-filtered data. [C522]

## "Polarization orientation estimation and applications: a review"

We review estimation algorithms and applications of polarization orientation angle shifts induced by terrain slopes. We develop a unified analysis of estimation algorithms based on circular polarization covariance matrix. The effect of radar frequency, scattering media, and polarimetric calibration will also be discussed. Applications to DEM generation, polarimetric SAR data compensation and ocean surface feature characterization will be mentioned. SIR-C, and JPL AIRSAR L-band and P-band polarimetric SAR images are used for demonstration. [C523]

## "Polarimetric scattering from inhomogeneous random media under a pulse incidence"

Polarimetric scattering from inhomogeneous random media of non-spherical scatterers under a pulse incidence is studied. The time-dependent Muller matrix solution of the vector radiative transfer for layered random media is derived. Co-polarized and cross-polarized bistatic and back-scattering are numerically calculated. The shape and intensity of polarized echoes depict well the inhomogeneous fraction profile of random scatterers. Its functional dependence upon the fraction profile, layer thickness, and other parameters are discussed. This technique is applicable to the reconstruction of inhomogeneous fraction profile and inversion of the media thickness. [C524]

## "Fast algorithm for estimating ocean surface velocity and coherence time"

This paper deals with the estimation of celerity and coherence time using array of equispaced sensors for observing the ocean surface. A fast algorithm based on array processing or spatial analysis is proposed. Initially, two-antenna synthetic aperture radars (SAR) system are used in order to obtain two images of the same surface of the ocean afterwards the analysis of these images by using the signal processing or spectral analysis leads to estimate phase difference between the images and finally the mean short-term Doppler shift of the scattering from the ocean surface is estimated on pixel by pixel basis. To improve velocity and time coherence estimation the multiple antenna system is introduced in SAR system. Indeed, the use of more than two-antennas allows to develop statistical methods or multidimensional signal processing algorithms. Interesting studies, in which the blind maximum likelihood algorithms are used, have been published. Its performance is proved to be more accurate than the two-antenna SAR system based methods. The proposed algorithm is based on the second order statistics of the received data. Both the correlation and the coherence matrices are used for estimating the noise power, the spatial correlation matrix of the speckle and the coherence time of the ocean surface. [C525]

## "Bayes-optimality based feature transform for high resolution range profile identification"

Many feature transform methods have been used for radar target identification. But most of them are based on scatter matrices or other statistics of the data, which do not directly correlate to classification accuracy. In this paper, a Bayes-optimality based adaptive feature transform method is proposed for radar target identification using high resolution range profile results show that this method is effective on radar target identification. [C526]

## "Adaptive radar detection of distributed targets in non-Gaussian noise"

This paper deals with the problem of detecting distributed targets in non-Gaussian noise with unknown statistics. At the design stage, in order to cope with the a priori uncertainty, we model noise returns as Gaussian vectors with the same structure of the covariance matrix, but possibly different power levels. We also assume that a set of secondary data, free of signal components, is available to estimate the covariance matrix of the disturbance. Since no uniformly most powerful (UMP) test exists for the problem at hand we devise and assess two detection strategies based on the Rao test and the Wald test respectively. Remarkably these detectors ensure the constant false alarm rate (CFAR) property with respect to both the structure of the covariance matrix as well as the power levels. Moreover, the performance assessment, conducted also in comparison with the generalized likelihood ratio test (GLRT) based receiver proposed in Conte et al. (2002), shows that the Wald test outperforms the others and is very effective in scenarios of practical interest for radar systems. [C527]

## "The stability of polarimetric features for target classification from SAR imagery"

This study investigates the information content of polarimetric SAR imagery for use within automatic target detection and classification algorithms. Key questions such as the stability of polarimetric information and its relationship with image resolution are addressed. Using relatively simple polarimetric features, such as the percentage of pure odd and even bounce scattering events, we show how it is possible to identify the differences between two classes of military vehicle. The use of the radial power spectral density is proposed as a measure of the spatial distribution of these odd and even bounce scattering events, again enabling the two classes to be distinguished. [C528]

## "Parametric localization of multiple incoherently distributed sources using covariance fitting"

A new algorithm for parametric localization of multiple incoherently distributed sources is proposed. Our algorithm is based on an approximation of the array covariance matrix using central and non-central moments of the source angular power densities. Based on this approximation, a new computationally simple covariance fitting-based technique is proposed to estimate these moments. The source parameters are then obtained from the moment estimates. Compared to earlier algorithms, our technique has lower computational cost and obtains the parameter estimates in a closed form. Also, it can be applied to scenarios with multiple sources that may have different angular power densities while other known methods are not applicable to such scenarios. [C529]

## "Radar target feature extraction by wavelet transform and KCN"

Feature extraction of radar target recognition using high range resolution profiles is discussed. A feature extraction scheme by using wavelet transform and Kohonen clustering network (KCN) is proposed from the points of reducing feature dimension and feature numbers to represent a target. To compare the performance of different feature extraction methods, Fisher distance measure is introduced which reveals the within-class compactness and the between-class separation. Experimental results show the effectiveness of this method. [C530]

## "Wide-band hybrid computational electromagnetic technique using an impedance/admittance interpolation method"

A hybrid technique linking the frequency-domain method of moments (MoM) and the finite difference time domain (FDTD) method provides a powerful and flexible approach to the numerical solution of a complex antenna structure in the presence of a large lossy dielectric body, especially if it is inhomogeneous. If broadband analysis is required, such as the transient response for a sub-surface radar, this can be accurately modelled by iterating the field propagation over the two different domains. To do this it is necessary to compute the fields on an equivalence-principle surface (the surface that couples the two domains), over the entire bandwidth. In this paper, the fields are computed using the method of interpolation of impedance/admittance matrices on the antenna side, using MoM. This saves execution time and memory requirements for the MoM. Basically, the inverse discrete Fourier transform (IDFT) is performed on the equivalence-principle surface within the FDTD domain and, on the other hand, the discrete Fourier transform (DFT) is used to account for the back-scattered fields for the MoM domain. The number of frequency samples required to predict the coupling fields between the two domains over the entire bandwidth is investigated and discussed. The positions of these samples over the selected bandwidth are also studied in relation to their effect on recovery of the time-domain fields for different resonant structures. Several examples are presented and the results are compared with available data. [C531]

## "Adaptive radar detection of extended targets via signature diversity"

The paper addresses adaptive detection of extended targets in Gaussian noise with unknown statistics. It is assumed that the radar can change the transmitted signal in azimuth. More precisely, it makes use of N N-dimensional signatures; the possible useful signal from each radar cell is a coherent pulse train while the disturbance is a Gaussian process, independent from cell to cell, but with the same (unknown) covariance matrix regardless of the illuminated one. Based on the above model, we propose an adaptive detector designed according to a two-step procedure. Its performance assessment and the comparison with a previously-proposed detector show that the proposed one can be a viable means to cope with uncertain scenarios. [C532]

## "A robust bearing estimator based on Jacobi-Anger expansion for large angular spread source"

In the estimation of the bearing of an angularly spread source, the Taylor-expansion is commonly used, which may lead to a distinct model approximation error, especially for the large spread case. In order to overcome this problem as much as possible, we employ the JA-expansion model. On one hand, the model accuracy mainly depends on the order of the JA expansion but has no direct relation with angular spread; on the other hand, as the coefficients of the JA expansion for array response are just the harmonics of the incident angle, and hence of the array, a covariance matrix can be computed exactly by the Fourier transform of the angular power density. For a symmetric angular spread, utilizing the structural knowledge of the array covariance matrix and the decoupling property of the JA-expansion model, a nonlinear least squares estimator is proposed. Numerical results demonstrate its robustness for large angular spread and extension of the array size. Its asymptotic performance is also examined for the large sample case. [C533]

## "A bandwidth extrapolation technique for improved range resolution of polarimetric radar data"

Radar resolution is limited in range by its bandwidth. One of the various super-resolution techniques for

improving resolution is bandwidth extrapolation (BWE). In this paper, the concept of BWE is extended, and a new algorithm called polarimetric bandwidth extrapolation (PBWE), applicable to polarimetric radar data, is proposed. It is shown through simulations that utilization of full polarization information allows PBWE to improve the resolution beyond the conventional BWE method. [C534]

## "Application of extended Huygens' principle to scattering discontinuities in waveguide"

A recently proposed extended Huygens' principle for scattering objects in a waveguide is reviewed. This technique allows the coupling of a finite element discretisation with a quasi method of moments (MM) surface element approach. Perfectly conducting posts are considered as test cases. Implementational details are discussed and results for the conducting post are presented. [C535]

## "Model of helicon isolator for meter and decameter wave ranges"

A series of possible realisations of broadband helicon isolators for meter and decameter wave ranges has been analysed. The node model and scattering matrix of the isolators has been obtained. The characteristics of the designed devices have been investigated. On the basis of the Y-parameter matrix obtained for a nonreciprocal transformer, which contains a helicon resonator, the characteristics of some realisations of helicon isolators has been calculated. Comparison with experimental data ensures the adequacy of the model. [C536]

## "Cylindrical obstacles in multi-port waveguide junctions"

The combination of an extended iterative scattering procedure and the orthogonal expansion method is used to obtain the scattering matrix for multi-port waveguide junctions. Frequency responses of the transmission coefficients in a rectangular waveguide, describing the resonances of the posts on the dominant waveguide mode, are derived. The validity and accuracy of the method is verified by comparing the numerical results with those given in literature. [C537]

## "A simple procedure for obtaining the scattering matrix of a two-port junction in the case of incompatibility with ports of VNA"

A procedure based on the fundamentals of bilinear-transformation is presented for obtaining the scattering matrix of a two-port junction from input reflection coefficients measured by the use of a VNA when the output port of the junction, which is incompatible with the port of the VNA, is loaded one after another in three short circuited lines of different but known electrical lengths. The method is bandpass, what makes it very useful. [C538]

## "Development of ferrite coupled lines gyrator"

New gyrators based on a ferrite coupled line section (FCL) are developed and investigated. The scattering parameters are calculated for microstrip and slot-line configurations providing the practical information for design of these components. As an example, an isolator using the microstrip gyrator is designed and its scattering characteristics are calculated and discussed. [C539]

## "Field theory design of ferrite-omega waveguide junctions"

A mode matching approach is formulated for determining the S matrix of a section of rectangular waveguide loaded with slabs of ferrite and pseudochiral Ω materials. The wave properties of the guide are analysed on the basis of a transfer matrix method. Several waveguides with different configurations and localizations of the ferrite-omega slabs are investigated and discussed. Novel properties arising from the field displacement phenomena are discussed, showing their application for phase shifter design. [C540]

## "The polar decomposition of the scattering matrix applied to the polarimetric image of the guard-rail"

The concept of scattering is one of the mechanisms that polarimetry seeks to express through data. A multiplicative decomposition of the scattering matrix is developed and it is applied to the polarimetric image of a guard-rail. The image contains just one scattering center and so it results are particularly suitable to investigate the information that the polarimetric property of an object can deliver. [C541]

## "Computation of isolation between waveguide-fed slot antennas"

A method for calculation of the isolation between radar transmitting and receiving waveguide-fed slot antennas is proposed. The mathematical model of the antenna is based on the antenna decomposition on two separately

investigated key-blocks: the antenna array and waveguide divider. The resulting scattering matrix of two antennas is obtained after calculation of the external mutual coupling effects. The practical realization of the model is based on the infinite PEC plane assumption, so it may be used for planar arrays or linear arrays on electrically large bodies. [C542]

## "Domain decomposition by iterative field bouncing"

In modeling geometries that involve two or more distinct partitions, an iterative field bouncing (IFB) method can be applied to substantially reduce total memory requirements. This approach also makes possible the use of several different techniques simultaneously, where the optimal analysis method can be chosen for each partition. Application of IFB accelerates solutions particularly in situations where each partition is moving with a velocity independent of the others. Results are shown for a typical application of IFB. [C543]

## "Statistical modeling of scattering matrix elements"

Attention is paid to distribution laws describing the statistical characteristics of scattering matrix elements. Taking into account the many mathematical difficulties to set up an analytical approach, it is shown how to use numerical methods as a promising alternative. The probability density functions of the real and imaginary parts of the measured scattering matrix elements, as well as modules and phase values are determined. They are used in the process of statistical modeling and lead towards distribution laws, which are in good agreement with the measured statistics. A search of best-fitted distribution laws has been carried out on the basis of generalized Pearson curve classes. [C544]

## "Conditions to the radar vector signal providing simultaneous measurements of all back-scattering matrix elements"

The properties of the illuminating waveforms and conditions of the signals, forming orthogonal (by polarization) vector sounding signals are discussed. These signals are needed in order to estimate the back-scattering matrix (BSM) of real media and objects. It is shown that the correct BSM estimation of fluctuating objects, having a-priori unknown ranges and radial velocities, is possible only when complicated orthogonal signals are being used. The principles of forming the needed radar waveforms as well as principles of backscattered vector signal processing, assuming Gaussian noise at the receiver is formulated. [C545]

## "Determination of polarization invariants of asymmetric scattering matrix"

Polarization invariants of the backscattering matrix in HV-basis are estimated for the case of an arbitrary non-reciprocal object. Two additional polarization invariants, which describe non-reciprocal properties of the object itself, are introduced supplemented to the well known Huynen-Euler invariants. Supposing the simultaneous measurement of all 8 quadratures of the scattering matrix's elements in the monostatic radar case, closed form expressions for calculation of 8 polarization invariants are found. The given approach can be used for research of various polarization effects in remote radar sensing of artificial and natural objects. [C546]

## "Theory of scattering by an array of lossy dielectric, ferrite and conducting cylinders"

The theory of scattering by lossy dielectric, ferrite and/or conducting cylinders is investigated using a combination of iterative scattering procedure and the orthogonal expansion method. The addition theorems for vector cylindrical harmonics, which transform harmonics from one coordinate system to another, are presented. [C547]

## "Electromagnetic scattering of large finite arrays of patch antennas"

We develop CG-FFT method based on multilevel block-Toeplitz matrices to analyse the scattering of a large finite array of patch antennas. In our approach, the sub-domains are divided only on the patches' surface. The rooftop basis function and Galerkin's method are applied to discretize the mixed potential integral equation (MPIE) and establish a matrix equation. The impedance matrix is consisted of four 4-level block-Toeplitz matrices. The matrix equation is solved by using the CG method, where the matrix-vector multiplications are performed by using 4-dimensional FFTs. The numerical results including current distribution on a patch antenna and RCS of a patch antenna array are verified. The RCS of 32Ч32 and 64Ч64 microstrip patch antenna arrays are presented. [C548]

## "Efficient RCS computation for multiple incident angles using the FMM/MNM technique"

We extend the MNM (Markov and Maxwell) technique, originally developed for frequency sweeping in the context of RCS computation, to speed up the iterative solution of MoM matrix equations with multiple right hand

sides, corresponding to different angles of incidence. We show that the use of this technique can reduce computation time while preserving the accuracy of the solution. The MNM itself places little additional computational burden on the iteration process and usually requires less than the time required for a single iteration in the CG (conjugate gradient) process. The time-saving realized over the zero initial guess can be significant, especially when the angular increment is small, which is needed to capture rapid variations of the RCS, typically associated with large or complex scatterers. [C549]

## "The Mueller matrix solution for polarimetric scattering from inhomogeneous random media of non-spherical scatterers under a pulse incidence"

Polarimetric scattering from inhomogeneous random media of non-spherical scatterers under a pulse incidence is studied. The time-dependent Mueller matrix solution of vector radiative transfer for layering random media is derived. Co-polarized and cross-polarized, bistatic and back scattering are numerically calculated. The shape and intensity of polarized echoes well depict the inhomogeneous fraction profile of random scatterers. Its functional dependence upon the fraction profile, layering thickness, and other parameters is discussed. This technique is applicable to reconstruction of the inhomogeneous fraction profile and inversion of the media thickness. [C550]

## "A new solution to polarimetric radar discrimination problem"

A new solution is proposed for polarimetric radar discrimination problem by using cross-entropy to measure the difference between two scatterers. Two cross-entropy measures in favor of one scatterer over another are obtained for two independent probability mass functions that indicate the average scattering mechanism and the scattering randomness, respectively. These probability mass functions are formed by the modified similarity parameters and the eigenvalues of target coherency matrix. The cross-entropy measures utilize the polarimetric information efficiently to show the difference between scatterers. The advantage of using cross-entropy for solving polarimetric radar discrimination problem is demonstrated by the simulation results. [C551]

## "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. [C552]

## "Synthesis of broadband microstrip uncouplers for multiport complex loads"

Methods of synthesis, mathematical models and parameters of broadband microstrip uncouplers for multiport multiport complex loads are considered in this paper. These circuits are used for a solution of an optimal broadband matching problem for an antenna array. Structure parameters and a synthesis of these networks are based on eigenvalues and eigenvectors of multiport scattering complex matrices. A microstrip realization of the uncoupler and its computer-aided simulation are described. [C553]

## "Ferrite coupled lines junction and its nonreciprocal devices"

The properties of axially magnetized ferrite coupled microstrip line junctions are investigated numerically, and good agreement with the previously published experimental results are obtained. The novel configurations of the circulator and novel quasicyclic devices comprising the FCL (ferrite coupled microstrip line) section are proposed, and their overall scattering is calculated and discussed. [C554]

## "Scattering properties of circular chiro-ferrite waveguide junction"

The paper presents the scattering properties of a section of circular waveguide containing a lossy chiro-ferrite (CF) medium. The nonreciprocity of the guide section, indicated by different values of rotation angle for opposite transmission or magnetisation, is predicted theoretically and verified experimentally. [C555]

## "COMESA: concurrent measurements of the elements of the scattering matrix"

Up to now, the full scattering matrix of a radar target can only be measured with a sequence of pulses where, in each pulse, a different sub-set of the scattering matrix is measured. In best case, a dual polarized receiver is

used and two pulses are needed to measure the full scattering matrix. Although for many applications this works fine, it has inherent limitations. For a correct measurement of the scattering matrix, all elements should be measured simultaneously. To do this, a method must be used to isolate the transmitted and received signals corresponding to the different scattering elements. This can be done using so-called orthogonal signals. In this paper, a first experiment is described showing the possibilities of orthogonal signals based on the FM-CW radar principle. The experimental set-up as well as the results are described in detail. Also a block scheme of a radar system using the principle based upon the use of orthogonal FM-CW signals is described. This new radar is called COMESA. [C556]

## "Matrix spectral form of the full polarization-Doppler response function"

This paper pays attention to the polarization-Doppler response function in time and spectral domain as a description for a complex radar object. The methods of partial polarization, partial coherence and their spectral description over a given bandwidth are used in the problem solution. The interest of these investigations has been increased because modern computing possibilities allow us to calculate the spectral density of the scattered field polarization parameters in real time. [C557]

## "Principles of simultaneous measuring the radar objects' full scattering matrix"

The principles of the correct estimation of backscattering matrix (BSM) under real conditions in monostatic radar are discussed. The term "correct" means that the estimate keeps all global properties of symmetry of a real object's "instantaneous" BSM. The relation between the required accuracy of BSM estimation and the base N (BT product of bandwidth and time interval of the measurement) of the illuminated vector signal is shown. [C558]

## "Polarimetric target decomposition and physical interpretation of NASA (JPL) AIRSAR data in mountainous terrain"

Two types of polarimetric Target Decomposition (TD) theories were used to investigate the effects of surface slopes on the physical scattering mechanisms over mountainous scattering surfaces. This study is implemented with the L- & P-band NASA (JPL) airborne SAR (AIRSAR) data, which was acquired during PACRIM-II Korea campaign in September 2000. Although the dominant scattering mechanism of mountainous forest area is volume scattering in pine forest scattering surface, detailed scattering mechanism varies with respect to the local incidence angle variations due to the local topography and wavelength. [C559]

## "Frequency dependence of scattering by dense media of small particles based on Monte Carlo simulation of Maxwell's equations"

The frequency dependence of scattering by geophysical media at microwave frequencies is an important issue because multi-frequency measurements are useful for remote sensing applications. Classically, the independent scattering theory states that if the particles are small, scattering is proportional to the fourth power in 3-D scattering and the third power in 2-D scattering. In this paper, we study rigorously the frequency dependence of scattering by dense media by Monte Carlo simulations of the solutions of both 2- and 3-dimensional Maxwell's equations. The particle positions are generated by deposition and bonding techniques. The sparse-matrix canonical-grid method has been applied to speed up the simulation of scattering by 2D small particles. Numerical solutions of Maxwell's equations indicate that the frequency dependence of densely packed sticky small particles is much weaker than that of independent scattering. The results are illustrated using parameters of snow in microwave remote sensing. [C560]

## "Land cover classification of polarimetric synthetic aperture radar (POLSAR) data based on scattering mechanisms and complex Wishart distribution"

The use of C- and L-band polarimetric synthetic aperture radar (POLSAR) data for classifying land cover features in a tropical area is investigated in this study. The POLSAR data were acquired during the NASA/JPL PACRIM-1 mission over the northern part of Peninsular Malaysia on 3rd December 1996. Prior to classification, the Lee polarimetric filter was applied to the complex covariance matrix for speckle suppression. In unsupervised classification, the scattering mechanism of each pixel in the speckle-suppressed images was analyzed and grouped into one of the three categories: (1) odd-bounce, (2) even-bounce, or (3) diffuse scattering. Training samples were then generated from the outputs of the unsupervised classification, to be used in subsequent supervised classifications of various frequency and polarization combinations. The Kappa statistics computed for classification using single-frequency fully polarized C- and L-band data were 0.69 and 0.73, respectively. An improvement to 0.79 was achieved by using the dual-frequency (combined C and L bands), fully polarized data in the classification. [C561]

## "Using cross-entropy for polarimetric SAR image classification"

In this paper, the concept of cross-entropy is introduced for measuring the difference between two scatterers in polarimetric SAR image classification. The difference between two scatterers is composed of three parts, i.e., the difference of average scattering mechanism, the difference of scattering randomness and the difference of the two spans of scattering matrices. The minimum cross-entropy principle is adopted to make the classification decision. The capability of this method is demonstrated by the experimental results. [C562]

## "Coherence region shape extraction for vegetation parameter estimation in polarimetric SAR interferometry"

Polarimetric SAR interferometry (POLINSAR) provides volumetric information about electromagnetic scattering processes, whereas standard INSAR assumes that only surface scattering is present. Instead of a single complex interferometric coherence for each pixel, POLINSAR observes a polarization-dependent coherence function whose range is called the coherence region. To estimate canopy parameters, the shape of this region must be matched to predictions from scattering models. For computational efficiency, the region must be represented by a small number of samples. Current sampling methods find the stationary points of coherence magnitude or phase; it is questionable whether the coherence region can be characterized adequately with so few samples. We have developed an algorithm for sampling the outer boundary of the coherence region. We formulate the problem of finding the minimum and maximum real part of the coherence as an eigenvalue problem. The solutions specify two points on the boundary. Other points are found by applying a phase shift to the POLINSAR cross-correlation matrix. The mathematical literature shows that the coherence region is convex, and hence the algorithm rinds the entire boundary. We present a comparison of boundary sampling to standard methods on L-band POLINSAR data from the SIR-C platform. It is evident that boundary sampling describes the shape of the coherence region more thoroughly than other methods. [C563]

## "Polarimetric scattering indexes and information entropy of the SAR imagery for surface classification"

The Mueller matrix solution and eigen-analysis of the coherency matrix for completely polarimetric scattering have been applied to analysis of the SAR (synthetic aperture radar) imagery. Usually, the polarization index is defined as a parameter to classify the difference between co-polarized scattering signatures from the terrain surfaces. In this paper, the eigen-values of the coherency matrix and information entropy are derived to directly relate with co-polarized and cross-polarized indexes. Thus, it combines the Mueller matrix simulation, the information entropy of the coherence matrix, and two polarization indexes to yield an overall theory for quantitative understanding of the SAR imagery. This theory is applied to the AirSAR images. [C564]

## "A low-complexity robust bearing estimator using reparameterization and covariance match for the distributed source"

Many methods were proposed to estimate the bearing of a spatially distributed source. They usually suffer from heavy computational load and are limited to small angle spread due to model approximated error. In this paper, the two problems are considered and the main contribution is two-fold. First, the unimodal symmetric space frequency distribution is introduced to describe the source model. The exact expression of the covariance matrix can be calculated without model approximation even in the case of a large angular spread. Second, using reparameterization and covariance match criteria, a novel estimator is proposed by solving a nonlinear least-square problem in the central space frequency. It can be implemented only by a FFT or a one-dimension search. Numerical examples show its robustness for the large angular spread. A statistical analysis is also included to show the asymptotic efficiency of the bearing estimate. [C565]

## "Hybrid antenna and scattering matrix based beamformer for wide-angle scanning"

This paper presents a new hybrid antenna design and beamformer, which is capable of electronic scanning over hundreds of beamwidths with little degradation in the antenna pattern. The new compound hybrid antenna designs are discussed, with emphasis on one design that is composed of a planar array surrounded by polynomially-defined reflector surfaces. The ratio between the reflector aperture and array areas is compared to the theoretical limit. A new approach to beamforming in hybrid antennas is also discussed. Using a scattering matrix model for the hybrid antenna system., a bi-directional transformation is developed that relates the signals at the hybrid system feed to the signals that would be present in a planar array at the location of the reflector aperture. This allows standard planar array analysis and synthesis techniques to be used with the hybrid system. Examples are provided for transmit and receive weight synthesis. [C566]

## "The Mueller matrix solution for polarimetric scattering from inhomogeneous random media of non-spherical scatterers under a pulse incidence"

Polarimetric scattering from inhomogeneous random media of non-spherical scatterers under a pulse incidence is studied. The time-dependent Muller matrix solution of vector radiative transfer for layering random media is derived. Co-polarized and cross-polarized bistatic and backscattering are numerically calculated. The shape and intensity of polarized echoes well depict the inhomogeneous fraction profile of random scatterers. Its functional dependence upon the fraction profile, layering thickness, and other parameters are discussed. This technique is applicable to the reconstruction of inhomogeneous fraction profile and inversion of the media thickness. [C567]

## "Seasonal and diurnal changes of polarimetric parameters from crops derived by the Cloude decomposition theorem at L-band"

The objective of this study is to analyse and interpret the seasonal and diurnal changes of polarimetric parameters derived by the Cloude decomposition theorem. The investigations were carried out on polarimetric E-SAR data at L-band. The seasonal scattering behaviour of cereals strongly depends on the local incidence angle. Mainly surface scattering and double bounce processes contribute to the radar backscatter. Broad-leaf crops are characterised by a pronounced contribution of all scattering processes to the radar signal. With respect to diurnal variations of the polarimetric parameters due to dew and interception no significant changes could be determined. Nevertheless, the changes of the σ0-values indicate an increase in volume scattering with moisture for all crops, whereby the contribution of the other mechanisms decreases for wet plant surfaces. [C568]

## "Classification of landslide surfaces using fully polarimetric SAR: examples from Taiwan"

Landslides typically denude forested hillsides, changing dominant scattering from multiple- to single-bounce. SAR polarimetry can be used to determine the dominant scattering mechanism of the terrain on a per pixel basis. Thus, hillslopes affected by landslides may be distinguished easily from adjacent, unaffected hillslopes. Based on the polarimetric eigenvalue decomposition and the relative amplitudes of scattering matrix terms, dominant scattering mechanisms can be determined. These mechanisms-odd- or single-bounce (bare surface), double- or even-bounce, and volume (diffuse) scattering-describe the total radar returns for each pixel. The modified approach of Kim and van Zyl (2001) include the radar vegetation index, pedestal height and entropy, all representative of forest. Our analysis follows Kim and van Zyl to reveal that at L-band, the landslide scar areas of the Tsaolong and Mt. Jou-Feng-Err mega-slides are dominated by single-bounce scattering and the surrounding forested regions are dominated by volume scattering. In addition, fully polarimetric SAR is sensitive to reforestation in tropical jungle environments as demonstrated by comparison with a panchromatic Indian Remote Sensing (IRS) image. Inversion of SAR polarimetry for terrain scattering mechanisms offers a new approach for landslide mapping that has significant operational advantages over traditional methods that rely on optical sensors for rapid response to and management of landslide disasters. [C569]

## "Direct estimation of vegetation parameters from covariance data in polarimetric SAR interferometry"

Polarimetric SAR interferometry (POLINSAR) is an emerging technique for the characterization of volumetric scattering processes. Each pixel of a POLINSAR interferogram is a 6Ч6 matrix of complex sample covariances among the polarimetric channels in the image pair. A model of polarimetric scattering from vegetation specifies the expected covariance matrix as a function of the vegetation parameters. The data matrix obeys a complex Wishart probability distribution that depends on the expected covariance. Using this, one can rind the maximum-likelihood estimate of the parameters from the data matrix. This paper presents the formula for the expected covariance matrix, as predicted by the model of Treuhaft and Siqueira for a random canopy over flat ground. An algorithm for computing the maximum-likelihood parameter estimate is derived. We test the algorithm on simulated data and compare its results to estimates derived from coherence samples. We conclude by discussing the extension of the direct estimation technique to more general POLINSAR scattering models. [C570]

## "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. [C571]

## "Eigenvector analysis of polarimetric SAR data"

Fully polarimetric SAR data analysis has found wide application for terrain classification, land-use, soil moisture and ground cover classification. New methods and algorithms continue to be developed and tested. One method that has gained great popularity is the Cloude-Pottier eigenvalue/eigenvector decomposition of coherency matrices (Cloude and Pottier 1996). The eigenvalue spectrum uniquely describes the scattering entropy, anisotropy and span (total power). The eigenvectors are employed in the calculation of averaged quantities. Typically though the eigenvector components have not been analyzed in much detail. Here we present a general analysis of the eigenvectors based on an earlier observation (Cloude 2001) that the eigenvectors may be parameterized by a set of rotations. [C572]

## "Advances in extra wide-band multi-modal air/space-borne radar polarimetry, POL-IN-SAR imaging and its applications"

Radar Polarimetry, Radar Interferometry and Polarimetric SAR Interferometry represent the current culmination in 'Microwave Remote Sensing' technology, but we still need to progress very considerably in order to reach the limits of physical realizability. Whereas with radar polarimetry the textural fine-structure, target orientation, symmetries and material constituents can be recovered with considerable improvement above that of standard 'amplitude-only' radar; by implementing 'radar interferometry' the spatial (in depth) structure can be explored. With Polarimetric Interferometric Synthetic Aperture Radar (POL-IN-SAR) imaging, it is possible to recover such co-registered textural and spatial information from POL-IN-SAR digital image data sets simultaneously, including the extraction of Digital Elevation Maps (DEM) from either Polarimetric (scattering matrix) or Interferometric (dual antenna) SAR systems. Simultaneous Polarimetric-plus-Interferometric SAR Imaging offers the additional benefit of obtaining co-registered textural-plus-spatial three-dimensional POL-IN-DEM information, which when applied to Repeat-Pass Image-Overlay Interferometry provides differential background validation and environmental stress-change information with highly improved accuracy. Then, by either designing multiple dual polarization antenna POL-IN-SAR systems or by applying advanced POL-IN-SAR image compression techniques, will result in 'POL-arimetric TOMO-graphic' (Multi-Interferometric) SAR or POL-TOMO-SAR imaging. [C573]

## "Scattering analysis of a large body with deep cavities"

First Page of the Article [C574]

## "ALOS-PALSAR image simulation in various polarization bases"

The ALOS-PALSAR is the first L-band space-borne SAR in the world equipped with a fully polarimetric data taking function. For the data utilization purpose, the authors have examined the polarimetric performance (scattering matrix and resultant images) over the Toyano area, Niigata City, Japan, using the airborne Pi-SAR radar. Since the resolution will be 20 m by 20 m on the ground surface by PALSAR, the Pi-SAR data (3 m by 3 m) are ensembled to be an equivalent size for ALOS-PALSAR image simulation. The polarimetric characteristics of terrain including paddy-fields, grass-fields, residential areas, etc., were examined to show the difference in the right-left polarization handedness basis and coherency vector, three-component scattering model, and polarimetric entropy. [C575]

## "Classification and interpretation of polarimetric interferometric SAR data"

In this paper is introduced an approach to the classification and interpretation of SAR data using the complementary polarimetric and interferometric information. An unsupervised polarimetric segmentation is applied to one of the separate interferometric dataset. The use of pertinent polarimetric indicators permits to give an interpretation of each resulting cluster scattering mechanism and to classify the observed scene into three canonical scattering types. The interpretation and the segmentation of an optimized interferometric coherency spectrum is applied, for each type of scattering, to initialize an unsupervised statistical interferometric classification procedure. [C576]

## "A technique for removing vegetation bias from polarimetric SAR interferometry"

This paper develops a technique for separating the ground and vegetation components from polarimetric interferometric SAR measurements. The objective is to use this technique to remove the vegetation bias in interferometric measurements of elevation in forested terrain. Initial results indicate that the technique is able to compensate for the vegetation bias and provide improved estimates of the terrain elevation. However, further

work is needed to estimate geophysical information about the vegetation canopy. [C577]

## "A new scattering enhancement scheme for polarimetric SAR images based on covariance matrix"

A new scattering mechanism enhancement scheme has been developed for natural targets based on the eigenvalues and eigenvectors of the covariance matrix in order to identify different scattering events. First, three new vectors were constructed by the eigenvectors of the covariance matrix with some modifications. Then, these modified vectors were weighted by the normalized eigenvalues of the covariance matrix as a weighting function. Thus, three vertices could be obtained in the three-dimensional space. In order to utilize them equally, a triangle was constructed by connecting these three vertices. The shape of the triangle may be changed due to the different scattering mechanisms because the vertices are obtained from the combination of eigenvalues and eigenvectors. The result indicated that different scattering mechanisms can be represented by using an exterior angle which derived from the interior angles of the triangle. [C578]

## "Polarimetric segmentation using Wishart test statistic"

A newly developed test statistic for equality of two complex covariance matrices following the complex Wishart distribution and an associated asymptotic probability for the test statistic has been used in a segmentation algorithm. The segmentation algorithm is based on the MUM (merge using moments) approach, which is a merging algorithm for single channel SAR images. The polarimetric version described in this paper uses the above-mentioned test statistic for merging. The segmentation algorithm has been applied to polarimetric SAR data from the Danish dual-frequency, airborne polarimetric SAR, EMISAR. The results show clearly an improved segmentation performance for the full polarimetric algorithm compared to single channel approaches. [C579]

## "Speckle filtering of polarimetric SAR interferometry data"

Polarimetric SAR interferometry has generated much interest for forest applications. In this paper, we study problems associated with interferometric coherence estimation and propose two algorithms to improve the accuracy in the coherence estimation based on speckle filtering of the 6 Ч 6 polarimetric interferometry matrix. [C580]

## "Polarimetric and interferometric noise modelling"

In this paper, a noise model for the extended six dimensions covariance matrix used in polarimetric synthetic aperture radar (SAR) interferometry is proposed. This noise model is able to interpret interferometric, as well as polarimetric noise characteristics for the diagonal and non-diagonal elements of the covariance matrix. [C581]

## "Design of Asymmetrical Coupled-HNRD-Guide Directional Couplers"

Directional couplers with flat coupling are designed by using an asymmetrical coupled-HNRD-guide consisting of two HNRD guides of different cross sections arranged closely. First, propagation characteristics of the asymmetrical coupled-HNRD-guide are analyzed by the transverse resonance technique. Next, the whole directional couplers including tapered sections are designed from the S-parameters of the coupled HNRD guides derived from a superposition of the even-like and odd-like modes. Finally, the validity of the design procedure is confirmed by an em-simulator (HFSS). [C582]

## "A calibration method for polarimetric radar surveillance in a multi-path sea environment."

The scope of this work is to describe a novel method of calibration for polarimetric radar surveillance in a multi-path propagation environment. The method presented in this paper is based on a mathematical model which computes the errors in the estimate of the scattering matrix elements (amplitude and phase) of a radar object caused by multi-path propagation induced by scattering from the sea surface. The `correct' scattering matrix of the radar object and its polarization properties are derived in the calibration process by the compensation of these multi-path induced errors. The results of the model show that these errors in the scattering matrix depend on the wave polarization (by the reflection coefficients) and multi-path propagation parameters e.g. number of scatterers at sea, degree of correlation between scatterers, sea state. The model predicts larger errors with increased reflectivity from the rough surface e.g by an increase of the reflection coefficients, the number of (multiple) scatterers at sea, the correlation between scatters, and lower sea state. [C583]

## "Higham-Cheng algorithm for solving the generalized eigenproblem applied to the computation of the characteristic modes"

In computational electromagnetics many problems are representable in the form Ax = λBx where the matrices A,

Bare Hermitian and Bis positive definite. These problems are solvable with high accuracy by the simultaneous diagonalization of the pair (A, B). However, it may happen that numerical approximations and rounding errors deteriorate the properties of the pair (A, B) in a way that the simultaneous diagonalization procedure results are inapplicable. In this work a new algorithm developed recently by Higham and Cheng (1999) is proposed as a method to be applied in these cases. In particular, the computation of the characteristic modes for the TM2, scattering by a conducting elliptic cylinder is addressed, and results are analyzed and discussed [C584]

## "A study of existing bistatic calibration techniques"

A performance evaluation of several existing polarimetric calibration techniques for bistatic radar cross section (RCS) measurements was performed. Several calibration test objects, including cylinders, a dihedral, a trihedral, a sphere, and other non-canonical objects were measured at the European Microwave Signature Laboratory (EMSL), Joint Research Centre (JRC), Ispra, Italy. Three calibration types were designated, based on their capability to predict each coefficient of a 20-term error model of the antenna polarization distortion matrix (PDM). Bistatic RCS predictions were completed using a commercially available method of moments code to validate the measurements for alignment precision and noise/distortion levels [C585]

## "Hybridization of finite methods with other techniques to solve complex problems"

Summary form only given. Finite methods are well-suited for modeling complicated geometries. Hybrid methods are often used to overcome the difficulty of modeling large complicated problems. In the past, finite methods have been coupled to modal methods, integral equation methods, and high frequency or asymptotic methods with various degrees of success. The difficulty comes in coupling the two different methods in an accurate and efficient manner. The coupling can be done in many different ways. Between finite methods and integral equation methods, the coupling is straightforward. However between finite methods and high frequency methods, the choice of how to couple the two methods is not as clear. Two rigorous mechanisms to perform the coupling are to use either a generalized scattering matrix or modal expansion at the interface between the two methods. This approach produces very good solutions, but may be computationally expensive. Another approach is to use approximations to decouple the multiple interactions which are present between the two methods. This approach is very efficient and simple in implementation, but may be inaccurate. We review what hybrid methods have been proposed in the past and where we see the future research directions in the use of hybrid methods to solve. real-world problems of interest [C586]

## "High-order method of moment solution for penetrable scatterers"

An efficient high-order method of moment (HO-MoM) technique, which has been introduced for the scattering of metallic structures, is extended to the solution of electromagnetic scattering by penetrable bodies. It is demonstrated that the HO-MoM solution leads to an exponentially convergent algorithm for scattering by penetrable bodies via the combined surface field integral equation. Both the current and the RCS realize exponential convergence. The proposed method is also computationally efficient in that it only requires a single integration for the computation of near interactions, and far interactions can be computed using a single point kernel evaluation. In general, it has been found that high-order quadrature order on large patches leads to the most computationally efficient solutions, in terms of memory and CPU time versus accuracy [C587]

## "A new measurement method for four-port scattering matrix of a dual-polarization antenna"

A new method to measure the four-port scattering matrix of a dual-polarization antenna is proposed. A two-port vector network analyzer is connected to the two excitation ports of the antenna to measure its 2Ч2 scattering matrix. The formulation is developed to solve the four-port scattering matrix of the dual polarization antenna from the measured two-port scattering matrix with two calibration scattering objects [C588]

## "Diffraction of a plane electromagnetic wave by a dielectric-coated cylinder with an infinite longitudinal slot in a conductive wall"

