remote sensing

Editorial

Editorial for Special Issue "Radar Imaging in Challenging Scenarios from Smart and Flexible Platforms"

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Abstract: Microwave radar imaging plays a key role in several civilian and defense applications, such as security, surveillance, diagnostics and monitoring in civil engineering and cultural heritage, environment observation, with particular emphasis on disasters and crisis management, where it is required to remotely sense the area of interest in a timely, safe and effective way. To address these constraints, a technological opportunity is offered by radar systems mounted onboard smart and flexible platforms, such as ground-based ones, airplanes, helicopters, drones, unmanned aerial and ground vehicles (UAV and UGV). For this reason, radar imaging based on data collected by such platforms is gaining interest in the remote sensing community. However, a full exploitation of smart and flexible radar systems requires the development and use of image formation techniques and reconstruction approaches able to exploit and properly deal with non-conventional data acquisition configurations. The other main issue is related to the need to operate in challenging environments, and still deliver high target detection, localization and tracking. These environments include through the wall imaging, rugged terrain and rough surface/subsurface. In these cases, one seeks mitigation of the adverse effects of clutter and multipath via the implementation of effective signal processing strategies and electromagnetic modeling.

This Special Issue (SI) is aimed at providing an overview of recent scientific and technological advances in the field of radar imaging from smart and flexible platforms, in terms of hardware, modeling and data processing.

The contributions of the SI can be generally classified into two groups.

The papers belonging to the first group [1–6] provide the description of the capabilities of newborn imaging radar systems designed to operate in challenging scenarios [1] or using smart and flexible aerial platforms, such as small airplanes [2], drones [3–5] or helicopters [6]. Overall, these contributions provide an interesting survey of the potential of lightweight and compact imaging radar sensors. The described systems cover a very wide range of the microwave spectrum, including the VHF band, up to the X-band. The papers under this group [5] provide a good survey of the radar hardware as well as the corresponding processing chain applied to the acquired data.

The contributions belonging to the second group [7–10] are focused on the description of novel data processing techniques aimed at achieving accurate radar imaging under complex acquisition geometries, such as in the case of airborne Synthetic Aperture Radar (SAR) [6–8], or in challenging scenarios, as in the case of Forward-Looking Ground-Penetrating Radar (FL-GPR) [9] or Lunar Penetrating Radar (LPR) [10].

As for the papers belonging to the first group, in [1], a newborn Ultra Wideband (UWB) Multiple-Input Multiple-Output (MIMO) radar system exploiting the Stepped-Frequency Continuous-Wave (SFCW) technology to detect human targets beyond the obstacle, is presented. More specifically, the design, as well as manufacturing processes leading to the realization of the overall radar system, which also includes a novel miniaturized Vivaldi antenna with 0.5–2.5 GHz bandwidth, are described. The radar system is successfully used for through-wall imaging applications by exploiting a data-processing algorithm based on the Cross-Correlation Time Domain Back Projection (CC-TDBP) technique.

In [2–4], two newborn SAR systems mounted onboard aerial platforms are presented. In particular, in [2], the imaging and topographic capabilities of a novel Italian airborne X-band SAR system, named AXIS, are discussed. The system is based on the Frequency-Modulated Continuous-Wave (FMCW) technology and is equipped with a single-pass interferometric layout. In this work, the description of the developed radar system is given along with a quantitative assessment of the quality of the SLC (Single Look Complex) SAR images and the interferometric products achievable through the system.

In [3,4], a novel Brazilian drone-borne SAR system operating in three different frequency bands, namely the C-, L- and P-band, is presented. The system is capable of exploiting a single-pass interferometric configuration at C-band, and full-polarimetric configurations at the L- and P-band. In [3], the description of the system and a quantitative assessment of the results achieved by applying the Differential SAR Interferometry (DInSAR) technique to the L-band data is presented. The work in [4] is focused on an interesting precision farming application scenario enabled by the exploitation of the drone-borne SAR system. More specifically, a novel methodology for obtaining growth deficit maps with an accuracy down to 5 cm and a spatial resolution of 1 m is presented. The proposed methodology is based on the DInSAR technique.

Another light and compact imaging radar system mounted onboard a small Multicopter-Unmanned Aerial Vehicle (M-UAV) is presented in [5]. In this case, the radar operates with 1.7 GHz bandwidth centered at 3.95 GHz, and the flight positions are obtained through the Carrier-Phase Differential GPS (CDGPS) technique. In particular, the work describes the overall radar imaging system in terms of both hardware devices and data processing strategy. The system is validated by collecting and processing a dataset through a single flight track to provide focused images of on surface targets.

In [6], a helicopter-borne integrated Sounder/SAR system operating in the UHF and VHF frequency bands is described. More specifically, the Sounder operates at 165 MHz, whereas the full-polarimetric SAR could operate either at 450 MHz or at 860 MHz. The system is developed under the auspices of a contract between the Italian Space Agency (ASI) and different private and public Italian Research Institutes and Universities. In this work, the first results relevant to a set of Sounder and SAR data, acquired during a campaign conducted in 2018 over a desert area in Erfoud, Morocco, are presented.

As for the papers belonging to the second group, they address the processing of three kinds of imaging radar data, namely, airborne SAR [7,8], FL-GPR [9] and LPR [10] data. For airborne SAR processing, exploitation of small and flexible aerial platforms to mount the radar systems makes the issues related to motion errors (that is, the attitude and position instabilities of the platform during the acquisition) coupled to the topographic variations of the observed scene even more critical; therefore, ad-hoc data processing strategies capable to properly account for these problems are needed.

In [7], the spatial variations induced on airborne SAR images by the motion errors are decomposed into three main parts: range, azimuth and cross-coupling terms. The cross-coupling variations are then corrected by means of a polynomial phase filter, whereas the range and azimuth terms are removed through Stolt mapping.

In [8], an extended back-projection approach is proposed to take into account the topography variations during the airborne SAR image formation process. In particular, the algorithm applies a time–frequency rotation operation to pursue high accuracy, while reducing the computational burden, typically required by standard back-projection algorithms operating entirely in the time-domain.

The FL-GPR allows fast scanning of large areas for real-time target detection, unlike its ground-coupled or near-ground down-looking GPR (DL-GPR) counterparts. This capability, however, comes at the expense of energy backscattered from the illuminated targets and limited image spatial resolution. Furthermore, the rough ground surface generates clutter that may obscure the buried targets, rendering target detection very challenging. In this respect, the work in [9] presents an enhanced imaging procedure for the suppression of the rough surface clutter arising in FL-GPR applications. The procedure is based on a matched filtering formulation of microwave tomographic imaging enhanced by a coherence factor (CF) scheme for clutter suppression.

The work in [10] is framed in the context of the planetary exploration and deals with the Lunar Penetrating Radar mounted onboard the Yutu lunar rover to detect the lunar regolith and the shallower subsurface geologic structures of the Moon. In particular, it is aimed at improving the capability of identifying response signals caused by discrete reflectors (such as meteorites, basalt and debris) beneath the lunar surface. To this end, a compressive sensing (CS)-based approach is proposed to estimate the amplitudes and time delays of the radar signals from LPR data.

In conclusion, this informative Special Issue would not have been possible without the hard work of all authors and reviewers. We also would like to extend our sincere appreciation to the Editorial Office of Remote Sensing for their professional and excellent management work.

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