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ТЕМАТИЧЕСКИЙ РЕФЕРАТИВНЫЙ СБОРНИК № 15-1

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

Журнальные публикации

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"Geometry-Induced Range-Dependence Compensation for Bistatic STAP with Conformal Arrays"

Radar space-time adaptive processing (STAP) is a well-suited technique to detect slow-moving targets in the presence of a strong interference background. We consider STAP for a radar operating in a bistatic radar configuration and collecting returns with a conformal antenna array (CAA). The statistics of the secondary data snapshots used to estimate the optimum weight vector are not identically distributed with respect to range, thus preventing the STAP processor from achieving its optimum performance. The compensation of the range-dependence (RD) requires the knowledge of the locus of the clutter signature. We use a new RANSAC-based method for estimating this locus or, equivalently, the flight configuration parameters. Based on this knowledge, we perform an RD compensation of the snapshots to obtain an accurate estimate of the clutter covariance matrix. End-to-end performance analysis in terms of signal-to-inference-plus-noise ratio loss shows that our method yields promising performance. [J1]

"Target Motion Ambiguities in Single-Aperture Synthetic Aperture Radar"

A simple approach to the detection and estimation of target motion based on phase measurements from a single-aperture synthetic-aperture radar (SAR) is presented. In this analysis the SAR is treated as a pure range-measuring device. Each stationary object in a scene produces a unique range-time history in the radar. Thus, ideal SAR processing is reduced to finding the response to the set of matched filters associated with stationary targets. For this purely geometrical model, it is shown that there exists a class of moving targets that are absolutely indistinguishable from a stationary target. These are targets that move in such a way that the range to the SAR is always identical to the range from the SAR to some stationary target. Moreover it turns out that most moving targets are also indistinguishable from some other moving targets. The idealized SAR is only sensitive to a single velocity component of the target, and thus most solutions are degenerate. Theoretical limits of the detection of motion are established that are dependent on SAR parameters and observation time. Fast-moving (e.g. spaceborne) SARs can detect along-track motions with less ambiguity than a slow-moving SAR. It is shown that most moving targets do produce apparent motion in sequences of multilook SAR imagery. These apparent motions can be used to estimate the measurable component of target velocity. [J2]

"Improvement of high-frequency surface waves radar performances by use of multiple-input multiple-output configurations"

A multiple-input multiple-output (MIMO) configuration has been studied for communication applications, offering a lot of advantages to mitigate propagation effects because of multipath and fading environments. More recently, MIMO techniques in radar have been proposed. MIMO is discussed in the context of high-frequency surface waves radar (HFSWR). After a short introduction to the MIMO radar technique (a technique which is not new; the RIAS developed by ONERA was probably the first MIMO radar), explores two different applications are explored. The first application aims at improving the resolution and accuracy of a coastal radar, proposed here in a bistatic configuration. Such a radar operates with a wide sparse frequency band and with an equivalent wide aperture, taking advantage of the MIMO configuration. Simulation over a congested area of targets demonstrates the benefit of MIMO over the conventional HFSWR radar, especially in terms of separation of targets. The second application consists in a more practical ship-borne HFWSR configuration compatible with space time adaptive processing (STAP) to improve the detection of slow targets. In this case, a limited number of receiving channels is considered whereas STAP uses the degrees of freedom offered by the transmitting array. The MIMO-STAP is compared with a conventional STAP, showing that theoretical performances should not be affected by the MIMO configuration even if the signals are no longer perfectly orthogonal, because of Doppler shift, once scattered by moving targets. [J3]

"Foundation for mitigating range dependence in radar space-time adaptive processing"

The problem of detecting slow-moving targets using a space-time adaptive processing (STAP) radar is

addressed. The determination of the optimum interference-rejection weights at each range is based on snapshots at neighbouring ranges. However, in virtually all bistatic configurations or/and when using conformal antenna arrays (CAA), snapshot statistics are range dependent, which results in poor detection performance. To address this issue, a foundation for range-dependence compensation in STAP in the case of Gaussian interference and noise is proposed. The realistic case where received snapshots are the only source of information for mitigating the range dependence is considered. To illustrate the usefulness of the proposed foundation, this foundation is used to design a method to adaptively compensate for range dependence in a challenging situation, that is, for a radar using a CAA and operating in a bistatic configuration. [J4]