The rigorous solution of the problem is given. The boundary-value method using the property of completeness of angular functions on the certain interval is employed to obtain the solution. Accurate numerical results are presented in the case of H-polarized waves. Diffracted far-field (DFF) and back radar cross section (BRCS) of the structure are evaluated asymptotically. It is shown that in the low-frequency region there is resonant penetration of an electromagnetic field inside the cylinder at a narrow slot. In this case, the BRCS of the structure is greatest and the form of the DFF pattern is close to circular [C589]

## "Polarimetric SAR processing using the polar decomposition of the scattering matrix"

The concept of scattering is one of the mechanisms that polarimetry seeks to express through data. A multiplicative decomposition of the scattering matrix is proposed in order to try to separate different kind of scattering and the applicability to polarimetric SAR images is investigated [C590]

## "Full wave CAD oriented technique for the analysis of airborne flat plate arrays"

A full wave method for the analysis of typical blocks forming a waveguide planar slot array is proposed. The method provides both the generalized scattering matrix of each block and the electric field over the radiating slots, thus making it suitable for CAD applications. Internal and external higher-order mode coupling, conductor thickness and dielectric covers are included in the model, based on a rigorous mathematical formulation with no restrictions on slot width [C591]

## "Multilevel fast multipole algorithm for electromagnetic scattering from conducting objects with material coating"

This paper discusses the formulation and the discretization of the volume-surface integral equation (VSIE), the implementation of multilevel fast multiple algorithm (MLFMA) to speed up the iteration in the conjugate gradient method for solving the matrix equation. Validation numerical examples are also provided to demonstrate the performance of the VSIE-MLFMA algorithm. The derivation is in the frequency domain, and the time factor of exp{-iωt} has been suppressed [C592]

## "Experimental results for adaptive radar imaging in a wide angular sector"

We investigate experimentally an adaptive imaging approach, namely that of a synthetic wideband, stepped CW transmitter and a multichannel adaptive array for receiving backscattered energy from short range objects in a full +/-90 degree field of view. The method is a hybrid one, using conventional Fourier processing for range and is adaptive in angle. The 12-element linear array that was constructed is able to form an image in range and angle without Doppler information, and was tested with targets embedded in natural background clutter. The results show how background clutter affects the angular resolution of the array due to the increase in rank of the signal-plus-clutter covariance matrix, whereas at the same time the rank of this matrix is reduced for closely spaced scatterers due to signal coherence. In addition to investigating some known angular enhancement methods, we propose a method to enhance angular resolution in the presence of clutter by a projection, which seeks to reduce the received signal to a lower rank approximation, without using eigendecomposition, thus having an implementation advantage. This method allows more control over the angular resolution and the background clutter level. Computer simulations as well as the experimental results are presented [C593]

## "Circuital Analysis of Open Space Scattering Problems"

The application of the circuit theory in open problems is a technique that is not very extended. Basically it has been applied, with excellent results, in closed problems like wave-guides, where the definition of the admittance and impedance matrices is very extended. This paper tries to probe the great benefits of the circuital theory in open problems. [C594]

## "Effects of internal clutter motion on STAP in a heterogeneous environment"

Clutter is typically modeled as stationary (i.e., zero Doppler shift) scatter from the surface. Thus for ground-based systems the clutter is contained at zero Doppler while airborne systems will observe clutter spread in Doppler due to platform motion (i.e., the classic angle-Doppler clutter `ridge'). However, motion internal to the background clutter of vegetation, etc., will result in the clutter having non-zero bandwidth. This effect, generally referred to as internal or intrinsic clutter motion, will tend to increase the rank of the clutter in the space-time adaptive processing (STAP) covariance matrix. We examine the effect of this phenomenon on STAP. We consider the effects of a heterogeneous environment and provide examples based on site-specific terrain data that illustrate the impact on STAP performance [C595]

## "Target-to-clutter contrast enhancement using radar Doppler polarimetry"

The connection between Doppler and polarimetric characteristics of targets is studied. It is shown that the Doppler polarimetric formalism provides more complete radar object description. These conclusions are supported by the model of simple compound object as well as by the radar observations of ground clutter. It is also shown that the clutter suppression which is based on Doppler polarimetric object description gives better contrast enhancement than the polarimetric optimization techniques [C596]

## "Polarization model of distributed radar object"

At present, the main approach in constructing polarization models of time-varying distributed objects is connected with a priori suggestions on probability density functions (PDF) of polarization parameters (invariants) of the scattering matrix (SM). The main idea of the authors' approach consists in determination of all SM's polarization invariants statistics with the use of results of the matrix elements quadratures measurements. The Gaussian law of the quadratures' probability densities is assumed. In the paper, analytical expressions for 6 invariants of the monostatic scattering matrix are given. The available results confirm the suggested approach advisability while constructing polarization models of distributed radar objects [C597]

## "Features of flat arrays based on printed chiral elements"

The problem of field control of scattering of the antenna arrays is very important. Two directions in development of an antenna engineering are considered in this report. In each of them the scattering field control of an antenna arrays allows one essentially to expand functionalities, of radio engineering sets. The first direction is the creation of auxiliary depolarizing reflectors for two-mirror antennas. The second direction is connected to application of antenna arrays for a reduction of a radar cross section of the radar tracking targets. Transformation of a field polarization by an antenna array allows one to achieve both these purposes [C598]

## "Iterative algorithm for the estimation of distributed sources localization parameters"

We present a novel algorithm for the estimation of the direction of arrival and angular distribution parameters of sources that, as a result from the scattering effects, cannot be considered as punctual. The algorithm is iterative and is based on the maximization of the likelihood function associated to the received snapshots at the antenna array (ML). It is proposed a computationally efficient method for estimating the localization and angular distribution parameters of more than one source transmitting at the same frequency in a noisy environment. This algorithm solves the problem of the joint maximization in the case of two sources by formulating two new problems of a single-source ML [C599]

## "Polarization model of distributed radar object"

At present, the main approach in constructing polarization models of time-varying distributed objects is connected with a priori suggestions on probability density functions (PDF) of the polarization parameters (invariants) of the scattering matrix (SM). The main idea of the authors' approach consists in the determination of all SM polarization invariant statistics with the use of the results of matrix element quadrature measurements. The Gaussian law of the quadrature probability densities is assumed. In the paper, analytical expressions for 6 invariants of the monostatic scattering matrix are given. The available results confirm the suggested approach for constructing polarization models of distributed radar objects [C600]

## "Characterization of the scattering centers of a radar target with polarization diversity using polynomial rooting"

We propose a new high resolution method with polarization diversity for the characterization of the scattering centers of a radar target, using a stepped-frequency radar system. The proposed method is based on the polynomial rooting technique. It allows one to optimally use the information contained in the polarization of the received wave while keeping the calculation cost moderate. Moreover, it can estimate the range and the polarization parameters of each scattering center in only one step. Simulation results are presented to show the performance of the algorithm [C601]

## "A new method for a posteriori polarimetric SAR calibration"

Fully polarimetric SAR data analysis has found wide application for terrain classification, land-use, soil moisture and ground cover classification. Critical to all analyses and applications is accurate calibration of the relative amplitudes of and phases between the various polarimetric channels. Here we develop a "minimalist" approach to polarimetric calibration, wherein only the weakest of constraints, reciprocity, is initially imposed upon the data. Additional parameters are self-consistently estimated from the data. In this manner channel imbalances and cross-talk are estimated without unduly biasing the resulting polarimetric information [C602]

## "Invariants measurement of back scattering matrix"

The estimation of BSM invariants can be carried out by indirect methods on the basis of quantities measurement, which are proportional to modules and arguments of elements of scattering matrix. Power quantities or the voltage characteristics of the received signal are preferred to be used as measuring parameters. In a number of

cases (e.g. in optics) the carrying out of phase measurements is impossible or difficult. Since the total amount of real parameters of BSM amounts to eight (four modules and four arguments) a measurement cycle of received signal levels is required. We consider a method of BSM invariants measurement based on the transmission and reception of polarization manipulated signals with two-channel single-position radar [C603]

## "Multi-sensor-systems at mm-wave range for automotive applications"

The concept of an automotive radar sensor and its design details in the 61 GHz ISM band are introduced. The sensor is capable of measuring several important parameters of automobile driving dynamics and boundary conditions at a time, e.g., velocity, pitch angle, distance to ground and condition of the road surface. The coherent system consists of two bistatically oriented microwave frontends with five receiving channels. There are two orthogonal polarization channels in each module and one additional reference channel. A dual frequency CW technique enables measuring of the distance and the Doppler shift while by measuring the polarimetric scattering matrix one can classify the road surface. To keep hardware costs low it is required to realize all the measurement capabilities in one multifunctional sensor device, which combines the two antennas and the microwave frontends in one case. For fast control a high update rate with a maximum of measurement accuracy is needed and the dual frequency mode is achieved with two fixed tuned sources by frequency stepping in time sequence [C604]

## "Multi-baseline airborne Pol-InSAR measurements for the estimation of scattering processes within vegetation media"

Interferometric decomposition permits the identification of arbitrary scattering mechanisms in two interferometric SAR images and the optimisation of the interferometric coherence, using mathematically independent phase centres related to these scattering mechanisms. Polarimetric SAR interferometry (Pol-InSAR) is sensitive to the distribution of oriented objects in vegetation layers. It has been demonstrated that the calculated scattering mechanisms have different vertical loci that can be related to certain vegetation structures. Additionally, theoretical models allow for the reconstruction of the quasi-three-dimensional spatial distribution of such scattering mechanisms within multi-layer morphologies and the derivation of vegetation-related physical parameters. The paper presents an evaluation of a coherent Pol-InSAR scattering model using simulations based on the configuration of a real airborne experiment. This experiment provides multi-baseline L-band scattering matrices acquired by the DLR experimental SAR system (E-SAR) [C605]

## "Polarimetric properties of boreal forest in L- and C-band SAR images"

In this study the usability of L- and C-band SAR polarimetry in boreal forest remote sensing is examined and discussed. The influence of snow cover, weather conditions, forest type and several other aspects to forest backscattering in L- and C-bands is investigated by using multitemporal polarimetric images [C606]

## "Polarimetric edge detector based on the complex Wishart distribution"

A new edge detector for polarimetric SAR data has been developed. The edge detector is based on a newly developed test statistic for equality of two complex covariance matrices following the complex Wishart distribution and an associated asymptotic probability for the test statistic. The new polarimetric edge detector provides a constant false alarm rate and it utilizes the full polarimetric information. The edge detector has been applied to polarimetric SAR data from the Danish dual-frequency, airborne polarimetric SAR, EMISAR. The results show clearly an improved edge detection performance for the full polarimetric detector compared to single channel approaches [C607]

## "Extraction of characteristics of a target"

The similarity parameter between two scattering matrices is introduced. This parameter is not only independent of the spans of the scattering matrices, but also independent of the target orientation angles. From the definition of this parameter, we derive the parameters of similarities to the scattering matrices of a plate (sphere), a diplane, a wire and two helixes, which are very convenient for analyzing the characteristics of a radar target [C608]

## "Radar target's reciprocity correction based on polarimetric measurement error model"

With the analysis of a polarimetric measurement error model, a novel radar target's reciprocity correction algorithm is presented based on a least degradation rule. After transforming the nonlinear optimal function of four variables with constraints to a nonlinear optimal function of two variables without constraints, the solution is given. Simulation results verify its feasibility and indicate its good performance [C609]

## "Polarization scattering characteristics of chaff cloud in outer space"

To meet the increasing need of modern ballistic missile countermeasure, it becomes more and more important to study chaff cloud's scattering characteristics in outer space more accurately. A coherent scattering model is presented to depict the polarization scattering process of chaff cloud in outer space instead of the traditional noncoherent model. Chaff cloud's polarization scattering matrix and RCS formulae are derived. These formulae reflect the fluctuation law of chaff cloud's RCS due to the variation of cloud's spatial distribution [C610]

## "Notes on invariant characters of radar cross sections"

It has been proved in a former paper (see Ke, Y.A., Proc. Int. Conf. of Radar, 2000) that three average radar cross sections (RCSs) have a simple relationship, Smav:Spav:Svav = 3:2:1, where Smavis RCS for polarization matched radar, Spavis RCS for common antenna radar and Svav is RCS for cross polarization radar. The relations are valid for an arbitrary target, at arbitrary aspect-angle and at arbitrary polarization base. So, we may call it the "3-2-1" theorem in radar theory. Here, the average is the probability mean and it is assumed that the radar transmitting polarization runs on the Poincare polarization sphere with uniformly distributed probability density function. Some further notes on the "3-2-1" theorem are presented, including a more general proof, showing its validity for random radar scattering matrices [C611]

## "Polarimetric classification of trees"

Since scattering matrix acquisition capability will be equipped with space-borne radar systems such as ALOS PALSAR to be launched in 2003, radar polarimetry is now an indispensable tool for monitoring the Earth's cover. The advantage of using the vector nature of electromagnetic waves is the information on the amplitude, phase and their relations pertaining to target. In this paper, we retrieve a useful index for classifying broad leaf trees and conifer (needle like leaf) trees based on the scattering characteristics of tree canopies. The index used is the polarimetric correlation coefficient derived by the elements of the Sinclair scattering matrix. It is shown that correlation coefficient defined in the circular polarization basis serves to distinguish conifer tree and broadleaf tree [C612]

## "Recent advances in extra-wide-band multi-modal POL-IN-SAR imaging"

Radar polarimetry, radar interferometry and polarimetric SAR interferometry present the current culmination in 'microwave remote sensing' technology, but we still need to progress very considerably in order to reach the limits of physical realizability. Whereas with radar polarimetry the textural fine-structure, target orientation, symmetries and material constituents can be recovered with considerable improvement above that of standard 'amplitude-only' radar; with radar interferometry the spatial (in depth) structure can be explored. With polarimetric interferometric synthetic aperture radar (POL-IN-SAR) imaging, it is possible to recover such co-registered textural and spatial information from POL-IN-SAR digital image data sets simultaneously, including the extraction of digital elevation maps (DEM) from either repeated-pass polarimetric (scattering matrix) or interferometric (dual antenna) SAR systems. Simultaneous polarimetric-plus-interferometric SAR imaging offers the additional benefit of obtaining co-registered textural-plus-spatial three-dimensional POL-IN-DEM information, which when applied to repeat-pass image-overlay interferometry provides differential background validation and environmental stress-change information with highly improved accuracies. Then, by either designing multiple dual polarization antenna POL-IN-SAR systems or by applying advanced POL-IN-SAR image compression techniques, will result in 'POL-arimetric TOMO-graphic' (multi-interferometric) SAR or POL-TOMO-SAR imaging. By advancing these EWB-D-POLIN/TOMO-SAR imaging modes, we are slowly but steadily approaching the ultimate goal of eventually realizing air-bome and space-borne 'geo-environmental background validation, stress assessment, and stress-change monitoring of the terrestrial and planetary covers' [C613]

## "Discrimination between low metal content mine and non-mine-targets using polarimetric ultra-wide-band radar"

In this paper we show that wide band radar polarimetry can be used for discrimination between surface laid AP mine and non-mine targets. To do this we employ two types of coherent radar decomposition theorem applied to wide band chamber measurement data from the European Microwave Scattering Laboratory (EMSL). Our main conclusion is that radar polarimetry should be further investigated as an important way to secure low false alarm rate from radar sensors in stand off mine detection [C614]

## "Optimal polarimetric decomposition variables-non-linear dimensionality reduction"

Polarimetric SAR image analysis often depends upon proper identification of the relevant degrees of freedom for

the problem at hand. Employing physical models of particular scattering processes simplifies identification of the appropriate polarimetric variables. Determining how well variables chosen on the basis of a particular model describe the region of applicability of that model is difficult. Here we attempt in a model independent manner to identify "optimal" variables to both segment an image and highlight the variation within each segment. The method presently employed is non-linear dimensionality reduction [C615]

### "A new method for characterizing depolarization effects in radar and optical remote sensing"

In this paper we consider a new approach to the parameterization of depolarization effects in electromagnetic scattering. We define a unitary reduction operator, which is used to generate an N-1 dimensional representation of depolarization in an N dimensional scattering problem. We illustrate the application of this technique to polarimetric radar backscatter from random media with various symmetries [C616]

### "Interpreting off-diagonal terms in polarimetric coherency matrix"

This paper addresses interpretation of off-diagonal terms in the coherency matrix of polarimetric SAR data. The off-diagonal terms, especially the correlations between copolarization and cross-polarization are frequently ignored in many studies. We will show that this misconception will introduce errors, especially when imaging rugged terrain areas [C617]

### "Object based analysis of polarimetric SAR data in alpha-entropy-anisotropy decomposition using fuzzy classification by eCognition"

Polarimetric SAR data possess a high potential for classification of the Earth surface. Various publications demonstrate detailed analysis of soil and vegetation properties and characteristics of man made structures on selected examples. To ensure wider application of these developments, integration in commercial systems should be studied. In a first approach, the object based image analysis eCognition is employed on alpha, entropy and anisotropy and the span of fully polarimetric L-band SAR data of the German airborne sensor, E-SAR. We show that by using eCognition land cover classes can be conveniently assigned to the scattering classes and ambiguities can be resolved by geometric and context object features [C618]

### "Multi-baseline polarimetric SAR data classification using the complex Wishart distribution and principal component analysis"

In this paper is introduced a classification approach for multi-baseline polarimetric interferometric SAR data sets, based on a principal component analysis of coherent scattering vectors. From the Wishart probability density function of a restricted data set, is defined a maximum likelihood decision rule to perform an iterative adaptive classification [C619]

### "Unsupervised classification and analysis of natural scenes from polarimetric interferometric SAR data"

In this paper is introduced a classification approach for polarimetric interferometric SAR data sets, based on the analysis of an interferometric (6Ч6) polarimetric coherency matrix properties. From the Wishart probability density function of this polarimetric representation, is defined a maximum likelihood decision rule to perform an iterative adaptive classification. Another classification scheme based on the derivation of the conditional probability of the cross-correlation between both data sets is presented [C620]

### "The scattering polarimetric response contrast between two wind-generated rough sea surfaces"

Polarimetry for SAR applications is an excellent technological method to extract more information about wind-generated rough sea surface according to the scattering mechanisms. With the use of the scatter matrix, i.e. Mueller matrix, and Stokes vector operator, the paper describes a comparison between the polarimetric responses of two types of wind-generated sea surface offshore Baogang, Hainan Province. It gives representative results for the polarimetric response of backscattering electromagnetic field from the rough sea surface and the characteristics of Mueller matrices' traces. The long wavelength sea surface and the short one can be determined by their polarimetric responses. The traces and determinant values of scattering matrices are related to the wind conditions. Some heuristic conclusions are given upon the results [C621]

### "On the relationship between the Mueller and the scattering matrices"

Radar polarimetry has gained more and more popularity in microwave remote sensing of the environment due to the progresses made on the technological and physical sides. In this paper a study on the relationship between

the Mueller matrix and the scattering matrix is presented. The study is based on the group theory approach [C622]

## "Calibration and field experiment of a C-band polarimetric scatterometer"

Presents the evaluation results of a full polarimetric C-band scatterometer system that has been designed and constructed at the Multimedia University, Malaysia. The system was tested at a football field. A metal sphere was used as the calibration target. Backscattering matrices of an 8" trihedral corner reflector and a 4"Ч8" dihedral corner reflector were measured. The dihedral was rotated at different angles to provide different sets of polarimetric data. The results were compared with the theoretical values to verify the effectiveness of the calibration technique. The external calibration and internal calibration procedures as well as the approach used in measuring the relative phase response are discussed [C623]

## "Statistical testing of the form of the Mueller matrix of terrain at millimeter wavelengths"

A number of target symmetries, such as azimuthal symmetry for natural terrain, have a consequence on the form of the Mueller matrix. If these symmetries are found to be plausible, it can greatly assist in the modeling of the polarimetric response from the class of targets that exhibit such symmetry. By applying the test to large numbers of measured covariance matrices organized by terrain class (i.e. tree canopies, dry snow near grazing, etc.), the plausibility of various forms of the covariance matrix is explored. An example of symmetry which gives rise to a form of the covariance matrix is the hypothesis that co-polarized backscatter can be dominated by single scattering, while cross-polarized backscatter is multiple scattering. This results in the coherence between co- and cross-polarized radar backscatter being zero. This hypothesis is put to the complex R2test for W-band backscattering from snow [C624]

## "Multilevel expansion of the sparse-matrix canonical grid method for two-dimensional random rough surfaces"

The authors study simulations of 3D scattering and emission problems by using the sparse-matrix canonical grid (SMCG) method. The near interactions among the source points and field points are computed using the exact Green's function. In contrast, the far interactions are computed by the fast Fourier transforms (FFTs) through a Taylor series expansion of the Green' s function about a flat surface (z=O). The near interactions can be computed repeatedly in the iterative solution, or computed once and stored depending on the computer memory available, which will lead to low computation efficiency or large memory storage requirement. Therefore, the applicability of the SMCG method highly depends on the memory storage or the computation efficiency of computing the near interactions and the accuracy of the Taylor series expansion of the far interactions when the rms height of the rough surface increases. To overcome the iimitatjon of the SMCG method on the surface roughness, they demonstrated that a multilevel expansion can be employed for 1-D rough surface with large rms height. That is to say, they are not restricted to expand the Green's function about the flat suface at z=0 as used in the SMCG method but about multilevel flat surfaces with different value of z with equal displacement In this paper, they extend this multilevei expansion approach to 2D perfect electric conductor and lossy dielectric surfaces [C625]

## "MMW polarimetric data base of terrain reflectivity and an associated image simulator"

SPRI, the Simulator of Polarimetric Radar Images, is a suite of PCI image processing programs which together can be used to simulate millimetre wave (MMW) radar images of terrain. SPRI is intended to produce images similar to existing imagery but with one or more significant changes to facilitate comparisons. These significant changes include radar frequency, angle of incidence, season of year, recent precipitation, etc. The heart of the simulator package is a scattering matrix generator which calls upon a data base of measured Mueller matrices of terrain. This generator program produces high-resolution single-look polarimetric images. Simulated images can be degraded in polarization, number of looks, resolution, etc. to match those of a particular radar sensor. Auxiliary programs have been written to help adapt existing images to the frequency and incidence angle desired. For example, a sub-suite of programs classifies shadows and manipulates them for incidence angle changes. The simulator relies upon a data base of over 2500 Mueller matrices measured at 35 and 95 GHz by instrumentation grade scatterometers. The data are organized by frequency, incidence angle, and terrain type, and are accompanied by extensive ground truth. This data base is a research tool in its own right, and as such has a password-protected Web interface [C626]

## "Comparison of decompositions for pol-SAR image interpretation"

A unique option provided by fully polarimetric data is the possibility to separate scattering contributions of different nature. For this purpose several decomposition techniques have been derived, and are currently being

applied to analyze and interpret polarimetric radar data. In this paper, various decompositions with applications to radar polarimetry are reviewed, and an attempt is made to assess their applicability to POLSAR data analysis, especially in relation to target identification and classification [C627]

## "Multi-look polarimetric SAR image filtering using simulated annealing"

Based on a previously published algorithm capable of estimating the radar cross-section in synthetic aperture radar (SAR) intensity images, a new filter is presented utilizing multi-look polarimetric SAR images. The underlying mean covariance matrix is estimated from the observed sample covariance matrices, and by applying a set of small orientation-dependent filters in an iterative scheme, the input image becomes highly filtered while maintaining most of the structures in the scene. Results using multi-look polarimetric C-band data from the Danish airborne polarimetric SAR, EMISAR, are presented [C628]

## "Polarimetric speckle reduction by using multi-texture maximum likelihood method"

The reduction of speckle in SAR (synthetic aperture radar) image is the prime problem in SAR image processing. The authors propose a new approach in polarimetric SAR speckle reduction. They estimate simultaneously the texture parameters of multi-polarimetric channels by the method of maximum likelihood under the assumption of multi-texture. This approach preserves the polarimetric properties, reduces the couple between polarimetric channels. They also compare it with the PWF (polarimetric whitening filter) [C629]

## "Image simulation of high resolution radar for polarimetric scattering from heterogeneous canopy surface"

Polarimetric imaging of high resolution SAR is one of most important advances in microwave remote sensing. This paper, using fully polarimetric Mueller matrix solution and ray tracing method. Simulates radar images for fully polarimetric scattering from heterogeneous canopy surface. Non-uniform 3D structures and non-uniform distribution of multi-components of surface canopy are taken into account. Simulated image texture demonstrates spatial variation of radar echoes due to canopy 3D-heterogeneity, and is also compared with an AirSAR image at P,L,C bands [C630]

## "An adaptive matched filter detector for distributed targets in homogeneous environment"

An adaptive detector of range-spread targets embedded in Gaussian noise with unknown covariance matrix is developed and assessed. The proposed receiver requires no prior knowledge about the target strength and its scattering geometry and achieves constant false alarm rate with respect to the noise covariance matrix [C631]

## "Rigorous analysis of large finite waveguide-fed slot arrays including the mutual internal and external higher-order mode coupling"

Large finite waveguide-fed slot arrays are rigorously analyzed based on the combination of the external and internal full-wave scattering matrices which are computed using a Green's function approach and the mode matching technique, respectively. For calculating the external mutual fundamental and higher order mode coupling, the waveguide eigenvectors are expanded into subdomain functions. Slots of arbitrary cross-section are involved by computing the corresponding eigenvectors by a 2D finite element (FE) method. The mode matching technique yields the generalized scattering matrices (GSM) of the complete waveguide feed network. The method is verified by available measurements at 9.75 GHz for an array with 48 round-ended slots fed by transverse slots in a waveguide manifold [C632]

## "Biomass retrieval for boreal forest using electromagnetic scattering model and neural networks"

Retrieval of stem volume of boreal forest from SAR images by using electromagnetic scattering model and neural network is presented. The experimental data of Danish Airborne SAR (EMISAR) for the NOPEX southern research area in Sweden were used to test the retrieval scheme. It has been shown that a neural network trained by calibrated electromagnetic scattering model with experimental data has the potential to retrieve the biomass for boreal forests [C633]

## "The polarization angular correlation function for detection of object buried in forest above rough surface"

Significant effort has been devoted toward the development of scattering models for forest canopies. However little theoretical modeling has previously been done to analyze coupling scattering between the deterministic object and its forest surroundings. With the introduction of fractal geometry, a new tool for modeling the forest

has become available such as L-system. The correlation of scattering by different branches included using their relative positions as given by the growth procedure. The memory effect of wave scattering from random media was discovered by Feng. The angular correlation function (ACF) has been used to detection buried target under a rough surface. In the present paper, forest canopies are modeled as fractal trees generated using stochastic L-system. The scattering matrix of finite length multi-layer dielectric cylinder modeling the trunks and sphere are calculated using the iterative algorithm and spherical vector wave function, respectively. The second order analysis which takes into account the scattering from adjacent two trunks and sphere-trunks pairs above rough surface is calculated by using the reciprocity theorem. Based on Foldy's approximation, the effect of attenuation and phase change of the coherent wave propagating in the discrete random medium is considered. The polarization angular correlation function (PACF) by using azimuthal averaging correlation is discussed at L-band, C-band, X-band for detection of a target buried in fractal trees [C634]

## "Multibaseline POL-InSAR experiment for the estimation of the scattering processes and their spatial distribution within vegetation layers"

The interferometric decomposition permits the identification of different scattering mechanisms and the optimization of the interferometric coherence, using the identified mathematically independent phase centers related to these scattering mechanisms. Combining polarimetric and interferometric observables, the polarimetric SAR interferometry (POL-InSAR) technique allows for a more appropriate reconstruction of the quasi-three-dimensional spatial distribution of scattering processes within natural media. The scattering mechanisms occur in different vertical positions and have a physical significance that can be related to certain vegetation structures. The authors have analyzed the interferometric decomposition as a function of the baseline and applied a singular value estimation using a multi-baseline approach. They can show for random volumes that-as a function of baseline-the coherence optimization algorithm is not able to minimize the height distribution of the effective scattering centers within a resolution cell to a single `point' but optimizes between the ground return and the volume decorrelation. The location of the estimated effective scattering centers is resolved by analyzing the differential phase between interferograms formed using the multi-baseline eigenpolarizations. These results are compared to differential interferometric heights between conventional multi-baseline interferometric elevations at various polarizations without applying the interferometric decomposition to the data set. For this experiment the multi-baseline Lake Baikal (Russia) L-band SIR-C data takes are used [C635]

## "Mueller matrix based classification of polarimetric SAR data"

A modified version of the unsupervised classification algorithm is proposed. In this method, multiple pixels are considered for classifying each pixel in the image during the classification procedure. First, the scattering matrix is used to calculate the corresponding Mueller matrices for each pixel. The Mueller matrices of all pixels in a window are then calculated and used to make a decision as described in J. J. van Zyl (1989). If all pixels (Mueller matrices) or more than N/2 pixels (more than 50 per cent of pixels, where N is the number of pixels in a window) in a window are classified into one category, then the pixel of interest (the Mueller matrix of the center pixel within the moving window) will be classified into the same category. In addition, one criterion is added for diffuse scattering. If the pixel properties are completely random, this means that, if fewer than N/√N (or equal N/√N) pixel properties in a moving window are classified into the categories (if odd number of reflections =<N/√N, even number of reflections =<N/√N, and diffuse scattering=<N/√N), the pixel property of interest will still be placed in the diffuse scattering category. Note that all three scattering properties occur in a small area. Therefore, the pixel of interest will be classified into the diffuse scattering category. If there is no significant pixel property belonging to the categories mentioned above in a moving window, then the pixel property of interest is unclassified. The window is then moved, and this process is repeated [C636]

## "Space-time adaptive radar detection of distributed targets"

This paper deals with radar detection of spatially distributed targets embedded in Gaussian noise with unknown covariance matrix. Precisely, noise returns are modeled as Gaussian vectors independent from range gate to range gate; they share the structure of the covariance matrix, but have possibly different power levels. A set of secondary data, free of signal components, is used to estimate the correlation properties of the disturbance. No a priori knowledge about the spatial distribution of the target scatterers is assumed. An adaptive detector is conceived and its performance is evaluated also in comparison with a previously proposed detection structure. Remarkably, the proposed receiver ensures CFAR-ness with respect to either the structure of the covariance matrix and the power backscattered from each cell. A performance assessment confirms its validity to operate in a heterogeneous environment [C637]

## "Invariant characters on radar cross section of polarized radar targets"

It is proved in this paper that for an arbitrary target at arbitrary aspect-angle the three average radar cross sections (RCS) for polarization matched radar, for common antenna radar, and for cross polarization radar, satisfy a simple proportional relation, i.e., 3:2:1. Here the average is the probability average, assuming that the radar transmitting polarization runs on the Poincare sphere with uniformly distributed probability density function [C638]

## "S-Pol: NCAR's polarimetric Doppler research radar"

S-Pol is a relatively new radar developed at NCAR to replace the CP-2 dual polarization research radar that served the research community for nearly twenty years. The purpose of S-Pol is to provide a cost-effective state-of-the-art polarimetric Doppler weather radar for world-wide deployment in meteorological research programs. S-Pol has several significant improvements compared with CP-2. Its container transportation method allows practical temporary deployments worldwide including remote and difficult geographic sites. Additionally, S-Pol uses a high performance modern transmitter, low sidelobe parabolic antenna with high isolation between the horizontal and vertical channels, and matched dual channel receivers. The NCAR VME signal processor and data system computes complete polarimetric scattering matrix parameters. S-Pol was first fielded during the summer of 1996 at the Front Range Airport in Colorado in close proximity to the Denver WSR-88D. Since then, S-Pol has participated in five additional projects including ones in Kansas (CASES-9'1), Florida (PRECIP-98), Brazil (TRMM/LBA-99) and Italy (MAP-99). Its next deployment in May 2000 in eastern Colorado (STEPS) will make an impressive total of seven projects in 4 years. Based on present requests, S-Pol deployments for the next 3 years are projected at a similar rate [C639]

## "Effects of clutter modeling in evaluating STAP processing for space-based radars"

RLSTAP is shown to be an effective tool for modeling clutter representative of that seen by an actual spaceborne system. Realistic effects, like the Doppler aliasing of the angle-Doppler clutter spectrum from a high velocity platform and the non-homogeneity of site-specific clutter, can be modeled and their impact on adaptive signal processing studied. The example simulated in this work demonstrates that the Doppler aliasing of the clutter spectrum impacts the requirements on the STAP processor. The processor requires four spatial degrees of freedom to effectively suppress the clutter, while in previous cases with slower platforms only two were sufficient. This should be considered in designing a space-based radar system. Additionally, the non-homogeneity of the site-specific clutter influences STAP requirements. Care must be taken to keep the required sample support small and to choose the secondary data cells such that they are as close as possible, statistically, to the data from the test range cell [C640]

## "Numerical Investigation of Micromachined Structures for Thin Layers"

In the present paper we analyze numerically the high-frequency behavior of different micromachined structures including MEMS. One special feature of micromachined structures is the presence of very thin layers-compared to other geometrical dimensions, resulting from the technological process. With usual numerical methods, where the entire domain is discretized, those thin layers are difficult to consider. The alternatives are a very small mesh size with the resulting extreme long calculation times and large storage requirements or approximate boundary conditions, which are usually less accurate. Here it will be shown how thin-layer structures can be analyzed very accurately with reasonable numerical effort by the Transmission Line Matrix method (TLM) and by the Method of Lines (MoL). The numerical methods will be presented, especially the means which are necessary to avoid long calculation times and which make these methods useful for an efficient design of the proposed structures. The obtained numerical results for the scattering parameters are compared with measurements in order to judge their accuracy. [C641]

## "Accuracy assessment in photo interpretation of remote sensing ERS-2/SAR images"

Three major technological advances have occurred in recent years in the use of Synthetic Aperture Radar (SAR) for the study of geophysical processes. The first is the launch and excellent performance of ERS satellites, which permits the study of global-scale dynamic processes. The second is the development of airborne polarimeter SARs, which provides a far more complete picture of the scattering properties of the Earth's surface than the “simple” systems flown in space. The third is the inception of interferometric SAR, which allows high resolution topographic data to be generated from spaceborne and airborne SAR systems, and can detect centimetric changes in the Earth's surface. Going hand in hand with these advances, there have been major achievements in backscatter modeling, developing viable statistical models of the data and in image understanding techniques. In this work we study the applications of the above concepts in characterizing “crushed” soils in terms of accuracy assessment in images of part of Puglia Region in Italy [C642]

## "ISAR imaging of small craft with roll, pitch and yaw analysis"

In this paper, we analyze the effect of roll, pitch and yaw rotations on inverse synthetic aperture radar (ISAR) imaging of small craft. An ideal ISAR image of a target with regular motion can be derived from the image projection plane and the radar line-of-sight (LOS) unit vector. Roll, pitch and yaw rotations can induce time-varying Doppler shifts that can be analyzed through the rotation matrix and the effective rotation vector. We use a commercial small craft ISAR data accompanied with roll, pitch and yaw data collected by the Trimble Tans Vector system with 4 GPS antennas to study the effect of rotational motion on ISAR imaging. For a target with regular motion, perturbations of roll and pitch motions may make for image blurring if conventional motion compensation is used. In this case, advanced imaging algorithms, such as the polar reformatting algorithm, that compensate the perturbations may improve the image [C643]

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

The authors introduce a new classification scheme for dual frequency polarimetric SAR data sets, based on the analysis of a (6Ч6) polarimetric coherency matrix defined from the polarimetric information of both images. From the Wishart probability density function of this polarimetric representation, is defined a maximum likelihood decision rule to perform an iterative adaptive classification. Another classification scheme, based on the derivation of the conditional probability of the cross-correlation between both data sets, is presented [C644]

## "Multi-frequency polarimetric SAR data analysis of ocean surface features"

Fully polarimetric SAR data analysis has found wide application for terrain classification, land-use, soil moisture and ground cover classification. New methods and algorithms for extracting geophysical parameters from polarimetric data continue to be developed and tested. Many of these methods are designed for specific environments and/or a particular target-type. The authors present general techniques for analysis of polarimetric SAR data. They illustrate these techniques with SIR-C full polarimetric data at L- and C-band [C645]

## "A novel approach in polarimetric covariance matrix eigendecomposition"

A new concept, the power normalized coherency matrix, is introduced to clarify the eigenvalue problem definition in SAR polarimetry. It is shown that the elements of the power normalized coherency matrix are good descriptors of polarimetric properties of SAR targets. An alternative scheme to alpha-entropy classification is proposed. It is shown that target entropy is closely related to the normalised coherency matrix determinant and the average alpha angle is related to the first element of the coherency matrix. This suggests that complicated eigenvalue calculations are not necessary in some SAR classification problems. The results also show that the average alpha and entropy parameters do not describe eigenvalue decomposition well, as similar parameters can be calculated without eigendecomposition. All results derived in this paper are based on general properties of Hermitian matrices [C646]

## "Quantitative comparison of classification capability: fully-polarimetric versus partially polarimetric SAR"

This paper addresses the land-use classification capabilities of partially polarimetric SAR versus fully polarimetric SAR. A variety of polarization combinations are investigated for application to crop and tree age classification. Based on the circular Gaussian distribution, maximum likelihood classifiers for all polarization combinations were used to assess quantitative classification accuracy. Thus, it allows optimally selecting the combination of polarizations for crop, tree and terrain classification [C647]

## "Interpretation of polarimetric radar covariance matrix for meteorological scatterers"

Modern dual-polarization radars provide the unique capability to measure the fields of all components of the covariance backscattering matrix including co-cross-polar correlation coefficients that haven't been explored much for linearly polarized radars. The authors present full polarimetric examples of such data obtained with the CSU CHILL and NCAR S-Pol research polarimetric radars. Both radars operate at the wavelengths of about 10 cm. The radars have two receivers that allow to measure simultaneously co-polar and cross-polar components of the backscattered electromagnetic wave. At least ten radar variables can be obtained simultaneously: radar reflectivity factor Z, differential reflectivity ZDR, linear depolarization ratio LDR total differential phase ΦDP, specific differential phase KDP, cross-correlation coefficient ρhv, and the magnitudes and the phases of the two co-cross-polar correlation coefficients |ρxh| (|ρxv|) and arg(ρ xh) (arg(ρxv)) respectively. First six variables have been studied quite well in the literature, whereas the information content of the co-cross-polar correlation coefficients ρ xhand ρxvneeds to be examined. This is a major focus of this study [C648]

## "Scattering from fractal dielectric profiles: the extended boundary condition method"

An electromagnetic model for the study of the scattering from natural rough surfaces is presented. The authors employ a Weierstrass-Mandelbrot (WM) fractal surface model in conjunction with the extended boundary condition method (EBCM). Dielectric profiles are considered. The property of the WM to be an almost periodic function allows one to generalise techniques employed for periodic functions. In particular, the authors express the scattered and transmitted fields as a superposition of Floquet modes, whose directions of propagation are evaluated by means of the grating equation, and whose amplitudes by means of the EBCM. The method leads the authors to express in matrix form the amplitude coefficients of the scattered and transmitted fields in terms of the amplitude coefficients of the known impinging field [C649]

## "Inversion of surface parameters from polarimetric SAR data"

The authors introduce a new model for the inversion of surface roughness and moisture from polarimetric SAR data, based on the eigenvalues and eigenvectors of the coherency matrix. They present how three parameters, namely the polarimetric entropy, the anisotropy and the alpha angle can be used in order to decouple roughness from moisture content offering the possibility of a straightforward inversion of these parameters [C650]

## "A dedicated computer system for FM-CW radar applications"

In this paper, a DSP based computer system for FM-CW radar applications is described. Besides data acquisition and storage, the computer system can be used for front-end data processing and system control. Processing includes filtering and clutter suppression. The radar for which the computer is designed is a multi parameter atmospheric profiler capable of doing Doppler and polarimetric measurements. The computer system allows for a measurement of the full polarimetric scattering matrix over 512 range cells and 512 Doppler cells in 2 sec. Radar system control includes the timing and the settings of the radar system together with linearity correction of the sweep oscillator [C651]

