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GUEST EDITORIAL

Guest Editorial: Selected papers from RADAR 2022—International Conference on Radar Systems (Edinburgh, UK)

It is our great pleasure to present you with this IET Radar, Sonar and Navigation special issue on the 'Selected Papers from RADAR 2022—International Conference on Radar Systems (Edinburgh, UK)'.

RADAR 2022 took place at Murrayfield Stadium, Edinburgh, on 24–27 October 2022 as a prime opportunity for radar specialists at all career stages to update and enhance their knowledge on the latest developments in advanced radar systems. As such, RADAR 2022 was attended by over 250 delegates from 22 countries who joined the conference to explore the latest technologies in radar systems.

Key topics of RADAR 2022 included new radar trends and developments, bistatic and multistatic radar, target detection (with particular emphasis on drones), Constant False Alarm Rate algorithms, tracking before and after detection, low-frequency radar, waveform diversity, performance evaluation, virtual prototyping, and cognitive radar. Presentations covered the latest radar developments and were complimented by a set of outstanding tutorials given by world-leading radar experts on key elements of radar technology, a radar competition and keynote addresses from leading experts.

In total, 126 papers were published in the proceedings of RADAR 2022. Out of all these, the authors of the approximately 30 best papers, that scored the highest peer-review scores in the conference review selection, were invited to extend their conference papers into a journal article for this special issue.

This special issue contains 17 papers which are based on extended work presented at the conference on topics that include waveform design, estimation, passive radar, multistatic radar, Synthetic Aperture Radar (SAR), radar clutter and target signatures for detection and classification. The papers published in this special issue contain at least 40% new material compared to the work published in the RADAR 2022 conference proceedings and underwent a brand-new, rigorous, and robust peer-review process as set out by very high common IET and Wiley standards.

1 | MULTISTATIC

An analysis of the parameter estimation uncertainty for the target location and velocity achievable using a single-transmitter multiple-receiver multistatic radar system is presented in Ref. [1]. The paper proposes a framework for establishing multistatic radar parameter estimation uncertainties by an expansion of the bistatic radar performance. The proposed technique employs analytical methods based on the Cramér–Rao Lower Bound, and these are applied to scenarios in a two-dimensional physical space with a single target exhibiting Doppler characteristics and a bistatic angle-dependent radar cross-section. The results indicate that angular separation between the transmitter and the centre of the receiver distribution is of greater importance than the quantity of receivers, though a minimum of two receivers must be available. Results also show that increasing the total number of receivers reduces the proportion of receivers required to achieve the minimal uncertainty.

A fundamental challenge in the practical implementation of multistatic radar systems is the requirement for precise time and frequency synchronisation between spatially separated radar nodes and, in Ref. [2], the authors evaluate the performance of different classes of commercially available Global Navigation Satellite Systems (GNSS) timing receivers, Local Oscillators and GNSS Disciplined Oscillators to determine the limitations of using GNSS Time and Frequency Transfer as a solution to provide network synchronisation.

Detecting, localising, and identifying low observable targets, such as drones and birds, in strong clutter requires both innovation in the radar hardware design and optimisation of processing algorithms. A paper from the University of Birmingham presents in Ref. [3] a testbed consisting of two L-band staring radars to support performance benchmarking using datasets of targets and clutter from a realistic urban environment. The paper highlights some of the challenges in installing the radars, and some detailed benchmarking results are provided from urban monostatic and bistatic field trials.

The papers describes the challenges of interfacing the radars to external oscillators to allow comparisons between different oscillator technologies.

2 | PASSIVE RADAR

A simple non-adaptive approach in proposed in Ref. [4] for the suppression of direct signal and clutter contributions in a passive radar system based on orthogonal frequency division multiplexing transmissions. The algorithms exploit the properties of a Reciprocal Filter to mitigate the limits posed by the waveform ambiguity function and produce a data-independent time-invariant response to a stationary point-like target echo. This feature enables simple clutter cancellation strategies, based on the subtraction of delayed portions of the surveillance signal, according to a conventional moving target indication solution. The performance of the proposed algorithm is investigated against simulated and experimental data of a digital video broadcasting-terrestrial-based passive radar scenario.

Passive space object detection using a single radio telescope from the European Low-Frequency Array (LOFAR) network of astronomical radio telescopes and commercial digital television transmitter illuminators is investigated in Ref. [5]. Experimental results are presented for the case of a single LOFAR radio telescope providing both the surveillance and reference channel in a passive radar configuration. The authors investigate how to suppress the strong direct-path component in the surveillance channel coming from the relatively close illuminator of opportunity. Results demonstrate the passive detection of the International Space Station and confirm the possibility of observing the space object flying in Low-Earth Orbit using the LOFAR telescope or another receiving system with a similar antenna array.

Emerging constellations of satellites are considered in Ref. [6] as space-based transmitters of opportunity candidates for passive radar applications. These transmitters offer some advantageous characteristics such as increased global coverage, better resolution, high received power on Earth surface and increased detection range, predictable trajectories, as well as network density and robustness. However, they also pose key challenges for the development of passive radar systems related to the need to track satellites with a narrow beam reference antenna and compensate range and Doppler migrations induced by the moving transmitting platform. The paper presents an analysis of capabilities and challenges with special emphasis on the estimation of performance and on the experimental characterisation of the transmitted signals.

GNSS-based passive multistatic radar for ship target detection and localisation is investigated in Ref. [7]. The proposed approach exploits the large spatial diversity offered by the GNSS constellation to provide maritime surveillance using short integration time windows. The technique proposed in the paper operates exclusively on the Cartesian plane and can provide target detection and localisation in a single processing stage. The theoretical and simulated performance are analysed, and the technique is demonstrated via experimental data acquired in a few representative scenarios of interest.

