

Guest Editorial: Electronic attack and protection for modern radar systems and radar networks

Abstract

It is our great pleasure to present you with this IET Radar, Sonar and Navigation special issue on “Electronic Attack and Protection for Modern Radar Systems and Radar Networks”. The recent development of fast digital to analogue converters (DACs) and analogue to digital converters (ADCs), field programmable gate arrays (FPGAs) and parallel computing has contributed to the development of modern radars that, at the same time, can also be more easily attacked using digital radio frequency memories (DRFMs). The development of passive and netted multiband, multistatic, multichannel radars has also changed the EW scenario significantly. Classical EA can be less effective against passive, multistatic and multichannel radars and, as a result, new methods and new technologies have to be developed for effective countermeasures. Multichannel and multistatic jammers have also started to play a role in the EW scene. The aim of this special issue was to gather some of the most recent work in this area. The result is a collection of 12 interesting and timely papers aiming to address current technical challenges in electronic warfare. The papers included in this collection covers areas around the more general electronic warfare context as well as address specific challenges of electronic attack and electronic protection as summarised below.

1 | ELECTRONIC WARFARE CONTEXT

Analysing the armed forces (AF) operational capabilities requires the construction of a formal model which can aid the analysis and assessment of selected aspects of electronic warfare. The essence of the impact of radio-electronic, like other forms of cyber warfare, on reconnaissance, command and communications systems is to hinder or prevent kinetic operations. A model proposed to identify and prioritise the required capabilities by defining key objectives is presented in Ref. [1]. The model key objectives include (a) the identification of the future security environment and within it the operational environment, (b) the identification of planning scenarios and requirements for future forces, including forces to execute electronic warfare (EW), (c) identification of specific tasks in relation to AF missions and tasks, and (d) the identification of the list of AF required capabilities in the AF capability catalogue.

Modern radar systems are critical infrastructure in defence and civilian applications. In the defence domain, modern radars operate in a highly contested, congested, and constrained electromagnetic environment. The challenges and key objectives in testing sophisticated modern radar systems are highlighted in Ref. [2] with the enabling technologies that can support test and evaluation of such systems. An architecture for hardware-in-the-loop testing, which leverages modular and flexible commercial-of-the-shelf hardware, is proposed together with an application software that allows the testing of radar with a radar target generator.

2 | ELECTRONIC ATTACK

Platform echo and cross-eye jamming signals are jointly considered to analyse the jamming performance on active-passive composite monopulse radar (APCMR) in Ref. [3]. A mathematical model of the cross-eye jamming against APCMR is established in the presence of the platform echo, and the jamming performance on active radar and passive radar is evaluated and compared in terms of cross-eye gain and its probability. In order to ensure the jamming performance on both active and passive radars, a guideline for the setting of jammer parameters is proposed based on numerical simulations.

An investigation of the sequential lobing radar (SLR) resistance against the scan rate modulation (SRM) jamming technique is presented in Ref. [4]. Unlike previous studies, here the authors analyse SLRs with sinc antenna patterns, enabling investigation of the sidelobe region's vulnerability. The theoretical results support the 20 dB jamming to signal ratio (JSR) requirement for SRM effectiveness, often cited in previous experimental literature.

Jammers aim to interfere with active radars during military operations. Still, they can strengthen capabilities on the battlefield if there are proper methods to exploit them. A demonstration of the possibility of utilising a ground-based barrage jammer (to jam radars or communications) as an illumination source for passive radar detection, tracking and ISAR imaging is presented in Ref. [5]. The results show the feasibility

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of using a jammer for cooperative (friendly jammer) and non-cooperative (hostile jammer) operations.

Accurate work state recognition of multifunction radar (MFR) is crucial in electronic warfare, as it helps understand the enemy's intention and evaluate potential threats. A pulse-level work state recognition method of MFR based on the residual block with spatial attention connected gated recurrent unit by features using metric coding and correlative embedding (MC-RSG) is proposed in Ref. [6]. The experimental work shows that the method is robust and achieves up to 97% recognition accuracy on the test dataset under ideal observation conditions and 5% higher than the comparison network in high noise observation conditions.

Radar work mode recognition is also crucial to analyse radar behaviour and intentions. There are some challenges limiting the recognition of long sequences with multiple mode classes, and current methods failing to deal with scenarios where multiple modes share the same state sequence. To address these problems, a novel forward matching method (FMM) is proposed in Ref. [7] which consists of a shortest path method (SPM) for intra-mode recognition, a matching strategy, and an adjustment mechanism. The model can explicitly characterise the mode transition probability, it is totally interpretable, and it can distinguish intentional ambiguities.