## "A microwave coherent polarimeter with velocity gating for road surface monitoring"

The presence of ice, water or snow on a road surface changes its microwave polarimetric scattering matrix. Safety in driving could be enhanced with a polarimeter able to warn the driver in real-time in case of dangerous situations. In this paper, a polarimeter realised with cheap components is presented [C652]

## "Propagation in rectangular waveguides with a pseudochiral Ω slab"

The transfer matrix approach is applied for analysis of waveguides loaded with a uniaxial pseudochiral Ω-slab. In particular a pseudochiral parallel plate and rectangular guides are investigated. Based on the numerical analysis the influence of the pseudochirality on propagation characteristics and field distribution are examined. Other features such as a field displacement phenomenon appearing in both the considered structures due to the pseudochirality are also discussed [C653]

## "Scattering in a section of rectangular waveguide with a pseudochiral Ω slab"

The mode matching approach is applied to a rectangular waveguide containing a pseudochiral Ω slab. From waveguide measurements carried out over a few placements of the slab in the guide the constitutive parameters are extracted. The extraction is performed numerically by a algorithm minimizing the difference between theoretical and measured values of resonance frequency and scattering parameters. The field displacement phenomenon becomes visible by the frequency responses of the scattering parameters and E-field patterns. The measured and theoretical results show the resonance effects which may be applicable in design of bandstop filters [C654]

## "Broadband helicon isolator for meter and decameter wave ranges"

The analysis of possible circuits for the realization of broadband isolators for meter and decameter wave ranges based on helicon resonators is carried out. The nodal model and matrix of scattering of an isolator is obtained. The possibility of extension of bandwidth up to an octave is shown [C655]

## "Geometrical representation of a monochromatic electromagnetic wave using the tangential vector approach"

Pulse radar has a very narrow band, so, to describe the state of the signal, it is possible to consider a single pulse as a monochromatic electromagnetic wave, which is completely polarized. A very useful representation of

the electrical field is its spinor form which contains the complete information, even the zero phase. The aim of this work is to develop a coherent polarimetric model and to find a geometrical description of a monochromatic wave. The spinor form of the electrical field, its links to the coherency matrix and the Poincare sphere are introduced with the aim of obtaining a geometrical representation of the spinor. It consists, from the `polarization point of view', of the polarization vector and a tangential plane to the Poincare sphere where it is possible to visualize the zero phase [C656]

## "Doppler polarimetric ground clutter identification and suppression for atmospheric radars based on co-polar correlation"

In this paper, a new clutter suppression technique is introduced. This clutter suppression method uses both Doppler and polarimetric information. Polarimetric properties of the target and clutter are calculated per Doppler frequency cell and, based on this information, clutter suppression is performed. This new clutter suppression technique is demonstrated with radar measurements of precipitation made by Delft Atmospheric Research Radar (DARR) [C657]

## "On the left eigenvectors of Stroh matrices"

The Stroh formalism is becoming a popular tool in the analysis of surface waves and related phenomena in anisotropic solids and piezoelectrics. It is shown that the left eigenvectors of a nonsymmetric matrix resulting from the Stroh system of equations governing wave motion in anisotropic piezoelectric halfspace, as well as of the analogous Stroh matrix for the electromagnetic case of certain anisotropic media, can be obtained by simple manipulation of its right eigenvectors. This can be helpful in many calculations exploiting the Stroh formalism, for example in evaluation of a functional approximation to the planar harmonic Green's function of anisotropic media [C658]

## "Recent advances in polarimetric-interferometric SAR theory and technology and its application"

The development of radar polarimetry and radar interferometry is advancing rapidly. Whereas with radar polarimetry the textural fine-structure, target orientation, symmetries and material constituents can be recovered with considerable improvement above that of standard “amplitude-only” radar, with radar interferometry the spatial (in depth) structure can be explored. In “polarimetric interferometric synthetic aperture radar (POL-IN-SAR) imaging”, it is possible to recover such co-registered textural and spatial information from POL-IN-SAR digital image data sets simultaneously, including the extraction of digital elevation maps (DEM) from either polarimetric (scattering matrix) or interferometric (single platform: dual antenna) SAR systems. Simultaneous polarimetric-plus-interferometric SAR offers the additional benefit of obtaining co-registered textural-plus-spatial three-dimensional POL-IN-DEM information, which, when applied to repeat-pass image-overlay interferometry, provides differential background validation, stress assessment and environmental stress-change information with high accuracy. Then, either designing “multiple dual-polarization antenna POL-IN-SAR” systems or applying advanced “POL-IN-SAR image compression techniques” will result in “POLarimetric TOMOgraphic (multi-interferometric) SAR” or “POL-TOMO-SAR” imaging. This is of direct relevance to wide-area, dynamic battle-space surveillance and local-to-global environmental background validation, stress assessment and stress-change monitoring of terrestrial and planetary surface covers [C659]

## "Approximate decomposition algorithm for solving integral equations"

The Far Field Approximation (FAA) is an approximate decomposition phase algorithm that is developed based on the distinction between near-field and far-field interactions in the spatial domain. The algorithm is found to have a computational complexity of O(N1.5 ) if the interactive solver method is used. For discussing the accuracy of FFA, a typical example, the bistatic RCS of TE-excited conducting circular and rectangular cylinders are calculated numerically in this paper [C660]

## "Numerical evaluation of the scattering matrix for raindrops"

Summary form only given. The signal used in classic radar is based on two informational parameters: the amplitude and the frequency. They allow the detection of the target as a dot, if the amplitude surpasses a certain threshold and mobility through Doppler frequency evaluation. In order to obtain more information, the processed signal should include a large number of parameters obtained from frequency, phase or polarization modulation. The paper investigates the polarimetric signature of the targets with a cross section less than the wavelength of the incident electromagnetic field. This field is analytically described by using a particular form of bi-complex quaternions. As a result, the target is defined by several parameters, which form the scattering matrix (the target signature). Their values depend on the range radar-target, the mobility and the geometric properties of the target. The paper presents the equations used to define cross section of the raindrops as a

function of the rain intensity. It also presents the mathematical fundamentals of the numerical method allowing the scattering matrix evaluation. This kind of object are investigated with an incident electric field having two orthogonal components (linear or elliptic). As a result, the scattering matrix for real targets has three complex components. The paper also presents the results obtained from scattered field of the different kinds of raindrops (equivalent sphere diameter less than 8 mm) [C661]

## "The application of network methods to distributed microwave circuit analysis"

The application of network methods to electromagnetic field problems is discussed. The field problem is systematically treated by the segmentation technique and by specifying canonical Foster representations for the subcircuits. Connection between different subdomains is obtained by selecting the appropriate independent field quantities via Tellegen's theorem. For each subdomain, as well as for the entire circuit, an equivalent circuit extraction procedure is feasible, either in closed form for subdomains amenable to analytical description or via the relevant pole structure description when a numerical solution is available. Several numerical examples are provided, based on modal techniques as well as on transmission line matrix (TLM) modeling [C662]

## "Coupled mode model of distributed ferrite microstrip line circulators"

A coupled mode approach has been applied to investigate the axially magnetized ferrite coupled (FCL) microstrip junction. The scattering properties of the junction are obtained and applications of FCL in microstrip distributed circulators are discussed. The performance of a microstrip FCL circulator is investigated by numerical experiment and good agreement with previously published results is obtained [C663]

## "Switched pulsed multiport for transmittance measurements"

The concept of a network for the measuring system of a scattering matrix of two-ports is presented. The network contains only two power meters instead of eight as in the classic dual six-port technique. The proposed design is not only more economical (fewer power meters) but also more accurate due to long-term instability of sensitivity. The main advantage of this circuit is the possibility of microwave pulse excitation. This circuit could be applied for measurement of power transistors in pulsed mode [C664]

## "Multimode analysis of waveguide discontinuities using the concept of generalised scattering matrix and power waves"

The application of the power scattering matrix for the FDTD algorithm with impedance boundary conditions is presented. The power scattering matrix is obtained when the waveguide ports of the analysed structure are terminated by any convenient impedances. The conventional scattering matrix is then obtained by the appropriate matrix conversion [C665]

## "Improvement of identification of weak-contrast radiolocation targets during monitoring of the Earth surface by radiopolarimetry"

This article deals with the aspects of application of polarization processing to improve identification of weak-contrast Earth covers. The closest attention is paid to the analysis of the influence of polarization characteristics of objects including phase and correlation properties of scattering matrix elements on their identification. The authors calculated values of the optimal polarization basis and contrast gain as compared with the initial for several Earth covers for the diagonal and cross elements of the scattering matrix [C666]

## "Scattering of a plane electromagnetic wave by a metal-dielectric composite cylinder"

The scattering of a plane electromagnetic wave by an infinite circular metal-dielectric cylinder (CMDC) is considered. The metal part of the cylinder is a sector of arbitrary angle of opening. One may use such structures in order to model the properties of a wedge-shaped load, which is frequently used in electromagnetic control applications. Since in some cases the analysis of the experimental data may be not reliable due to the small magnitude of the measured reflection coefficient and relative errors of the measurement equipment, there is a need for a closed-form analysis of the model structures. In the presented study the method of reexpansion in the basis functions at a given interval is used (Smirnov 1957; Shepilko 1979). The resulting field is presented in terms of the Bessel and Hankel functions. Applying the boundary condition to the Fourier series representation of the scattered field, the problem is reduced to the solution of a matrix equation with unknown expansion coefficients, which can be calculated with controlled accuracy. The scattered field is evaluated asymptotically and the backscattering radar cross section (BRCS) expression is derived. Accurate numerical results are presented in the case of E-polarized waves [C667]

## "Identifying radar secondary data for signal detection"

In signal detection, one is interested in the problem of detection of a given radar signal s which is a complex vector in the presence of noise in transmission. The signal may be a set of voltages that an EM wave from the selected search directions induces on a number of receiving elements. The actual observed data Y may be a pure noise vector n or the signal s plus a noise vector n. It is assumed that the noise follows a complex multivariate normal distribution with mean O and covariance matrix Σ. Statistically, the model can be described as Y=s+n where s is a specific signal and n is a noise random vector. The goal is to test the null hypothesis that Y=n versus the alternative hypothesis that Y=s+n. Reed et al. (1974) discussed an adaptive procedure for the above detection problem in which two sets of input data are used, which are called the primary and secondary data. A radar receives primary data Y0which may or may not contain a signal, and secondary data Y1,Y2,…,Yn which are assumed to contain only noise, independent of and statistically identical to the noise components of the primary data. The goal is to test H0:μ=O versus H1:μ=s where μ is the population mean of Y0. Kelly (1986) used the likelihood ratio principle to derive a test statistic for the above hypothesis testing problem. Chen and Wicks (1999) proposed a selection procedure which compares the covariance matrices of the secondary data with that of the primary data. It is used to identify and eliminate those observations that have a different covariance structure from the secondary data. It retains homogeneous radar data for further investigation. As described in Chen and Wicks (1999), this procedure can be applied prior to the step of estimating the covariance matrix of the secondary data in Kelly (1986). The selection procedure is discussed together with a simulation study [C668]

## "Extension of the Kennaugh null theory"

In radar polarimetry, Kennaugh (1952) first introduced the concept of the characteristic polarization states. This paper introduced the concepts of the co-null and the co-null Abelian group for extending the Kennaugh null theory to the case of two independent polarization states. For two arbitrary targets, it is proved that there exists one pair of polarization states such that the received powers of both targets equal zero. This polarization states' pair is called the co-null of the two targets, which can easily be obtained by solving an eigenvalue problem. Based on group theory, another concept- the co-null Abelian group is introduced for the symmetric scattering matrix case, and many important results are presented: e.g., the relations between the co-null and the co-pol/X-pol nulls, the structure of the co-null Abelian group, and the relations between the co-null Abelian group and two classes of targets: symmetric targets and H-targets. Finally, the co-null for the asymmetric scattering matrix case is studied. The concepts of the mono-co-null Abelian group and the bi-co-null Abelian group are introduced, and the relations between both groups are presented [C669]

## "Low-grazing-angle scattering by a triangle model of an ocean wave"

The boundary value problem (BVP) is reduced to a 1-D integral equation of the 1stkind and then to an ill-conditioned matrix equation. A new iterative method is proposed for such equations' solution, which produces a robust and adequate solution. This solution is compared with the genetic algorithm solution and good agreement is obtained. A strong backscattering for a 1° grazing angle is revealed from a resonant-sized foaming-like ocean wave, that is comparable in order with radar “sea-spikes” [C670]

## "Large scale computations using FISC"

FISC (Fast Illinois Solver Code) is designed to compute the RCS of complex three-dimensional targets. The problem is formulated by the method of moments, where the RWG basis functions are used. The resultant matrix equation is solved iteratively by the conjugate gradient (CG) method. The multilevel fast multipole algorithm (MLFMA) is used to accelerate the matrix-vector multiply in CG. Both complexities for the CPU time per iteration and memory requirements are of O(NlogN), where N is the number of unknowns. Some computations other than the matrix-vector multiply in FISC may have higher complexity than O(NlogN). When the translation matrix in MLFMA is calculated directly, the complexity is O(N3/2). For calculating the bistatic RCS or radiation pattern on a one-plane cut, the number of observation angles (M) is proportional to the frequency for a surface scatterer. So the complexity of calculating bistatic RCS or radiation pattern is O(NM) or O(N1.5). In this paper, we use interpolation to calculate the translation matrix and the complexity is reduced to O(N). MLFMA has been implemented to calculate the bistatic RCS or radiation pattern reducing its complexity to O(M)+O(NlogN). With these improvements, we have solved the problem of scattering from a 120λ sphere with 9,633,792 unknowns and VFY218 at 8 GHz with 9,990,918 unknowns. MLFMA has also been implemented for targets with a perfect electric conductor (PEC) ground plane [C671]

## "Multiple sweep method of moments (MSMM) analysis of electromagnetic scattering from targets on ocean-like rough surfaces"

This paper presents the multiple sweep method of moments (MSMM) analysis of scattering from targets on ocean-like sea surfaces, and is, to our knowledge, the first attempt to numerically solve three dimensional (3D) targets on the ocean-like rough surfaces. Our results show that the MSMM converges for problems that the method of ordered multiple interactions (MOMI) (and forward-backward method) fails to converge [C672]

## "Adaptive detection of distributed targets in partially-homogeneous environment"

This paper deals with adaptive detection of range-spread targets (with unknown amplitudes) embedded in Gaussian noise with unknown covariance matrix. For estimation purposes, we assume that a secondary data set, free of signal components, is available. All of data vectors share the same structure of the covariance matrix, but the (common) power level of the secondary data can be different from that of the cells under test. We resort to the GLRT and come up with adaptive detectors that able to operate in this partially-homogeneous scenario. In particular, we investigate the suitability of one-step and two-step GLRT-based detectors. A one-step receiver performs the GLRT over the totality of data while the design of a two-step detector assumes that the covariance matrix (or its structure only) is known; a fully adaptive structure is obtained by substituting the sample covariance, based upon secondary data, in place of the unknown matrix. Remarkably, both procedures lead to detectors ensuring the CFAR property with respect to the noise statistics. The performance assessment shows that the one-step GLRT and one of the two-step GLRTs, achieve the same performance under situations of relevant interest. Hence, the two-step approach is to be preferred since it leads to a simplified structure without loss of performance. Finally, such a detector is compared with a receiver which assumes a knowledge of the covariance matrix of the noise; the comparison confirms the suitability of the GLRT approach for operating in real radar scenarios [C673]

## "Radar image simulation from fully polarimetric scattering of heterogeneous canopy surface"

Polarimetric imagery of high resolution SAR is one of most important advances in microwave remote sensing. This paper, using the fully polarimetric Mueller matrix solution and ray tracing method, simulates radar images for fully polarimetric scattering from a heterogeneous canopy surface. Non-uniform 3D structures and non-uniform distribution of the multi-components of the surface canopy are taken into account. Simulated image texture demonstrates the spatial variation of the radar echoes due to canopy 3D-heterogeneity, and is also compared with an AirSAR image in the P,L,C bands [C674]

## "Segmentation of a road from a vehicle-mounted radar and accuracy of the estimation"

This work treats a problem relevant to automatic road following, collision avoidance, and maneuver control. A millimeter-wave radar is placed on the front of the vehicle and an image of the radar backscatter of the terrain is acquired in polar coordinates. This image contains both road and off-road scatter components which must be segmented from each other Geometric constraints on the road edges are naturally formulated in the Cartesian cartographic domain. However, to use the recorded data directly, we apply the road constraints in polar coordinates. Moreover our estimator is based on a criterion which is largely insensitive to the off-road scatter. Numerical results are given for real data and illustrate the accuracy and robustness of our approach. Finally, we derive the Fisher information matrix for evaluation of the achievable accuracy of segmentation for our model via the Cramer Rao bound [C675]

## "Constant co-polarized echo curves on the Poincare sphere"

A set of useful formulae has been presented allowing for computation of the equipower curves on the Poincare sphere of the co-polarized radar returns for both monostatic and bistatic scattering [C676]

## "Orthogonal bases of smooth local cosines for EM scattering"

The Smooth Local Trigonometric (SLT) functions are alternatives to traditional wavelets. The SLT system is more general than the wavelet packet bases, which can only divide the subdomain into dyadic intervals. Employing the SLT as the basis and testing functions in the method of moments (MoM), sparse impedance matrices are obtained. The SLT system is particularly effective for electrically large scatterers, where the integral kernel behaves in a highly oscillatory manner. Numerical examples show good accuracy and efficiency in the solution of scattering of electromagnetic waves from 2D objects [C677]

## "On the parallelization of electrodynamic multilevel fast multipole method on distributed memory computers"

In recent years, the Multilevel Fast Multipole Method (MLFMA) has been developed into one of the most powerful techniques for accelerating the iterative solution of integral equations of electromagnetics. It has been

shown that the MLFMA reduces the computational complexity of a matrix-vector multiply from O(N2) to O(N log N), where N is the number of unknowns. In an attempt to extend the range of problems that can be solved using this technique, we have recently developed an application independent, parallel MLFMA kernel, called ScaleME, for distributed memory computers using MPI. In this paper, we shall discuss the characteristic features which distinguishes it from its static counterpart, such as work required for each level, the size of multipole expansions and interpolation/filtering operations, and their influence in the parallel algorithm design. We shall follow it with a discussion of major issues in the parallelization which are unique to the dynamic MLFMA, such as reducing the memory requirements for translation operators and the reduction of replicated geometric data structures. We shall also briefly discuss the load balancing strategies. Finally, we shall present some representative numerical results from some ScaleME accelerated electromagnetic scattering codes, including a simulation involving 4 million unknowns and that of the radar cross-section computation of a full scale aircraft on a Beowulf class cluster [C678]

## "Computation of the RCS of 3-D coating conductor with arbitrary shape by using FMM and IBC"

The fast multipole method (FMM) and the impedance boundary condition (IBC) are used to attain an efficient computation of RCS of a 3-D coating conductor. FMM expedites greatly the matrix-vector multiplication in iterative process. Meanwhile a sparse technique combined with precondition conjugate gradient method is used to carry out the computation of two sparse matrices AÏ, BÏ. The present method is very efficient for solution of scattering from the impedance coating conductor with arbitrary shape and large electrical sizes [C679]

## "Development of a 3-D GPR simulator using the FDTD method"

The Monte Carlo method is used to simulate the electromagnetic scattering from a target buried in a layer of randomly distributed trunks. Using the moment method checks the validity of the second-order scattering field (interaction of target-trunk pairs). An iterative algorithm and spherical vector wave function are used to calculate the scattering matrix of the finite-length multi-layer dielectric cylinder and target (sphere) respectively. Finally, the influences of the bark layer and the roughness of the surface on the scattering pattern of the target (sphere) are discussed for the L band, C band and X band. Because of the effect of random media such as trunks, the scattering coefficients for the target become smaller. The low frequency can be used for the purpose of target detection and recognition buried in random media. The present work provides a theoretical basis for the simulated scattering from targets buried in forest canopies including the effects of multiple scattering [C680]

## "Methods for rapid computation of RCS in aircraft design"

Techniques are presented for improving the computational performance of radar cross section (RCS) prediction for aircraft. The motivation is to bring RCS and other electromagnetic requirements into a multidisciplinary, integrated design environment where optimization is likely to be employed. Techniques directly applicable to the method of moments and high frequency approximations are discussed [C681]

## "SAR target decomposition for stochastic natural targets for L- and C-band"

The authors propose a new fast algorithm for calculating target entropy and scattering mechanism (alpha angle) estimates for polarimetric SAR data. This new approach applies only for natural targets and it is validated with L- and C-band data. The algorithm is based on the fact that averaged covariance matrix for natural distributed targets presented in Pauli basis has a nearly diagonal form and additional diagonalisation applying eigenvalue calculation is not necessary. The proposed algorithm reduces computing times and allows calculation of the target entropy and scattering mechanism type for large polarimetric SAR images. The algorithm can be used in various applications where small error in calculations is allowed. Some illustrative calculations using full polarimetric L- and C-band SAR data are presented [C682]

## "Discriminating polarimetric parameters for radar images analysis"

Investigates the discriminating properties of the numerous polarimetric parameters and their potential to retrieve electromagnetic mechanisms. This discussion is based on two different approaches: a theoretical work on the connections between the various sets of parameters and the knowledge acquired from the analysis of full polarimetric SAR images provided by several RAMSES campaigns [C683]

## "Fitting a two-component scattering model to polarimetric SAR data"

Classification, decomposition and modeling of polarimetric SAR data has received a great deal of attention in the literature. The objective behind these efforts is to better understand the scattering mechanisms which give rise to the polarimetric signatures seen in SAR image data. The author describes an approach which involves the fit of

a combination of two simple scattering mechanisms to polarimetric SAR observations. The mechanisms are canopy scatter from a cloud of randomly oriented oblate spheroids, and a ground scatter term, which can represent double-bounce scatter from a pair of orthogonal surfaces with different dielectric constants or Bragg scatter from a moderately rough surface, seen through a layer of vertically oriented scatterers. An advantage of this model fit approach is that the scattering contributions from the two basic scattering mechanisms can be estimated for clusters of pixels in polarimetric SAR images. The solution involves the estimation of four parameters from four separate equations. The model fit can be applied to polarimetric AIRSAR data at C-, L- and P-band [C684]

## "Polarimetric target matrix decompositions and the `Karhunen-Loeve expansion'"

This contribution is concerned with polarimetric target matrix decomposition theorems for incoherent backscattering from distributed targets described by complex random 2Ч2 Sinclair matrices. The polarimetric covariance matrix concept is used to establish connections between the target decomposition theorems of Cloude and Barnes-Holm and the classical Karhunen-Loeve expansion of discrete random processes [C685]

## "A possibility of various interpretations of polarimetric SAR signatures analyzed from propagation and transmission points of view"

Derivation of the relation called the `reversal' transformation, joining matrices in the two alignments, is presented. To arrive at the solution, a concept of `polarization and spatial phase' vectors for antennae and waves, different from complex antenna heights and complex wave amplitudes, has been applied. For Sinclair and Jones matrices, describing the same physical phenomenon of nondepolarizing scattering, two different Poincarer' sphere models have been proposed based on decomposition of a Sinclair matrix into two transformations of inversion and rotation of the Poincare sphere of incident polarizations. For the Jones matrix model another Sinclair matrix has been determined followed by an additional orthogonality transformation. Such a difference in construction of the two models can explain diverse physical interpretations of their operation. Limited number of simple formulae describing scattering will be obtained when applying to radar polarimetry a special `engineering approach' introduced in the paper [C686]

## "The potential of full polarimetric SAR data to classify dry snowcover"

The authors propose two polarimetric techniques to evaluate the potential of full polarimetric SAR data to classify dry snowcover. These decomposition methods can be used to compare different images of a site in order to characterize polarimetric variations that are closely linked to properties of the observed medium [C687]

## "The simulation study on polarimetric synthetic-aperture radar"

The simulation study on polarimetric synthetic-aperture radar (SAR) is presented in this paper. Compared with conventional SAR simulation methods, the approach uses a model of the target with phase information that is required by the polarization synthesis. After introducing the polarimetric SAR general operation, the paper comes to the mathematical model of the backscattering mechanisms of the point target. The complex scatter amplitude against scatter cross section is a key to build this model. The imaging process and scattering matrix computation are then discussed. The approach is used in studying the effect of polarization cross talk on the scattering matrix measurement of two kinds of point target; the results show us the effectiveness of the proposed theoretic model. This simulation approach is useful for the study and analyses of polarimetric SAR features. It will help us to understand SAR polarization characteristics [C688]

## "Classification of full polarimetric SAR-data using artificial neural networks and fuzzy algorithms"

Within recent years several investigations have reported the use of polarimetric data to map Earth terrain types and land covers. For the operational application some demands, besides the accuracy requirements, must be fulfilled. In order to make the handling of the classification easy for the common user, the algorithm has to be data set independent and the handling must be possible without a priori knowledge. The authors outline a classification based on the entropy (H)-α decomposition theorem extended by the use of the first eigenvalue of the coherency matrix. Fuzzy algorithms as well as artificial neural network (ANN) strategies are applied to improve the classification accuracy and to enhance the handling. The algorithms are applied to a L-band data set of the test site Oberpfaffenhofen, Germany, acquired with the DLR's airborne Experimental SAR (E-SAR) in April 1997. The classification results are discussed and compared to reference data i.e. topographic maps in the scale 1:25000 (maps 7833 and 7933) and airborne optical data acquired with a ZEISS RMK A30/23 Camera in August 1997 [C689]

## "The Mueller and coherency matrices solution for polarimetric scattering simulation of tree canopy in SAR imagery at C band"

A theoretical model of multi-level, non-spherical scatterers is developed for fully polarimetric scattering from a tree canopy in SAR imaging at C-band. The amplitude functions of non-spherical particles with randomly spatial orientation are derived by the generalized Rayleigh-Gans approximation. The nondiagonal extinction matrix and the Mueller matrix solution are constructed. Numerical solutions of polarimetric scattering of four Stokes parameters from random, non-spherical scatterers are obtained. To physically identify polarimetric scattering of the Mueller matrix solution, the coherency matrix and its eigen-analysis are discussed. Functional dependence of the coherency matrix and entropy upon various parameters are obtained. As an application, analysis of AirSAR images at P-, L-, C-bands is discussed [C690]

## "Fast multipole method for scattering from an arbitrary perfectly conducting target above or below a lossy half space"

The fast multipole method (FMM) was originally developed for perfectly electric conducting (PEC) targets in free space. Here, the FMM is extended to the scattering from a PEC target above or below a lossy half space. The “near” terms are handled via a method-of-moments (MoM) analysis, wherein the half-space Green's function is evaluated through application of the method of complex images. The “far” interactions utilize an approximation to the Green's function dyadic. The algorithm is validated through comparison with rigorous MoM results [C691]

## "Polarimetric radar calibration using distributed target"

Accurate knowledge of the polarization scattering matrix is essential for understanding physical properties of the target. Conventional calibration uses a point target located in the boresight of the antenna. This calibration assumes that it is sufficient to measure amplitude and phase in one point of the antenna pattern. However most of the investigated targets are spatially distributed and observed by the complete antenna pattern. Thus a new calibration technique taking into account the complete antenna pattern is necessary. The simplest way for such a calibration is to use a distributed target with well known polarimetric properties. Since such an artificial target is not available, the choice of a natural target is unavoidable. Use of rain as the calibration target is discussed and results of the calibration are presented. This calibration was performed using the Delft Atmospheric Research Radar (DARR). DARR is a Doppler-polarimetric S-band radar located on the roof of a 92-m high building. The DARR system has a cross polarization isolation of 27 dB for a distributed target. As a result of the calibration, an effective polarization isolation of 34 dB is achieved [C692]

## "Polarimetric Techniques for SAR Contrast and Resolution Enhancement"

First Page of the Article [C693]

## "Monte-Carlo simulations of emissivities of random dielectric rough surfaces and comparisons with the small perturbation method"

Wave scattering from a two-dimensional lossy dielectric random rough surfaces (three-dimensional scattering problem) with large permittivity is studied by using numerical simulations. A physics-based two-grid method (PBTG) is extended from 1D surfaces to 2D surfaces to deal with the problem. The sparse matrix canonical grid method (SMCG) is used in conjunction with the PBTG to speed up computation. Applying this method, the emissivities of random dielectric rough surfaces are calculated. The results are compared with those from the second order small perturbation method [C694]

## "Calibration standards and uncertainties in radar cross section measurements"

Standards for radar cross section measurements are being developed cooperatively by NIST and DoD scientists. Three technical areas were defined as the foundation of such an effort: (1) monostatic single-channel calibration, (2) full polarimetric calibration using a scattering matrix formalism, and (3) analysis of radar cross section calibration and measurement uncertainty. The authors reviews the results of assessment of calibration data accuracy using a set of cylinders as artifact standards, examines the theory of polarimetric calibrations, and discusses essential areas of radar cross section uncertainty analysis [C695]

## "Convergence analysis of stochastically-constrained spatial and spatio-temporal adaptive processing for hot-clutter mitigation"

Further considers the use of spatio-temporal adaptive array processing in radar applications in order to remove nonstationary multipath interference (known as “hot clutter”). Since the spatio-temporal properties of hot clutter

cannot be assumed constant over the coherent processing interval, conventional adaptive techniques fail to provide effective hot-clutter mitigation without simultaneously degrading the properties of the backscattered radar signals (known as “cold clutter”). The stochastically-constrained spatio-temporal adaptive processing (SC STAP) approach incorporates multiple data-dependent (“stochastic”) constraints to achieve effective hot-clutter suppression, whilst maintaining distortionless output cold-clutter post-processing stationarity. Here we discuss the efficiency of the algorithm with respect to the number of training snapshots [C696]

## "Performance bounds for interference mitigation in radar systems"

This paper addresses the problem of interference suppression in airborne radar systems. Both hot clutter (terrain-scattered interference) that is induced by interfering sources (jammers, etc.) and cold clutter that results from radar transmitter reverberations are considered. A new method is presented for the calculation of the space-time covariance matrix that will be observed under specific topographical conditions. The method incorporates site-specific phenomenological data as well as system effects such as array geometry, receiver filtering, and system bandwidth. This approach differs significantly from the usual approach in which sampled-data analysis is used to estimate the covariance matrix. The new approach allows direct calculation of the degree to which the interference can be mitigated for a specific heterogeneous terrain environment. From these results, one can infer performance bounds which are tighter and thus more meaningful than the thermal noise floor limit [C697]

## "A microwave scattering model for an electrically dense vegetation medium"

It is known that radar response from a vegetation medium can be studied theoretically by modeling the medium as a discrete random medium with scatterers such as disks, needles and cylinders. However, at the low frequency end of the microwave region, the spacing between the scatterers may be comparable or smaller than the wavelength and the medium is considered as electrically dense. This means that the coherence effect of the scatterers should be considered as scattering from each scatterer is no longer independent from each other. In addition, when the dimensions of the scatterers (such as radius of deciduous leaves and length of branches) are comparable to the spacing between the scatterers and the wavelength, near field interaction needs to be considered. These effects are incorporated by introducing two types of correction to the phase matrix of the scatterers, namely amplitude and phase corrections. The amplitude correction is obtained from the near field amplitude term of the scattered field. The phase correction consists of two components: the Fresnel phase term and the array phase term. The Fresnel phase correction term comes from the higher order terms in the phase of the scattered field from a scatterer. The array phase correction term takes into account the phase contributions by various correlated scatterers. The corrected phase matrices for disks, needles and branches are then used in the radiative transfer formulation where second order iterative solutions are solved. Theoretical results show that the array phase correction is important for electrically dense medium. When the frequency increases and enters into the Fresnel region, the amplitude and Fresnel phase corrections are required [C698]

## "Polarimetric detection and estimation of ship wakes"

Classification of Earth natural components within a full polarimetric SAR image is one of the most important applications of radar polarimetry in remote sensing. An unsupervised classification procedure, based on neural networks with competitive architectures, is applied to the full polarimetric SAR images of sea surface and ship wakes for segmentation and clustering of different ocean components. The linear feature vector used during the classification procedure is defined from a new scheme for parameterising polarimetric scattering problems, which has application in the quantitative analysis of polarimetric SAR data. The method relies on an eigenvalue analysis of the coherency matrix and employs a 3-level Bernoulli statistical model to generate estimates of the average target scattering matrix parameters from the data [C699]

## "Applications of air-borne polarimetric-interferometric and tomographic SAR: POL-IN/TOMO-SAR repeat-pass imagery to environmental stress-change monitoring"

In polarimetric interferometric synthetic aperture radar (POL-IN-SAR) imaging it is possible to recover textural and spatial information from POL-IN-SAR digital image data sets simultaneously including the extraction of digital elevation maps (DEMs) from either polarimetric (scattering matrix) or interferometric (dual antenna) SAR systems. Simultaneous polarimetric-plus-interferometric SAR offers the additional benefit of obtaining co-registrated textural-plus-spatial three-dimensional POL-IN-DEM information which when applied to repeat-pass image-overlay interferometry provides differential background and environmental stress-change information with high accuracies. Then, by either designing multiple dual polarization SAR antenna POL-IN-SAR systems or by applying advanced POL-IN-SAR image compression techniques will result in polarimetric tomographic (multiple interferometric) SAR or POL-TOM-SAR imaging. This novel three-dimensional high-resolution fine structure

stress-change sensing and imaging technique is of direct and immediate relevance to wide-area dynamic surveillance and local-to-global environmental background, stress and stress-change monitoring of the terrestrial and planetary covers [C700]

## "Comparative analysis of polarimetric SAR image exploitation algorithms for environmental stress-change monitoring"

Theoretical advances in scene classification using single and multi-frequency POL-SAR techniques have provided a wealth of tools for application to important environmental issues involving ground cover classification and the discrimination of change due to natural versus man-made stress. Among these are techniques which have evolved from the Navy International Cooperative Opportunities Program (NICOP), and although initial emphasis within the present discussion has been placed on NICOP results, a broader base of algorithms is currently being evaluated, with partial results included in this paper. A portion of the multi-frequency POL-SAR data being considered is from the Southern Maryland area, and in particular the entropy based scheme of Cloude (1997, 1998) and the fuzzy c-means technique by Kersten (1997) are used as an initial baseline for this work. The three-component scattering mechanism described by Krogager et al. (1997) and other techniques are incorporated as the work continues [C701]

## "Soil-moisture estimation using polarimetric SAR data"

In this paper we outline the role of polarimetric decomposition in the application of soil roughness and soil moisture inversion algorithms. We investigate how the eigenvector decomposition of the covariance matrix may be used to improve the performance of the inversion algorithms. Finally we demonstrate and discuss the resulting advantages of the proposed method using experimental SAR data acquired by DLR's ESAR system [C702]

## "Surface roughness and polarimetric entropy"

In this paper we relate the eigenvector formulation of polarimetric backscatter to published coherence and amplitude ratio approaches to surface roughness measurement. Several important relationships appear and the formulation leads us to propose a new model for the analysis of surface data which promises to provide separable roughness and moisture parameters [C703]

## "An efficient algorithm for the RCS modulation prediction from jet inlet-engines"

The electromagnetic scattering from the interior of a complex jet engine inlet contributes significantly to the overall radar cross section (RCS) of a modern jet aircraft. Previously we have presented a general multi-domain and multi-method coupling scheme, based on generalized scattering matrices computations of three-dimensional inlet subdomains. This method is really suitable in a context of parametric investigations (local inlet engine modifications). In this paper we discuss a new algorithm providing the radar modulation due to a set of rotating blades computed with only one solution for any blade position. A validation of this method is presented on a simplified rotating structure connected with an evolutive inlet [C704]

## "The effect of complex loads on the scattering from a microstrip dipole"

The scattering of a plane wave by a microstrip dipole antenna has been analyzed by a frequency-domain MoM method with rooftop basis functions and Galerkin's procedure. The time-domain responses of the scattered field are obtained via the inverse FFT and the poles and residues of the time-domain response are extracted by the generalized pencil-of-function (GPOF) method. The results show that the various loads have a great effect on the transient scattered fields, but not much effect on the resonant frequencies. This characteristic is beneficial to identify a scatterer by its complex natural resonance [C705]

## "An efficient high-frequency boundary integral equation"

In this paper, we start from the simple observation that scattering processes tend to become local at high-frequencies, as confirmed, for instance, by the successes of the geometrical theory of diffraction. This observation, suggests an efficient integral equation formulation leading to sparse and very well-conditioned matrices. The construction of this integral equation is carried out in two steps. The first step consists in defining a generalization of the well-known combined field integral equation. This generalization inherits the well-posedness, at all frequencies, from the classical one but its regularity is better and allows the use of iterative methods requiring very few iterations. The second step consists in exploiting the asymptotic localization property. We propose a perturbation of the first formulation to define an integral equation accounting for “hidden faces”. This means, that a coefficient in the stiffness matrix, relating to basis functions whose supports are not “mutually

visible" becomes the more negligible as the wave-number becomes large. Numerical experiments show, that this formulation leads to very well conditioned systems, which can be rapidly solved through iterative methods, maintaining a good accuracy when small coefficients are neglected even with rather high thresholds [C706]

## "Effects of the fast multipole method (FMM) parameters on radar cross section computations"

The method of moments (MoM) has been successfully applied to all types of electromagnetic scattering and radiation problems. As is well known, conventional MoM techniques lead to fully populated interaction matrices. This aspect limits the electrical size of the problem that can be solved on a given computer with limited memory. Previously introduced fast methods, such as the adaptive integral method (AIM) and fast multipole method (FMM), provide for reduced memory and CPU requirements. In this paper we consider the implementation of FMM to MoM matrices associated with 2nd order curvilinear elements. Particular emphasis is given on the convergence properties and accuracy of FMM acceleration schemes. It is demonstrated that preconditioning is often essential when dealing with FMM matrices generated from curvilinear element implementations. Also, choices of lower order multipole expansions can lead to much faster speeds but lower accuracy [C707]

## "Fast multipole method for targets above or buried in lossy soil"

We demonstrate the accuracy of the half-space fast multipole method (FMM) by considering two targets: a model unexploded ordnance (UXO) buried under soil and a rectangular box situated above the ground. In both examples, the bistatic radar cross sections (RCS) is computed via the FMM developed here, as well as with a rigorous method of moments (MoM), wherein the half-space Green's function is evaluated rigorously via the method of complex images. The results show an excellent agreement between the FMM and MoM, for co- and cross-polarized RCS. The RAM and CPU requirements of the half-space FMM are about twice to three times compared to the free-space FMM (caused by the extra set of real images and the additional Fourier transforms), but the complexity of N 3/2is unchanged [C708]

## "The 3DV-FMM method to calculate scattering from inhomogeneous dielectric objects"

Numerical methods for fast and efficient solution of electromagnetic (EM) scattered fields from arbitrary shaped, 3-D scatterers are of great importance not only in EM scattering simulation but also in scattering inversion. Since the integral equation satisfies the radiation boundary condition, the MOM method is usually applied. However, a dense matrix derived by using the MOM method requires a large computer memory and long CPU time. Thus, application of the conventional MOM to the integral equation is always restrictive. In this paper, the fast multipole method (FMM) is developed to solve the 3D volume integral problems. Scattering from a complex 3D dielectric object can be efficiently and accurately calculated. Numerical simulations of scattering from 3D inhomogeneous, multiobjects are discussed and are compared with the conventional MOM results [C709]

## "The 3DV-FMM method to calculate scattering from inhomogeneous dielectric objects"

The fast multipole method (FMM) is developed to solve the 3-D volume integral problems. Scattering from complex-shaped inhomogeneous 3D dielectric objects can be efficiently and accurately calculated. Numerical simulations of scattering from 3D inhomogeneous multi-objects are discussed and compared with the conventional MOM results. [C710]

## "Plane wave scattering by a step on infinite perfect conducting plane surface"

First Page of the Article [C711]

## "Plane wave scattering by a step on infinite perfect conducting plane surface"

Plane wave scattering by a three-dimensional step discontinuity on an infinite perfect conducting plane surface is studied in the case where the scattering problem is reduced to the frequency or time domain electric field integral equation (EFIE). The conducting surface is modeled by planar triangular patches for numerical solution and results show that the current induced by the incident wave is highly perturbed because of the presence of a three-dimensional step. [C712]