The use of WiFi signals is investigated in Ref. [8] to provide a small, compact, and easy-to-deploy passive system that can provide target detection without the need of a copy of the transmitted waveform at the radar receiver. The paper presents a passive processing scheme that exploits the invariant a priori known initial portion of the physical layer protocol data unit of the WiFi, and we investigate its limitations in practical applications. As an alternative, the authors also consider a forward scattering approach that exploits only the amplitude modulation of the received signal in the presence of a moving target. Advantages and drawbacks of the two reference-free approaches are presented, and experimental results are reported for the detection of people and drones using WiFi transmissions in the 2.4 and 5 GHz band.

3 | TARGET SIGNATURES

A statistical analysis of the Radar Cross Section (RCS) of two small fixed-wing drones is presented in Ref. [9] using measured data from typical flights. The work provides estimations of typical RCS mean values, medians, and standard deviations, as well as common fitting target probability distributions and RCS decorrelation times, which are necessary for the design and assessment of the detection performance. A simple and effective Bayesian scheme to maintain tracks in drone surveillance radar is presented in Ref. [10]. The proposed technique allows the simultaneous tracking of the drone body and of micro-Doppler components induced by the motion of rotors onboard an unmanned air system. The solution delivers more accurate multi-target tracking and substantially improves radar automatic target classification capability.

One of the challenges of autonomous marine vessel sensors is to detect and avoid large air breathing aquatic or semi-aquatic mammals (i.e., whales), which are protected species. To this end, a millimetre wave radar was used to collect signatures of sea lions in Ref. [11] to study the radar amplitude and Doppler signatures of the animals when their full body or part thereof is above water. The data was collected using 24 (K-band) and 77 GHz (W-band) Frequency Modulated Continuous Wave radars, and results show that the sea lions can be clearly detected with suitable Signal to Noise Ratio (SNR) at approximately 40 m.

The capability to design, manufacture and test Hypersonic Glide Vehicles (HGVs) has been demonstrated by a few nations, and these platforms have increasingly become part of existing military assets. HGV represents a significant new threat and a key detection challenge for ground-based Ballistic Missile Early Warning Systems and Space Object Surveillance. To understand the RCS of these targets and predict radar detection performance, the simulated monostatic RCS of a generic HGV is presented in Ref. [12] for five frequency ranges, HF, VHF, UHF, L, and S-bands. The data is used to carry out a statistical analysis and identify the probability density functions that provide a good fit and can be used to achieve HGV detection.

A simple model is proposed for the radar returns from a slow-moving target with a wake on the sea surface based on measurements of returns from a submarine mast in Ref. [13]. This model is used to investigate the effect of a wake with a broad Doppler spectrum on the detection of a slow-moving target in sea clutter. Results in this paper show how the relative magnitudes of the returns from the target and its wake affect detection performance, and a comparison between non-coherent and coherent detectors is presented as well.

4 | ADVANCED RADAR PROCESSING TECHNIQUES

With the advent of constellations of SAR satellites and the possibility of swarms of SAR Unmanned Aerial Systems, there is increased interest in multistatic SAR image formation as a means to provide key advantages such as three-dimensional image formation free of clutter overlay, improved image resolution and increased scattering information. Results from a multistatic polarimetric SAR experimental campaign carried at the Ground-Based SAR lab of Cranfield University, Shrivenham, are presented in Ref. [14] to demonstrate the utility of the approach for fully sampled 3D SAR image formation and for sparse aperture SAR 3D point-cloud generation with a novel volumetric multistatic interferometry algorithm.

Co-registration of SAR images is one the most important and challenging tasks, especially when images are acquired at different times and present low SNRs. Commonly, to co-register a series of multitemporal SAR images, a single image is selected as the master, and the remainder images are separately registered to it. The technique proposed in Ref. [15] investigates a new strategy that jointly co-registers a stack of multitemporal SAR images. The solution is based on the exploitation of the second order cross-correlations, computed as cross-correlation of the cross-correlations of the extracted patches. The technique performance is tested against the Gotcha Volumetric SAR dataset, and results show the effectiveness of the proposed algorithm.

An algorithm for fast source direction-of-arrival (DOA) estimation with fully augmentable sparse arrays is proposed in Ref. [16]. The solution is a modified RELAX algorithm based on iterative coarray-domain beamforming that exploits the deterministic centralised nature of the noise in the coarray domain and the Hermitian symmetry of the spatial autocorrelation function. The solution efficiently incorporates source number estimation within the iterative framework and, as a result, allows low-complexity, fast DOA estimation of more sources than sensors, without resorting to computationally expensive.

The design of waveforms for the sake of informationally optimal adaptive-on-transmit radar operation is presented in Ref. [17]. A framework based on the marginal Fisher information (MFI) metric is developed, and the Polyphase-Coded FM waveform model is utilised to produce a constant-modulus, spectrally contained signal amenable to transmission with high-power amplifiers. The efficacy of the MFI waveform design and minimum mean square error estimation is experimentally demonstrated. These concepts are used to maximise the information extracted by a radar operating in a congested spectrum where the available bandwidth is limited.

5 | CONCLUSION

The papers presented in this special issue represent excellent key contributions on very timely technical challenges of modern radar systems. We hope this special issue can be a key starting point for further literature review and to steer readers in a useful direction in addressing their research questions. It has been a pleasure to guest-edit this collection, and we take this opportunity to congratulate with all authors and thank them for their contributions.

KEYWORDS

radar, radar signal processing

AUTHOR CONTRIBUTIONS

Carmine Clemente: Project administration; Resources; Visualization; Writing—original draft; Writing—review and editing. **Alessio Balleri**: Project administration; Resources; Visualization; Writing—original draft; Writing—review and editing.

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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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