3 | ELECTRONIC PROTECTION

Distributed array radar can be used to suppress mainlobe jamming by increasing the array aperture by the deployment of auxiliary arrays. However, when the aperture of an auxiliary array is smaller than that of the main array, residual jamming in the auxiliary arrays, after beamforming, affects the performance of the radar system. A mainlobe and sidelobe jamming joint suppression method with eigen-projection matrix processing (EMP) and null constraints is proposed in Ref. [8]. The method, firstly, performs adaptive beamforming with EMP in the main and auxiliary arrays to suppress sidelobe jamming with mainlobe maintenance. Then, the null constraints based on the Capon spectrum of the main array are applied to suppress the residual jamming in the auxiliary arrays before using minimum mean square error (MMSE) beamforming to cancel mainlobe jamming.

Interrupted-sampling repeater jamming (ISRJ) is an effective intra-pulse coherent jamming technique based on digital radio frequency memory. It appears as a group of false targets that are difficult to distinguish on the range profile after pulse compression and seriously affects target identification and tracking. A new method is proposed for ISRJ parameter estimation and jamming suppression based on block sparse recovery in Ref. [9]. The transmitted signal is divided into several random phase-encoded sub-pulses. The pulse number and time delay of the received echo are estimated by block orthogonal matching pursuit and then, the jamming slices are identified based on the sampling duty ratio and the Doppler frequency is estimated through matching, to reconstruct the jamming slices and eliminate ISRJ. Numerical experiments in representative scenarios show that this method can effectively suppress ISRJ.

Mitigation in the presence of main lobe deceptive jamming is investigated in Ref. [10]. A novel main lobe jamming suppression method is proposed which is based on the blind source separation (BSS) method and energy detection to solve the issues related to amplitude ambiguities, which knowingly cause a failure of the monopulse angle measurement after jamming suppression.

A method for Underdetermined Blind Source Separation is proposed in Ref. [11] using third-order cumulants and tensor compression. The third-order cumulant is considered to effectively suppress symmetrical distributed noise, and the complexity of high-dimensional tensors is reduced through high order singular value decomposition (HOSVD) for compression purposes. The theoretical analysis and simulation results demonstrate that the proposed method effectively suppresses the influence of Gaussian noise, reduces computational complexity, and saves computational time.

An experimental setup to allow measurements of chaff dipole elements, over a large bandwidth, in free space and with no requirement for an anechoic chamber is presented in Ref. [12]. The setup is used to collect reflectivity data from chaff made of copper wire, micro wire and aluminised glass and subsequently to compare chaff RCS characteristics with respect to the existing theory, composition material and fabrication process. The results are important to design and compare different chaff types, different element compositions and different fabrication techniques.

KEYWORDS

electronic warfare, radar

AUTHOR CONTRIBUTIONS

The authors have all contributed to writing up the editorial manuscript and to running the Special Issue.

CONFLICT OF INTEREST STATEMENT

This is to confirm there are no conflicts of interest associated with this research and this publication.

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DATA AVAILABILITY STATEMENT

No new data were created or analysed during this study. Data sharing is not applicable to this article.

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Alessio Balleri received the Laurea degree in telecommunication engineering (summa cum laude) (five legal years) from the University of Pisa, Italy, in 2004, and the Ph.D. degree in electronic and electrical engineering from the university college London (UCL), London, U.K., in 2010. From February 2010 to March 2012, he was a Research Associate in radar systems with the Department of Electronic and Electrical Engineering, UCL. From June 2004 to December 2004, he was a Visiting Research Scholar

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Dietmar Matthes received the Dipl.-Ing degree in telecommunications and high-frequency engineering from the University of Erlangen-Nuremberg in 1994. From 1996 until today he was Research Scientist at the Fraunhofer Institute for High-Frequency Physics and Radar Techniques (Fraunhofer FHR), former FGAN e.V., Wachtberg, Germany. His research interests include advanced system concepts, technologies and signal processing for radar electronic warfare. He was Co-Chair of the NATO Science & Technology Organisation's Specialists Meeting on EW in 2016 and 2023. Currently he is Chair of the STO Task Group SCI-332 on “RF-based Electronic Attack to Modern Radar”.



Dr. Lo Monte has comprehensive experience in applied Radar, RF, DSP, EW system design and prototyping, from small companies, consulting, academia, research institutions, to large defence contractors and government agencies worldwide. He serves as Chief Scientist at Telephonics, a top-100 defence corporation specialising in ISR, with the role of translating research innovations into commercial products. Prior to that, he was an Associate Professor at the University of Dayton, where he created the courses “Intro to Radar,” “Radar/RF Systems Design,” and “Intro to Electronic Warfare.” He was also the Director of the Mumma Radar Laboratory. Dr. Lo Monte has published over 70 peer-reviewed journal and conference papers and two book chapters. Throughout his career, he gained experience in HF-to-W Band radar systems prototyping, including monopulse, radar transmitters, early warning radars, multistatic and MIMO radar, ISAR and tomography,

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2024-11-01

Institution of Engineering and Technology (IET)

<https://doi.org/10.1049/rsn2.12666>

Balleri A, Matthes D, Lo Monte L, Kulpa K. (2024) Guest Editorial: Electronic attack and protection for modern radar systems and radar networks. IET Radar, Sonar & Navigation, Volume 18, Issue 11, November 2024, pp. 2077-2080