## "The generalized forward-backward method for analyzing the scattering from targets on ocean-like rough surfaces"

The iterative forward backward (FB) method has been proposed to solve the magnetic field integral equation for smooth one-dimensional rough surfaces. This method has proved to be very efficient, converging in a very small number of iterations. Nevertheless, this solution becomes unstable when some obstacle, like a ship or a large

breaking wave, is included in the original problem. In this paper we propose a new extension of the FB method: the generalized forward backward (GFB) method, to solve such kinds of composite problems [C713]

## "Fast generalized forward-backward method by using a spectral acceleration"

The generalized forward backward (GFB) method is a generalisation of the previous forward-backward (FB) method to compute the electromagnetic scattering from targets on ocean-like rough surfaces. In this paper, the spectral acceleration algorithm introduced by Chou and Johnson for the FB method is adapted to the GFB. This reduces the computational cost of the GFB from O(N2) to O(N) per iteration [C714]

## "Adaptive wavelet packets and matrix sparsification"

Matrix sparsification using adaptive wavelet packets is described. An approach with column-row alternate search is proposed to implement the adapted decompositions. Typical sparsified results using Daubechies-8 wavelets for different kinds of matrices are presented. [C715]

## "Antenna gain and scattering measurement using reflective three-antenna method"

A novel method is proposed to combine the concepts of three-antenna method and RCS measurement method to measure the antenna gain and its structural scattering characteristics without involving the reference antenna or polarimetric calibration. In this method, the measurement arrangement including the transmitting and receiving antennas is considered as a two-port network with reference planes at the input port for each antenna as shown. By connecting three different known terminators at the receiving antenna port and measuring the reflection coefficients at the transmitting antenna port, the scattering parameters of this two-port network can be derived. They are shown to be related to the product of two antennas' gain. Therefore one can follow the three-antenna method to find the gain of each antenna. In addition, the structural scattering characteristics of each antenna can be solved [C716]

## "Effect of medium symmetries in limiting the number of parameters estimated with polarimetric interferometry"

The addition of interferometric backscattering pairs to the conventional polarimetric SAR data over forests and other vegetated areas increases the dimensionality of the data space, in principle enabling the estimation of a larger number of parameters. The effect of medium symmetries on the number of independent interferometric measurements is studied. Reflection, rotation, and azimuthal symmetries are considered. In each case, the number of independent elements of the interferometric covariance matrix is derived, which puts an inherent limit on the number of scatterer parameters that can be estimated using single-baseline polarimetric interferometry [C717]

## "Contractions, Hadamard products and their application to polarimetric radar interferometry"

Considers two new approaches to extend the concept of coherency from the scalar to the vector wave case in electromagnetic interferometry by the inclusion of polarimetric effects. One approach is based upon the application of the concept of contraction to the coherency matrix formulation of interferometry, the other uses Hadamard products data processing [C718]

## "Crop classification by polarimetric SAR"

Polarimetric SAR-data of agricultural fields have been acquired by the Danish polarimetric L- and C-band SAR (EMISAR) during a number of missions at the Danish agricultural test site Foulum during 1995. The data are used to study the classification potential of polarimetric SAR data using the Wishart distributed covariance matrix. In general, the improvement of using polarimetric SAR data compared to multipolarization SAR data is larger at L-band compared to C-band. On the other hand, the variability due to natural variation and different incidence angles is larger at L-band compared to C-band [C719]

## "Estimation of the terrain surface azimuthal/range slopes using polarimetric decomposition of POLSAR data"

The estimation of geophysical parameters, such as surface roughness, soil moisture, etc., is often affected by the terrain elevation. To correct the polarimetric effects caused by terrain having significant relief, it is necessary to introduce a remote sensing technique which is directly capable of estimating terrain surface slopes both in the azimuthal and ground-range directions. The target vector used during this procedure is defined from a new scheme for parameterising polarimetric scattering problems, which has application in the quantitative analysis of

polarimetric SAR data. The method relies on an eigenvalue analysis of the coherency matrix and employs a 3-level Bernoulli statistical model to generate estimates of the average target scattering matrix parameters from the data. Based on the original idea proposed by Schuler et al., a new remote sensing technique using the average target parameters, derived from the polarimetric decomposition, produces profiles of “terrain” slopes both in the azimuthal and ground-range directions [C720]

## "A scattering operator of random complex radar object and its spatially-spectral properties"

The scattering of electromagnetic waves by a complex radar objects, having a random distribution of scattering centers, cannot be described with the use of the well known scattering matrix (SM). The definition of SM is correct for the “one-point” radar object only. The use of this definition can not explain the facts of scattered field polarization parameters dependence both from of positional angle and from frequency of incident wave. A new definition of scattering operator (SO) of a random complex radar object (RC-RO), using spatially-spectral properties, is considered [C721]

## "Polarimetric scattering coefficients of half-space heterogeneous medium"

Almost all natural media such as a rain, ice, fog, snow, clouds, leaves, forests, surface soil layer, agricultural plants, etc. can be considered as some kind of heterogeneous random medium embedded with nonspherical discrete particles. In this paper the polarimetric backscattering coefficients of half-space random medium are calculated for the purposes of the environmental remote sensing using polarimetric radars. The stochastic model of the half-space heterogeneous medium consists of a random current propagating in a hypothetical isotropic medium. The parameters of the model used in this paper are derived by the aid of strong permittivity fluctuation theory under a bilocal as well low-frequency approximations. The symmetry of scattering matrix F was proven in backscattering direction of measurement of scattered electromagnetic field in the atmosphere. It was shown that the polarimetric covariance matrix C consists of two polarimetric covariance matrices of unperturbed and random parts of scattered electromagnetic field. It was as well shown that in backscattering direction the scattering coefficients σhv, σhhhv, σhvvvare different from zero in general. The expressions of polarimetric backscattering scattering coefficients given in this paper are valid for arbitrary joint probability density function P(θ,φ) of scatterers spatial orientation. The obtained results can be used for the purposes of polarimetric remote sensing of heterogeneous natural media embedded with discrete scatterers having non spherical geometry [C722]

## "Speckle filtering of SAR data for polarimetric interferometry applications"

The authors propose a new method for the speckle filtering of polarimetric interferometry data. Polarimetric interferometry is a new research area that has great potential for vegetation characterization and tree height estimation. As in other SAR applications, speckle is a problem. The commonly applied 5Ч5 boxcar filter has the undesirable effect of blurring both amplitudes and phases. The phase terms from the cross-correlation between two polarimetric SAR data sets contain the important interferometry information. The new method emphasizes not introducing cross talk, preserving polarimetric and interferometric information. Comparison will be made with the commonly applied 5x5 boxcar filter. Repeat-pass polarimetric interferometry data is used for illustration [C723]

## "Computation of radar cross section of waveguide arrays"

A review of the open literature shows that not much information has been published on the radar cross-section (RCS) of waveguide arrays. An accurate method for the computation of the RCS of active waveguide arrays is presented. It combines the plane wave angular spectrum method used by Stalzer et al. (1978) to find the active element radiation pattern of an infinite phased array and the generalized scattering matrix (GSM) approach to periodic waveguide array analysis. The active scatter pattern of an element in an infinite array is obtained in terms of the reflection coefficients of the free space Floquet modes found by the GSM procedure. This active scatter pattern is employed in the computation of the RCS of a finite array by assuming that it is identical for all elements of the array and ignoring the edge effects in the process. The accuracy of this model has been validated by the good agreement observed between predictions and published test results of arrays of various sizes [C724]

## "Higher-order MoM implementation to solve integral equations"

Higher-order basis functions have received intensive attention for solving electromagnetic problems with the finite element and Galerkin's methods. The advantage of using higher-order basis functions lies in their ability to model the fields and sources, as well as geometries, more accurately than conventional low-order methods. We investigate the convergence properties of divergence conforming interpolatory higher-order basis functions for evaluating the Galerkin's solution of integral equations. Both the electric field integral equation (EFIE) and the

magnetic field integral equation (MFIE) are used to obtain the scattered field from perfectly conducting objects. Our solution is first validated by comparing the radar-cross section (RCS) with the corresponding Mie series solution for conducting spheres. Next, we calculate the error convergence of the RCS from objects such as spheres and plates for several orders. In the case of objects with no analytical solution such as plates, over discretized solution is taken as the reference solution and the error results are then calculated [C725]

## "A novel design of an ultra-fast wideband polarimetric radar"

Accurate high resolution measurements of both clutter and man-made targets at millimeter-wave frequencies have become an essential requirement for the development of optimal target detection and tracking algorithms. Towards this end, an ultra-fast wideband polarimetric instrumentation radar was developed by The University of Michigan for millimeter-wave frequencies applications. With this new design, the scattering matrix of a target can be measured over a bandwidth of 840 MHz in less than 32 μsec, hence, one foot resolution fully polarimetric radar images can easily be generated using this system. The design is directly applicable to microwave instrumentation radars [C726]

## "Simulation model and eigen-analysis for polarimetric scattering in SAR imaging"

In this paper, to simulate fully polarimetric scattering from tree canopies applicable to SAR imaging at C band, the scattering amplitude functions of randomly oriented, non-spherical particles (e.g. leaves with thin thickness, branches with small radius) are derived in the generalized Rayleigh-Gans (GRG) approximation. Numerical results show the difference between the GRG and conventional Rayleigh approximations. These functions averaged over randomly spatial orientation are employed to construct the non-diagonal extinction matrix and the Mueller matrix solution. Four Stokes parameters of scattered fields are coupled. It is different from the conventional iterative solution of isotropic scattering media. Further, to physically identify polarimetric scattering of the Mueller matrix solution, the coherency matrix and its eigen-analysis are discussed. Information of the eigenvalues and entropy from the Mueller matrix measurement is related with polarimetric scattering process and medium randomness, and can be used to investigate directly the influence of different scattering mechanisms in complex scenarios on observable parameters. As an application, the eigenvalues and entropy derived from the Mueller matrix measurement of an AirSAR image are demonstrated [C727]

## "Quasi-invariants for recognition of articulated and non-standard objects in SAR images"

Using SAR scattering center locations and magnitudes as features, invariances with articulation (i.e., turret rotation for the ZSU 23/4 gun and T72 tank), with configuration variants (e.g. fuel barrels, searchlights, etc.) and with a depression angle change are shown for real SAR images obtained from the MSTAR public data. This location and magnitude quasi-invariance forms a basis for an innovative SAR recognition engine that successfully identifies real articulated and non-standard configuration vehicles based on non-articulated, standard recognition models. Identification performance results are given as confusion matrices and ROC curves for articulated objects, for configuration variants, and for a small change in depression angle [C728]

## "Electromagnetic scattering from large, deep, and arbitrarily-shaped open cavities"

The analysis of electromagnetic scattering from a large, deep, and arbitrarily-shaped open cavity is a very difficult task because of a large number of unknowns resulting from the discretization of the cavity. We present a very efficient technique to deal with this problem. This technique is based on the finite-element method (FEM) that is known for its capability to handle arbitrary geometries and complex material composition. The FEM mesh at the cavity aperture is terminated in an exact manner by the boundary-integral method. The technique exploits the unique features of the finite-element equations and, more importantly, the unique features of the problem of scattering by a large and deep cavity. It is designed in such a manner that it uses a minimal memory, which is proportional to the aperture size of the cavity and independent of the depth of the cavity, and its computation time increases only linearly with the depth of the cavity. Furthermore, it computes the scattered fields for all angles of incidence without requiring significant additional time. The technique is applied to both two and three dimensional cavities whose interior may be coated with radar absorbing materials [C729]

## "An analysis of the scattering of discrete scatterers in an electrically dense medium"

A theoretical model based on the radiative transfer theory is developed to study the scattering mechanisms in an electrically dense medium where the average separation between the discrete spherical scatterers is comparable to the wavelength. For an electrically dense medium, two types of correction, the amplitude and the phase corrections, are required to be incorporated in the phase matrix. The amplitude correction is incorporated by including near field terms in the phase matrix expressions of the Mie scatterers, whereas the phase correction is implemented by multiplying a phase correction factor to the Stokes matrix of the scatterer. The phase correction

factor is developed based on the antenna array concept. The comparison between the phase matrices with and without phase and amplitude corrections is carried out, with the illustrations of three dimensional model of these matrices. The results show that it is necessary to incorporate amplitude and phase corrections in an electrically dense medium. The phase matrix with amplitude and phase corrections is later used in the backscatter model and the effect of these corrections to the backscattering coefficient is also examined [C730]

## "Scattering from arbitrarily shaped microstrip patch antennas using the theory of characteristic modes"

A full-wave MoM solution to the problem of plane wave scattering by an arbitrarily shaped patch printed on a dielectric slab, using the theory of characteristic modes, is presented. Computed current distributions for the microstrip patch are presented. The method proposed seems promising for the exact analysis of arrays of microstrip antennas reducing the number of unknowns and the corresponding computational effort [C731]

## "Polarimetric SAR image interpretation and target detection with covariance matrix"

This paper studies the polarimetric synthetic aperture radar (SAR) image interpretation and target detection. The polarimetric target decomposition theorem and dominant scattering mechanism identification approach have been used widely in polarimetric SAR image interpretation. In order to get a good performance, we present a three-step image interpretation approach which involves speckle reduction and image classification, as pre-processing before the classical interpretation approach. Furthermore, we study the target detection based on the covariance matrix decomposition, and an odd-scattering detector and an even-scattering detector are formed and analyzed. Experimental results are given to verify the effectiveness of the image interpretation approach and to quantify the presented polarimetric detectors [C732]

## "Experimental validation of an entropy-based classification scheme using a wide-band polarimetric radar"

The extension of an entropy-based classification scheme based on polarimetric SAR for land applications and inversion of biophysical parameters is currently being investigated. In this paper, the potential and limitations of this technique are outlined by using a number of wide-band polarimetric data sets acquired in the European Microwave Signature Laboratory under fully controlled conditions. The targets used in this experimental validations include various tree types and maize plants of different densities and heights. These data sets have been analyzed by displaying the loci of the measured data in the entropy-alpha plane. The application of this scheme leads to interesting results and the subsequent interpretation gives an indication about the dominant scattering mechanism associated to a given target (as a function of the working frequency and the incidence angle). For example, the estimated scattering mechanism of trees with disk-shape (e.g. ficus) or needle-shape (e.g. fir tree) leaves is clearly different and shows an opposite trend in the entropy-alpha space as the frequency is increased. Other interesting results include the different responses from a single tree and a group of trees. A group of fir trees, to take an example, presents a minor spread in the loci, a higher entropy and a lower dependence on the incidence angle compared to an individual tree [C733]

## "An extension of multi-look polarimetric whitening filter for speckle reduction in polarimetric SAR images"

With the availability of fully polarimetric SAR data, there is the possibility to reduce the image speckle polarimetricly. Novak et al. has proposed a polarimetric whitening filter (PWF) that processes the single-look polarimetric SAR data to generate an intensity image with minimum speckle. And the PWF has been extended to the multi-look case to form a multi-look PWF (MPWF). The drawback of the PWF and MPWF is that they do not preserve the polarimetric information. In this paper the authors present an extended MPWF (EMPWF). Based on a polarimetric multiplicative speckle model, the EMPWF combines the texture estimation produced by the original MPWF and the adaptively estimated polarimetric covariance to generate a filtered covariance matrix. It can now preserve the polarimetric information while removing the speckle, and is thus a fully polarimetric speckle filter. Experimental results with NASA/JPL L-band 4-look polarimetric SAR data demonstrate the effectiveness of the EMPWF [C734]

## "Comparison of scattered powers from a layer containing randomly distributed particles, calculated from a few radiative transfer equations"

Let us consider the problem of active remote sensing for detecting water content in soil. A theoretical approach for this problem is one of the important subjects in civil and agricultural engineering as well as experimental approaches. Moist soil can be regarded as a mixture of air, soil, bound water and free water. Then it is

considered as a dense random medium. A conventional radiative transfer equation (CRT) has been commonly used to analyze the propagation and scattering of wave intensity in a random medium, but it becomes invalid for a dense random medium. Another radiative transfer equation, which is called the dense medium radiative transfer equation (DMRT), has been derived from a wave equation with the quasi-crystalline approximation with coherent potential (QCA-CP) and ladder approximation. Under these approximations, the random medium can be replaced with a homogeneous medium with effective permittivity evaluated by QCA-CP. In this paper, we consider a three layered model, composed of air, moist soil layer and perfect conductor. The moist soil layer is assumed to be a homogeneous soil layer with densely distributed water particles. For this model, we have used a DMRT with effective permittivity evaluated by the method presented by Tateiba to calculate the backscattering cross section of the soil layer when a plane wave is incident on the moist soil layer. The numerical results of our method are compared with ones of QCA-CP [C735]

## "Generalized vector radiative transfer and applications to pulse scattering, nonspherical particles and wave correlations in the atmosphere"

We present our studies related to wave propagation and scattering in the atmosphere. First, we consider pulse scattering. General formulations are given for two-frequency radiative transfer and two-frequency complex Stokes vectors. The problem of a short pulse incident on a plane parallel scattering medium is formulated, and numerical examples are given for optical pulse scattering in fog and millimeter pulse scattering in rain. Included in this study is the case of resonance scattering where particle sizes are comparable to a wavelength. Phase, group, and energy velocities are identified, and distinction is made for coherent and incoherent pulse waves. Next, we consider vector radiative transfer applied to nonspherical particles such as ice particles and Pruppacher-Pitter raindrops in the atmosphere. General extinction matrix formulations and first-order solutions are presented with numerical examples for microwave scattering. Generalizations of polarization signature and angular, frequency and polarization correlations are then discussed, including imaging and vector radar equations in the atmosphere [C736]

## "Bound carbon estimates from biomass measurement using multi-polarisation, multi-wavelength (AIRSAR) radar data in the North Island, New Zealand"

Multi-polarisation, multi-wavelength SAR data from the 1996 NASA/JPL PACRIM mission was evaluated to determine radar suitability for mapping evergreen forest and scrub biomass in New Zealand. Biomass, species, tree height, stem number and density were measured for test sites in both indigenous vegetation and exotic plantation forest. These measurements were compared with various radar indices, including total power, scattering matrix values, and various arithmetic combinations of scattering matrix values. Results show a significant correlation between biomass and total power (exotic sites) and between biomass and scattering matrix VV:HH ratio (indigenous sites). An examination of co- and cross-polarisation plots show that exotic and indigenous vegetation can be clearly identified using P- and L-band imagery, and that these two classes can themselves be discriminated using C-band data. The results of the study show that the required targets for biomass measurement can be identified, and above-ground biomass estimated, from multi-polarimetric data [C737]

## "On the formulation of hybrid finite-element and boundary-integral methods for 3D scattering using multi-level fast multipole algorithm"

The hybrid finite-element and boundary-integral (FE-BI) method is a powerful numerical technique for computing scattering by inhomogeneous objects. Although the application of edge-based finite elements and the combined field integral equation (CFIE) in the FE-BI method has successfully removed the difficulties of the treatment of dielectric interfaces, sharp conducting edges and corners, spurious solutions, and interior resonance problems inherited in the original FE-BI method using node-based elements and the electric-field integral equation (EFIE) or magnetic field integral equation (MFIE), the FE-BI method still has a bottleneck which is the dense matrix generated by the boundary integral equation (BIE). Our renewed interest in the FE-BI method originated from the recent development of the fast multipole method (FMM) and the multilevel fast multipole algorithm (MLFMA). Our objective is to apply MLFMA to BIE to completely remove the aforementioned bottleneck for general 3D problems. During the course of pursuing this goal, we have encountered several problems associated with the efficiency and accuracy of the FE-BI method implemented using the edge-based elements and CFIE. This paper reports our study of these problems and the implementation of MLFMA in the FE-BI method [C738]

## "ISAR imaging radar with time-domain high-range resolution algorithms and array antenna"

To increase the range resolution in ISAR imaging radar, time adaptations of the MUSIC algorithm and of Capon MLM are applied on each azimuth bin. The covariance matrix of each azimuth bin is estimated from the

corresponding azimuth bin of ISAR images made with different carrier frequencies to avoid cross-correlation between scatterers. Simulation results are shown as well as some preliminary measurement processings [C739]

## "Requirements scaling properties in large scale computing"

The Fast Illinois Solver Code (FISC) is a code to tackle large scale computing and scattering problems using multi-level fast multipole algorithms. FISC requirements for memory and CPU time are discussed. Some empirically derived formulas and charts are given. The examples used to get these conclusions are also plotted. FISC is designed to compute the RCS of a target described by a triangular facet file. Both complexities for the CPU time per iteration and memory requirements are of O(NlogN), where N is the number of unknowns [C740]

## "An approach for utilizing known terrain and land feature data in estimation of the clutter covariance matrix"

The secondary data for estimation of the clutter covariance matrix in space-time adaptive processing (STAP) is normally obtained from range rings in the vicinity of the test range ring. The assumption is that near-by range rings are representative. However, this is not always true. A clutter model is developed and the condition necessary for obtaining a good estimate of the clutter covariance matrix are discussed. A theoretical basis for choosing reference rings which contain clutter patches that are equivalent to one or two patches within the test range ring is provided. A proposal for using a priori map data to classify clutter patches based upon the type of features contained within them is presented. It is conjectured that patches with equivalent classifications will have representative radar returns. An application to post Doppler radar processing is presented [C741]

## "Enhanced target recognition using optimum polarimetric SAR signatures"

We present a new method for automatic target/object classification by using the optimum polarimetric radar signatures of the targets/objects of interest. The use of optimum polarimetric signatures for enhancing target recognition using synthetic aperture radar is explored. The polarization scattering matrix is used for the derivation of target signatures at arbitrary transmit and receive polarizations (arbitrary polarization inclination angles and ellipticity angles). Then an optimization criterion that minimizes the within class distance and maximizes the between class metrics is used for the derivation of optimum sets of polarimetric signatures. Then from sets of real fully polarimetric SAR imagery arbitrary polarization attributes are extracted. The performance of the automatic target detection and recognition algorithms using optimum sets of polarimetric signatures are derived and compared with those associated with the non-optimum signatures. The results show that noticeable improvements can be achieved by using the SAR signatures obtained via optimum transmits and receives over non-optimum signatures. This work indicates that by optimally adjusting the radar polarization-by using polarization filters-the target classification performance can be improved and targets that may not be easily separable can be separated [C742]

## "Angular correlation function and scattering coefficient of electromagnetic waves scattered by a buried object under a two-dimensional rough surface"

The authors study electromagnetic wave scattering from a buried object under a two-dimensional (2D) random rough surface using the sparse-matrix canonical-grid (SMCG) method. Both the scattering coefficient (normalized RCS) and angular correlation function (ACF) are calculated based on azimuthal angular averaging. It is found that the ACF is more effective in suppressing the clutter due to the rough surface scattering, and the cross-polarization components of ACF can be more useful than co-polarization components for the detection of the buried object [C743]

## "Polarimetric analysis of SAR-interferograms in L- and P-band"

The authors consider how polarimetric investigation of interferometric SAR data can be used for the qualitative interpretation of interferograms. The polarimetric analysis of scattering matrix data enables the extraction of the relevant scattering mechanisms and the determination of scattering processes. An entropy-α-decomposition of full-polarimetric interferometric L- and P-band airborne SAR data has been performed, and the polarimetric properties are discussed, with respect to the interferometric behaviour [C744]

## "Analysis of forest regions by SAR and optical images"

This paper presents techniques for automatic analysis forest regions using radar and optical orbital instruments. Input data were the images of Altai regions territories obtained with RESURS-01 MSU-E, RESURS-F1M, SIR-C/L-SAR (total power, HH, HV,VV), and also the NOAA-AVHRR radiometer data. The resolution of SAR images was around 25 m per pixel. The textural and polarization properties of SAR images were used as additional

information. The results were supplemented by classification of images MSU-E and RESURS-FIM by synchronous ground measurements [C745]

## "Radar backscatter modeling of 3D vegetation structure"

The authors' current 3D radar backscatter model treats vegetation layers or tree crowns as homogeneous volumes consisting of various scatterers. The volume scattering and attenuation properties of the vegetation layers used in radiative transfer models were calculated by averaging the Stokes matrix (incoherent summation) or the scattering matrix (coherent summation) from these scatterers. This averaging process, by integration over the size and orientation distributions of the scatterers, eliminates the discrete nature of the vegetation structure and creates a continuous medium description of vegetation structure. Certain scattering properties based on the discrete nature and relative position of scatterers, for example, the corner reflectors formed by branches, have been lost in the model. Trees simulated from a tree growth model were used to investigate the effect of crown discrete structure on radar backscattering. This paper presents preliminary results from modifying models for this purposes [C746]

## "Cloude's target decomposition theorems applied to EMISAR data acquired during EMAC'95 snow campaign"

In this study the possibilities of using polarimetric L- and C-band microwave SAR data in snow mapping are investigated. Covariance matrix eigenvalue based decomposition theory, proposed by Cloude (1992) was applied to polarimetric EMISAR data. SAR images and ground truth data were collected during the European Multisensor Airborne Campaign (EMAC'95) in Northern Finland over boreal forest areas. The influence of snow depth and forest stem volume to SAR signal was investigated. L-band reacts strongly to forest stem volume while snow conditions influence backscattering in C-band [C747]

## "Airborne polarimetric SAR interferometry"

The authors show for first time the applicability of polarimetric interferometry techniques on high resolution interferometric scattering matrix airborne data. They point out the main requirements considering system hardware as well as data processing and calibration algorithms which are important for the polarimetric interferometric data evaluation and describe their implementation in the case of the DLR's experimental SAR system (E-SAR) [C748]

## "Characterization of circular waveguide containing chiral rod"

Here we study the electromagnetic properties of circular waveguides containing a lossy isotropic chiral rod. The effects of the chirality on the polarisation state (electromagnetic field rotation and axial ratio AR) of the fundamental mode propagating in the guide are discussed and verified experimentally [C749]

## "Injection problem in powerful quasi-optical modulator"

Theoretical investigation of injection problem in powerful quasi-optical modulators is presented. It is shown that the possibility of increasing current and the level of controlling power is thanks to the optimal regime of injection for surface integrated p-i-n structure with “deep” junctions. The increase of the diffusion coefficient due to existing electromagnetic wave and the criterion of high-power wave are obtained [C750]

## "Advances in polarimetric SAR interferometry and its application to geo/eco-environmental stress change monitoring"

Radar polarimetry has established itself in high resolution POL-SAR imaging, image target characterization and selective image feature extraction. With the addition of single platform dual antenna interferometers, digital elevation mapping (DEM) was made possible (which can be recovered in most cases equally well from standard fully polarimetric POL-SAR image data utilizing the Schuler purely polarimetric DEM algorithms not requiring an interferometer). In order to be able to fully describe direction-sensitive environmental stress changes, it is necessary to rapidly advance repeat-pass (RP) fully polarimetric (POL: scattering matrix) differential (D) interferometric (In) SAR imaging systems (RP-POL-D-InSAR) which have emerged with the SIR-C/X-SAR Missions 1 and 2. In pursuing this goal, Cloude and Pottier (1997) introduced the polarimetric entropy/anisotropy method and Cloude and Papathanassiou (1997) introduced the polarimetric-interferometric phase coherence optimization (PIPCO) procedure. This PIPCO procedure is verified in this paper by utilizing an ideally matching repeat-pass pair of the SIR-C/X-SAR Mission 2, Tien-Shan tracks within the Russian Academy of Sciences, Siberian Division, Buriat Natural Science Center (RAS-SD-BNSC) SE Baikal Lake, Selenga Delta (Kabansk-Kudara-Oymur: 52.16° N, 106.67° E) Geo-environmental Sanctuary, the “Kudara Polygon” for which various

institutes of RAS-SD-BNSC have collected extensive geographic (geo-ecological and geo- tectonic) environmental information and vegetative groundtruth data over several decades [C751]

## "Multidimensional sidelobe target editing with applications to terrain scattered jamming cancellation"

We consider the problem of false alarms resulting from targets in the sidelobes of an adaptive beam. While such false alarms occur in many beamforming applications, the problem is especially troublesome in radar systems designed to cancel nonstationary multipath interference (e.g., terrain-scattered jamming). Because these systems process data in multiple dimensions, false target detections are often widely separated (e.g., in angle, Doppler and/or range). We describe a general technique for automatically classifying and removing sidelobe target detections. The technique is evaluated using simulated airborne radar data that has been adaptively beamformed using our optimized 3D STAP beamformer [C752]

## "A new ring microstrip diplexer"

An original structure, a method and results of computer-aided synthesis of a new ring microstrip diplexer are considered. These diplexers for matched loads give ideal decoupling between sources and practically pure resistive inputs over the whole frequency band. A scattering matrix for any order filters and results of scattering parameter analysis of ring diplexer when operating into an unmatched load are presented. The frequency characteristics obtained are compared with parameters of a ring hybrid on transmission lines [C753]

## "The Application of Wavelet Like Transform for the Solution of Electromagnetic Field Problems"

Three types of adaptive multiscale moment methods, which are based on the wavelet-like basis, are presented here for analyzing electromagnetic scattering from perfectly conducting two-dimensional electrically large objects. The conducting structures are assumed to be in a free-space medium and is illuminated by a TM plane wave. The three algorithms decompose the conventional method of moment matrix into a scaled-block matrix through a matrix multiplication. The numbers of unknowns corresponding to the linear equations at increasing scales can be automatically reduced by using a suitable threshold and the solution obtained from previous scales. Numerical results for the monostatic radar cross section of several electrically large objects are presented. Comparison has been made with respect to the numerical solution obtained by the moment method. The objective of this paper is to illustrate that a possibility exist for efficiently reducing the size of the linear equations in an automatic fashion utilizing the adaptive multiscale moment methods. [C754]

## "Scattering of eccentric multilayered cylinder with multi-cylinder inside: microwave equivalent network analysis"

Electromagnetic scattering from an eccentric multilayered cylinder with multi-cylinder inside is analyzed by an equivalent network formed by hybrid-aggregated T-matrix method and generalized scattering matrix technique. Both RCS and near-fields are presented to verify the method in either TM or TE polarization [C755]

## "Wavelets: a promising approach to linear and nonlinear modeling of electromagnetic problems"

A topic of considerable current interest in applied mathematics is wavelets. The promises of wavelets are based upon their localization in both spatial and spectral domains, better convergence properties, their computational speed, and the two parameter invariance under analytic representations. Recently wavelets have been used in signal processing and computer vision with great success. In electromagnetics (EM), orthonormal wavelets have been applied to the method of moments as basis and testing functions in the integral equations to replace the pulse, triangle, and PWS (piecewise sinusoidal) functions. Very sparse coefficient matrices have been obtained due to the vanishing moments, localization, and MRA (multiresolution analysis) of the wavelets. In the modeling of microwave active devices, the interpolating wavelets (IWL) were employed to solve nonlinear equations with great success. In this paper we introduce the basic wavelet theory, summarize the wavelet properties and present the applications of wavelets to the lossy and dispersive transmission lines, EM wave scattering and semiconductor modeling problems [C756]

## "Direct construction of a ξ-pulse from natural frequencies and evaluation of the late-time residuals"

An important type of target identification utilizes the natural frequencies of the target, these being poles in the complex-frequency s-plane as expressed in the singularity expansion method. Since the location of these natural frequencies sαin the s-plane is aspect independent, this simplifies the identification problem to the comparison of the target pole patterns stored in some target library. In order to implement the pole pattern as a target discrimination scheme one needs some scheme to find the sαin experimental data (scattered fields), either

explicitly or implicitly. Some of the early schemes used what is referred to as the Prony method in which one fits a sum of dumped sinusoids to a waveform. This had various limitations which have been overcome to some degree by a matrix pencil method. These and related techniques are explicit in that they determine a set of sαfrom one or more waveforms which are then compared to the target library. In contrast, implicit methods do not generate a set of sαfrom the data, but utilize predetermined sets of sαfor various targets which are then manipulated with the data in some way which transforms it to a form in which the discrimination can be more readily performed. Those used to date have used temporal functions with two-sided Laplace transforms with zeros corresponding to the sα(poles) of preselected targets. Convolving these with target impulse response removes (annihilates) the late-time response for the properly chosen target. These go by various names such as K-pulse and E-pulse. In the present paper we go further into this latter type of target identification [C757]

## "Two bistatic target signatures: the bistatic equations and the bistatic polarisation fork"

The object of this article is to present two mathematical supports which allow a better knowledge of the target in a bistatic polarimetric radar configuration. These aids are firstly the nine bistatic target equations which link together the new sixteen bistatic target parameters, and secondly the bistatic polarisation fork which visualises the sixteen characteristic polarisation states of the target on the Poincare sphere [C758]

## "Phase decomposition in polarimetric SAR interferometry"

The authors formulate a new coherent decomposition algorithm for polarimetric SAR interferometry which allows the decomposition of interferometric problems into a set of coherent scattering mechanisms. The proposed algorithm allows the generation of interferograms related to certain independent scattering mechanism and consequently the extraction of the height difference between them. The potential of the proposed technique is demonstrated by first results from the evaluation of full-polarimetric interferometric airborne data [C759]

## "Terrain slope and surface roughness studies using circularly polarized SAR backscatter"

The authors use a new SAR technique for measurement of terrain slopes in the azimuthal (along-track) direction for correction of terrain slope-related polarimetric effects in SAR surface roughness, or soil moisture, inversion studies. A second goal is determination of the sensitivity of a circular polarization correlation function for the measurement of terrain slopes and surface roughness [C760]

## "Textural-partially correlated polarimetric K-distribution"

A generalized polarimetric K-distribution is derived for characterizing multi-look fully polarimetric SAR data, on the basis that the underlying texture structures in polarization channels assume a trivariate joint gamma distribution with partial correlation and that the co-polarized and cross-polarized speckle components are de-correlated. Since the resulting K-distribution is in the form of a one-dimensional integral-difficult to be tested experimentally-a validation scheme for the model is then suggested using the theoretical joint moments corresponding to the generalized K-distribution [C761]

## "Unsupervised classification using polarimetric decomposition and complex Wishart classifier"

The authors propose a new method for unsupervised classification of terrain types and man-made objects using polarimetric SAR data. This technique is a combination of the unsupervised classification based on the polarimetric target decomposition (Cloude and Pottier, 1997) and the maximum likelihood classifier based on the complex Wishart distribution (Lee et al., 1994). The advantage of this approach is that clusters may be identified by the scattering mechanisms from the target decomposition. The effectiveness of this algorithm is demonstrated using JPL/AIRSAR and SIR-C polarimetric SAR images [C762]

## "Numerical studies of low grazing angle backscatter from 1D and 2D impedance surfaces"

Numerical simulations of near grazing angle backscattered fields from ocean-like impedance surfaces are described. Both one dimensional and two dimensional surfaces are considered, and efficient algorithms are applied to allow simulations for the large surface sizes required in the near grazing angle region. The algorithms used are based on Monte Carlo simulation using either the sparse matrix-flat surface iterative approach with canonical grid (SMFSIA/CAG) or a recent improved forward-backward technique which allows larger surface heights to be considered. Backscattering cross sections are illustrated for linear hydrodynamic surfaces described by a Pierson Moskowitz spectrum at grazing angles from 1 to 10 degrees in the one dimensional case, and at 10 degrees in the two dimensional case. Variations with surface spectrum low frequency cutoff are investigated, and demonstrate that improved hydrodynamic models for the ocean surface are required to observe “sea-spike” behaviors at low grazing angles [C763]

## "Enhanced segmentation of SAR images using non-Fourier imaging"

This paper demonstrates that synthetic aperture radar (SAR) images formed using modern spectral estimates can be more accurately segmented than traditional SAR images. Classical FFT based Fourier image formation algorithms produce imagery with strong speckle and sidelobe artifacts that hinder the segmentation process. We show that imagery formed using Capon's minimum variance spectral estimate changes the statistics of the SAR imagery in a way that increases the separation between the various classes of natural terrain. The increased class separation leads to more accurate segmentation. We use the MSTAR dataset to show the statistical changes and demonstrate the improvement in segmentation relative to Fourier imagery [C764]

## "Synthetic aperture radar interferometry: a model for the joint statistics in layover areas"

The joint statistics of coregistered SAR images are studied, concentrating particularly on the statistics of the signals in layover areas of the SAR image. A new model for the joint statistics in layover areas (i.e., where several parts of the scene map into the same range bin) is derived. It is shown that, under certain assumptions, the statistics in layover areas may be modelled by a jointly circular Gaussian probability distribution, parameterized by the so-called covariance matrix. It is shown that the coherence between two SAR images may be expressed as the weighted average of the complex coherence values of each of the individual regions whose mappings are overlaid. The model is verified with simulated data [C765]

## "Electromagnetic scattering by dielectric cylinder half-immersed in the perfectly conducting half-space"

To investigate the features of various media by means of electromagnetic radiation, it is necessary to know the field scattered by the nonhomogeneities of this media. This problem can be solved with sufficient accuracy and adequacy by using, as a basis, a rigorous solution of the basic model (Nefedov 1979). One of the basic models for this purpose can be the considered structure. The aims of this paper are to investigate the scattering of a plane wave by a circular dielectric cylinder (CDC), half immersed in the perfectly conducting half-space; the method of re-expanding in terms of the basis functions at the given interval is used (Smimov 1957; Shepilko 1979). Applying the boundary condition to the Fourier-Bessel series representation of the scattered field, our problem is reduced to the solution of a matrix equation for unknown expansion coefficients. These coefficients are determined numerically with high accuracy after truncation of the matrix equation. The scattered field is evaluated asymptotically and the backscattering radar cross section (BRCS) expression is derived. Accurate numerical results are presented for the E- and H-polarized waves [C766]

## "Target recognition based on characteristic polarizations, in the optics region"

In this paper, characteristic polarizations are used to describe the stability properties of target's spatial polarization structure in optics region on the wideband polarimetric radar. On this basis, polarization features are extracted to classify four kinds of aircraft. Recognition results show that these features are insensitive to target's posture to a great extent and this method based on characteristic polarization is effective and feasible [C767]

## "An exploration of features for SAR classification"

Summary form only given. Classification of SAR images usually is constrained by the choice of features to use. Often the powers, in dB, for several frequencies and polarizations are used. However, there are very many other features one could use, some that include the spatial variability between neighboring pixels. This paper explores the utility of using some of these non-standard features in a standard Bayesian classification framework. Some features make the frequency relationships explicit by forming gradients of the standard powers in the frequency domain. Others use the differences between the polarizations and the same or different frequencies. Still others form statistics based on some small neighborhood surrounding each pixel. One such is called texture which is the standard-deviation without the contribution from speckle. Others use the geometrical relationship between the pixels, examples are: lacunarity, grey-level co-occurrence matrices, others?… . For full-polarimetric data there is also available the co-pol phase-difference statistics, which are known to correlate well with the scattering mechanisms associated with the target. There are also less well-known features: (1) polarization for maximum power, (2) polarization for minimum power, (3) power image calculated based on maximum separability between 2 classes, (4) Eigenvalues and vectors of the scattering matrix. For interferometric data there are also some other features: (1) Coherence, (2) Statistics of height information, (3) Differences in height information between different polarizations and frequencies. Each of these features will be evaluated for its usefulness to classification and various optimum scenarios will be presented for different sensor combinations [C768]

## "SIR-C polarimetric calibration by using polarization selective dihedrals and a polarimetric active radar calibrator"

A novel approach to calibrate a polarimetric SAR is proposed and tested in the SIR-C/X-SAR experiment. The present technique needs one PARC (polarimetric active radar calibrator) and two PSDs (polarization selective dihedrals). Since PSDs have wide frequency coverage, only addition of another frequency PARC allows to calibrate a multi-frequency polarimetric SAR [C769]

## "Coherence optimisation in polarimetric SAR interferometry"

The authors outline a general formulation for vector wave interferometry and then solve the optimisation problem involving maximisation of phase. In this way the authors are able to show that wave polarisation effects play an important role in the extraction of information from radar interferograms [C770]