"Airborne along-track interferometry for GMTI"

Synthetic Aperture Radar (SAR) Along-Track Interferometry (ATI) has been used extensively to measure ocean surface currents. Given its ability to measure small velocities (-10 cm/s) of relatively radar-dark water surfaces, there is great potential that this technique can be adapted for ground moving target indication (GMTI) applications, particularly as a method for detecting very slow targets with small radar cross-sections. Herein, we describe preliminary results from an ATI GMTI experiment. The SAR data described were collected by the dual-frequency NASA/JPL airborne radar in its standard dual-baseline ATI mode. The radar system imaged a variety of control targets including a pick-up truck, sport utility vehicles, passenger cars, a bicycle, and pedestrians over multiple flight passes. The control targets had horizontal velocities of less than 5 m/s. The cross-sections of the targets were not purposely enhanced, although the targets' reflectivities may have been affected by the existence of the GPS equipment used to record the targets' positions. Single-look and multiple-look interferograms processed to the full azimuth resolution were analyzed. In the data processed to date, all of the targets were observed by visual inspection in at least one of the four combinations of dual-frequency, dual-baseline interferometric data. This extremely promising result demonstrates the potential of ATI for GMTI applications. [J5]

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

The problem of adaptive radar detection in clutter which is nonstationary both in slow and fast time is addressed. Nonstationarity within a coherent processing interval (CPI) often precludes target detection because of the masking induced by Doppler spreading of the clutter. Across range bins (i.e., fast time), nonstationarity severely limits the amount of training data available to estimate the noise covariance matrix required for adaptive detection. Such difficult clutter conditions are not uncommon in complex multipath propagation conditions where path lengths can change abruptly in dynamic scenarios. To mitigate nonstationary Doppler spread clutter, an approximation to the generalized likelihood ratio test (GLRT) detector is presented wherein the CPI from the hypothesized target range is used for both clutter estimation and target detection. To overcome the lack of training data, a modified time-varying autoregressive (TVAR) model is assumed for the clutter return. In particular, maximum likelihood (ML) estimates of the TVAR parameters, computed from a single snapshot of data, are used in a GLRT for detecting stationary targets in possibly abruptly nonstationary clutter. The GLRT is compared with three alternative methods including a conceptually simpler ad hoc approach based on extrapolation of quasi-stationary data segments. Detection performance is assessed using simulated targets in both synthetically-generated and real radar clutter. Results suggest the proposed GLRT with TVAR clutter modeling can provide between 5-8 dB improvement in signal-to-clutter plus noise ratio (SCNR) when compared with the conventional methods. [J6]

"Post-adaptive processing time-delay beamforming for clutter suppression in airborne radar"

A novel beamforming architecture is presented in which time delay steering is applied after the application of space-time adaptive processing (STAP) in a phased array for airborne radar. Improved clutter suppression and slow moving target detection performance can be achieved over that associated with STAP and conventional time delay steering in wideband sideways looking applications. The architecture also provides a computationally efficient means of applying time-delay beamforming in conjunction with STAP in applications where multiple receive beams are required. [J7]

"Along-track interferometry for ground moving target indication"

Synthetic aperture radar (SAR) along-track interferometry (ATI) has been used extensively to measure ocean surface currents. Given its ability to measure small velocities (-10 cm/s) of relatively radar-dark water surfaces, there is great potential that this technique can be adapted for ground moving target indication (GMTI) applications, particularly as a method for detecting very slow targets with small radar cross-sections. Herein, we describe preliminary results from an ATI GMTI experiment. The SAR data described were collected by the dual-frequency NASA/JPL airborne radar in its standard dual-baseline ATI mode. The radar system imaged a variety of control targets including a pickup truck, sport utility vehicles, passenger cars, a bicycle, and pedestrians over

multiple flight passes. The control targets had horizontal velocities of less than 5 m/s. The cross-sections of the targets were not purposely enhanced, although the targets' reflectivities may have been affected by the existence of the GPS equipment used to record the targets' positions. Single-look and multiple-look interferograms processed to the full azimuth resolution were analyzed. In the data processed to date, all of the targets were observed by visual inspection in at least one of the four combinations of dual-frequency, dual-baseline interferometric data. This extremely promising result demonstrates the potential of ATI for GMTI applications. [J8]