## "3D electromagnetic modeling using staggered finite differences"

The method of finite differences has been employed to solve a variety of 3D electromagnetic (EM) forward problems arising in geophysical applications. Specific sources considered include dipolar and magnetotelluric (MT) field excitation in the frequency domain. In the forward problem, the EM fields are simulated using a vector Helmholtz equation for the electric field, which are approximated using finite differences on a staggered grid. To obtain the fields, a complex-symmetric matrix system of equations is assembled and iteratively solved using the quasi-minimum method (QMR). Perfectly matched layer (PML) absorbing boundary conditions are included in the solution and are necessary to accurately simulate fields in propagation regime (frequencies >10 MHz). For frequencies approaching the static limit (<10 kHz), the solution also includes a static-divergence correction, which is necessary to accurately simulate MT source fields and can be used to accelerate convergence for the dipolar source problem [C771]

## "A finite difference time domain (FDTD) simulation of electromagnetic wave propagation and scattering in a partially conducting layered Earth"

A finite difference time domain (FDTD) simulation of electromagnetic propagation in partially conducting layers was performed. The simulation was constructed to model the case of a source antenna in close proximity to the Earth's surface with receiving antennas both in the ground and on the Earth's surface. The objective of the modeling and simulation was the prediction of the back scattered temporal and spatial waveforms from various objects buried in the partially conducting subsurface layers of the Earth. In the author's investigation three primary modifications were performed to the simulation code. First, the code was ported from a mainframe computer to a Sun work station. This involved splitting the simulation into a data calculation phase and an interactive data display phase. During the calculation phase, all the simulation results are computed to create time histories of the total electromagnetic field in a region of space which included both the source antenna and all the receive antenna locations. The receive antennas were located both on the surface of the Earth as well as buried within the subsurface layers of the Earth. The calculation phase creates a large matrix of time histories of the transmitted, scattered and total electromagnetic fields at all the sampled receive locations. An interactive display module was developed using MATLAB on the Sun workstation to view the results of the simulation. The second extension of the simulation code was the incorporation of coherent transmit and receive waveforms into the simulation. An analytic formulation of the transmit pulse into real and imaginary parts allows coherent signal generation and analysis. This permits the calculation of both amplitude and phase information for the incident, scattered and total electromagnetic fields during the calculation phase of the simulation. The third modification to the simulation code was the inclusion of the capability to place multiple scattering objects within the subsurface layers. The objects were allowed to be partially conducting and to have random statistical distributions of both size and spatial location. This represents a first attempt at providing simulation results for a simple two media model of an inhomogeneous layer. The simulation results to be shown include a variety of antenna and scattering object locations for various combinations of layered Earth models. The results are shown as color plots of the two dimensional maps of the electromagnetic fields as well as a pseudo animation of the two dimensional spatial maps. These pseudo animation results were obtained by sampling the hard copy color outputs of the simulation and display and combining them into a temporal record which approximates the time history animation results obtainable using the interactive display module. The matrix of simulation results of the complex values of the vector E and H fields may be processed with signal processing algorithms to create detection maps and image reconstructions. The model produces time histories of the complex field values at all points in the simulation volume. Since the field values are coherent, the data created by the simulation may be processed with temporal and spatial signal processing algorithms to develop simulated results of particular Earth models and scattering object geometries. This allows the creation of performance predictions of candidate signal sensing and processing approaches for the detection of man made objects buried in the Earth. A proposed

sensing and processing system is described which allows the detection and imaging of man made buried objects [C772]

## "High-range resolution radar for the identification of approaching targets: effects of parameters and measurements"

With radar signals without compression, the resolution is fixed by the pulse lengths. For short targets, the scatterers are closely spaced and their echoes overlap making them indistinguishable. To overcome this, an algorithm based on the MUSIC algorithm was developed and simulations have shown the improvement on the radar's range resolution. In the present work, we have carried on with the simulations to estimate the effects of the most important parameters needed by the algorithm and we have made measurements to demonstrate the possible use of the method in the real world [C773]

## "Polarimetric effects in repeat-pass SAR interferometry"

The authors examine the role wave polarisation play in the interpretation of interferograms. They first propose a general formulation for vector wave interferometry and differential interferometry which includes the conventional scalar interferometry as a special subcase. Then they demonstrate how polarimetric target decomposition theory can be introduced in interferometry for the physical interpretation of the interferometric phase. The potential of polarimetric SAR interferometry (POL-InSAR) is demonstrated by first results from the evaluation of fully polarimetric interferometric SIR-C/X-SAR data [C774]

## "Ocean clutter suppression for an HF ground wave radar"

At HF frequencies, the sea echo or clutter return is quite significant and can mask signals from targets travelling at or near the same Doppler of the resonant (Bragg) ocean waves. This paper presents a systematic method of reducing clutter signals so as to enable detection of targets travelling at speeds near the Bragg Doppler. The algorithm uses a Hankel rank reduction method that assumes that targets and ocean clutter can be modelled as time varying sinusoids. Several examples of clutter suppression are shown from data that was collected at the Cape Race facility. A cooperating vessel was used to show that a clutter supression algorithm may be used to enhance target detection when the target's speed is near the Bragg Doppler frequency [C775]

## "A study of dense medium effect using a simple backscattering model"

In an electrically dense medium, when the spacing between the scatterers is comparable to the wavelength, it is important to incorporate the near field effect, both amplitude and phase, into the backscattering theory. In this paper, a simple backscatter theory based on radiative transfer (RT) theory is presented. The random medium, bounded on top and bottom by a rough surface, contains a layer of randomly distributed spherical scatterers. The phase matrix for these closely packed discrete scatterers is obtained using the dense medium phase and amplitude correction theory (DM-PACT) and the rough surface is characterized by the IEM model. The integro-differential equations of radiative transfer theory are solved iteratively up to second order solutions. Scattering terms for direct surface, direct volume, surface-volume and volume-volume interactions are identified. These results are compared with full model solutions using the matrix doubling method [C776]

## "Littoral remote sensing using polarimetric SAR"

Polarimetric SAR has been successfully applied for, terrain and land-use classification, soil moisture and biomass measurements, and many other areas of remote sensing. However, its application to ocean and coastal areas has not been developed. This paper describes several remote-sensing applications for the littoral zone using polarimetric SAR. SIR-C L- and C-band and JPL AIRSAR images are used for illustration [C777]

## "An electromagnetic scattering model for tree trunks over a tilted rough ground plane"

Remote sensing of forest canopies is dominated by the interaction between tree trunks and ground at lower microwave frequencies and/or when the crown layer is tenuous. An efficient and complete electromagnetic scattering model for tree trunks above a tilted rough ground plane has been performed and enhanced. The individual trunks are modelled as finite-length stratified cylinders, with an external corrugated bark layer. The ground plane is modelled as a rough dielectric half space underlying the cylinders. Realistic natural conditions can be simulated by properly setting the parameters of this model. Results have been computed for the mean square error of the bistatic scattering pattern, by means of a Monte-Carlo simulation [C778]

## "Determination of propagation parameters from fully polarimetric radar data"

The polarization characteristics of the electromagnetics waves, as related to its interaction with targets, is an important aspect in remote sensing applications. This polarization information is usually contained in either the scattering matrix or the covariance matrix depending on the target under consideration. Often, propagation effects are normally not considered in obtaining them. In clear-air conditions this a reasonable assumption, but when rain, or any other type of precipitation, exists in the ray-path, depolarization of the waves may not be negligible anymore. The anisotropy that precipitation media present causes this depolarization and that could greatly affect the scattering or covariance matrix measurements. Consequently, the real target information may be hidden in those measured matrices and it could be necessary to apply different algorithms to correct for depolarization effects prior to target information extraction. Depolarization effects can be determined and accounted for if the characteristic polarizations of the medium and their respective propagation constants are known. It is found that for precipitation media that generally present reflection symmetry these polarizations are linear and orthogonal. Then it is shown that differential attenuation can be obtained from copolar power measurements and differential phase shift from copolar correlation measurements. Considering the statistics of these covariance matrix elements and temporal correlation between successive pulses from the target, statistics of propagation parameters are analyzed [C779]

## "On the proper polarimetric scattering matrix formulation of the forward propagation versus backscattering radar systems description"

Jones matrices and Sinclair matrices are 2Ч2 complex matrices that determine forward (transmission) and backward scattering, respectively. Under a unitary change of polarization basis they transform by ordinary unitary similarity and by unitary consimilarity, respectively, forming equivalence classes with common invariant polarimetric features. In most applications the Jones matrices T are normal and, thus, have orthogonal eigenvectors; whereas, Sinclair matrices S are symmetric and have orthogonal coneigenvectors. For forward scattering the term homogeneous is used in this case. Recently, inhomogeneous Jones and Sinclair matrices characterized by non-orthogonal eigenvectors and coneigenvectors have attracted attention. The present contribution considers some characteristics of these matrices. In particular it is shown that the graphical field-of-value representation of inhomogeneous Jones matrices leads to an interesting characterization of the degree of inhomogeneity, often characterized by the (cosine of the) angle between the normalized eigenvectors. Applications of the resulting theorems to both optical (transmission) and radar (backscattering) polarimetry are demonstrated, together with identifying the inherent mathematical intricacies and physical complexities which are integral to radar and optical polarimetry [C780]

## "Calibration of polarimetric radar systems"

The calibration of reciprocal radar systems has been studied previously, where it was shown: (1) that full polarimetric calibration of radar systems can remove cross-polarization errors from the measurements, and (2) that for reciprocal radars Fourier analysis of polarimetric data obtained using a rotating dihedral can reduce the noise and background errors in the calibration. To calibrate nonreciprocol radar systems, we must obtain full polarimetric data from two objects whose scattering matrices have independent eigenvectors. Thus, in addition to a rotating dihedral, a sphere or a flat plate is needed to solve for the transmitting and receiving characteristics of the system. We find the current methods of solution of the calibration equations unattractive for the following reasons: (1) noise and clutter rejection is not built into the analysis, and (2) the mathematics seems unnecessarily complicated. In addition to mathematical simplification, several ways to verify data integrity are presented, so that system problems can be detected early in the calibration phase [C781]

## "Polarimetric responses of underground targets using an hybrid transfer function FDTD method"

Polarimetry has become a very powerful tool to enhance the performance of all sort of radar detection systems. However, to the knowledge of the authors, it has found little or no interest up to now for a very special variety of radar systems: ground penetrating radars (GPR). The reason for this is the range at which the target is located. Due to the highly lossy media into which the wave propagates, the transmitting and receiving antennas are generally located close to the ground interface, for a maximum power transfer and a better signal reception. Objects at shallow depths cannot be considered to be in the far field. At the base of radar polarimetry is the scattering matrix which, unfortunately, is defined by the ratios of the scattered to the incident far fields components. Other results, have shown that the near field can be obtained easily using a standard FDTD computer code with some modifications. This paper goes a step further by explaining how to compute the far field scattering matrix and the polarimetric responses. The contribution of the interface to the polarimetric responses is also discussed [C782]

## "Characterization of fracture surface by polarimetric borehole radar"

Borehole radars have successfully been applied to various fields such as geological survey, geophysical exploration and subsurface crack measurement. However, only single polarization measurement has been performed in conventional single-hole borehole radar measurement because dipole antennas which radiate an electric field parallel to borehole axis are usually used. Radar polarimetry is a promising technique to extract more information such as size, shape, orientation or surface condition of radar targets in borehole radar measurement. We developed a system which uses an axially oriented slot antenna on a conducting thin cylinder which radiates an electric field perpendicular to the borehole axis in order to obtain the polarimetric information. We also developed a method to compensate the characteristics in each antenna which gives a target scattering matrix. We present the result of application of the polarimetric borehole radar measurement to characterization of surface roughness [C783]

## "Road condition recognition using microwaves"

A dual use of car-born radars is demonstrated. The information of the radar signal has been examined and a method of road condition measurements has been found. Theoretical aspects have been analysed. In a series of measurements, the data has been investigated, following these aspects. Results of this investigation are demonstrated. These results validate the expectation, that road condition monitoring with microwaves is a valid method for potential safety improvements [C784]

## "Application of PR cosine-modulated filter bank to multichannel superresolution radar imaging"

In this paper, we present a multichannel superresolution radar imaging (MSRI) approach. Our approach for extracting the two-dimensional (2-D) scattering center model is based on combination of the cosine-modulated filter bank with perfect reconstruction condition (PR-CMFB) and TLS-ESPRIT with the matrix enhancement (TLS-ESPRIT-ME) method. The basic idea underlying the proposed approach is that the analysis banks are first used to implement the multichannel decomposition of the scattering signal in the frequency-aspect domain, the synthesis banks are then used to recombine the decomposed signals, and to conveniently obtain several separable subregional signals with enhanced signal-to-noise ratio (SNR) and without loss of information. Thus the TLS-ESPRIT-ME method can be employed in every subregion independently and simultaneously, making the approach efficient and possessing superior noise performance. The simulations show that such a combination works well and can be used for target identification using low-resolution radars efficiently [C785]

## "Solving some surface integral equations by using MoM with curved triangular patches"

Wilkes and Cha (1991) extended the flat triangular patch moment method solution developed by Rao, Wilton and Glisson (1982) to the curved triangular patch. Song and Chew (1995) divided an arbitrary surface into a number of parametric quadratic surfaces with fourth order polynomials. In this paper, we solve the electric field integral equation (EFIE), magnetic field integral equation (MFIE), and combined field integral equation (CFIE) by using curvilinear triangular patches with line matching. We define a basis function with no line charge accumulation on each point of the common edge of adjacent cells. We extract the self-term and near-neighbor-term singularities of EFIE, MFIE, and CFIE, and evaluate them in closed forms so that the matrix elements can be obtained by standard numerical integration methods. The current distribution and the scattered fields of an arbitrary 3-D surface can also be obtained. Numerical results are given [C786]

## "Polarimetric radars to identify sea swell full wave approach"

The statistical characteristics and the orientation of a remotely generated swell superimposed upon a local wind generated rough sea surface are determined from polarimetric data. The full wave approach is used to determine the incoherent backscatter Mueller matrix elements and the incoherent backscatter Graves power matrix elements as functions of azimuth and elevation angles, and rough sea surface (with swell) parameters. Using the optimal backscatter angle and polarization of the incident and scattered fields, the ability to reliably determine the orientation and statistical characteristics of remotely generated swells is enhanced [C787]

## "Electronically scanned millimeter wave antenna using a Rotman lens"

Georgia Tech developed a Ka-band (33 to 37 GHz) millimeter wave Rotman lens that is being integrated with a beam switching system and horn array to produce a low cost electronically scanned antenna system. The MMW lens was designed and analyzed by generating various lens configurations as input into a mathematical model. This model uses a contour integral equation formulation to obtain the scattering matrix associated with a particular lens design. The optimized lens configuration was fabricated, and the S-matrix of the device was measured and processed to obtain the beam patterns and insertion loss. Maximum sidelobe levels ⩽-30 dB were achieved by applying an ideal -40 dB Taylor weighting function to the measured data. The measured insertion loss (Taylor weighting loss not included) ranged between 0.8 and 2.3 dB depending on the particular

beam port that was excited and the frequency that was used. The lens has 32 active antenna element ports, and 17 active beam ports. Although the maximum scan angle for the present design is only ±22.2 degrees, greater scan angles up to ±45 degrees as well as frequencies up to 95 GHz are possible with different lens designs [C788]

## "The principles of polarimetric filtering"

Filtering can be used either to reconstruct the information bearing parameters in polarimetric images or to produce intensity images with reduced `speckle'. These two approaches are analysed through the product model, using both model-free and model-specific texture, and performance criteria described [C789]

## "Polarimetric SAR speckle filtering and its impact on classification"

Speckle reduction of polarimetric SAR imagery has been studied using several different approaches. Most of these approaches exploited the statistical independence between HH, HV and VV channels. The statistical characteristics, such as correlation between channels, and polarimetric signature preservation, were not addressed. This paper proposes a new approach in polarimetric SAR filtering. This new approach emphasizes introducing no cross-talk, preserving polarimetric properties and statistical correlations between channels. In addition, the image sharpness is better maintained. The impact of using this polarimetric speckle filtering on terrain classification is also studied. NASA/JPL Les Landes polarimetric P-band and C-band SAR data is used for illustration [C790]

## "An AIM based analysis of scattering from cylindrically periodic structures"

The problem of scattering from jet engine inlets is very important in applied electromagnetics, but standard numerical methods are expensive to employ, due to excessive memory and CPU time requirements. To reduce the computational cost the inherent cylindrical periodicity of the geometry is exploited, in conjunction with the adaptive integral method (AIM), one of the so-called “fast algorithms”, with memory requirements and complexity as low as O(N1.5) and O(N 1.5log2N) respectively. We investigate the application of AIM for radar cross section computations of simplified jet engine inlet models [C791]

## "Foundations of bistatic radar polarimetry theory"

The radar polarimetry first theoretical approach in the bistatic case is presented and derived from the classical monostatic case theory. Moreover, using a geometrical construction on the Poincare sphere, we show how to define the scattered received polarisation state vector from a knowledge of the target parameters (Euler angles $\psi$, $\tau$, $\nu$, $\gamma$) [C792]

## "Experimental investigations of efficiency for adaptive space-temporal polarimetric selection"

Criteria and results of the experimental valuation of the efficiency of the polarisation selection methods of radar-tracking objects on background of reflections from spreading surface and hydrometeoobjects are considered. On the basis of experimental data the comparison of the known methods of adaptive polarisation selection is conducted. The obtained results confirm the efficiency of the polarisation methods for stationary object selection and can be used to design target detection radars [C793]

## "Accounting for the effects of mutual coupling in adaptive antennas"

This paper presents a method to account for the effects of mutual coupling in least squared error adaptive algorithms. The mutual coupling is quantized using the method of moments. The method of moments admittance matrix is used to compensate for the mutual coupling [C794]

## "Optimal target identification based upon ultra high resolution radar profiles"

A new methodology for identifying aircraft using high range resolution radar is developed. The identifier maximizes the probability of target identification in dependent complex Gaussian noise, without being forced to decide from a limited number of categories. The results from experiments using ultra high range resolution (HRR) data demonstrates the fact that the proposed identifier provides a reasonable probability of detection and identification and is amenable to real time signal processing [C795]

## "Experiments in bistatic scattering phenomenology"

This paper describes a fully-polarimetric bistatic radar test bed system developed for large bistatic angle

scattering studies of aircraft targets and terrain surfaces. The radar consists of a high power (1 MW) S-band transmitter and a remote, dual-polarized receiver separated from each other over baseline distances up to 30 km. The transmitter emits vertically (V) and horizontally (H) polarized pulses on alternate pulse repetition intervals, and the receiver simultaneously measures the V and H components of the scattered wave. Phase coherence is maintained between the transmitter and receiver subsystems by using atomic (cesium) clocks to stabilize the microwave oscillators at the two equipment sites. This permits computation of the polarization scattering matrix and the Stokes operator of the scatterers, thereby retaining full polarimetric information about the scattering process. The design and hardware configuration of the radar are given in this paper, and bistatic scattering measurements of forested terrain clutter and a small aircraft are presented [C796]

## "Polarimetry in remote sensing: basic and applied concepts"

One of the great challenges for modern radar is to classify, sort and identify targets of all kinds for military battlespace surveillance as well as for civilian geo-environmental stress change monitoring purposes. Whereas, in military radar utilization of complete polarization scattering matrix radars is not yet fully accepted, in remote sensing on the other hand, radar polarimetry seems to have been accepted as an indispensable tool, and convincing results have been obtained for geo-environmental applications in agriculture, forestry, hydrology, flood plain and rural infrastructure maintenance, volcanology and seismology, archeology, etc. However, there still exists a large void in standardization and proper handling of basic and applied polarimetric theory and concepts. In this paper a succinct assessment of the current state-of-the-art is presented summarizing the basic polarimetry concepts spelled out in Boerner et al. (1997). It is the purpose of this paper to draw attention of the IEEE Geoscience and Remote Sensing community to this recent compendium on `Polarimetry in Remote Sensing' [C797]

## "Topography sensing by polarimetric SAR: theoretical basis and application using orthogonal-pass AIRSAR data"

The authors have recently proposed an algorithm to derive topographical information from polarimetric SAR data. The algorithm is based on empirical comparisons between the terrain local slope angle and the corresponding changes in the relative position of the co-pol polarimetric signature maximum, and was supported by some preliminary theoretical analysis. Also the algorithm has been validated experimentally using data sets acquired over different geographical areas, over different types of natural targets (forest, bare soil) and using different digital elevation models as reference system. This paper presents some theoretical considerations on the scattering mechanisms which underpin the phenomenological aspects of the topography sensing method. A simplified closed form approximation to the relationship between the co-pol maximum shift and the measured covariance matrix elements is introduced. This step highlights the major contributions to the co-pol maximum shift and suggests an interpretation in terms of the azimuthal symmetry properties of the target. Covariance matrices generated from experimental or modelling data can then be used as input variables to establish the relationship between the true and estimated terrain tilt angle. An example of the theoretical analysis relative to the influence of the incidence angle on the estimator error for a slightly rough surface is reported. From the algorithm's application point of view a new technique is finally demonstrated, whereby using two pass orthogonal acquisition data the elevation surface can be generated as a solution of a Poisson type differential equation with only one tie-point [C798]

## "Terrain classification in polarimetric SAR using wavelet packets"

POL-SAR data acquired from the two 1994 flights of the SIR-C/X-SAR platform has illustrated the variability of measurements due to seasonal, spectral, and angular changes. Consequently statistical techniques for terrain classification make robust, unsupervised classification problematic. We present an algorithm for classifying terrain that accounts for variability in terrain signatures by deriving a single representative process for each terrain from a family of stochastic scattering models. A best-basis search through a wavelet packet tree, using the Bhattacharyya coefficient as a cost measure, determines the optimal unitary basis of eigenvectors for the representative process and offers a scale-based interpretation of the scattering phenomena. The associated eigenvalues and means are determined through iterative algorithms. The technique is illustrated with a simple example [C799]

## "Scattering and emission from dry snow in the range 35-140 GHz"

Scattering and emission models for an irregular layer of dense inhomogeneous medium is developed and applied in the analysis of dry snow scattering and emission in the range 35-140 GHz. The models are developed based on the matrix doubling formulation, and accounts for full incoherent multiple scattering inside the snow layer. The effects of close spacing and first order coherent interactions between scatterers inside the snow layer are

included in the model via a dense medium phase matrix. The dense medium phase matrix is derived using the extended concept of three-dimensional antenna array theory which accommodate randomly located scatterers. The final expression for the dense medium phase matrix differs from the conventional (sparse medium) one in two major aspects in that there is an amplitude and a phase correction. The rough interfaces of the air-snow and snow-ground (or snow-ice) boundaries are modeled using the IEM rough surface model. Emission model predictions agree well with field measurements reported in the literature. Backscattering calculations from the theory are compared with measurements from field measurements of dry snowpack. Predictions from such a theory agree well with the measured data [C800]

## "Mueller matrix associated with diffuse scattering from two-dimensional random rough surfaces-full wave analysis"

In earlier work, it was shown that there is good agreement between the full wave results and experimental data or numerical results based on Monte Carlo simulations for one dimensionally random rough surfaces [Bahar and Lee 1994, 1995]. In this work, the full wave solutions for the diffusely scattered fields from two-dimensional random rough surfaces [Bahar and Lee, 1994] are used to evaluate elements of the 4Ч4 Mueller matrix. The modified Mueller matrix elements are related to the like and cross polarized radar cross sections as well as to the relative phase of the vertically and horizontally polarized waves. The 4Ч4 Mueller matrix elements completely characterize electromagnetic scattering from targets (rough surfaces, in this case). The full wave solution presented here can be applied to surfaces with a wide range of roughness scales. Computation time for the full wave Mueller matrix elements is significantly less than the numerical results based on the Monte Carlo simulations even for one-dimensional random rough surfaces [C801]

## "A dedicated radar imaging statistical model of the scattering matrix initially characterised in an anechoic chamber-Application to the Huynen parameters sensitivity analysis"

A noise scattering matrix statistical model of the AnechoГґВЇc Chamber measurement channel is first developed in the frequential domain, then in the time domain and in the holographic radar images domain. Building these models allows one to analyse the sensitivity of a common target classification tool, the Huynen parameters, for any target and then to construct a prediction model of the Huynen parameters sensitivity based on the measure of a single target scattering matrix [S]. [C802]

## "The matrix theory of non uniform waveguide structures excitation"

The present paper suggests a new matrix-electrodynamics method, which is based on the selection among the direct and backward waves of a more narrow class of waves, marked in correspondence with the location of excitation sources relative to the region being considered. A non-uniform waveguide structure (WS) means any fast or slow change of the form or size of its cross section, parameters of dielectric filling, metal or dielectric ledges, probes, coupling apertures, etc. As an example, the authors consider a waveguide-microstrip junction [C803]

## "Processing and evaluation of multichannel airborne radar measurements (MCARM) measured data"

Rome Laboratory's (RLs) Multichannel Airborne Radar Measurements (MCARM) program has collected clutter and target data employing an L-band airborne phased array radar testbed. The data collection is at the output of an electronically steered active array mounted on BAC1-11 aircraft. The MCARM array has 16 columns, each consisting of two four-element subarrays. Each subarray has its own output or is combined into a single output per column with up to 24 outputs for the array. Space-time adaptive processing (STAP) techniques simultaneously combine the signals from the elements of an array antenna and pulses of a radar waveform to suppress interference and provide target detection. To obtain adequate clutter power with the limited power-aperture product of the array for STAP analysis, the transmit mainlobe power can be focused in the receive beam sidelobe region or the transmit beam can be spoiled for broader angular coverage. In addition, the data is collected at different platform altitudes and radar waveforms over different terrain. The performance improvement achievable against Doppler-spread clutter that can be achieved with STAP using the L-band data is demonstrated. We present processing results of representative MCARM data files to demonstrate that the adaptive processing can help to detect targets in a nonhomogeneous environment. The limitations of the number of independent clutter samples in estimating the covariance matrix and its impact on target cancellation are examined by processing files with real and synthetic targets [C804]

## "Reduced-rank terrain scattered interference mitigation"

Radar systems are particularly vulnerable to the interference produced by jammer multipath reflections known as terrain scattered interference (TSI) or hot clutter. This interference is due to the diffuse scattering of jammer energy off large patches of terrain and consequently is present over large angular regions and large range intervals. Cancellation methods attempt to exploit the temporal correlation present in the TSI by using a large number of temporal taps. However, the adaptive degrees of freedom typically required for cancellation to the noise floor tend to be very large, motivating the investigation into various rank reduction strategies. In this paper we look at various methods of reducing the computational complexity of the canceller while maximizing the cancellation achieved. The canceller used is based on a beamspace transformation that is shown to yield certain advantages for rank reduction purposes. Results are demonstrated on experimental data collected as part of the Navy/ARPA Mountaintop program [C805]

## "Aircraft target recognition based on polarization invariable"

In this paper, target's polarization invariables are investigated in the wide-band case in optics region. On this basis, airborne target polarization features are extracted with respect to depolarization coefficient. Recognition results on five kinds of aircraft show that these features are insensitive to target's posture to a great extent and this method based on polarization invariables is effective and feasible [C806]

## "High-resolution polarimetric radar targets recognition based on the fractal characterization"

For high-resolution radar, target recognition is performed by using one-dimensional range profile. In this method, a radar target is described as composed of several kinds of scattering centers with different geometric shapes and structures. However, one-dimensional range profile is so extremely sensitive to aspect angle that a useful target recognition procedure is very unlikely to evolve from it. A novel idea is to use polarimetric range profile understanding technique to improve the recognition performance. In this paper, a study is performed on the fractal characterization of one-dimensional range profiles of high-resolution polarimetric radar targets at four kinds of polarimetric states (HH, HV, VH, VV), and a new concept of the fractal matrix is proposed [C807]

## "Summary of science results from spaceborne imaging radar (SIR-C/X-SAR)"

SIR-C/X-SAR (Spaceborne Imaging Radar-C/X-band Synthetic Aperture Radar) is the most advanced imaging radar system to fly in Earth orbit. Carried in the cargo bay of the Space Shuttle Endeavour in April and October, 1994, SIR-C/X-SAR simultaneously records SAR data at three wavelengths (L-, C-, and X-bands; 23.5, 5.8 and 3.1 cm, respectively). In addition, the full polarimetric scattering matrix may be obtained at L- and C-band. Scientific investigations are continuing using SIR-C/X-SAR data in topics in geology, hydrology, ecology, oceanography and radar remote sensing techniques. Vegetation classification, biomass measurement, forest-floor flood imaging, snow cover distribution and wetness, and soil moisture estimation are some of the quantitative measurements that can be conducted using SIR-C/X-SAR data. In addition, a number of longer-term processes bearing on global change are being studied, including conditions of alpine glaciers, forest ecosystem health, volcanic activity, and desert processes. The October flight included acquisition of experimental repeat-pass interferometry data that have been used to generate digital elevation models and for detection of surface motions in volcanic, tectonic and glacial terrains [C808]

## "Optimal multi-look polarimetric speckle reduction and its effect on terrain classification"

This paper presents an multi-look polarimetric whitening filtering (MPWF) method to reduce the image speckle using complete multi-look polarimetric SAR data. The amount of speckle reduction achievable by using the MPWF is quantified particularly for nonhomogeneous scenes. Experimental results with NASA/JPL L-band 4-look polarimetric SAR data are given for illustration. With the class separability index, we show how the speckle reduction can improve the terrain classification performance, and the classification results with the speckle-reduced data are also given [C809]

## "SIR-C polarimetric image segmentation by neural network"

In this paper, the results of the segmentation process of polarimetric multiband SAR images are shown. Purpose of the work is the image interpretation in absence of ground-truth. The segmentation process is performed by the self organizing map network which is an unsupervised neural network. The objective of the segmentation is the selection of homogeneous regions on the image and the results are evaluated in terms of grey level statistics on same restricted areas (urban and salina areas) [C810]

## "Target recognition based on extraction of dynamic polarization structure features"

In this paper, the wide-band model of target's polarization structure is constructed on the basis of wideband

polarimetry radar system. Target's pseudo-eigenpolarization is utilized to describe the dynamic characteristics of target's polarization structure in the wideband case. A new recognition method is presented based on fuzzy dynamic features. The results on five kinds of aircraft show that this method is effective and feasible [C811]

## "A coherent scattering model for forest canopies based on Monte Carlo simulation of fractal generated trees"

A coherent scattering model for tree canopies based on a Monte Carlo simulation of fractal generated trees is investigated in this study. In contrast to the incoherent models based on the radiative transfer theory, the present model is capable of preserving the relative phase of individual scatterer which give rise to the coherent effects and predicting the absolute phase of the backscattered field or equivalently the scattering phase center. In the procedure for Monte Carlo simulation, first tandem generation of tree architectures is implemented by employing the Lindenmayer systems (L-systems), a convenient tool for creating fractal patterns of botanical structures. Since the generating code of tree structures is faithful in preserving the fine features of the simulated tree types, this study provides an efficient approach to examine the effects of tree structures on the radar backscatter. After generating a tree structure, the electromagnetic scattering problem is then treated by considering the tree structure as a cluster of scatterers comprised of cylinders (trunks and branches) and disks (leaves) with specified position, orientation, and size. The scattering solution is obtained by invoking the single scattering theory for a uniform plane wave illumination. In this solution scattering from individual tree components when illuminated by the mean field is computed and then added coherently. The mean field at a given point within the tree structure include the attenuation and phase change due to the scattering and absorption losses of vegetation particles. Finally, the backscattering coefficients are simulated at different frequencies based on the results of the Monte Carlo simulations obtained from a large number of independent trees [C812]

## "Radar backscatter components from ponderosa pine forests"

The authors used a signal decomposition method to study scattering mechanisms in pine forests near Mt. Shasta, CA. Signal decomposition was applied to two sets of the JPL multifrequency airborne synthetic aperture radar (AIRSAR) backscatter data acquired during a wet spring (1991) and a dry summer (1989) conditions. The scattering mechanisms decomposed were scattering power with an odd number of reflections, scattering power with an even number of reflections, and diffused scattering power [C813]

## "Calibration of bistatic polarimetric scatterometers"

The recent interest in bistatic and multistatic radar has led to a need for information concerning the bistatic reflectivity of clutter viewed by such systems. Unfortunately, little information is available describing calibration for a bistatic radar system. This paper presents a new calibration technique for bistatic scatterometers. This technique assumes perfect isolation between antenna ports. It is shown that all magnitudes and phases (relative to one of the similarly polarized linear polarization configurations) of the radar transfer function can be calibrated without knowledge of the scattering matrix of a reference target. Only the use of the direct path between the transmitter and receiver is required. The technique is particularly useful for calibrating a radar under field conditions, because it does not require a set of calibration targets [C814]

## "Topographic measurements using polarimetric SAR data"

A technique using polarimetric SAR has been developed which is capable of directly sensing terrain surface slopes in the along-track (or azimuthal) direction. The method involves measuring the shift in orientation angle of the maximum in the polarimetric signature. The technique has measured slopes and derived elevations for both open and forested terrain. The method of polarization signature decomposition has been employed to identify components of the covariance matrix which produce the shift in the polarimetric peak position. Selected examples of terrain slope/elevation measurements made using both L- and P-band polarimetric SAR data will be given for heavily-forested areas near Freiburg, Germany and in northern California [C815]

## "Method of virtual autonomous blocks in matrics-electrodynamical theory of microwave components"

First Page of the Article [C816]

## "A numerically derived electromagnetic scattering model for grass grain heads"

An easy to use semi-empirical model for the scattering from grass grain heads has been developed with the assistance of the T-matrix method for determining scattered fields. It is shown that that physical grain model is significantly different than the more commonly employed dielectric cylinder nuclei and that the derived empirical

model can be used to efficiently replicate results obtained from the numerical analysis [C817]

## "An analysis of adaptive DPCA"

A low complexity space-time adaptive processing (STAP) scheme, called the adaptive displaced phase centered antenna (ADPCA) technique, is analyzed for airborne radar. Conditions are given under which this scheme is optimum for the case of observations with a known covariance matrix. An interesting interpretation of the ADPCA scheme is provided which may explain its good performance under some conditions. For some cases with noise and ground clutter only, the ADPCA scheme approximates a pulse cancelling scheme applied to optimally whitened pairs of pulses. The detection performance was analyzed for a case where the training data does not include the effects of a discrete scatterer that contaminates the range cell under test. Here the ADPCA scheme outperforms the scheme which is optimum for the case of a known covariance matrix [C818]

## "Diffraction by the dielectric disk and by the circular dielectric window in the perfectly conducting screen"

The geometrical theory of diffraction (GTD) can be applied to dielectric structures with a surface wave, but it is necessary to solve new canonical problems and to generalize the definition of the diffraction coefficient. As an example of the new canonical problem, we consider electromagnetic wave scattering by an edge of the semi-infinite dielectric slab. It is appropriate to describe the interdependence between amplitudes of the incident waves and scattering or reflecting waves (space and surface) in matrix form. Our task is to find the radar cross-section of the dielectric disk [C819]

## "Performance evaluation and error analysis of monopulse radar comparator"

Simulations are carried how S-parameters of comparator varies with variations in dimensions of hybrid ring and their connecting waveguide dimensions due to fabrication errors. A practical method is suggested to eliminate the effect of fabrication errors on the performance of the comparator with the help of movable short connected at match-terminated port of comparator. Results are presented how S-parameters of comparator very with respect to the position of movable short. This relaxes stringent conditions laid for fabrication of comparator for monopulse radar particularly at high frequencies [C820]

## "Polarimetric SAR image classification based on target decomposition theorem and complex Wishart distribution"

Polarimetric SAR data have been frequently utilized to classify terrain types. This paper compares two terrain classification approaches: 1) classification based on the target decomposition theorem, and 2) classification based on the multivariate complex Wishart distribution. Target decomposition theorems were developed recently for extracting geophysical information of scattering media. The averaged Mueller matrix or its equivalent was decomposed into components for a thorough study. Parameters were introduced to characterize the physical aspect of the scattering process and they are used for unsupervised classification. From a different point of view, the statistical property of the polarimetric covariance matrix has been modeled with a complex Wishart distribution. Supervised and unsupervised classification based on this distribution reported good results. The authors present results of supervised classifications using both methods. Comparisons are made on the accuracy of these two classification schemes. Possible reasons for the cause of errors are discussed. The NASA/JPL San Francisco data is chosen for illustration [C821]

## "Partially correlated K-distribution for multi-look polarimetric SAR imagery"

A partially correlated polarimetric K-distribution model is presented to characterize statistical properties of multilook polarimetric SAR data from urban areas. The model was derived using a more general matrix form of the product model that uses separate gamma distributed texture variables for different polarization channels and assumes that these texture variables be partially correlated. Experimental assessment of the model was conducted using NASA/JPL polarimetric SAR data from an urban area, showing improvement in better characterizing urban polarimetric backscattering [C822]

## "FEMATS: a general-purpose scattering code using the finite element method"

The focus of the article is the code FEMATS, developed at the Radiation Laboratory of the University of Michigan. FEMATS is a general-purpose code for computing the radar cross-section (RCS) of arbitrary three dimensional targets with material inhomogeneities. It employs state-of-the-art techniques in finite element modeling of open structures, the latest sparse matrix solutions and graphical user interface for pre- and post-processing of the geometry and data files. Although the code has been primarily used for finding the echo-area

of targets, FEMATS can be easily extended to solve open domain problems related to antennas, microwave circuits and cellular phones. The power of FEMATS comes from two features inherent in the technique: (i) the ability to model complicated geometries in three dimensions having arbitrary material fillings without code modification; (ii) the O(N) memory requirement of the method due to the employed local mesh termination techniques conformal to the target. This feature essentially implies that the technique scales favorably with problem size and thus very large problems can be tackled with minimal usage of computer memory and time [C823]

## "Multilevel fast multipole algorithm (MLDM) for complex objects"

The fast multipole method (FMM) and multilevel fast multipole algorithm (MLFMA) have been applied for solving integral equations of electromagnetic scattering iteratively. FMM reduces the complexity of a matrix-vector multiply from O(N2) to O(N(1.5)), where N is the number of unknowns. MLFMA further reduces the complexity to O(NlogN). It requires O(NlogN) memory, and hence, can solve a large problem on a small computer. The numerical results for the RCS of some simple objects can also be carried out. Since they are closed smooth objects, which are not very thin, the combined field integral equation (CFIE) with uniform grid has a small condition number, and converges very fast. In this paper, we apply MLFMB to large complex 3D objects. The preconditioner, near singularity extraction, and the choice of first guess are discussed. The RCS of a wing is discussed as an application [C824]

## "An AIM based analysis of electromagnetic scattering from jet engine blades"

In this paper we investigated the application of the adaptive integral method (AIM) to scattering from structures occurring in jet engine terminations. The method was applied to a curved perfectly electrically conducting blade, and the results were shown to be in excellent agreement with the method of moments. Given the method's low memory and CPU requirements, AIM is considered very promising for the accurate analysis of realistic, very large scale jet engine problems [C825]

## "A sub-space method for high resolution bathymetry"

To increase the accuracy and the rate of coverage of a given area in shallow coastal waters, light-detection and ranging (lidar) airborne laser ranging systems have been introduced. A new formulation for ocean-depth measurement using the frequency-domain approach as proposed. This technique uses a high-resolution eigensubspace method to estimate the ocean-depth from backscattered noisy data. The problem is addressed for complex attenuation coefficients by utilizing a double eigenstructure decomposition procedure on a Hankel matrix structure. The approach is similar to obtaining the best rational approximation that fits the actual measured data in a least-square sense [C826]

## "SAR images interpretation using data analysis techniques"

The paper presents the analysis of the full polarimetric SAR image of San Francisco Bay by the three tools described. In polarimetric data the average Mueller Stokes matrix offers a complete description of backscattering polarisation properties of areas (for fixed frequencies and aspect angles). A particular graphical representation known as the polarisation signature is useful. We describe here a new graphical representation of the information of the Mueller Stokes matrix and a new feature vector. This feature vector is built by analysis of the Mueller Stokes matrix on three basis vectors of Stokes representation space, and by separation of the polarised and unpolarised (fluctuation) part for each backscattered vector corresponding to each basis vector. The projections of these vectors on a polarisation map leads to a new graphical representation where it is very easy to compare different classes (different scattering areas) with their fluctuations. The natural classes are found by a clustering process combining a k-means algorithm and an ascendant hierarchical clustering. The pixels of the image are labelled. A small part of the pixels is used by a learning process. When learned the decision function is applied to all the pixels of the full image. The procedure is mostly based on regression trees techniques and kernel estimates. It supports the following functions: feature automatic selection, Bayesian risk evaluation, extrapolation control, new classes detection, and new classes automatic learning. A generalised classification rate is presented [C827]

## "Large electromagnetic scattering computation using iterative progressive numerical method"

The progressive numerical method (PNM) is an effective way of dealing with electromagnetic scattering by electrically large objects. The PNM is based on the moment methods (MM). It is known that the solutions of the electric or magnetic field integral equations, using the MM, can be reduced to a matrix equation. The process of the PNM is started by selecting a small region at the centre of the illuminated side of the scatterer to reduce the interactions from the remaining sections of the object. However it is usually difficult to do so for asymmetrical

scatterers. It is also noted that the accuracy of the solutions for the TE case is poorer than that of the TM case. This is due to the fact that for the TE case the induced currents are circumferential. An iterative step is incorporated with the PNM for better accuracy. To examine the behavior of the solution using iterative PNM, a perfect conducting infinite rectangular cylinder (TM case) is assumed [C828]

## "Target recognition based on polarization frequency stability"

In the high-resolution and polarimetric case, the concept of PFS (polarization frequency stability) is presented. A Poincare sphere is used as the representation of polarization. The concept of PSD (polarization states distance) is presented to describe target dynamic polarization characteristic. On this basis polarization features are extracted and recognition results show that the method based on the description of target PFS is effective in optics region in the high-resolution case [C829]

## "Target recognition based on multi-dimensional polarization feature space"

The target depolarization characteristic is investigated based on the wideband polarization radar system. Ellipse parameters are adopted to describe target polarization characteristic in optics region. Considering target posture effect on polarimetry in the wideband case, a multi-dimensional feature space is constructed. On this basis, recognition experiments on five kinds of aircrafts are made and results show that the recognition method presented is effective and feasible [C830]

## "A New Algorithm For Space Time Adaptive Processing Using The Conjugate Gradient Method"

First Page of the Article [C831]

## "High resolution radar target structure description using modified Prony model"

This paper presents an approach to high resolution radar target structure description that exploits the relationship between the physical structure and the down-range cross section of the measured backscatter response. A modified Prony model is used to represent the radar backscatter signal measurements as a set of down-range scattering centers, each of which is characterized by its range, amplitude, and a polarization ellipse. The modified Prony model presented uses an algorithm of singular decomposition and an algorithm to automatically select the order of the model according to the radar measurement data processed. These algorithms can also remove the spurious scattering centers. The model is applied to full polarization, stepped frequency measurements of five aircraft models at different aspect angles. It is shown that this method provides a clear and robust description of radar target and has significant evaluation of performance in noise [C832]

## "A numerical study of the composite surface model for ocean scattering"

A numerical study of ocean backscattering for surfaces rough in two dimensions is presented. The numerical model is based on Monte Carlo simulation using the sparse matrix-flat surface iterative approach with canonical grid (SMFSIA/CAG), which is a more efficient version of the method of moments that allows large two dimensional surfaces to be treated. Backscattering cross sections are illustrated for perfectly conducting power law spectrum ocean surface models at angles from 0 to 60 degrees from normal incidence. Variations with surface spectrum low frequency cutoff (ranging over spatial lengths from 64 λ to 2 λ) are investigated, and demonstrate the accuracy of the composite surface model [C833]

## "Approach to the fractal features of high-resolution polarimetric radar targets"

For high-resolution radar, a novel idea is to use the polarimetric range profiles understanding technique to improve recognition performance. In this paper, a study is performed based on the fractal characterisation of one-dimensional range profiles of high-resolution polarimetric radar targets at four kinds of polarimetric states (HH, HV, VH, VV), and a new concept of the fractal matrix is proposed [C834]

## "Polarimetric image classification using optimal decomposition of radar polarization signatures"

The technique of weighted least squares (WLS) is used to obtain the optimal decomposition of radar polarization signatures, in which, backscatter is assumed to consist of odd, double, Bragg and cross scattering mechanisms. The results of the decomposition agree with our understanding of radar backscatter, providing information for polarimetric image classification [C835]

## "Automatic target recognition based on correlation matrix memory"

Correlation matrix memory is one of the models of the association memory, and can be applied to high range resolution radar target recognition. In this paper, the association memory matrix is used to memorize a great number of encoded profiles belong to different targets. Results show that it is robust to noise and aspect changes [C836]

## "Polarimetric scattering properties of natural targets at 80 GHz"

Although a large volume of data describing the properties of the scattering matrices of natural targets has been presented in the literature, the vast majority of these data were measured at frequencies under 10 GHz, very little polarimetric data has been presented at millimetric wavelengths. Interest in the scattering properties of terrain in this band has been stimulated by the interest in collision avoidance radars for use on motor vehicles. These will operate at 77 GHz. Measurements of the scattering matrices of a variety of natural targets are described, and an overview of the principal scattering properties is given. A simple parameter referred to as the cross polar ratio (CPR) is then introduced and shown to characterise the scattering matrices measured of tree canopies. A discussion of the depression angle dependency of the scattering matrix of grass is then presented [C837]

## "Time-dependence of backscattered intensities of a sphere illuminated with very short electromagnetic pulses"

Scattered time-dependent intensities from a dielectric sphere illuminated with a very short pulsed plane wave are calculated. The time dependence of the incident pulse is considered to be a rectangular or a Gaussian function. The results are obtained for a sphere on a resonant mode. The frequency spectrum of the scattered field at a point is calculated using the incident field spectrum and the transfer function at that point. The transfer function at any frequency of the sphere at a space point is calculated using the T-matrix method. The inverse Fourier transform of the frequency spectrum is used to calculate the time-dependence of the scattered electric field. The scattered intensities are calculated for pulses of durations (~10 ps) smaller than the resonant lifetime. The computer codes are capable of calculating the scattered intensity of a shorter pulse. The computations for such shorter pulses depend on the capacity and speed of the computer system. The main factors which affect the behavior of the scattered pulse are the incident pulse spectrum (or duration) and the lifetime of the resonant mode of the sphere [C838]

## "Analysis and comparison of polarization: characteristics for different terrain types"

This paper deals with polarization characteristics analysis and comparison for different terrain types. A method for the optimization of the completely polarized component involved in a partially polarized wave is used to extract three basic polarization characteristics parameters, the maximum received power, the optimal polarization states for transmission and reception, and the optimal degree of polarization. We also use an unsupervised classification method to qualitatively analyze the scattering mechanisms of each typical scattering class. We compare these quantities between different ground-cover types by using L-band polarimetric SAR data, and specify the polarization characteristics for each typical terrain type discussed [C839]

## "Feature-extracting and recognition based on radar target's dynamic polarization structure"

Based on wide-band polarimetric radar, a model of the radar target's polarization structure is proposed. On this basis, pseudo-eigenpolarization is used to describe the dynamic properties from which fuzzy-dynamic-features are extracted. The experimental results show that the method of identifying aircraft is effective and feasible [C840]

## "Adaptive beamforming for rapidly moving arrays"

Adaptive beamforming procedures based on linear least squares estimation of a wanted signal have been shown to successfully excise unwanted interference from the beamformer output when the signal environment is stationary. However under non-stationary conditions, such as those experienced by an array mounted on a rapidly moving platform, performance may be significantly degraded. By modelling the dynamic behaviour of the beamforming weights the losses in performance may be recovered. In particular we show that through the estimation of a beamforming weight vector and its rate-of-change, we are able to compensate for the effects of a constant angular rotation of the array [C841]

## "Partially correlated K-distribution for multi-look polarimetric SAR images"

A partially correlated polarimetric K-distribution model is presented to characterize statistical properties of multi-look polarimetric SAR data acquired over urban areas. The model was derived in terms of a matrix product

model in which different texture variables are assigned to different polarization channels. The joint distribution of these textural variables are assumed to be partially correlated Gamma. Experimental assessment of the model was conducted using NASA/JPL polarimetric SAR data of urban areas, showing improvement in better characterizing urban polarimetric SAR backscattering [C842]

## "A procedure to calculate the in-situ contribution to body scattering caused by conformal cavity-backed apertures"

This paper presents a theoretical procedure whereby a conformal aperture's in-situ contribution to the total radar cross section (RCS) of a body can be efficiently and accurately calculated. The result is equivalent to subtracting the RCS of the body with the aperture shorted from the RCS of the body with the aperture present. In RCS measurements, this technique is commonly referred to coherent fixture subtraction. The approach presented uses the electric current density at the aperture location on the body (computed with the aperture shorted) to derive new excitation and measurement vectors for the fields scattered by the conformal aperture. These surface currents may be obtained from a number of well-validated computer codes, such as JRMBOR CARLOS 3-D or PARAMOM. The electromagnetic characteristics of the cavity-backed aperture are rigorously modelled by an admittance matrix, which is calculated by a finite element method and assumes an infinite planar or singly curved installation environment. Fixture effects, such as surface wave and creeping wave excitation of the aperture, are also accurately accounted for in this procedure [C843]

## "Analysis and design of wide-band matched waveguide bends including discontinuities"

Waveguide bends with small radii of curvature are realized by using properly selected discontinuities which, placed inside the curve, allow low return losses to be achieved over large band-widths. The component is designed by using an efficient computer code which employs the focal modes approach to analyze curved sections, while discontinuities are rigorously accounted for by considering their accessible modes. Theoretical simulations are compared with experimental results showing very good accuracy [C844]

## "Mode matching analysis of metallic blades in a cylinder"

Scattering from a set of coplanar blades mounted on a centre shaft and located inside an open cylinder is investigated by the formally exact field matching technique. The blades are assumed to extend the entire radius of the cylinder. This allows the scattering from the blades to be treated rigorously. An incoming plane wave illuminates the cylinder. The circular guide modes induced at the aperture by this plane wave are found by field matching. These modes propagate down the cylinder and encounter first a circular guide-coaxial guide junction and then the coaxial guide-blade junction. Waves transmitted through the blades are assumed to be perfectly terminated. The set of coplanar blades is represented by a ring of sectoral waveguides of finite thickness. If the generalised scattering matrices (GSM) of the two junctions are known, they can be cascaded together with that of the intervening coaxial guide to give a complete characterization of the scattering by a set of blades. The GSM of the first junction, the circular guide-coaxial guide transition, may be readily obtained by matching the electric and magnetic fields at the interface, and then forming vector cross-products using the respective mode functions. The resulting mode coupling integrals between the circular guide modes and the coaxial guide modes may be evaluated in closed form. This procedure is straightforward. The S-matrix description of the coaxial guide-blade junction is considered next. Then results from an investigation on a set of blades in an electrically small cylinder are presented [C845]

## "MODE-type algorithm for estimating damped, undamped or explosive modes"

We propose a new algorithm for estimating the parameters of damped, undamped or explosive sinusoidal processes. The algorithm resembles the MODE (method of direction estimation) algorithm which is commonly used for direction of arrival estimation in the array signal processing field. The algorithm is asymptotically (for high SNR) optimal. Nevertheless it is computationally simple and easy to implement. Numerical examples are included to illustrate the performance of the proposed method [C846]

## "Full space-time clutter covariance estimation"

For an airborne radar array, beamforming and detection are problems in both space and time. To null clutter, it is necessary to exploit both dimensions, and to do so optimally requires knowledge of the full space-time covariance matrix and the array steering vectors. This paper derives an expectation-maximization (EM) algorithm for the estimation of full space-time covariance matrices while simultaneously estimating array steering vectors. The EM approach iterates between estimating the spatial steering vectors and power associated with clutter scattering from different angles and the formation of a full space-time covariance matrix. The final result is an estimate of the set of array steering vectors and an estimate of the space-time covariance matrix. In practice,

one would never need to form this covariance since all calculations could be performed using the SVD of the appropriately weighted clutter space-time steering vector matrix. The technique is capable of providing a positive definite estimate of the space-time covariance and complete array calibration with only a single space-time data sample [C847]

## "Modelling and inversion techniques for radar applied to archaeological investigations"

As test sites for ground penetrating radar (GPR), archaeological sites offer a set of demanding (high-resolution) application contexts in a situation where repeated studies may be made over a range of non-trivial targets (i.e. not always clearly defined or predictable, hence requiring diagnosis and evaluation, rather than mere detection). When the points above are further taken into account, they offer excellent opportunities for the test, evaluation and development of equipment, modelling approaches, and interpretational/processing tools. The modelling approach discussed is the transmission line matrix method (TLM). This method represents the volume of interest as a mesh of two-wire transmission lines and provides a formalism where Maxwell's equations governing propagation of an electromagnetic wave through a variable media can be described in a discrete circuit theory form. A discrete-time approach is taken where scattering takes place at the nodes of the mesh due to discontinuities in the line impedances: the propagation of the waves can then be established over time, with one time-step being defined by the node-node travel time. The approach can be successfully applied to the use of GPR systems in a wide variety of contexts and can cope with complex subsurface structures [C848]

## "SAR image reconstruction for an arbitrary radar path"

Considers the problem of spotlight-mode synthetic aperture radar (SAR) imaging for an arbitrary radar path. A general imaging scenario involves a 3-D scattering surface with data collected along an arbitrary 3-D radar path. This approach is useful, for example, in military applications where the radar platform may undergo some maneuvers, and in radar astronomy where the relative motion is, at least in part, determined by the natural paths of celestial bodies. The authors show that nonideal platform motion can create phase variations in the data which lead to spatially-varying shifts and blurring. A correction procedure is proposed and demonstrated [C849]

## "On the applicability of 2-D damped exponential models to synthetic aperture radar"

This paper examines the modeling of synthetic aperture radar (SAR) phase histories with 2-D damped exponential models of low order. The use of a low order model is warranted when the radar returns are attributable to a small number of point scatterers. We show that the fit of the widely used damped exponential model is highly dependent on the image scene. Specifically, current high resolution methods have limited applicability due to mismatch between the assumed model and observed data [C850]

## "Random rough surface scattering based on Monte Carlo simulations with the sparse-matrix flat-surface iterative approach"

With the advent of modern computers, numerical methods for solving Maxwell's equations are gaining popularity. In the authors' approach, the exact solutions of Maxwell's equations for scattering by a two-dimensional (2D) random rough surface are calculated with a sparse-matrix flat-surface iterative approach/canonical grid (SMFSIA/CAG). Numerical examples are illustrated with up to 131,072 surface unknowns, surface areas between 256 square wavelengths and 1024 square wavelengths, and rms heights of 0.5 wavelength and 1 wavelength. The scattering solution for each surface realization takes less than two CPU minutes for 32768 surface unknowns. Therefore, simulations based on Monte Carlo technique are illustrated with up to 1000 realizations. In this paper, backscattering enhancement of electromagnetic wave scattering from a perfectly conducting 2D random rough surface is studied with Monte Carlo simulations. The numerical simulation results are in excellent agreement with controlled laboratory experiments without adjustable parameters. SMFSLA/CAG has also been extended to the case of electromagnetic wave scattering from 2D dielectric surfaces [C851]

## "Dense medium phase and amplitude correction theory for spatially and electrically dense media"

The conventional scattering phase matrix is developed based on the assumption that the scatterers are in the far field of one another. In an electrically dense medium where there is more than one scatterer within the distance of a wavelength, this approximation no longer holds. Generally two types of corrections are necessary: the amplitude and the phase correction. In this paper, a new phase matrix for a volume of densely packed discrete random spherical scatterers is discussed. This phase matrix differs from the conventional one in that both amplitude and phase corrections are included. By invoking the antenna array concept, the phase matrix is found to be the Stokes matrix of the single scatterer multiplied by a dense medium phase correction factor. The amplitude correction due to close-spacing appears in the Stokes matrix. Using this phase matrix, the volume

scattering coefficient of a unit volume of spherical scatterers is calculated. The backscattering coefficients from a layer of spherical scatterers are also calculated based on the matrix doubling formulation. This study shows that phase coherency and close-spacing amplitude modifications are two separate corrections necessary for an electrically dense medium. When the wavelength decreases, both the volume scattering coefficient and the backscatter of the layer approach the usual results under the far-field condition, even though the scatterers are spatially dense. Whether or not a medium behaves as a dense medium in scattering, the incident wavenumber times the average spacing between adjacent scatterers is the important parameter. Thus, there is a need to distinguish between spatially and electrically dense media [C852]

## "Polarimetric radar covariance matrix algorithms and applications to partially polarized waves"

Characterization of complex or non-stationary targets, which backscatter partially polarized waves is considered first. The possibility of constructing the covariance matrix from coherency matrix measurements is shown and an algorithm to obtain optimum polarizations and other parameters of interest is briefly described. Using the model described in Hendry et al. (1987) for meteorological targets the covariance matrix for this class of scatterers is built. Optimum polarizations are obtained and symmetry properties are examined [C853]

## "Investigations of soil moisture inversion from polarimetric radar responses based on integral equation model"

A polarimetric surface scattering model based on the integral equation model is used to study the dependence of backscattering coefficient on surface roughness and dielectric constant in a wide range of surface conditions as well as incident frequencies and angles. Then the sensitivity of the surface parameters to polarization states was investigated to aim at selection of optimum polarization angles which minimize the effects of surface roughness in order to extract the surface roughness and soil moisture. Because the inversion can be highly nonlinear, a dynamic learning neural network was adopted. When surface rms slope is less than 0.5, the cross-pol. response is negligible compared to co-pol. response. Useful data channels are thus selected from the co-pol. polarimetric responses as inputs to neural network for training and operation. It is found that the use of polarimetric data, particularly when only single angle-single frequency data available, increases the range moisture content and thus significantly enhances the capability of soil moisture retrieval from microwave remote sensing data [C854]

## "Ninth International Conference on Antennas and Propagation (Conf. Publ. No.407)"

The following topics were dealt with: antenna phased arrays; TLM analysis; mobile measurements; microstrip antennas; antenna measurements; Olympus results; finite difference time domain methods; array optimisation; building and vegetation scatter; ionospheric propagation; reflector antennas; personal communication antennas; rain effects on Earth-space paths; ionosphere measurements; smart antennas; active antennas; shaped reflectors; tropospheric propagation; feeds; millimetre wave propagation; propagation aspects of frequency planning; method of moments; radar and radio meteorology; vehicle antennas; radomes and absorbers; propagation simulation; broadband and HF antennas; adoptive antennas; loops and helical antennas; ray tracing techniques; frequency selective surfaces; satellite mobile communication [C855]

## "Vegetation and soil characteristics in SIR-C data"

The authors compared polarimetric C- and L-band and ground truth data from bare soil, young wheat and mature maize fields of the agricultural test site Flevoland in the Netherlands collected during the SIR-C campaign in April and October 1994. The authors find that the L-band is more sensitive to the soil roughness than the C-band. In particular L-band HH gives the best discrimination between different degrees of soil roughness. The influence of young wheat with a ground cover of less than 25% is first noticeable in the C-band co-polarised correlation coefficient. By applying a decomposition technique to resolve different backscatter components in polarimetric data the authors find that the backscatter from mature maize fields is dominated by the vegetation in the C-band, while both the soil and vegetation contribute significantly to the backscatter in the L-band [C856]

## "A study of the invariance properties of textural features in SAR images"

Compares the performance of a number of different texture features for SAR image analysis. These features are derived from the gray-level co-occurrence matrix, local statistics, and lognormal random field models. The features are compared based on: (i) their invariance or robustness with respect to natural changes in SAR signatures; and (ii) their discrimination ability and classification accuracy. The invariance of the texture features is investigated on a set of 13 ERS-1 SAR images of the same scene, captured under different conditions. Two main conclusions can be drawn from this study: (i) the texture features are not invariant with respect to natural changes in the mean backscatter values; and (ii) texture fusion and selection by combining texture features

obtained by different models significantly improve the classification accuracy [C857]

## "Classification of multifrequency radar polarimetric data: role and contribution of vectorial filters"

A vectorial filter is applied to AIRSAR polarimetric radar images to reduce the fluctuations of the data due to speckle. The single frequency and multifrequency classifications of raw data and filtered data are compared in terms of classification accuracy and the best selection of filter parameters (choice of elements of the observation vector to be filtered and running window size) are determined [C858]

## "Polarization identification of high resolution range profiles"

In this paper, a novel effective polarization identification method is presented for vehicle sized ground target identification application. The method uses wide band FMCW orthogonal duel-polarization technology to obtain the degraded PSM of each scattering center in high resolution range profile. For different type of scattering center, different matching weight vectors of transmitting and receiving are used to process the PSM data of range profiles. Finally, power or amplitude output matched to different type of scattering center is obtained and used to identify target by means of the information about the kind of scattering centers the target is constructed. The method is more effective than those which use features obtained from only one polarization channel [C859]

## "Moment method simulation of rough surface scattering based on wavelet representation"

The electromagnetic wave scattering from randomly rough surfaces is studied by means of moment method using the wavelets to represent the surface tangential fields or currents. Conventional moment method usually forms the matrix by uniform sampling. Since the density of the surface currents is dependent on the roughness of the surface, or more precisely the surface local slope. As a result, the matrix usually is densely distributed. When the surface becomes rougher or wavelength is larger, the size of the matrix is extremely large which is computational prohibitive. By making use of the wavelet expansion, due to its highly localized and adaptive sampling properties, the pattern and size of the resulting matrix can be accordingly adjusted. This merit is especially well suited for the simulation of rough surface scattering, particularly in the problems of three dimensional surfaces. In this study, the authors adopt the orthonormal and compactly supported wavelets proposed by Daubechies. The dependence of the number of coefficients on surface roughness, correlation function and wavelength are investigated. Then the validity and performance of the proposed approach is evaluated and tested on a broad range of parameters [C860]

## "On the statistics of polarimetric synthesized images"

Presents selected results of a study on the statistical properties (to the first order) of the polarimetric radar signal, when it is represented in a vector basis other than the (H,V) basis (polarimetric synthesis). The concept of polarimetric texture signature is introduced, which is a convenient tool to represent in condensed form the statistical properties of the synthesized backscattered power. Experimental results are then reported, where the authors observe a modulation of the second normalized moment at different polarization configurations. In order to explain some of the trends in the polarimetric texture, they resort to a Monte Carlo simulation. Also some considerations are made on the closed form PDF of the intensity of the cross-polarized channel, when the covariance matrix is transformed by the polarization synthesis. Finally the authors hint to an on-going investigation based on texture modeling, to verify the statistical behavior of the underlying radar reflectivity in a depolarizing random target [C861]

## "RF propagation from a flatplate array antenna with polarizing lenses"

Under a previous IR&D project the capability of an airborne Ku-band slotted flatplate array was expanded to include polarization diversity for automatic target recognition (ATR). A lightweight meanderline polarizer lens was designed, which transmits linearly polarized RF and receives simultaneously both co-polarized and cross-polarized target returns. An optional configuration, obtainable using an RF switch, transmits right-hand circular and receives simultaneously right- and left-hand circularly polarized returns. Either configuration detects two time-correlated polarization scattering states. Such data are useful in target identification either through partial polarization whitening of the image or by supplying feature information for matching against a target model. The addition of a second RF switch to the design allows pulse-to-pulse alternating transmission of both polarizations, in which case the full polarization scattering matrix can be obtained. The linearly polarized aperture of the original array design permits the antenna to support air-to-air pulse doppler monopulse, high resolution synthetic aperture radar ground mapping, and ground moving target track radar modes. The high gain and efficiency of the flatplate array, combined with pulse compression techniques and high transmitter power, give the system a long range, high resolution, ground mapping capability unusual in a nose mounted radar system. With the incorporation of the polarizer lens, the new ATR capability makes this antenna a more powerful tool in air-to-

ground combat and surveillance [C862]

## "On the influence of vegetation and soil in microwave backscatter from vegetated surfaces"

Presents a technique for a decomposition of polarimetric data into a vegetation, a soil and a vegetation-soil component. Results are given for polarimetric L- and C-band data of winter wheat, obtained during the MAC'91 campaign at the Dutch Flevoland testsite [C863]

## "Simultaneous 35, 95, and 225 GHz fully polarimetric measurements of fallen snow"

During the winter of 1994, a three frequency polarimetric radar system operating at 35, 95, and 225 GHz was configured to take simultaneous measurements of the Mueller matrix and normalized radar cross section (NRCS). In addition to the radar measurements, in situ data characterized the snow pack and meteorological parameters. It was found that NRCS is inversely related to the amount of liquid water content in the snow pack up to the depth of penetration. Additionally, a supervised classification using the minimum distance classifier was used to classify the data into four snow type categories with a 97% accuracy [C864]

## "A fully polarimetric multiple scattering model for agricultural fields"

A discrete model has been developed at Tor Vergata University, which describes vegetation as an ensemble of discs and cylinders overlying a homogeneous half-space with a rough interface. The model predicts the backscatter coefficient including multiple scattering effects. The first version, which was based on a scalar approach (2 Stokes components) has now been improved in order to get a fully polarimetric approach (4 Stokes components). Soil scattering is represented, for each pair of incidence and scattering directions, by a 4Ч4 scatter matrix, computed by means of the small perturbation approximation (for smooth soils) and the geometrical optics approximation (for rough soils). The vegetation layer is subdivided into many thin layers, each filled with discs and/or cylinders. The scattering and transmission properties of a thin layer are represented, for each pair of incidence and scattering directions, by two 4Ч4 scatter matrices (for upper and lower half-spaces respectively) and, for each incidence direction, by a 4Ч4 extinction matrix. Matrices are computed by means of Rayleigh-Gans or physical optics approximations, depending on frequency. Finally, the contributions of the various thin layers and that of the soil are combined by means of the matrix doubling algorithm. In this paper, the authors' recent modeling advances are described. In particular, the differences between the scalar approach and the polarimetric approach are emphasized. The polarimetric model results are compared with experimental radar data obtained over agricultural fields of the Italian Montespertoli site during the MAC-91 Campaign. In particular, the crop biomass effects are investigated at L-band in the case of sunflowers. Some polarimetric features, like backscatter coefficients in linear and circular polarizations, and phase difference between VV and HH channels are considered [C865]

## "Measurements of the Mueller matrix elements using a fully polarimetric optical scatterometer"

The scattered or transmitted electromagnetic fields from a multilayered structure with irregular interfaces can be fully characterized by the Stokes vectors. The scattered or transmitted Stokes vectors are related to the incident Stokes vectors through the (4Ч4) Mueller matrix. The measurements of microwave or optical wave interactions with irregular multilayered structures have important civilian and military applications, such as in thin film analysis and in remote sensing. The TASC (True Angle Scatter Coordinate System) polarimetric scatterometer housed in the Center for Electro-optics at University of Nebraska-Lincoln can measure the 4Ч4 Mueller matrix as well as the BSDF (bi-directional scatter distribution functions) for scattered or transmitted light from a sample [C866]

## "Polarimetric radar signatures of oil slicks for measuring slick thickness"

In the event of an oil spill at sea, the most critical information needed is an estimate the amount of the spill and how it is dispersing. The thickness of the oil slick provides information needed to assess both these needs. Polarimetric synthetic aperture radar has been used to estimate the thickness of oil slicks. However, since a model that describes the measurements of a fully-polarimetric radar was not available, it was difficult to optimize this measurement technique. The two-scale, resonant scattering model is utilized to derive the backscatter cross-section of ocean surfaces that are covered by thin oil slicks. The model defines the complex scattering coefficients of the co-pol and cross-pol backscattered signals. The scattering coefficients are found as a function of the thickness of the oil slicks and its dielectric constant. The scattering matrices are converted to the corresponding Stokes matrices. The Stokes matrix is used to synthesize the backscattered signal for a variety of different polarizations. The scattering cross-section is found as a function of the ellipticity angle and the ellipse orientation angle. This information is used to train an artificial neural network to find the optimum polarization as a function of the dielectric constant and slick thickness. This artificial neural network is used to extract the slick thickness. Estimates of the resolution of the thickness measurement are also given. The effect of phase noise

and speckle on the accuracy of the thickness measurement are also estimated. It is concluded that a fully polarimetric, millimeter wave radar, such as a 33 GHz SAR, is adequate for estimating the thickness of most moderately thick oil spills [C867]

## "A fast multiresolution moment method algorithm using wavelet concepts"

It is well known that the application of the conventional moment method to boundary integral equations results in a dense matrix equation that is very time-consuming to solve. To speed up the moment method calculation, a number of fast algorithms have been developed. There is also interest in applying wavelet concepts to solve integral equations arising in electromagnetics. However, direct application of wavelet basis to sparsify the moment matrix still results in the same order of computational complexity. The reason is that the electromagnetic Green's function is an oscillatory kernel. We present a method of reducing the computational complexity using a different wavelet concept. The idea is to take advantage of the multiscale nature of the k-space Green's function. In the far field it has small-scale features around k0 and in the near field it has large-scale features over all k [C868]

## "Quaternion presentations polarization state"

For considering the dynamics of an electromagnetic wave, a variety of presentations differing in the values being observed can be suggested. The following can be used as such values: electric intensity and magnetic induction vectors, electric and magnetic intensity vectors or vector potential. Finally, field amplitude or energetic characteristics, including, the description of the polarization state, can be used as observed values. The polarization state can be described after characteristics to be observed have been chosen. The point is that any descriptions connected by isomorphic (mutually unambiguous) transformations are completely equivalent to each other: it is possible to pass from one description to the other without losing anything from its contents [C869]

## "Permittivity of sea ice at Ka-Band"

Measurements of the complex permittivity of sea ice at Ka-Band (26.5 to 40 GHz) were collected in the laboratory using a step frequency radar. Columnar and granular sea ice samples were prepared from cores of laboratory grown sea ice sheets with salinities ranging from 3 to 8 ppt. The authors measured the permittivity at temperatures from -30 to -12C in three orthogonal directions. They found, for all samples, that the imaginary part of the dielectric constant is highly dependent on the brine volume of the sea ice, which in turn depends on the bulk salinity and the temperature of the sample. For the columnar ice, consisting of approximately ellipsoidal brine pockets embedded in an ice matrix, they found that the imaginary part of the dielectric constant was anisotropic, and depended on the relative orientation of the electric field and the axes of the brine pockets. The highest values of the imaginary part of the permittivity were measured when the electric field was oriented parallel to the direction of ice growth, or along the longest axes of the brine pockets [C870]

## "Bistatic polarimetric extension of GO/PO and GTD/PTD inverse scattering theories to aerial RCS analyses in wideband POL-SAR image interpretation"

In order to correlate high resolution/precision interferometric POL-SAR images with the underlying ground truth, it is essential to develop the RCS matrix expressions for simple, canonical shapes in closed analytic form and to provide numerical algorithm verification analyses. This is achieved by extending the common geometrical optics (GO) and physical optics (PO) scalar RCS closed form solutions via the Geometrical Theory of Diffraction (GTD) of J.B. Keller and the Physical Theory of Diffraction (PTD) of P.Ya. Ufimtsev to the full polarimetric, slightly bistatic cases as required for proper implementation in modern wideband (multi spectral and impulse) POL-SAR systems calibration and image normalization procedures [C871]

## "Scattering reduction of a microstrip patch with an in-plane biased ferrite cover layer"

A full-wave moment-method analysis of scattering from a microstrip patch with an in-plane biased ferrite cover is presented. A modified exponential-matrix method is employed to facilitate the computation of the Green's function for layered media including non-reciprocal layers. The analysis enables the investigation of the scattering characteristics due to the effect of a biased ferrite cover layer. It is observed that there is significant resonant RCS reduction when the biased field is in the direction of the resonant-mode current. This RCS reduction is due to the existence of the extra-ordinary wave and the magneto-static waves within the ferrite layer [C872]

## "Physical optics analysis of rotating blades in a cylinder"

A relatively simple model is employed to predict the spectral level at the modulation frequency of the scattered

return from a set of coplanar blades located inside an open conducting cylinder. The cylinder is assumed to be illuminated by a plane wave. Waveguide modes induced at the aperture of the cylinder are found by the field matching method whereby an S-matrix characterization of the waveguide-free space interface is obtained. Both `horizontal' and `vertical' degenerate sets of circular waveguide modes are needed for an accurate description of the scattering process. The excited modes propagate into the cylinder and illuminate a set of blades. Mode conversion occurs at this interface where modes of a given degenerate type are converted not only into modes of the same type but also into modes of the second degenerate type. This conversion process is modeled by first finding the induced currents on the blades through the physical optics principle. These currents, in turn, give rise to reflected modes which are found by the reciprocity formula The reflected modes propagate back towards the aperture where they radiate into free space. For the present investigation, the transmitted modes at the blade junction are terminated in their characteristic impedances. As the modal content at the cylinder aperture changes with the position of the blades, the resultant field pattern of the aperture modes exhibits a temporal variation. The blade modulation spectrum is obtained by Fourier transforming this time periodic signal. The adequacy of this model is tested [C873]

## "A polarimetric ultra-wide band field scatterometer"

“TERESA” (TErrestrial Radar Equipment for Scattering Analysis) is a ground-based, fully polarimetric scatterometer operative in the S, C, X, and Ku bands. It has been designed to obtain the complete backscattering matrix of terrain and oceanographic surfaces with extensive information of its variation with frequency and incident angle. The system is able to measure the Doppler spectrum of the illuminated scene as well. The paper briefly describes the specifications and structure of the system and the first results obtained [C874]

## "Polarimetric contrast optimization"

It is often desirable to select radar antenna polarizations that maximize the contrast in received powers from two classes of scatterers. A terrain-mapping radar may use polarization to maximize the contrast between forested areas and farmland. For another radar, polarizations may be chosen to optimize an aircraft target return relative to clutter. Polarizations chosen for either purpose may give a target return that is small compared to external noise or internal receiver noise, and it may therefore be more appropriate to choose polarizations that maximize signal-to-noise ratio. An outline of methods for choosing polarizations in all of these cases is presented [C875]

## "Polarization properties of the coherent lossless TEM transmission channel"

Mutual dependence between elements of two transmittance and two reflectance Sinclair matrices of a polarimetric two-part are considered for the reciprocal and lossless case. Poincare sphere models of those matrices showing mutual positions of their polarization forks are presented together with a numerical example of the polarimetric two-port [C876]

## "Novel slotted waveguide antenna with polarimetric capabilities"

Presents a novel dual polarised slotted waveguide array antenna. It is intended for an advance synthetic aperture radar with polarimetric capabilities. Special emphasis is given to achieve a compact subarray design with large bandwidth, high polarisation purity, low loss and high port to port isolation. A breadboard antenna example is presented at 9.6 GHz having a scan range of ±23° transverse the subarray axis [C877]

## "Scattering from a conducting cylinder shielded with a dielectric bead"

Modal theory of electromagnetics in combination with Fourier transform techniques are used to formulate a three-dimensional scattering problem. A perfectly conducting circular cylinder of infinite extent is shielded partially with a homogeneous dielectric bead. Exact interior eigenfunctions are utilized as whole-body expansion functions in the moment method formulation of the scattering problem. Exploiting the natural internal modes in the moment solution results in a significant reduction in the number of unknowns and ultimately a marked computational advantage. Numerical results pertaining to the interior EM fields and the convergence properties of the series expansions are presented. Effects of the dielectric coating on the backscattered field as well as bistatic scattering are also studied [C878]

## "Cross-polarized power returned from a random surface: application to the rough sea surface"

Summarizes the scattering properties of a rough surface as a function of observation parameters, physic and geometric characteristics of the surface. This study is applied to the oceanic surface. Results are presented in the form of polarimetric signature as a function of the transmitter location and receiver location for a bistatic

radio-link over the rough sea surface. The like- and cross-polarized received power are directly calculated using the scattering coefficients, without calculating the Mueller matrix. The Kirchhoff model and the small perturbation method are applied to determine the scattering coefficients. The polarization states, obtained for the minima and maxima received power in order to increase the performance of a bistatic radio-link, or to improve the discrimination power of a radar target are investigated. It is observed that for a fixed transmitter location and receiver location it is possible to choose a polarization state minimizing the scattered power from a rough sea surface, independently of the sea state. An electromagnetic wave scattered from a target is a vectorial quantity containing polarimetric information. This information is a function of the target, and also depends on the observation parameters. The purpose of this paper is to present, the polarimetric signature of the rough sea surface in order to increase the performance of a bistatic radio link (decreasing fading effect, for example), or to improve the discrimination power of a radar target or to identify a target [C879]

## "Polarimetric enhancement of pol-SAR imagery applied to JPL-AIRSAR polarimetric image data"

Radar polarimetry (the full utilization of EM vector wave information) has become an indispensable tool in terrain imaging technology. Polarimetric imaging (polarization filtering) has been carried out by many investigators. Boemer's group developed the polarimetric-filtering principle for both coherent and incoherent cases using the polarization ratio and Stokes vector formulations. The CAL-TECH/JPL(NASA) group applied the principle based on the Stokes vector formulation to the imaging of polarimetric SAR data acquired at NASA JPL. Touzi et al. proposed a filtering technique for SAR images for reducing speckle. Swartz et al. and Boerner et al. solved the problem by using a decision-theoretic covariance matrix approach. Although many other approaches are available for polarization filtering, the distinct radar channel formulation is used, i.e., either the matched, the co- or cross (X)-polarization channel. This paper applies the principle to SAR imagery for these three possible polarimetric radar channels and compares the resultant imagery. The radar channels considered are co-pol, x-pol, and matched-pol. channels [C880]

## "An application example of Cloude approach in radar polarimetry"

Polarimetric radars provide a complete information on the scattering matrix of observed targets. In remote sensing applications, where the targets are random, the Stokes parameters and associated Mueller matrix are the most used tools. Among the various methods proposed for extracting the information, the target vector and its associated covariance matrix appear quite promising. It is applied in this article to data collected over the Freibourg test site, with the JPL airborne SAR, during the MAESTRO campaign of 1989 in Europe. [C881]

## "Radar target decomposition theorems and unsupervized classification of full polarimetric SAR data"

Classification of Earth terrain components within a full polarimetric SAR image is one of the most important applications of radar polarimetry in remote sensing. An original unsupervised classification procedure, based around neural networks with competitive architecture, is proposed in this paper. This process, based on the study of the sensitivity of the synaptic coefficients of the network, is applied to the full polarimetric SAR images of San Francisco Bay (NASA/JPL 1988) for segmentation and clustering of different Earth terrain components. Then, an identification procedure, based on polarimetric decomposition theorems is presented from which a new approach to the interpretation of different scattering mechanisms is obtained after clustering. [C882]

## "Target decomposition theorems applied to multiple scattering of polarised waves"

Recent SAR observations of polarised backscatter from the Greenland Ice sheet have shown anomalous behaviour (Rignot, 1993), with several features in common with earlier earth based radar observations of the icy Galilean satellites (Ostro, 1990). In particular, the observed circular and linear polarisation ratios are much higher than those observed for any other type of natural scattering mechanism and this, combined with a larger than expected reflectivity, has set a challenge for the modelling community. A common feature of all feasible models is the assumption of wave propagation in low loss but highly anisotropic media. This implies that the observed radar signal is the result of many scattering events, each of which is polarisation dependent. That any polarisation structure survives such averaging is indeed surprising but is entirely consistent with recent analytical and numerical studies of enhanced backscatter or weak localisation in random media (Mishchenko, 1993). The present author proposes a probabilistic Target Decomposition (TD) theorem based on eigenvector analyses of the observed coherency matrix. This the author suggests provides a unified framework in which to investigate the polarisation properties of such anomalous behaviour. After outlining the main features of the polarimetric observations the key features of the target decomposition are briefly summarized approach and applied to a simplified model of multiple scattering from low loss particles. In this way a probabilistic model is proposed for the study of depolarisation effects in random media problems. [C883]