"Bistatic Linear Antenna Array SAR for Moving Target Detection, Location, and Imaging With Two Passive Airborne Radars"

In this paper, we propose a bistatic linear array synthetic aperture radar (BLA-SAR) system for moving target detection, location, and imaging. In the BLA-SAR system, a geostationary satellite is used as a transmitter, and two airborne linear array radars are used as passive receivers, where the transmitted waveforms from the geostationary satellite may have two different carrier frequencies, two linear array antennas on two different airplanes may be equipped with different spacings, or two airplanes may fly with two different velocities. It is shown that, using the BLA-SAR, not only the stationary clutter can be suppressed but also locations of both slow and fast moving targets can be accurately estimated. Furthermore, an effective BLA-SAR algorithm of moving target imaging is also proposed. Lastly, some numerical experiments are given to demonstrate the effectiveness of the BLA-SAR [J9]

"Framework and Taxonomy for Radar Space-Time Adaptive Processing (STAP) Methods"

The goal of radar space-time adaptive processing (STAP) is to detect slow moving targets from a moving platform, typically airborne or spaceborne. STAP generally requires the estimation and the inversion of an interference-plus-noise (I+N) covariance matrix. To reduce both the number of samples involved in the estimation and the computational cost inherent to the matrix inversion, many suboptimum STAP methods have been proposed. We propose a new canonical framework that encompasses all suboptimum STAP methods we are aware of. The framework allows for both covariance-matrix (CM) estimation and range-dependence compensation (RDC); it also applies to monostatic and bistatic configurations. Finally, we discuss a taxonomy for classifying the methods described by the framework. [J10]

"HRR Detector for Slow-Moving Targets in Sea Clutter"

The radar detection of targets in the presence of sea clutter has historically relied upon the radial velocity of targets with respect to the radar platform either by exploiting the relative target Dopplers (for targets with sufficient radial velocity) or by discerning the paths targets traverse from scan to scan. For targets with little to no radial velocity component, though, it can become quite difficult to differentiate targets from the surrounding sea clutter. This paper addresses the detection of slow-moving targets in sea clutter using a high resolution radar (HRR) such that the target has perceptible extent in range. Under the assumption of completely random sea clutter spikes based on an epsiv-contaminated mixture model with the signal and clutter powers known, optimal detection performance results from using the likelihood ratio test (LRT). However, for realistic sea clutter, the clutter spikes tend to be a localized phenomenon. Based upon observations from real radar data measurements, a heuristic approach exploiting a salient aspect of the idealized LRT is developed which is shown to perform well when applied to real measured sea clutter. [J11]

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

Radar systems are an important component in military operations. In response to increasingly severe threats from military targets with reduced radar cross sections (RCSs), slow-moving and low-flying aircraft hidden in foliage, and in environments with large numbers of targets, knowledge-based (KB) signal and data processing techniques offer the promise of significantly improved performance of all radar systems. Radars under KB control can be deployed to utilize valuable resources such as airspace or runways more effectively and to aid human operators in carrying out their missions. As battlefield scenarios become more complex with increasing numbers of sensors and weapon systems, the challenge will be to use already available information effectively to enhance radar performance, including positioning, waveform selection, and modes of operation. KB processing fills this need and helps meet the challenge. [J12]

"GMTI along-track interferometry experiment"

Synthetic aperture radar (SAR) along track interferometry (ATI) has been used extensively to measure ocean surface currents. Given its ability to measure small velocities (10 cm/s) of relatively radar-dark water surfaces, there is great potential that this technique can be adapted for ground moving target indication (GMTI) applications, particularly as a method for detecting very slow targets with small radar cross-sections. In this

paper we describe preliminary results from an ATI GMTI experiment. The SAR data described herein were collected by the dual-frequency NASA/JPL airborne radar in its standard dual-baseline ATI mode. The radar system imaged a variety of control targets including a pickup truck, sport utility vehicles, passenger cars, a bicycle, and pedestrians over multiple flight passes. The control targets had horizontal velocities of less than 5 m/s. The cross-sections of the targets were not purposely enhanced, although the targets' reflectivities may have been affected by the existence of the GPS equipment used to record the targets' positions. Single-look and multiple-look interferograms processed to the full azimuth resolution were analyzed. In the data processed to date, all of the targets were observed by visual inspection in at least one of the four combinations of dual-frequency, dual-baseline interferometric data. This extremely promising result demonstrates the potential of ATI for GMTI applications. [J13]