## "Polarimetric modeling and parameter estimation with electromagnetic vector sensors"

The authors analyze two polarimetric models in which the complete electromagnetic field is measured. The first model considers estimation of the polarimetric response of a surface by measuring the reflections of actively generated plane waves. The second model considers estimation of the polarization of passively generated plane waves. In both models the authors provide a natural parametrization of the distribution of the received electromagnetic signal. Using the Cramer-Rao bound on the variance of unbiased estimates of the parameters, they show that this parametrization, which has a simple geometrical interpretation, also has good statistical properties. These models are fitted into a common framework and are compared. [C884]

## "Optimum polarizations for radar meteorology"

Specular null polarization theory has recently been introduced for the case of coherent scattering where a 2Ч2 scattering is sufficient to describe the scattering process (Hubbert, 1994). In this paper specular null polarization theory is extended to the case of incoherent scattering. Optimum polarization states are derived and the results are discussed in relation to the established radar optimum polarization states. Modeling of ensembles of precipitation particles using the transition (T-) matrix approach is used to illustrate the results of the analysis [C885]

## "Studies of large scale random rough surface problems with the sparse-matrix flat-surface iterative approach"

Scattering of the TE incident wave from a perfectly conducting random rough surface is studied. First, the vector electromagnetic scattering from a two-dimensional rough surface with a surface area of 81 square wavelengths is illustrated. Monte Carlo results show backscattering enhancement for the co-polarized component. Secondly, the TE scattering from a one-dimensional random rough surface with a Gaussian roughness spectrum is studied. Specifically, a grazing incident angle at 86° with a surface length of 800 wavelengths is presented. Lastly, backscattering intensities from Gaussian and non-Gaussian rough surfaces are compared. Numerical results are illustrated as a function of rms height and slope [C886]

## "Polarimetric radar discrete scatter model of vegetation"

A microwave bistatic scatter model which predicts the scattering matrix (or Mueller matrix) is developed by using the discrete modelling technique for the vegetation. Vegetation is modelled as a random collection of scatterers. Leaves are modelled by a circular disc and branches are modelled by a circular cylinder. The modelling procedure assumes that the fractional volume of the plant material is small. The matrix of the polarimetric bistatic scattering coefficients is derived by employing the distorted Born approximation and the result is valid for the P-, L-, and C- band SAR frequencies [C887]

## "A method of range-polarization reconstructing of radar target and its application in target recognition"

A novel method of two dimensional reconstructing of radar target under strong clutter background is presented for target recognition application. In this method, the wide-band FMCW technology and orthogonal polarization signal processing technology are used. A matrix computation based signal processing method is proposed to obtain radial range dimensional superresolution and to obtain each polarization scattering matrix (PSM) of the every strong scattering center of radar target. Then the relations between geometrical features of canonical scattering centers and the polarization descripter are established by using degraded PSM matching classification algorithm. The range profile with signs of polarization description is called two dimensional range-polarization imaging and it is helpful for target recognition [C888]

## "Development of polarimetric vector signal and tensor image processing in wideband interferometric POL-RAD/SAR signature analysis"

Based on the complete transmission versus scattering matrix description and the availability of the associated sets of four distinct matrices, vector signal (PMSF) and tensor image (PMIF) signature processing algorithms are introduced for the optimization of useful target versus clutter ratios. The usefulness of implementing the "Optimal Polarimetric Constant Enhancement Coefficients (OPCEC)" into the PMSF/PMIF formulations is verified. It is shown how these concepts can be applied in the extrawideband multi-spectral polarimetric sensing and imaging for Optical Image Feature Extraction (OPIFE) in "Wideband Interferometric Sensing and Imaging Polarimetry (WISIP)" with applications to wide area surveillance of the terrestrial and planetary covers. [C889]

## "A new extended target decomposition scheme"

The conventional decomposition from a distributed target is to seek a solution of average single target MT, which preserves symmetry parameters A0, C, and D and a part which consists solely of non-symmetric parameters B0T-BT, ET, and FT. These parameters with index T are determined easily from four equations. The novel feature is to create a variable A0Tin addition to the four non-symmetric target parameters of the old scheme. The new variable A0Nextracts out of the general symmetry-preserving A0a special target variable A0T, such that A0=A0T+A0N. The A0Tnow becomes part of the average single target parameters: A0T, B0T, BT, C, D, ET, FT, G, and H. In this scheme C, D, G, and H, the target symmetry and coupling parameters, are still preserved intact. What is new in the scheme is A0Twhich before was A0, "the generator and preservator of target symmetry". It is kind of ironic that the "symmetry-preserving" generator A0itself is not preserved in the new scheme, but is split into A0Tand A0N! That was why this new decomposition took so long in coming to development. The physical interpretation of the new scheme is a decomposition of the distributed target into a single average target MTand an N-target (N here standing for non-symmetry) and a background cloud of spherical particles. The C, D, G, and H still are preserved intact but the symmetry generator A0is split, one part A0Tcontributing to the average single target MTand one new part A0N(N stands for new here!) forms a background cloud of elementary spheres. An example is shown consisting of a cloud of dipoles being averaged into a single dipole, a non-symmetrical N-target, and a new background cloud of elementary spheres, determined by A0N. [C890]

## "Analysis of scattering from rough surfaces at small grazing angles using a periodic-surface moment method"

The moment method is used to calculate electromagnetic backscattering from one-dimensionally rough surfaces at near-grazing incidence (angles of incidence up to 89°). A periodic representation of the scattering surface is used to prevent edge effects in the calculated scattering without the use of an artificial illumination weighting function. A set of universal series common to all elements of the moment interaction matrix are derived that allow the inclusion of an extremely large number of periods in the surface description with only a slight increase in computation time. The scattering from surfaces with Gaussian roughness spectra and various roughness scales is calculated at both horizontal and vertical polarizations and compared with the theoretical predictions of the small-perturbation model (SPM) and Kirchhoff approximation (KA). SPM yields extremely accurate predictions of the horizontal-polarized backscattering from small-scale surfaces at incident angles up to 89°. At vertical polarization micro-shadowing causes a rapid drop in the scattering at large incident angles that is not predicted by SPM. KA provides accurate estimates of the scattering from large-scale surfaces at incident angles up to 83° at horizontal polarization and up to 70° incidence at vertical polarization. Surface shadowing becomes important at higher incidence angles, rapidly decreasing the validity of the Kirchhoff approximation. Compensation for surface shadowing decreased the accuracy of the Kirchhoff approximation [C891]

## "Polarimetric backscattering signatures from thin saline ice under controlled laboratory conditions"

The authors carried out an experiment to measure polarimetric backscattering signatures from thin ice at the US Army Cold Regions Research and Engineering Laboratory. The purpose of the experiment is to provide data for understanding scattering mechanisms in sea ice to develop models relating polarimetric signatures to physical, morphological, and electromagnetic properties of sea ice. Saline ice was grown in an indoor pit with the air temperature kept about -20°C to simulate the cold arctic condition. During the ice growth, a C-band polarimetric scatterometer was used to acquire backscattering matrices as functions of incident angles for ice thicknesses up to 12 cm. Moreover, the authors investigated polarimetric signatures of thin ice under various modified conditions including frost flower, ice warming, surface flooding, and slush layer. Ice characterization parameters and samples were collected to relate ice properties to the microwave polarimetric signatures [C892]

## "Scattering by dielectric filled grooves using a combination of higher order impedance boundary conditions and edge conditions"

In this paper higher order impedance boundary conditions, (HOIBC), are used in combination with edge conditions to solve the problem of scattering by a two dimensional dielectric filled groove in an infinite ground plane. This object can be used to model a perturbation in an otherwise homogeneous large conducting body such as hatches, ports, and seams between panels. The conducting boundary of the groove is of arbitrary shape, and the dielectric filling the groove is assumed to be comprised of discrete layers oriented parallel to the ground plane. Higher order impedance boundary conditions which are determined using a spectral domain method, are applied to the problem of scattering by multilayer grooves with arbitrary profiles, and the effects of discontinuities on the boundary conditions, i.e. sharp corners, are addressed by incorporating the proper edge conditions. Monostatic and bistatic RCS results will be compared to those from an exact solution which is based upon a mode matching/scattering matrix approach for the interior region [C893]

## "Edge-based finite element analysis of singly- and doubly-periodic scatterers using absorbing and periodic boundary conditions"

The versatility of the finite element and finite difference techniques in modeling complex material geometries and the ease of code development make them attractive choices for analyzing many configurations of practical interest. In this paper we describe our efforts in developing an edge-based FE code using a simple finite element mesh consisting of orthogonal but nonuniform bricks to predict the scattering characteristics of both periodic and aperiodic structures. Useful insights into the power and weakness of the FE method, gained during the course of our numerical experiments, are provided. While the ABC-based FE method is conceptually simple, to-date its application to the analysis of periodic structures has not been reported in the literature [C894]

## "Efficient 3-D RCS prediction technique for steps and grooves on an arbitrary shaped surface"

The objective of the paper is to develop an accurate and efficient three-dimensional (3-D) analytic solution for predicting the radar cross section (RCS) of steps and grooves on an arbitrary shaped surface utilizing available two-dimensional (2-D) analytic or numerical solutions. It describes an efficient computational technique, which is referred to as the uniform field integration method (UFIM), to predict accurate 3-D backscattering or bistatic RCS levels from steps and grooves on an arbitrary shaped surface utilizing simple 2-D scattered field formulations. The grooves can be either a conducting or dielectric filled slab which is embedded in a ground plane. This technique utilizes a simple geometrical deformation of the piecewise continuous contour on the scattering object so that the available 2-D scattered field formulations can be directly applied. The essential feature introduced is that one can represent a piecewise continuous contour in the limiting case by a series of stairs where the stair step approaches zero and an analytical evaluation is used to carry out the line integration [C895]

## "Ray mode coupling analysis of EM wave scattering by a partially filled trough"

In this paper, a high frequency asymptotic ray technique has been applied to analyze electromagnetic plane wave scattering by a partially filled trough. In the formulation, the modal description has been retained inside the waveguide region. Coupling between the waveguide modes and coupling between modes and rays at the aperture are treated systematically by using matrix form. Though multiple diffraction effects are included here, we also need to consider the radiation contribution from evanescent modes. This can be a considerable amount when the width of the aperture gets very narrow, and only very few modes become propagating ones in the parallel plane waveguide region [C896]

## "Scattering by a material filled groove using cavity mode impedances"

Scattering by a 2-D trough in an infinite conducting ground plane may be formulated using integral equations, impedance boundary conditions, and mode coupling to cylindrical harmonics. An efficient technique requiring no matrix inversions is developed here for the case of a rectangular groove containing homogeneous isotropic material defined by complex εrand μr. Although the formulation is based upon a large aperture approximation, it has been found to provide accurate results for apertures as small as 1.25λ0 [C897]

## "Doa Estimation of Point and Scattered Sources-Vet-Music"

First Page of the Article [C898]

## "SAR imaging via spectral estimation methods"

This paper discusses the use of modern 2-D spectral estimation algorithms for SAR imaging. We provide a synopsis of the algorithms available, and discuss their relative merits for SAR imaging. SAR data collected of two commercial ships is used to compare the characteristics of imagery produced by a variety of 2-D spectral estimators [C899]

## "Optimum Costas-like decompositions of Costas arrays for channel characterization and communications"

In the paper we show that any subset or decomposition of Costas arrays are themselves non-full Costas arrays with ideal auto-, and cross-ambiguity and multiple access properties. The decomposed waveform's “thumbtrack” like auto-ambiguity functions, and their low cross-ambiguity or mutual interference would make them applicable in various multiple access and/or communication systems. The original Costas array and its subsets can be used individually in a matched filter receiver. Also for the single transmitted Costas array we can obtain several channel responses by generating and using several different subsets. The post processing can combine them in

a semi-coherent processing scheme or as abutted waveforms for new techniques which require two waveform to provide enhanced range-Doppler resolution and reverberation rejection [C900]

## "2-D polarimetric imaging by an FM-CW radar"

Radar polarimetry, i.e., the full utilization of vector nature of electromagnetic wave information, has become an indispensable tool for advanced radar systems. If the principle of radar polarimetry could be incorporated into a wideband FM-CW radar, it would become a highly advanced imaging system in the short range region, since the FM-CW radar utilizes the continuous wave principle for which the range resolution is determined by the frequency resolution. It also has the potential for precisely measuring distances in the near range with considerably simple equipment compared to pulsed radar systems. This paper applies the principle of radar polarimetry to a synthetic aperture FM-CW radar and presents a two-dimensional (2-D) full polarimetric imaging result of linear targets. It is shown that the polarimetric target reflection coefficients obtained by the synthetic aperture FM-CW radar act as elements of the Sinclair scattering matrix, although the coefficient is derived by a wideband signal. Using the scattering matrix optimization procedure, a 2-D polarimetric imaging experiment of an orthogonally placed linear target set was successfully carried out in a laboratory at a frequency of 8.2-9.2 GHz [C901]

## "A finite element-modal technique for scattering by complex 3-D cavity terminations and code parallelization"

The simulation of radar scattering from 3D cavities with complex terminations is an important step towards the characterization of many aircraft structures. The authors describe the FEM-modal method, and the role of the modal scattering matrix for interfacing the FEM and ray/modal fields at a connection boundary in a 3D cavity configuration. The authors discuss implementation issues of the FEM technique including shape functions, application of boundary conditions and truncation of the FEM mesh at the open end through the use of an optimized, fictitious, material absorber. Computational gains from parallelization of the FEM code are emphasized, and the authors discuss a parallel sparse iterative linear system solver. The extension of this parallel solver to fully exploit the geometric symmetry in angularly periodic fan-like terminations (such as a jet engine face) is also addressed. Results are presented which validate the proposed hybrid FEM-modal method and show the utility of an artificial absorber for terminating the FEM mesh [C902]

## "Reduced representation of matrices generated by the method of moments"

In this paper, an algorithm is presented that accelerates the iterative solution of boundary integral equations. The matrices generated in the MoM discretization of boundary integral equations exhibit special properties, which are exploited in the proposed algorithm. In fact, the algorithm does not require the computation of the entire MoM matrix, but, rather, only calls for the computation of a judiciously selected, small set of elements of the original matrix. As a consequence, the algorithm can easily be incorporated into existing MoM codes. We show that knowledge of the set of elements suffices to compute the product of the dense MoM matrix and a trial solution vector. A single-stage version of the algorithm reduces the computational cost of a matrix-vector multiplication from O(N2) to at least O(N1.5), and a multi-stage version further reduces the cost, in principle, to O(NlogN). The proposed algorithm is motivated by the fact that the fields in an observation domain due to sources in a `well separated' source domain can be represented in terms of the fields radiated by a reduced set of equivalent sources. The number of sources in the reduced set is directly related to the number of degrees of freedom (DOF) of the field radiated by the original set in the direction of the observation domain. The algorithm exhibits similarities with the multilevel algorithm proposed by Brandt (1991) [C903]

## "A detailed study of the backscatter characteristics of snowcover measured at 35, 95 and 225 GHz"

Presents 35, 95 and 225 GHz polarimetric backscatter data from snowcover. It compares measured backscatter data with detailed in situ data measurements of the snowcover including microstructural anisotropies within the snowpack. Observations of radar backscatter at 35, 95 and 225 GHz were made during melt-freeze cycles, and measurable differences in the normalized radar cross-section (NRCS) between older metamorphic snow and fresh low density snow were observed. In addition, the authors' polarimetric measurements show that the average phase difference between the co-polarized terms of the scattering matrix, S vvand Shh, is nonzero for certain snow types. These measurements are explained by the effects that the microstructure of the snow has on propagation within the snowpack. A simple vector radiative transfer model that includes the propagation effects is seen to predict the Mueller matrix for dry snowcover reasonably well [C904]

## "Efficient speckle filtering of SAR images"

A new promising method of speckle filtering is described and applied to both, synthetically generated and real

SAR-images. The new method, which the authors call EPOS (Edge Preserving Optimized Speckle-filter), is based upon the statistical properties of speckle noise. The knowledge of speckle variance allows the distinction of homogeneous areas from those, containing edges or single scattering targets. This discrimination method is used within a variable sized filter matrix to choose a region, which is suitable for calculating an intensity average, that is typical for the center pixel. Also a method for estimating speckle noise parameters is presented [C905]

## "Monostatic polarimetric calibration via target spinor"

A new polarimetric calibration method is proposed based in the scattering matrix decomposition, via Pauli matrices, which works with target spinor instead of the scattering matrix. The base elements of target spinor are the target spinor corresponding to the usual calibrators like sphere, dihedral and 45° rotated dehedral. This fact allows the error coefficients to be calculated by a direct and easy way. This paper shows experimental results obtained from measurements of a metallic sphere carried out in a compact range using TSC (target spinor calibration) [C906]

## "Backscattering from sea ice with vertical structural variation: a model analysis"

Based on the matrix doubling method, a sea ice scattering model which accounts for the effects of vertical structural variation is developed. The sea ice layer is modeled as many sublayers with different physical characteristic determined by the vertical structural variation profile. Each sublayer is assumed to be statistically homogeneous. In addition to the effects of vertical structural variation, the developed sea ice scattering model also accounts for the effects of scatterer close spacing and rough top and bottom layer boundaries. Model verification has been carried out using measurements from well characterized sea ice. Preliminary model analyses are carried out for saline and desalinated ice. In the saline ice case, better salinity profile sensitivity is observed at 5 GHz than at 10 GHz. On the desalinated ice case where the scatterers are air bubbles, the sublayer with larger scatterers dominates the back scattering level even though its thickness is less than 1/10 of the signal penetration depth [C907]

## "Statistical models for polarimetric SAR data"

Agricultural areas in low resolution AirSAR polarimetric data exhibit K distributed statistics. The order parameter of the K distribution shows considerable variation with frequency and vegetation type. At C-band, all vegetation types give large order parameters, so that they are essentially gaussian, but order parameters decrease with frequency, markedly so for cereal crops. Coniferous woodland is gaussian at all frequencies. Root crops show intermediate behaviour, being better fitted by K distributions whose order parameters are not as low as those of cereals. These results indicate that five parameters are sufficient to describe distributed agricultural targets at higher frequencies, but an extra parameter is available at lower frequencies [C908]

## "K-distribution for multi-look processed polarimetric SAR imagery"

A K-distribution has been developed to characterize the statistical properties of multi-look processed polarimetric SAR data. The probability density function (PDF) was derived as the product of a gamma distributed random variable and the polarimetric covariance matrix. The latter characterizes the speckle and the former depicts the inhomogeneity (texture). For multi-look data incoherently averaged from correlated one-look samples, the authors found that, for better modeling, the number of looks has to assume a non-integer value. A procedure was developed to estimate the equivalent number of looks and the parameter of the K-distribution. Experimental results using NASA/JPL 4-look and 16-1ook polarimetric SAR data substantiated this multi-look K-distribution. The authors also found that the multi-look process reduced the inhomogeneity and made the K-distribution less significant [C909]

## "Proceedings of IEEE Antennas and Propagation Society International Symposium and URSI National Radio Science Meeting"

The following topics were dealt with: wavelets in electromagnetics; reflector antennas; computer based engineering education; digital beam forming and clutter suppression; random media; electromagnetic theory; antenna measurements; microstrip antennas; mobile antennas; parallel computing and modeling; absorbing boundary conditions; EM scattering problems for complex structures; multilayer microstrip antennas and surface wave suppression; array theory and analysis; near field measurements and analysis; neural networks; high frequency techniques; radar cross sections; materials characterization and heating; numerical techniques; microstrip and planar antenna elements; active and phased arrays; space antennas; reflector feeds; mobile satellite communications; discontinuities in guided wave structures; rough surface scattering; TLM methods; microstrip circuits and coupling techniques; broadband antennas; atmospheric propagation; multilayered media;

hybrid methods for scattering; realizations and applications of soft and hard surfaces; microstrip array analysis; adaptive antennas; polarimetric radar; inverse scattering; microstrip discontinuities and components finite element method in electromagnetics; FDTD methods and applications; microstrip array design; mobile propagation; waveguide structures; microwave and radar imagery; space systems antennas; finite difference methods; frequency selective surfaces; 3-D method of moments; slot antennas and ground effects; integral equation methods; tomography, Born approximation, and source identification [C910]

## "3D method of moments scattering computations using the fast multipole method"

The fast multipole method (FMM) dramatically reduces the time and memory required to compute radar cross sections and antenna radiation patterns compared to dense matrix techniques. We have implemented the FMM in a method of moments (MoM) program to compute electromagnetic scattering from large bodies of arbitrary shape. We compare the memory and time required using the FMM to that for direct and iterative solutions using a dense impedance matrix [C911]

## "The use of polarimetry in subsurface radar"

Extraction of target information from the measurement of the state of polarization of the scattered wave has been a promising area of research for a number of years. This paper discusses the theory and implementation of a stepped frequency CW polarimetric subsurface radar. The extended Prony method is used to obtain high resolution range profiles from which the scattering matrices are extracted. The results of laboratory trials are presented. These include measurements of the scattering matrix for a pipe and plate conducting targets, buried in a large sand box. Polarization responses for these targets are plotted to emphasize the use of the scattering matrix for target discrimination [C912]

## "Backscatter Mueller matrix elements for irregular stratified media"

Full wave solutions are presented for electromagnetic waves scattered from irregular stratified structures consisting of three media. These solutions are expressed in terms of the Mueller (phase) matrix. The Mueller matrix relates the scattered Stokes vector to the incident Stokes vector. The authors consider the case in which the uppermost interface (facing the source) is a random rough surface. In addition to scattering and depolarization upon reflection, the incident wave also undergoes scattering and depolarization upon transmission across the rough interface. The six independent backscatter Mueller matrix elements are presented as functions of the incident angle for isotropic random rough surfaces with different toughness parameters. These Mueller matrix elements can be used to select the optimum backscatter angle and the wavelength that could be used to remotely detect the presence of coating materials deposited upon flat substrates [C913]

## "Retrieval of storm microphysics using Ka band radar observations"

Polarimetric radar measurements can be used to deduce the shape and orientation of non-spherical scatterers in the Rayleigh scattering regime. At Ka-band and for larger sized particles, Mie scattering effects dominate by introducing oscillations in differential backscattering parameters. Albeit at these frequencies deducing the mean shape of non-spherical scatterers might be difficult, radar backscattering signatures like the linear depolarization ratio (LDR), differential propagation phase (KDP) and co-polar cross-correlation coefficient provide information about the thermodynamic phase state of the scatterers. Tumbling non-spherical particles such as graupel and hail, exhibit enhanced depolarization characteristics which can be used to delineate regions of ice, melting-ice and rain. Additionally, forward scattering parameters such as attenuation and differential attenuation between H and V polarized waves display monotonic increase with the size of the scatterer. Polarimetric radar modeling of hydrometeors such as graupel, hail and rain at 35 GHz (Ka-band) based on the Mueller matrix formulation is presented. The various transitory thermodynamic phase states of ice hydrometeors have also been incorporated in the modeling. In the Rayleigh regime scattering parameters such as differential reflectivity and LDR are used to investigate the feasibility of deducing the mean axis-ratio and spread in the canting angle distributions of these types of hydrometeors. The modeling results could be applied to understand and interpret LDR signatures recorded by airborne radars with vertical incidence [C914]

## "A dielectric measurement technique for cylindrical objects with known cross section"

Motivated by the need for an accurate method to measure the complex dielectric constant of pine needles at microwave frequencies both in situ and in vivo conditions, the problem of scattering from a dielectric post in a rectangular waveguide is considered. In this analysis, the dielectric post is assumed to be uniform in cross section and dielectric constant and is placed vertically in a rectangular waveguide supporting TE10mode. The dielectric constant is computed from the measured voltage reflection coefficient of a matched waveguide containing the dielectric post. The author describes an inversion algorithm for computation of dielectric constant ε

from the reflection coefficient which is based on the method of moments and eigen analysis. In this method the integral equation for the polarization current induced in the dielectric post is cast into a matrix equation and then the contribution of ε to the resulting reflection coefficient is expressed explicitly using the eigen analysis. It is shown that the dielectric constant is a solution to a complex polynomial function which can be obtained numerically using the conjugate gradient method. Practical aspect of dielectric measurement using this technique is discussed. The HP-8510 network analyzer is used to measure the reflection coefficient of dielectric posts in an X-band waveguide sample holder. Metallic and known dielectric posts are used for both S11calibration and validation of the dielectric measurement technique [C915]

## "A simplified calibration technique for polarimetric radars"

Polarimetric imaging radars require accurate calibration of channel imbalance and cross-talk to provide meaningful data. Current calibration techniques, which depend on ground-based reflectors or active radar transceivers within a scene, are labor intensive and sensitive to target orientation. This paper presents a new technique for performing calibration that simplifies the calibration process and minimizes the use of ground-based calibration targets. The technique is applicable to both airborne and spaceborne imaging radar systems [C916]

## "The Mueller matrix in radar polarimetric measurements"

Two different operators are used in radar polarimetry: the first one relates the Stokes parameters of the scattered wave to those of the incident wave while the second one provides the expression of the power received by the radar, given the polarization characteristics of the receiving antenna. Some confusion exists in the literature between these two operators, and their properties of symmetry for the backscattering case. This paper is a plea for a clear distinction to be maintained, and for some agreement on denominations and notations [C917]

## "Development of `Optimal polarimetric contrast enhancement coefficients: OPCEC' for the analysis or depolarization due to rain, ice and surface scatter utilizing POL-RAD and POL-SAR measurements"

In order to fully analyze depolarization effects of various kinds of surface and volumetric scatterer ensembles both the coherency and the stochasticity of the scatter returns need to be optimized. This is achieved, first by solving the eigenvalue and optimization problems for the scattering matrices [S(AB)],[G(AB)], [C(AB)], [M] and [K] from which the optimal (characteristic) polarization states are derived; second, by optimizing the stochasticity expressions (degree of coherency and polarization) and by equally or more importantly devicing the exact and correct expressions for the enhancement of the 'optimal contrast' between two (or more) classes of scatterer ensembles. In general, two distinct classes of scatterers may be defined as T' and 'C', where T defines the desirable (useful) scatterer, the target: T, and 'G' the undesirable scatter ensemble, the clutter 'G', against which T is to be discriminated or to be optimally contrasted. The formal development of the related 'OPCEC' expressions associated with a specific matrix description in terms of either [S], [G], [Σ], [K] and/or any combination of such is addressed in this presentation. The formal solutions of various 'OPCEC' expressions for [S], [G], [4, [M] and [K] are presented and the obtained canonical results are compared [C918]

## "Backscattering from forest canopies over slanted terrain"

A model based on the radiative transfer formulation has been modified to account for the effects of the terrain slope on the total backscattering return from a forest canopy. To the first-order, the forested area may be modeled as a plane parallel forest but over a slanted ground plane. Thus the phase matrix for the volume scattering from any forest component remains the same as that of the same forest component over a flat ground plane. But the phase matrices for the canopy-ground interaction and direct ground scattering are different. This approach gives simple and intuitive view of the problem and helps to identify the important scattering elements. It is shown that the overall effect of the terrain slope is dependent on frequency, incident angle, and polarization. In the cases of P-band, and for small look angles and VV polarization, the backscattering coefficient increases as the ground tilts towards the radar. On the other hand, for HH polarization, the backscattering coefficient is maximum when the slope is zero and decreases if the slope deviates from zero [C919]

## "AIRSAR and POLARSCAT cross-calibration using point and distributed targets"

It has become common practice over the past few years to use point calibration targets with known scattering properties as a means for calibrating imaging SAR systems. The calibration accuracy associated with this approach is vulnerable to two sources of error. The first is related to the linearity of the system transfer function. To meet the required high signal-to-clutter ratio, the point calibration targets are designed to have a very large

radar cross section, which places the return from such targets in the extreme upper part of the system's dynamic range. In contrast most terrain targets produce returns in the lower part of the system's dynamic range. Nonlinearities between the lower and upper segments of the system transfer function will translate into a calibration bias error. The second error source is related to the calibration algorithm itself, namely the fact that “point” targets are used to calibrate radar intended for measuring “distributed” targets. To evaluate the SAR calibration accuracy, a cross-calibration experiment was conducted involving the JPL AIRSAR and the University of Michigan's truck-mounted polarimetric scatterometer (POLARSCAT). The experiment was conducted at a test site near Pellston, Michigan. Two calibration algorithms were used with the SAR. The first was based on the responses from trihedral corner reflectors that had been deployed in the field. The second algorithm was based on the responses from distributed targets (bare soil surfaces, short grass, and tall grass fields) whose Mueller matrices were accurately measured by the calibrated polarimetric scatterometer. The results of this study demonstrate that calibrating a SAR using distributed targets is inherently a more accurate process [C920]

## "Comparison of optimization procedures for radar/lidar scattering matrices: a unified radar/lidar inversion approach"

The basic principles of radar polarimetry are introduced and various optimization procedures for the propagation (scattering) range operator equation and the received power voltage expressions are presented and compared [C921]

## "Comparison of radar polarimetric and lidar scattering matrix measurements and systems calibration methods"

A systematic approach to the measurements of the four basic scattering matrices used in radar and also recently more frequently in lidar metrology of isolated scatterers and distributed scatter ensembles is considered. The pertinent scattering matrices in use are the 2Ч2 complex JONES propagation matrix [T] or the 2Ч2 complex Sinclair scattering matrix [S] for the coherent point scatter case; the 2Ч2 complex radar power GRAVES matrix [G]=[S] [S] for the coherent case; the 4Ч4 real power density Mueller propagation matrix [M] or the 4Ч4 real power density Kennaugh scattering matrix [K] and the 3Ч3 symmetric (4Ч4 asymmetric) case covariance matrix [Z] for the partially polarized cases, which all are distinct but can be related to one another. The authors provide a comparison of polarimetric methods. Measurement made with respective radar and lidar systems are compared with specific applications for assessing EMC noise and clutter signatures. This study shows that the covariance matrix provides the greatest utility [C922]

## "On radar polarimetry in FM-CW radar"

This paper attempts to apply the principle of radar polarimetry to wideband synthetic aperture FM-CW radar and presents a basic polarimetric detection result of a linear target in a laboratory measurement. Although the principle of radar polarimetry has well been established for the completely polarized wave and for the monostatic case, it still needs to be extended to wideband radar system. The FM-CW radar utilizes a wideband signal and the resultant beat signal whose frequency is proportional to range is different from the scattered wave in pulse radar. This paper points out that the Fourier transformed complex beat spectrum obtained by an synthetic aperture FM-CW radar acts like an element of the scattering matrix which plays the most important role in polarimetric imaging. The fact was verified by a polarimetric detection in a laboratory, demonstrating the validity of FM-CW radar polarimetry and indicating an establishment of a full polarimetric and synthetic aperture radar system [C923]

## "Analysis of speckle filtering in polarimetric SAR imagery"

The principle of speckle reduction in polarimetry is reconsidered. It is shown that polarimetric data can be speckle reduced if and only if all the elements of the Mueller matrix are filtered, which is equivalent to filtering the scattering vector covariance matrix. Assuming that speckle is multiplicative and stationary, the method proposed by Goze et al. (1993) is extended to filter the covariance matrix of reciprocal and non-reciprocal targets on one-look and multi-look images. The usual methods of estimation of the first and second order speckle statistics are discussed, and a solution is proposed for one-look and multi-look images [C924]

## "Scattering from a three-dimensional dielectric hump above an impedance surface"

A numerical solution of the scattering problem of a three-dimensional dielectric object above an impedance surface is sought. First, the dyadic Green's function of the problem which is amenable of numerical calculation is derived using an integral transformation. Then, the integral equation for the polarization current is cast as a matrix equation by employing the method of moments. Numerical results are presented [C925]

## "A method for polarimetric contrast optimization in the coherent case"

The authors consider the problem of optimizing the polarimetric contrast between two targets or target and clutter for the coherent bistatic case. It is assumed that the scattering matrices for the target and clutter are known a priori. The objective is to use this information to find ways to achieve optimal signal contrast. The proposed method is applicable when one has to fix the receiving and transmitting polarizations. To validate the method the authors have compared the received power after maximizing the contrast power ratio due to different objects with known scattering matrices, and compared it with the attainable maximum [C926]

## "Scattering by coated bodies of revolution using higher order impedance boundary conditions"

Higher order impedance boundary conditions (HOIBCs) are applied to three-dimensional dielectric coated bodies of revolution (BOR). Differential equations describing the HOIBC which are based on a locally planar approximation, must first be transformed onto the double curved body of revolution. These equations are then solved along with a standard integral equation to obtain either the monostatic or bistatic radar cross section for the coated BOR. Since the Fourier series expansion of the currents is still applicable to the HOIBC solution, all of the advantages of the standard BOR formulation are retained, along with a reduction in the total number of unknowns required in the solution [C927]

## "An array processing algorithm for reconstruction of distributed targets in incompletely defined correlated noise"

An algorithm for the extraction of Gaussian noise of unknown spatial correlation from data received from distributed targets at an arbitrarily configured array is developed. Knowledge of the sampling procedure is used to build a basis set representation of a spectrum constrained only by the condition that it be bandlimited. By adopting maximum a posterior (MAP) criteria it is shown that it is possible to optimally remove noise of unknown correlation from this spectrum. An application of this technique is the problem of identifying point targets in sea surface clutter environments. In this case, it is common that some knowledge is available about the noise correlation, but that this knowledge is often incomplete. This prior knowledge is used to develop a new class of objective functions that can be optimized to significantly enhance the resolution attainable through application of the conventional MAP approach [C928]

## "An overview of high-resolution spectral estimators for range-Doppler imaging"

Modern spectral estimators based on parametric and nonparametric models are widely used to enhance the resolution of target range profiles, Doppler profiles and range-Doppler imagery. The authors review the different spectral approaches proposed in the open literature as applied to range-Doppler imaging. they then discuss some important problems yet to be resolved and the rationale of the high-resolution imaging approaches. In range-Doppler image formation, scatterer features are considerably enhanced via one-dimensional, hybrid two-dimensional, and two-dimensional spectral estimator techniques [C929]

## "The fast multipole method for electromagnetic scattering calculations"

A practical, but not rigorous, exposition of the fast multipole method (FMM) is presented. The FMM provides a sparse decomposition of the dense impedance matrix obtained by the use of the method of moments in the solution of boundary integral equations. The consequent reduction in computational complexity will allow accurate numerical modeling of far larger electromagnetic scattering and radiation problems than is now possible. An elementary derivation and physical interpretation of the FMM are given for three-dimensional electromagnetic problems [C930]

## "Current distribution on a convex-concave cylinder with impedance boundary"

Current distribution on a convex-concave cylinder with impedance boundary condition is investigated by a novel iteration method. The proposed method, combining the Toplitz transform and superrelax iteration, can deal with the problem of a 2-D electrically large body. It can determine the optimum parameter of radar absorbing film on the surface of a scattering cylinder to reduce RCS Numerical examples and experimental measurements are presented [C931]

## "Scattering computation using the fast multipole method"

The fast multipole method (FMM) computes scattering cross sections from large targets with several orders of magnitude reduction in the CPU time and memory storage compared to traditional method of moments (MoM) techniques. The authors compare the memory usage and CPU times for FMM with traditional MoM results using

both direct and iterative solvers. It is shown that dramatic reductions in CPU and memory requirements can be realized by using the FMM to compute scattering and radiation from large objects. In the test cases considered, 2D objects with perimeters longer than about 12 wavelengths required less memory than using traditional MoM techniques. Using the FMM to compute scattering from objects with perimeters larger than about 30 wavelengths required less CPU time than using iterative solvers with a dense Z matrix [C932]

## "Parallelization of a finite element code for 3D scattering"

The authors present the implementation details of a FE-ABC (finite-element absorbing boundary condition) code and describe the numerical considerations involved in optimizing this code. The linear equation solver and the sparse matrix generation were parallelized on the KSR1 (Kendall Square Research) shared-address space distributed-cache architecture with substantial speedup. Benchmarking was also done on the CM-5 (Connection Machine) with encouraging results. The parallel version of the FE-ABC code was run for a 1.5λ Ч 1λ Ч 1λ pec inlet and the monostatic radar cross section compared with measured data for HH-polarization [C933]

## "A finite element-boundary integral method for cavities in a circular cylinder"

The authors extend the FEM-BI (finite-element boundary-integral) method formulation for aperture antennas conformal to a cylindrical metallic surface. Formulas required for the computation of the matrix entries, excitation due to an obliquely incident plane wave, and the far-zone scattered field are given. To verify the accuracy of the finite elements used to discretize the cavity, the authors compare numerically computed resonant wavenumbers with their exact values. The percent error is within the expected bounds [C934]

## "Absorbing boundary conditions on arbitrary boundaries for the scalar and vector wave equations"

In order to minimize the size of the domain to be meshed and, consequently, the number of unknowns, it may be advisable to implement ABCs (absorbing boundary conditions) devised for outer boundaries of arbitrary shapes. Such ABCs are obtained for the 3-D scalar and vector wave equations. Most already published boundary conditions for the 2-D and 3-D problems are found to be particular cases of the ones presented here. The numerical implementation of these ABCs is particularly simple and, when used in conjunction with a finite element technique, they lead to symmetric matrices. The numerical results derived by using these ABCs compare favorably to those obtained by using a rigorous hybrid finite element-integral equation formulation [C935]

## "The effects of noise on polarimetric SAR data"

Polarimetric SAR data can provide a great deal of information about the scattering behavior of the surface under observation. Polarimetric SAR systems often measure the scattering matrices of the areas under observation in linear polarizations (H and V). From the scattering matrix commonly used forms such as the covariance matrix and the Stokes matrix can be easily derived. Other measures derived from polarimetric SAR data include correlation coefficients between scattering matrix terms and the mode and variance of phase differences between scattering matrix terms. The effects of additive system noise on these measurements is not often considered in the literature on this subject. In this paper, the effects of additive system noise on measurements derived from polarimetric SAR data are examined. It is shown how first-order noise effects can be removed and how second-order noise effects can be reduced for some measurements. Some commonly occurring characteristics of polarimetric SAR data which may be attributed to noise, such as the pedestal on a polarization signature, or a broadening in the distribution of the HH-VV phase difference over an area, or a reduction in the magnitude of a correlation coefficient, are identified. The appearance of azimuth ambiguities in polarimetric SAR data is also addressed [C936]

## "A new scheme for combining numerical and analytical methods for rigorous analysis of waveguide circuits"

A novel scheme is proposed for rigorous analysis of waveguide circuits which are composed of a number of discontinuities. The scheme combines numerical techniques with analytical techniques, such as the mode-matching method. For a general complicated segment of the waveguide circuit, a numerical technique is used to generate the multimode general scattering matrix, while the mode-matching technique is used to deal with all the regular discontinuities. The final result is obtained by cascading the general scattering matrices. To validate the scheme, a numerical example is given. The results obtained with the proposed scheme agree very well with results obtained using full numerical techniques and experimental results. [C937]

## "Extraction of textural information in polarimetric SAR"

The main purpose of this paper has been to show the potential of using the covariance matrix eigenvalues in order to estimate the texture information of span polarimetric images. Comparison with experimental results from the JPL airborne SAR campaign demonstrates the capability of the eigenvalues of predicting the scattering behaviour of the scene through a texture analysis. In the case of low signal-to-noise ratio, the texture variance of the span polarimetric image deteriorates strongly, suggesting the use of the covariance matrix information to predict sensor anomalies. Future research will be devoted to the analysis of non-Gaussian clutter and to a quantitative formulation of the effects of sensor parameters (signal-to-noise, crosstalk, etc.) on the covariance matrix eigenvalues [C938]

## "Electromagnetic vector sensors and active target localization and identification"

A new model for actively localizing and identifying targets using electromagnetic vector sensors is developed and analyzed. Target dependent variables are introduced that provide a natural parametrization of the statistics of the target's reflection characteristics (scattering matrix) to arbitrarily polarized transmitted signals. Cramer-Rao bounds on the variance of unbiased estimators of these parameters are derived to show how an estimator's expected performance depends on the target's state and the transmitted signal. The parameters are shown to have physical interpretations and to represent characteristics intrinsic to the target.> [C939]