"Statistical analysis of multilook SAR interferograms for CFAR detection of ground moving targets"

This paper examines the statistics of the phase and magnitude of multilook synthetic aperture radar (SAR) interferograms toward deployment of along-track interferometry (ATI) for slow ground moving-target indication (GMTI). While the known probability density function (pdf) of the interferogram's phase (derived under the assumption of Gaussian backscatter) is shown to agree almost perfectly for a wide variety of backscatter conditions, the corresponding magnitude's pdf tends to deviate strongly in most cases. Motivated by this discrepancy, a novel distribution is derived for the interferogram's magnitude. This pdf, called the polynomial or p-distribution, matches the real data much more accurately, particularly for heterogeneous composite terrain. For extremely heterogeneous terrain, such as urban areas, both pdfs for interferometric phase and magnitude fail and are extended. Based on these statistics, a completely automatic detection scheme with constant false-alarm rates (CFARs) for slow moving targets is proposed. All involved parameters required to determine the detection thresholds are estimated from the sample data. It is demonstrated, on the basis of experimental airborne SAR data, that this detector is capable of detecting slow moving vehicles within severe ground clutter. [J14]

"Detection, location, and imaging of fast moving targets using multifrequency antenna array SAR"

In this correspondence, we generalize the linear antenna array synthetic aperture radar (SAR) from transmitting single-wavelength signals to transmitting multiple-wavelength signals (called multifrequency antenna array SAR). We show that, using multifrequency antenna array SAR, not only the clutters can be suppressed but also the locations of both slow and fast moving targets can be accurately estimated: A robust Chinese remainder theorem (CRT) is developed and used for the location estimation of fast and slowly moving targets. Simulations of SAR imaging of ground moving targets are presented to show the effectiveness of the multifrequency antenna array SAR imaging algorithm. [J15]

"Radar imaging of moving targets in foliage using multifrequency multiaperture polarimetric SAR"

Because of the low signal-to-clutter ratio, it is a difficult problem to detect and image moving targets in foliage. In this paper, a multifrequency multiaperture polarimetric synthetic aperture radar (MFMA POLSAR) system is proposed for imaging of moving targets in foliage. The MFMA POLSAR extends the multifrequency antenna array SAR (MF-SAR) system to multiple polarizations. Full polarization is used in MFMA POLSAR to achieve an optimal polarization adaptive to the environment such that the images obtained by different apertures are of the best coherence that is used to obtain the highest accuracy of the phase estimation. It is also shown that the MFMA POLSAR cannot only accurately locate both the slow and the fast moving targets but also reveal moving targets in foliage. [J16]

"Techniques for improving STAP performance in high PRF applications"

A novel beamforming architecture is presented in which space-time adaptive processing (STAP) for clutter suppression in airborne radar is implemented with tap delays of multiple PRIs. The resulting output is combined with the unadapted output. This can result in improved detection performance for targets obscured by clutter that covers only a small proportion of the unambiguous Doppler extent, as often occurs in high PRF modes [J17]

"Application of the fractional Fourier transform to moving target detection in airborne SAR"

As a useful signal processing technique, the fractional Fourier transform (FrFT) is largely unknown to the radar signal processing community. In this correspondence, the FrFT is applied to airborne synthetic aperture radar (SAR) slow-moving target detection. For airborne SAR, the echo from a ground moving target can be regarded approximately as a chirp signal, and the FrFT is a way to concentrate the energy of a chirp signal. Therefore, the FrFT presents a potentially effective technique for ground moving target detection in airborne SAR. Compared with the common Wigner-Ville distribution (WVD) algorithm, the FrFT is a linear operator, and will not be influenced by cross-terms even if multiple moving targets exist. Moreover, to solve the problem whereby

weak targets are shadowed by the sidelobes of strong ones, a new implementation of the CLEAN technique is proposed based on filtering in the fractional Fourier domain. In this way strong moving targets and weak ones can be detected iteratively. This combined method is demonstrated by using raw clutter data combined with simulated moving targets. [J18]

"Ultrawideband radar images of the surface disturbance produced by a submerged, mine-like object"

This paper describes an ultrawideband, imaging radar designed to image the fine structure of the surface disturbances caused by submerged objects and presents images of the surface wake generated by a sphere immersed in a current. The system was deployed on a research pier on the Outer Banks of North Carolina as part of the Mine Surface Effects (MISE) program, a program designed to investigate the feasibility of using microwave radar to detect submerged mines. The radar achieves extremely high range resolution, approximately 4 cm, through the use of a short pulse with a 3 dB bandwidth of 3 GHz and a center frequency of 9 GHz. Azimuthal imaging is achieved through the use of a linear array of receive antennas and a time-domain beam-forming technique. Radar images from the MISE program are presented which show the surface disturbance generated by a 91 cm-diameter sphere immersed in a 40-60 cm/s current. A surface wake is clearly visible in the imagery, both during the low phase of the tide, when the sphere broached the surface, and during high tide, when the sphere was completely submerged. Closer examination of the imagery reveals that when the target was fully submerged, the backscatter from the wake was primarily composed of long-lived (>1.5 s), isolated echoes that translated downstream at a velocity close to that of the measured surface current. Photographs of the wake suggest that these echoes are generated by sharp-crested surface features that form where the slow moving water of the turbulent, subsurface wake impinges the surface. [J19]

"Space-time adaptive processing for manoeuvring airborne radar"

Space-time adaptive processing (STAP) techniques provide simultaneous rejection of jamming and clutter in airborne radar. The greatest benefits over conventional MTI (moving target indication) approaches are in terms of a capability to detect slow-moving targets which possess the same Doppler frequency as mainlobe clutter returns. This paper examines the effects of platform manoeuvre on STAP clutter and jamming rejection performance for a forward-facing array (i.e. where the array is orientated transversally to the direction of travel). It is shown that STAP slow-target detection performance is not sensitive to the radar platform orientation. It is also demonstrated that, under conditions of manoeuvre, STAP can provide better jammer rejection performance than architectures which cascade conventional clutter filtering and spatial adaptive beamforming [J20]

"VSAR: a high resolution radar system for detection of moving targets"

The velocity SAR (VSAR) is a conceptual radar imaging system capable of reconstructing the three-dimensional range/azimuth/velocity image for a scene that contains moving objects. It combines the high resolution imaging capability of SAR with the clutter rejection capability of MTI systems. The clutter rejection and motion estimation capabilities of VSAR make it potentially useful for a variety of missions. The system concept is described, the basic signal-processing algorithms are developed, and a performance analysis of the VSAR system in the context of detecting low-RCS ground targets is provided. The VSAR system is able to estimate the speed of moving targets, down to slow speeds of the order of 0.5 m/s [J21]

СПИСОК ЛИТЕРАТУРЫ

J1. Ries P. Geometry-Induced Range-Dependence Compensation for Bistatic STAP with Conformal Arrays. / Ries P., Lapierre F.D., Verly J.G. // IEEE Transactions on Aerospace and Electronic Systems. - 2011. - Vol. 47, No. 1. - P. 275-294.

J2. Chapman R.D. Target Motion Ambiguities in Single-Aperture Synthetic Aperture Radar. / Chapman R.D., Hawes C.M., Nord M.E. // IEEE Transactions on Aerospace and Electronic Systems. - 2010. - Vol. 46, No. 1. - P. 459-468.

J3. Lesturgie M. Improvement of high-frequency surface waves radar performances by use of multiple-input multiple-output configurations. IET Radar, Sonar & Navigation. - 2009. - Vol. 3, No. 1. - P. 49-61.

J4. Lapierre F.D. Foundation for mitigating range dependence in radar space-time adaptive processing. / Lapierre F.D., Ries P., Verly J.G. // IET Radar, Sonar & Navigation. - 2009. - Vol. 3, No. 1. - P. 18-29.

J5. Chapin E. Airborne along-track interferometry for GMTI. / Chapin E., Chen C.W. // IEEE Aerospace and Electronic Systems Magazine. - 2009. - Vol. 24, No. 5. - P. 13-18.