## "Estimation of wind on sea surface from polarimetric scattering"

A classical method used to obtain the RCS of the sea surface is the small perturbation model. This method is extended to the vectorial case, to obtain the polarimetric signature of the ocean surface, from a classical two-scale surface for sea surface model. An expression of this signature is first given by the sea surface Mueller matrix. The study of the terms of the averaged Mueller matrix shows that the number of coefficients can be reduced to a vector whose dimension is minimal (five). From this defined reduced vector, a Bayes estimator is built (maximum likelihood ratio test), enabling the direction and speed of the wind to be estimated, from an averaging of measurements of the polarimetric sea surface backscattering. A second formalization of the sea surface backscattering signature is proposed, which consists of a backscattering model for a single instantaneous measurement. For this purpose, the instantaneous signature of the sea surface is formalized by a `polarization fork', which is described by the five Euler parameters [C940]

## "The rotating-symmetric parameter of the radar targets"

A method for calculating this parameter is provided. The parameter values of some special targets are given [C941]

## "Kennaugh's optimal polarization and eigenvalue problem"

The left and right Kennaugh eigenvectors of the symmetric scattering matrix are first introduced. It can be shown that the Kennaugh optimal polarizations of the transmitter and receiver are eiαx1and eiβy1, where x1and y1are the right and left Kennaugh eigenvectors of the symmetric scattering matrix, respectively. Then, the left and right generalized eigenvectors of the asymmetric scattering matrix are considered. It can also be proved that the Kennaugh optimal polarizations of the transmitter and receiver are eiαx 1and eiβy1, where x1and y1are right and left generalization eigenvectors of the asymmetric scattering matrix, respectively [C942]

## "Application of the polarimetric matched image filter to the enhancement of characteristic features of POL-SAR imagery"

The authors investigate the potential of an exclusively polarimetric image filtering method which takes full advantage of matrix data provided on a pixel-by-pixel basis, and complements the existing scalar contrast optimization and speckle reduction techniques. The goal is contrast optimization without the help of incoherent averaging over pixels/look. In order to improve the efficiency of the polarimetric filtering method, one must combine it with other image processing and statistical communication theory techniques. In particular, the filter efficiency depends critically on peak sharpness of the histograms and one may use multilook incoherent averaging, block discretization, and nonuniform quantization to improve 'peakedness.' Also, a continuous mapping in three-color space of the three independent polarizations (e.g., HH, VV, VH) can be used in combination with the polarimetric matched filter to enhance visual detectability of the polarimetric rough surface scattering dependence without destroying the geometric integrity of the image. Finally, an incoherent polarimetric imaging via the 4*4 real Mueller matrix may lead to an even more efficient speckle reduction procedure, in particular, for multilook and multifrequency images.> [C943]

## "Calibration of a polarimetric synthetic aperture radar using a known distributed target"

Existing methods for external calibration of polarimetric synthetic aperture radars (SAR) are all based on point calibration targets. The quantity of interest in radar measurement of distributed targets is the backscattering coefficient which is different from the radar cross section (RCS) formulated for point targets. Therefore, in order to infer the backscattering cross section of a distributed target from a point target rigorously, the polarimetric ambiguity function of the SAR is needed. In the paper a calibration algorithm is proposed that circumvents all problems associated with the point target calibration methods. It is shown that the radar distortion parameters and calibration constant can be obtained from a distributed target with known differential Mueller matrix. The distortion parameters are then used to provide the calibrated differential Mueller matrix for the other homogeneous targets in the image. This algorithm is tested for the JPL L- and C-band SAR using four different distributed targets measured with polarimetric scatterometers [C944]

## "Intensity and phase statistics of multi-look polarimetric SAR imagery"

Polarimetric SAR data are frequently multi-look processed. The statistical characteristics of multi-look data are quite different from that of single-look data. In this paper, the authors investigate the distributions of intensity and phase. In particular, the probability density function (PDF) of the multi-look phase difference between co-polarized components is derived for the first time, and expressed in closed form. The PDF is found only depending on the complex correlation coefficient and the number of looks. Also included are PDFs of multi-look intensity and amplitude ratios. These PDFs are verified with NASA/JPL AIRSAR data. The results of this paper can also be applied to the interferometric radar for studying the decorrelation effects [C945]

## "Retrieval of forest spatial pattern from SAR images"

The spatial structure presented by forest stands and openings is of interest to scientists studying forest ecosystem dynamics. The ability to characterize forest spatial properties in terms of patch size and surface type is useful for initializing ecosystem models as well as, understanding the processes contributing to forest development. In this study, forest units with low biomass were classified from synthetic aperture radar images into several categories based on their spatial structure and different scattering mechanisms. In addition to non-forest classes several classes were identified with varying tree heights and/or tree densities that reflect natural and anthropogenic induced conditions. Optimal variables derived from Stokes matrices of P, L and C-band AIRSAR images were selected based on the separabilities between designated classes. After image classification, the number, area, and perimeter of each patch for these categories were calculated. The spatial patterns were also categorized in terms of simple spatial statistics including fractal dimensions [C946]

## "Classification of wetland vegetation by texture analysis methods using ERS-1 and JERS-1 images"

Images obtained by the C-band (5.3 GHz, 5.7 cm) VV-polarized ERS-1 SAR and the L-band (1.275 GHz, 23.5 cm) HH-polarized JERS-1 SAR were analyzed for the classification of wetland vegetation types. Both scenes were obtained when the wetland vegetation was at the maximum biomass stage. The authors applied texture analysis method using the cooccurrence matrix to classify the vegetation of the Kushiro mire. The result of the classification was evaluated comparing with the result using the SPOT data. As a result, it is shown that several texture features of SAR images are useful for the wetland vegetation classification. The authors especially demonstrate that the bog and the fen vegetation in the wetland can be segregated using JERS-1 image, and also the swamp forest can be delineated from the fen vegetation using ERS-1 image [C947]

## "A simple polarimetric calibration method which utilizes a reference target"

A polarimetric measurement radar can be calibrated with a simple, single calibration target method rather than the more complex multiple calibration target method if the transmit matrix and receive matrix are symmetric and identical. Because of the presence of nonreciprocal devices such as switches and circulators in the RF network, the matrices are usually different and nonsymmetric. However, the symmetry can be restored and the effective transmit and receive matrices can be made identical through the use of a reference target. In addition, this method has no phase ambiguity associated with the cross-polarized terms as with other single target methods. When the test object measurement matrix elements are defined by target/reference ratios, the effective antenna matrix can be obtained, inverted, and applied on both sides of the measurement matrix to provide calibrated polarimetric data. Application of the method to the measurement of a 12" sphere is shown [C948]

## "High-Resolution Stepped-Frequency Isar Imaging via Matrix Pencil"

First Page of the Article [C949]

## "Radar Partially-polarized Backscatter Description Algorithms And Applications"

First Page of the Article [C950]

## "Radar Polarimetry -- A State-of-the-Art Overview"

First Page of the Article [C951]

## "Narrow-to-Broadband Scattering Matrix Measurement, Their Modeling and Processing"

First Page of the Article [C952]

## "Calibration of polarimetric radar system using three perfectly polarization-isolated calibrators"

The calibration method of T.J. Chen et al. (see IEEE, Trans. Antennas Propag., no.8, p.1188, 1991) is generalized in such a manner that the requirement that each polarization-isolated calibrator have the same copolarized RCS (radar cross section) is not needed. Only the copolarized terms in the polarimetric scattering matrix of the first calibrator are required. The range and copolarized RCSs of the other two calibrators and the rotation angle of the third calibrator can be derived in the calibration process and used to verify the calibration. Measurement results of the copolarization ratio of a conducting cylinder with a diameter of 2.54 cm and a length of 128.5 cm are shown [C953]

## "A new time domain and polarimetric measurement algorithm for complex target reconstruction"

With the aim of a practical validation of theoretical models, software was developed using the high-frequency-domain assumption. This permits one to construct a database of polarimetric behavior for a large number of saddle points such as dipole, infinite half-plane, tip, edge, wedge, surface wave, progressive wave, cylinder, sphere, concave surface, dihedral, trihedral, and plane surface. The inverse problem in which it becomes possible with a simple measurement of the scattering matrix to recognize the target shape is presented. All the measurements are made using a vector network analyzer with a time-domain option. With a selective time acquisition and analysis of the main saddle points of the target, information concerning distance and polarimetric behavior can be obtained. By comparison, with data calculated previously for elementary saddle points, most realistic objects can be determined. Good agreement between experimental measurements and predicted ones is observed in the Xband (8-13 GHz) [C954]

## "Recent Developments in Radar Polarimetry: A Review"

First Page of the Article [C955]

## "S-Matrix Eigenvector Dynamics of the Poincare Sphere"

First Page of the Article [C956]

## "Polarimetric Speckle Filters For SAR Data"

First Page of the Article [C957]

## "Scatterometer Measurement of Differential Mueller Matrix of Distributed Targets"

First Page of the Article [C958]

## "Limitations of multiple feeds in a polarimetric-radar compact range"

It is found that two feeds, one for transmit and one for receive, can be used in a polarimetric-radar compact range provided they are located symmetrically with respect to the reflector focus. Such a configuration will conserve the coherence of the polarization matrix. However, the use of four separate feeds, two for each transmit polarization and two for each receive polarization, will destroy the coherence of the polarization matrix for scatterers off of the range axis. Significant phase errors will be introduced between the elements of the polarization matrix with the result that the measured matrix will be incorrect [C959]

## "A full RCS calibration technique using a dihedral corner reflector"

A full RCS (radar cross section) calibration technique using a dihedral corner reflector is presented. This method differs from several previous studies in the following aspects: (1) the frequency responses of four measurement channels can be mutually independent and thus no special care has to be taken for signal paths; (2) only

scattering matrix measurements of the dihedral at two orientations about the line-of-sight direction are needed since the transmitter and receiver are related through the reciprocity theorem; and (3) simple and useful expressions are used to solve for the calibration parameters. The proposed calibration technique was evaluated by calibrating the cross-polarized return of a sphere, which should be zero. Time domain responses illustrate about a 10-dB overall improvement by using the full calibration procedure [C960]

## "Error Effects on Bayesian Reconstruction of Subsurface Radar Images"

First Page of the Article [C961]

## "Polarimetric Remote Sensing of Sea Ice in the Beaufort Sea"

First Page of the Article [C962]

## "Evaluation of optimization procedures for the 2 x 2 sinclair and the 4 x 4 mnueller matrices in coherent radar polarization and its application to radar target versus background clutter discrimination in pol-sar sensing and imaging"

First Page of the Article [C963]

## "Mean Backscattering Properties Of Random Radar Targets: A Polarimetric Covariance Matrix Concept"

First Page of the Article [C964]

## "Texture Analysis in Polarimetric Sar Using the Covariance Matrix"

First Page of the Article [C965]

## "Scattering by coated superquadric cylinders: a higher order boundary condition approach"

A spectral formulation, based directly upon the tangential components of the fields, is used to derive appropriate boundary conditions. These boundary conditions are then used to compute the scattering from a special class of dielectric-coated conductors, uniformly coated conductors in the shape of a superquadric cylinder. This class of objects is chosen because it includes dielectric-coated circles, squares, ellipses, and rectangles as special cases, allowing the investigation of the effects of finite radii of curvature in a systematic fashion. For simplicity the investigation is limited to the case of H-polarization. The case of E-polarization can be handled similarly. Computations of radar cross sections of several dielectric-coated superquadric cylinders are presented [C966]

## "Comparison of optimization procedures for radar scattering matrices"

Summary form only given. Basic principles of radar polarimetry were introduced, and various optimization procedures for the propagation (scattering) range operator equation and the received power expressions were presented and compared. It was assumed that the radar is a complete coherent dual orthogonal (A,B) transmit/receive antenna system of high channel isolation and antenna sidelobe reduction, where in the case of wave interaction with a discrete stationary point target the propagation (scattering) matrix is given by the 2Ч2 coherent Jones (Sinclair) matrix and/or the 3Ч3 or 4Ч4 complex covariance matrix, and the 4Ч4 Mueller (Kennaugh) power density matrix for the symmetric or the asymmetric partially coherent cases, respectively. Separate optimization procedures were introduced for the symmetric case, demonstrating that for the coherent (deterministic) scattering scenario the solutions are identical, and so approximately also for the partially polarized case, whereas for the partially coherent case a more elaborate optimization procedure for the 3Ч3 covariance and/or 4Ч4 Mueller matrices is employed [C967]

## "A hybrid approach for 2-D RCS imaging"

The use of a hybrid 2-D spectral analysis method in RCS (radar cross section) imaging is presented. The hybrid scheme uses the standard FFT (fast Fourier transform) technique and the super resolution MUSIC algorithm subsequently to form the 2-D image. This approach can have the advantage of improving the resolution in the dimension where short data records are available. This hybrid approach was applied to the 2-D RCS analysis of a cube. The results are given for the case where the RCS data over an aspect angle of 10° are considered. They indicate that by using the hybrid scheme, the scattering centers associated with the target are resolved as expected, whereas the standard 2-D FFT algorithm failed to identify the scattering centers [C968]

## "A new classification method of the radar targets by using the Gershgorin disks of the Mueller matrices"

A novel classification method is proposed for radar targets, in which Gershgorin disks are utilized. It can be seen that the new method will be better than the eigenvalue method for the classification of radar targets. Three examples are considered: a spherical target, a horizontal trough, and a symmetric target [C969]

## "Scattering by a circular aperture in a dielectric-loaded conducting spherical shell"

The problem considered deals with the scattering of a plane wave by an infinitely thin perfectly conducting spherical shell with a circular aperture of arbitrary subtended angle and loaded with a dielectric shell whose permittivity may be different outside the shell from inside. The fields in both regions are expanded in terms of spherical wave functions and the proper boundary conditions are imposed. The modal expansion coefficients are approximated by applying the least square error method to the equations resulting from matching the fields at the aperture. The scattering pattern and radar cross section are presented for a wide range of parameter variations [C970]

## "Investigation of radar scattering from conducting and dielectric targets in the resonance region"

Theoretical and experimental studies of radar scattering from conducting and dielectric targets in the resonance region are described. The formulation used is based on the equivalence principle which relates the total electric and magnetic fields on the surface of dielectric targets to that of the equivalent surface currents Jand M . Measurements were conducted for two orthogonal linearly polarized transmit signals, and both the amplitude and phase of co- and cross-polarized return signals are measured over a wide frequency band. The monostatic scattering pattern of metallic cube of size L=2.46 cm is presented along with the backscattering pattern of a conducting rectangular strip of size L, thickness of 0.21L, and width of 0.074L, for a vertically polarized incident plane wave [C971]

## "TM-scattering from a rectangular channel in a conducting plane"

Transverse magnetic (TM) plane-wave scattering from a rectangular channel engraved in a perfectly conducting plane is investigated. A Fourier-transform technique is employed to express the scattered field in the spectral domain in terms of parallel-plate waveguide modes. An approximate series solution for scattering is presented in a closed-form which is valid for the high-frequency scattering regime. Approximate solutions which are valid for the quasi-static and low-frequency scattering regimes are also obtained. Using the stationary phase approximation, the far-zone scattered field is obtained and its scattering behavior is studied in terms of the scattering angle, frequency, and channel size [C972]

## "Classification of multi-look polarimetric SAR data based on complex Wishart distribution"

An optimal feature classification scheme is developed for multilook polarimetric SAR (synthetic aperture radar) imagery based on a multivariate complex Wishart distribution. The purpose is to identify various ground covers, such as forest, vegetation, city block, ocean, and sea ice type. Multilook polarimetric SAR data can be represented either in Stoke's matrix form or in complex covariance matrix form. The latter has a complex Wishart distribution. A simple but effective classifier is then developed using the complete information of the complex covariance. This algorithm is further extended to classification using multifrequency polarimetric data. A procedure for assessing the classification errors is also developed using a Monte Carlo simulation. The effectiveness of this algorithm is demonstrated with NASA/JPL (Jet Propulsion Laboratory) P-, L-, and C-band polarimetric SAR data [C973]

## "Polarimetric radar backscatter algorithms for partially polarized waves"

Summary form only given. Theoretical and practical aspects of the partially polarized backscatter are considered. The analytical properties of the covariance matrix are examined, and a 3Ч3 basis transformation matrix is developed. The relationship between the coherency matrix and the covariance matrix is outlined. It is shown that, by measuring two coherency matrices and using some of the derived analytical properties, the covariance matrix can be determined [C974]

## "Polarimetric observations of millimeter-wave backscatter from snowcover at 95 and 225 GHz"

Two high-power millimeter-wave polarimeters, operating at 95 and 225 GHz, have been developed by the University of Massachusetts Microwave Remote Sensing Laboratory for field experimentation. Utilizing these instruments, polarimetric measurements of backscatter from snowcover were carried out between 1989-1992 for

both fresh and refrozen snowcover. These data indicate that the Mueller matrix for snowcover consisting of spherical ice particles (sleet) has a relatively simple form, with ten of the sixteen elements approximately zero. Measurements of new-fallen snow consisting of predominantly nonspherical snow crystals exhibited more complex scattering behavior, fitting the general form of the Mueller matrix for natural surfaces [C975]

## "The polarimetric matched image filter: application to speckle reduction and optimal background clutter discrimination in microwave sensing and imaging"

Summary form only given. Scattering matrix optimization procedures were applied to the complex scattering matrix, associated covariance matrix, and power density matrix and their Lie SU(n)-group theoretic expansions (n=2,3,4), in order to derive a set of more robust target detection, speckle reduction, and clutter suppression algorithms. The covariance matrix invariance ratio was introduced and found to provide a good measure of speckle reduction as well as being useful for obtaining an optimal high resolution image. A PMSF/PMIF (polarimetric matched signal filter/image filter) filtering process, which is based on the target/clutter characteristic polarization state plus optimal stochasticity coefficient approaches, was developed. Results were obtained for POL-SAR image data sets collected with the airborne NASA-JPL (P/L/X)-band SAR polarimetric system over the San Francisco Bay area [C976]

## "Polarimetric scattering model for grassy terrain"

Summary form only given. Information obtained from the polarimetric scattering response of a soil surface can lead to an accurate estimate of its soil moisture content. A scattering model has been developed which provides an exact numerical solution to scattering from stalks and leaves of arbitrary cross sections, orientations, and lengths. Because the constituent cross sections are assumed to be electrically small, a 2D Rayleigh scattering approximation was employed and polarizability tensors were determined numerically. The dipole moments per unit length were then calculated, and integrating these values over the length of each constituent resulted in an expression for the total scattered field. These results were combined with a statistical description of a grassy vegetation cover to provide the phase and extinction matrices required for a first order vector radiative transfer scattering model. This model was used to investigate the dependence of the total polarimetric scattering response on both soil and vegetation parameters [C977]

## "Scale-space clustering and classification of SAR images with numerous attributes and classes"

Describes application of scale-space clustering to the classification of a multispectral and polarimetric SAR image of an agricultural site. After polarimetric and radiometric calibration and noise cancellation, the authors extracted a 12-dimensional feature vector for each pixel from the scattering matrix. The algorithm was able to partition without supervision a set of unlabeled vectors from 13 selected sites, each site corresponding to a distinct crop, into 13 clusters. The cluster parameters were then used to classify the whole image. The classification map is much less noisy and more accurate than those obtained by hierarchical rules. The algorithm can handle variabilities in cluster densities, cluster sizes and ellipsoidal shapes [C978]

## "Wideband polarimetric radar imaging"

Summary form only given. The relationship of the polarization dependence of the corresponding radar cross-section matrices in the frequency domain with that of the target eigen-resonance maps is demonstrated, leading to the concept of polarimetric wavelets, which offers a useful interpretative tool for polarimetric UWB (ultrawideband) target versus clutter discrimination and analysis. Utilizing available sets of multiband continuous wave spectral polarimetric scattering matrix data sets in the (30) 300 MHz to 3 (30) GHz region, the authors demonstrated the relevance of a `polarimetric extension' of the UWB impulse radar approach with the specific aim of identifying the important wide-ranging applications of future UWB (non-carrier frequency) polarimetric impulsive radar (POL-RAD) synthetic aperture radar (POL-SAR), and inverse synthetic aperture radar ISAR (POLISAR) systems not only to low-radar cross section-target analysis but even more so to under-burden (foliage/poorly conductive media) penetration for detecting hidden conducting objects (tanks, mines, etc.) in wide area site/environmental security monitoring [C979]

## "Reduction and minimization of antenna scattering"

The authors analyze the radar cross section of antennas under various load conditions over a wide frequency range. Special emphasis is given to the polarization characteristics of radiated and scattered fields and their influence on the total scattered antenna field. Several techniques for reduction and minimization of antenna scattering are discussed. It is demonstrated how the total scattered field of an antenna can be modified and minimized using appropriate load reflection coefficients. However, in the general case this minimization is only realizable in a narrow frequency range, for certain aspect angles and polarizations [C980]

## "Full polarization scattering matrix Ka -band measurements on a large volume compact range"

GTRI conducted a study for the US Army Missile Command to determine suitable radar ranges at which full polarization scattering matrix (PSM) Ka-band measurements of tactical ballistic missiles (TBM) could be conducted. The study determined that McDonnell Douglas Technology Inc., (MDTI) operates the only commercially available Ka-band-capable facility which is fully polarimetric on a pulse-to-pulse basis and employs polarization distortion matrix (PDM) calibration routines in their data processing. Measurements were made to assess performance of an MDTI Ka-band radar and compact range. Radar performance was assessed by a variety of measurements, including measurements to characterize the Ka-band RF head and measurements of simple targets, support structures, and the background to assess the signal-to-background, coherent processing, polarization isolation, and resolution characteristics of the radar [C981]

## "High power, precision beamforming networks for radar phased arrays"

A suite of software permits rigorous analysis of waveguide branch guide couplers and derivation of the complete scattering matrices of multiport power dividers incorporating these couplers and including other waveguide components such as bends. This is used in conjunction with a design procedure which can achieve a nominally frequency invariant output distribution over a wide bandwidth using couplers with the minimum number of branches. Coupling values close to -3 dB are used where possible to reduce manufacturing costs. A manufacturing methodology enables beamformers to be constructed at high frequency without the need for expensive techniques such as spark erosion. A number of designs have been undertaken at C-band and J-band and use of the software has enabled units to be manufactured without the need for empirical optimisation [C982]

## "Real-time polarization-diverse features extraction and automated target identification using neural networks"

The authors have mapped the polarization-diverse features extraction problem onto the Lyapunov energy function of the Hopfield model neural network to obtain the real-time solution of the feature, i.e., the ellipticity, the tilt angle and the amplitude of the fit ellipse, derived from this parameterization. Simulated results are presented to shows its real-time capacity in the context of the polarization-diverse features extraction problem by using the Hopfield net as well as its strong target identification ability by applying the back-propagation neural network employing the resulting feature sets. The approaches considered here are expected to have a faster computational speed than those of the traditional approaches such as the LMS (least mean square) approximation method and classical pattern recognition [C983]

## "Kennagh's optimal polarization for the multistatic radar"

For a monostatic radar, the optimal polarization theory associated with a symmetric scattering matrix was first introduced by E.M. Kennaugh (1952). In the present work, the optimal polarization theory is extended to the case of multistatic radar. The mathematical model in which the total effective echoing area is optimized as a function of the transmitting and receiving antenna polarizations is presented, and the optimal transmitting and receiving antenna polarizations are provided [C984]

## "A transmission-line-type eight-port hybrid"

A novel transmission-line-type eight-port hybrid is proposed and investigated theoretically and experimentally. A bandwidth comparable with that of a branch-line 3 dB hybrid is obtained for moderate values of characteristic admittances of line sections. This circuit is useful for applications to a comparator circuit in a four-port monopulse radar system and a four-way power combiner/divider with four input/output arms isolated from one another [C985]

## "Spectral propagation algorithm for RCS of perfectly conducting cavities"

An iterative spectral propagation algorithm is developed which introduces new features that improve the numerical efficiency and accuracy of the spectral iteration technique and the spectral incremental propagation procedure. The new spectral algorithm is particularly useful for analyzing closed problems where the boundary structure is too large for low-frequency matrix methods and too complex for high-frequency approximations. The scope of application includes the radar cross section of cavities, waveguide discontinuities and filters, and conformed or corrugated horn antenna analysis. The method is also valid for scattering problems in free space, but the continuous spectrum of nonperiodic fields together with the periodicity of the discrete Fourier transform require a very high number of field samples. For that reason, the efficiency of the algorithm may be worse than that of matrix methods for very complex scatterers and worse than that of high-frequency methods for large and

simple objects. The main drawback is that boundary conditions are restricted to perfect electric or magnetic conductors, so that electric loading cannot be considered [C986]

## "3-D polarimetry for target acquisition and classification with electronically steered planar array systems"

Presents a new approach to the measurement of an antenna scattering matrix. The matrix include not only the polarisation characteristics of the antennas but also the influences of the corresponding transmit or receive amplifiers and signal processing. A planar array antenna with and without polarisation is examined, as is the matrix transformation with the reflection from a sphere [C987]

## "Optimisation methods in radar polarimetry"

There are several methods available for the calculation of optimum polarisations in radar scattering. These are target specific transmit and receive antenna polarisations which are used to enhance or suppress radar backscatter for the purposes of improved detection or contrast enhancement. There has been interest in obtaining optimum states for distributed targets such as clutter and hydrometeors. In such cases the object cannot be represented by a single scattering matrix, but instead a second order statistical representation is required. This is obtained from the target Mueller matrix, covariance matrix or coherency matrix, all of which contain the same basic information on correlation properties of the scattering medium. The author outlines a classification of these various methods and discusses their advantages and disadvantages [C988]

## "The characteristic polarization states for the coherent and partially polarized case"

Basic principles of radar polarimetry are introduced. The target characteristic polarization state theory is developed first for the coherent case using the three step, the basis transformation, and the power (Mueller) matrix optimization procedures. Kennaugh's and Huynen's theories of radar target polarimetry are verified for the monostatic reciprocal case. It is shown that there exist in total five unique pairs of characteristic polarization states for the symmetric scattering matrix. The theory is verified by an example in which the polarization fork co-polarized and cross-polarized power density plots are presented. In a next step, the partially polarized case for completely polarized wave incidence is presented and compared with the results for the coherent and the partially coherent cases, the latter still being unresolved [C989]

## "Use of polarimetric radar information for the classification and microphysical description of random targets"

The usefulness of a coherent polarimetric radar for applications in microwave propagation (satellite communications) and cloud physics research is demonstrated with the DLR C-Band weather radar as an example. These radars permit the characterization of statistically distributed targets such as rain by a time series of relative scattering matrices, the Stokes-matrix, and the covariance matrix. This means, the whole information, inherent to the scattered wave due to the interaction with the target for the aspect angle and frequency under consideration, may be extracted. Coherent polarimetric backscatter measurements in combination with advanced signal processing algorithms proved to be extremely valuable for the discrimination of different targets and the derivation of (microphysical) information about the targets. The techniques applied to meteorological targets are also of great benefit to remote sensing of the Earth by synthetic aperture radars [C990]

## "Multiple beam slotted waveguide antenna for spaceborne synthetic aperture radar"

The application of a multibeam slotted waveguide antenna for a synthetic aperture radar (SAR) in space is discussed. The feasibility of a dual-beam SAR antenna using ERS-1 technology has been shown. Some predicted and measured results of a dual-beam slotted waveguide antenna are presented and a very good agreement has been found. A multiport scattering matrix for the feed network has been derived for both dual and triple-beam antenna designs [C991]

## "Broadband scattering matrix measurements and their modelling"

The authors present measured broadband scattering matrix (SM) data and extend results on the description and modelling of broadband polarimetric data. The SM depends on the transmitted frequency and on the illumination direction of the radar, which is characterized by the directional vector in the target coordinate system. The bandwidth of the measurement data is 8.5 GHz, fo=18.0 GHz. Several scale model aircraft were measured under monostatic constraints in an anechoic chamber for different directions. The broadband SM variation of different targets at the same aspect angle is shown [C992]

## "Measured small- and broadband scattering matrix data their modeling and processing"

The signal processing part of polarimetric radars works on multivariate vector sequences or partitions of scattering matrix vectors. In the case of a smallband pulse radar, the index represents SM-measurements at different time instances. In the context of broadband polarimetric radars, however, the index represents a SM-measurement taken at different carrier frequencies. The description and modeling of both types of SM-sequences and their relations to the polarimetric signal processing are the subject of this paper. Such models are of great interest because their use gives a better understanding of the reflection mechanism and allows use of model-dependent signal processing structures [C993]

## "Recursive T-matrix algorithms for 1-D and 2-D clusterings of strips"

Two recursive T-matrix algorithms were introduced for EM scattering by W.C. Chew (1989), W.C. Chew and Y.M. Wang (1990). In the present work, the authors discuss the application of these algorithms to conducting strip geometries, and analyze the complexities of the algorithms. The two algorithms are shown to have complexities of O (N2P) and O(NP2 ), where Nis the number of unknowns in the problem, and Pis the number of terms that satisfies a convergence criterion in the addition theorems for the cylindrical wave functions [C994]

## "Matrix Pencil And Multidimensional Sinusoids"

First Page of the Article [C995]

## "Polarimetric observations of trees at 35 and 94 GHz"

Two different kinds of trees were measured with a newly developed polarimetric radar at 35 and 94 GHz. The first was a rhododendron with a planophil leaf orientation distribution and an average leaf area of 40 cm2; the second was a spruce blue shiner with a uniform leaf orientation distribution and an average needle length of 1.5 cm. The system is based on the coherent-on-receive technique and is capable of measuring the Mueller matrix directly. The degree of polarization, phase statistics, and polarization signatures are presented. Results show that the degree of polarization is sensitive to the radar frequencies and tree types [C996]

## "Numerical analysis for the scattering by a waveguide cavity with complex configuration"

It is shown that coupling wave theory combined with the finite-element method can be used to treat scattering by a waveguide cavity of complex configuration. This technique is efficient and accurate; it can manage to calculate the scattering from a curved and variable cross-section tube. Experimental and numerical results have verified this [C997]

## "Polarimetric scattering from natural surfaces at 225 GHz"

The authors present polarimetric radar measurements at 225 GHz which demonstrate that the normalized Mueller matrix may be approximated in terms of a single parameter, The depolarization ratio, defined as the ratio of cross- to copolarized normalized radar cross-sections, is shown to accurately predict backscatter from vegetation (trees and grass), and scattering from terrain at low incidence angles (snowcover and sand) [C998]

## "Optimum Input Parameters For Classification Of Multifrequency Polarimetric Sar-data Using Neural Networks"

First Page of the Article [C999]

## "Model And Measurements Of The Phase Statistics Of The Scattering Matrix Of Distributed Surfaces"

First Page of the Article [C1000]

## "Performance of a Polarimetric Sar Calibration Algorithm"

First Page of the Article [C1001]

## "On-Board Polarimetric Processing For Synthetic Aperture Radar"

First Page of the Article [C1002]

## "Stokes Matrix Statistics In Sea Ice Polarimetric SAR Images"

First Page of the Article [C1003]

## "Distribution Of The Stokes Parameters And The Phase Difference In Polarimetric SAR Data"

First Page of the Article [C1004]

## "Electromagnetic scattering from three-dimensional cavities via a connection scheme"

Computer memory constraints often dictate the number of unknowns which can be realistically handled in three-dimensional problems of electromagnetic scattering from cavities. To partially alleviate this constraint, the authors apply a connection scheme which allows the entire cavity to be subdivided into sections and each section to be analyzed completely independently of other sections. This entails applying the boundary-integral formulation of each section and determining the generalized admittance matrix representation of the section. Using the concept of input and load admittance, the aperture admittance matrices of different regions can then be cascaded together to form the overall cavity aperture admittance. Numerical results generated by the formulation are validated against published data for regular geometries [C1005]

## "Pulsed polarimetric millimeter-wave radars that utilize extended interaction amplifier and oscillator tubes"

The University of Massachusetts has developed two high-power portable polarimetric radars operating at 95 and 225 GHz. The 95 GHz polarimeter employs an extended-interaction klystron amplifier capable of 1500 W peak power output. The system is configured to measure the complex scattering matrix of a target by transmitting a pair of orthogonally polarized pulses in rapid succession. A noncoherent 225 GHz polarimetric radar which directly characterizes the target Mueller matrix by transmitting a sequence of six polarization states has also been developed. The 225 GHz system utilizes an extended-interaction klystron oscillator that generates a 60 W peak power pulse. The authors review the design of the 95 and 225 GHz radars, and highlight significant measurements and applications [C1006]

## "A unified SQRT-free rank-1 up/down-dating approach for recursive least-squares problems"

Planar (Givens) and hyperbolic rotations are the most commonly used methods in performing QRD up/downdating. Since the square-root operation takes up much area and its computational time is slow (due to many iterations), the associated area/time efficiency is poor. This is the first effort to establish the basic understanding toward all known square-root-free QRD algorithms, from which the basic criterion is seen to be simple. This unified approach provides a fundamental framework for the square-root-free RLS algorithms essential for practical VLSI implementations [C1007]

## "Comparison of optimization procedures for the 2Ч2 Sinclair and the 4Ч4 Mueller matrices in coherent radar polarimetry and its application to radar target versus background clutter discrimination"

Basic principles of radar polarimetry are introduced. The target characteristic polarization state theory is developed first for the coherent case using the three-step, the basis transformation, and the power (Mueller) matrix optimization procedures. Kennaugh's and Huyen's theories of radar target polarimetry are verified for the monostatic reciprocal case. It is shown that there exist in total five unique pairs of characteristic polarization states for the symmetric scattering matrix, of which two pairs, the cross-polarization null and the copolarization max pairs, are identical, whereas the cross-pol max and the cross-pol saddlepoint pairs are distinct. The fifth pair, the co-pol null pair, lies in the plane spanned by the co-pol max/cross-pol null and the cross-pol max pairs, which determines the target characteristic circle on the polarization sphere reestablishing Huynen's polarization fork concept. The theory is verified by an example in which the co-polarized and cross-polarized power density plots are presented next to the polarization fork [C1008]

## "Some relations between microwaves and optics"

Summary form only given. The many quasi-optical techniques used with microwaves are now well-known, but the development of these provides a number of interesting case histories. In addition to the ties based upon field theory, there were important interchanges in circuit concepts, Schelkunoff demonstrated the importance of impedance concepts in wave problems, the scattering matrix approach found use with lumped-element circuits, and filter concepts were interchanged between the two fields. More recently, systems concepts based upon chirp radar and spread-spectrum techniques have played a role in the development of the ultrashort optical pulses.

These pulses in turn have been used in the study of materials in the millimeter-wave region [C1009]

## "Decomposition of the radar target scattering matrix with application to high resolution target imaging"

The basic theory of polarimetric radar and various decomposition theories are briefly reviewed. A novel decomposition of the scattering matrix is then presented with special reference to high-resolution imaging. By decomposing the scattering matrix into three different components, it is possible to resolve different types of scatterers even if they are within the same resolution cell of the image. This allows for a better resolution of the target scattering properties as well as a better characterization of the type of scattering for the individual contributions. The usefulness of this decomposition and the advantage in general of utilizing full polarimetric data in connection with radar target imaging are demonstrated by applying the decomposition to simulated images of a complex target model composed of a number of individual scatterers. The extra information contained in the full polarimetric data as compared with single polarization data should greatly improve the possibility of noncooperative target recognition by radar [C1010]

## "Numerical Microwave Synthesis by Inversion of the TLM Process"

In this paper, the principles of a novel TLM time domain synthesis procedure for microwave structures are presented. This procedure permits the reconstruction of primary and induced sources from their radiated fields in space and time by reversing the TLM time stepping process. The ability to reconstruct induced sources implies that the topology of discontinuities and scatterers in the field space can be determined from the full knowledge of the incident and the scattered fields, thus opening the way to numerical field synthesis of microwave structures as an alternative to synthesis by iterative optimization. [C1011]

## "The method of relative phase applied to wire-type scattering structures"

The method of moments in conjunction with the method of relative phase is used to determine the radar cross section (RCS) response from a collection of planar wire-type elements which may conform to a cylindrical surface. The method of moments is used to define the scattering matrices of each wire-type element which completely describes the object in 4pi-space within a given bandwidth. The individual element responses are then combined using the relative phase differences, with the assumption that the phase-center is at the center of the wire object. Correlation is good between relative phase approximation predictions, moment-method predictions, and RCS measurements for element-to-element spacings greater than one wavelength. Two cases were investigated between 6-18 GHz for vertical polarization: (1) a loosely spaced arrangement of 4 star elements of the same size; and (2) a closely spaced arrangement of 17 star elements of different sizes [C1012]

## "Electromagnetic wave interaction with coniferous trees: theory and experiment"

A multilayer scattering model has been developed to investigate the relation between the tree architecture and the backscattering measurements from three kinds of coniferous trees at X-band. Each layer contains different types of scatterers to account for the tree components (leaves, branches, trunk). The Helmholtz integral along with the radiative transfer equations is used to calculate the phase matrices of the tree components and the backscattering coefficients of the trees. It is found that the echo area within any tree can be very different between VV and HH, especially at the tree top. For a group of trees. the levels of VV and HH are of the same order and their angular trend depends on the tree architecture. The main contribution to the backscattering coefficients is due to the branches [C1013]

## "A radar coal thickness sensor"

A radar coal thickness sensor is being developed by the Bureau of Mines to measure both the dielectric constant and thickness of a coal seam as part of a sensor array supporting a computer-assisted coal mining machine. The noncontacting stepped-CW (continuous wave) radar sensor measures the complex reflection coefficient of the coal/shale interface to resolve the coal thickness to subwavelength accuracies. The technique uses a monostatic antenna configuration. Transfer function errors are identified by using spatial modulation created by antenna motion. Synthetic range gating is used for clutter rejection. Finally, polarimetric scattering matrix techniques are used to calculate the dielectric constant and thickness of the multilayered coal/shale media. Data taken both in the laboratory and in an underground mine, in the 0.6 to 1.4 GHz range, with a network analyzer and dipole antenna, have validated the technique. Accurate in-situ measurements were made of a coal seam 6 in (15.2 cm) thick with a dielectric constant of 4 [C1014]

## "Hybrid wavefront-resonance representation for transient scattering by an open cavity"

Short pulse scattering signals furnish valuable information for classification or identification of radar signatures. For targets comprising of open-ended enclosures with interior-exterior coupling an effective parametrization of the scattered field is provided by expressing the contribution of the internal field and of the wave interactions around the exterior boundaries in terms of complex resonances and traveling waves, respectively. This hybrid concept is illustrated for the prototype configuration of an open ended perfectly conducting parallel plate waveguide cavity. The authors introduce a systematic matrix procedure which may actually be applied to other open cavity configurations. The properties of the hybrid parametrization are contrasted with those of the global SEM representations. The numerical calculations construct the early time field as a rapidly decaying series of external wavefront interactions, while at intermediate times the internal resonances synthesize the dispersive guided mode return. Finally, the late time observables carry the signature of a cluster of high-Q internal resonances that occurs near modal cutoff frequency, in the form of slowly decaying typical waveform which is independent of the incident angle or of the excitation pulse but is related to the cavity dimensions [C1015]

### "Direction finding using uniform arrays and the constrained total least squares method"

Direction finding using snapshots collected from a uniform array is equivalent to estimating the two-dimensional frequencies of sinusoids from a set of double indexed samples. The authors present a novel technique for estimating the two-dimensional frequencies which is based on a generalization of the constrained total least squares technique, to nonlinear equations whose coefficients have been perturbed by additive noise. Multilinear prediction on the data is used to arrive at these equations, and the frequencies are extracted directly from the solution of these equations. Simulation results are used to compare the resolution and accuracy of this technique with the corresponding Cramer-Rao bound for a variety of signal scenarios [C1016]

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