J6. Ramakrishnan D. Adaptive Radar Detection in Doubly Nonstationary Autoregressive Doppler Spread Clutter. / Ramakrishnan D., Krolik J. // IEEE Transactions on Aerospace and Electronic Systems. - 2009. - Vol. 45, No. 2. - P. 484-501.

J7. Herbert G.M. Post-adaptive processing time-delay beamforming for clutter suppression in airborne radar. / Herbert G.M., Richardson P.G. // Electronics Letters. - 2008. - Vol. 44, No. 5. - P. 378-379.

J8. Chapin E. Along-track interferometry for ground moving target indication. / Chapin E., Chen C.W. // IEEE Aerospace and Electronic Systems Magazine. - 2008. - Vol. 23, No. 6. - P. 19-24.

J9. Gang Li. Bistatic Linear Antenna Array SAR for Moving Target Detection, Location, and Imaging With Two Passive Airborne Radars. / Gang Li, Jia Xu, Ying-Ning Peng, Xiang-Gen Xia. // IEEE Transactions on Geoscience and Remote Sensing. - 2007. - Vol. 45, No. 3. - P. 554-565.

J10. Greve S.D. Framework and Taxonomy for Radar Space-Time Adaptive Processing (STAP) Methods. / Greve S.D., Ries P., Lapierre F.D., Verly J.G. // IEEE Transactions on Aerospace and Electronic Systems. - 2007. - Vol. 43, No. 3. - P. 1084-1099.

J11. Blunt S.D. HRR Detector for Slow-Moving Targets in Sea Clutter. / Blunt S.D., Gerlach K., Heyer J. // IEEE Transactions on Aerospace and Electronic Systems. - 2007. - Vol. 43, No. 3. - P. 965-974.

J12. Capraro G.T. Knowledge-based radar signal and data processing: a tutorial review. / Capraro G.T., Farina A., Griffiths H., Wicks M.C. // IEEE Signal Processing Magazine. - 2006. - Vol. 23, No. 1. - P. 18-29.

J13. Chapin E. GMTI along-track interferometry experiment. / Chapin E., Chen C.W. // IEEE Aerospace and Electronic Systems Magazine. - 2006. - Vol. 21, No. 3. - P. 15-20.

J14. Gierull C.H. Statistical analysis of multilook SAR interferograms for CFAR detection of ground moving targets. IEEE Transactions on Geoscience and Remote Sensing. - 2004. - Vol. 42, No. 4. - P. 691-701.

J15. Genyuan Wang. Detection, location, and imaging of fast moving targets using multifrequency antenna array SAR. / Genyuan Wang, Xiang-Gen Xia, Chen V.C., Fielder R.L. // IEEE Transactions on Aerospace and Electronic Systems. - 2004. - Vol. 40, No. 1. - P. 345-355.

J16. Genyuan Wang. Radar imaging of moving targets in foliage using multifrequency multiaperture polarimetric SAR. / Genyuan Wang, Xiang-Gen Xia, Chen V.C. // IEEE Transactions on Geoscience and Remote Sensing. - 2003. - Vol. 41, No. 8. - P. 1755-1764.

J17. Herbert G.M. Techniques for improving STAP performance in high PRF applications. Electronics Letters. - 2003. - Vol. 39, No. 23. - P. 1674-6.

J18. Hong-Bo Sun. Application of the fractional Fourier transform to moving target detection in airborne SAR. / Hong-Bo Sun, Guo-Sui Liu, Hong Gu, Wei-Min Su. // IEEE Transactions on Aerospace and Electronic Systems. - 2002. - Vol. 38, No. 4. - P. 1416-1424.

J19. Sletten M.A. Ultrawideband radar images of the surface disturbance produced by a submerged, mine-like object. IEEE Transactions on Geoscience and Remote Sensing. - 2000. - Vol. 38, No. 6. - P. 2506-2514.

J20. Richardson P.G. Space-time adaptive processing for manoeuvring airborne radar. Electronics & Communication Engineering Journal. - 1999. - Vol. 11, No. 1. - P. 57-63.

J21. Friedlander B. VSAR: a high resolution radar system for detection of moving targets. / Friedlander B., Porat B. // IEE Proceedings - Radar, Sonar and Navigation. - 1997. - Vol. 144, No. 4. - P. 205-218.

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