3-D electromagnetic signal processing for environment characterization.

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About the co-supervisors  This work is also supervised by Professor Laurent Ferro-Famill of the University of Rennes 1, Professor Yide Wang of the University of Nantes and Dr. Cédric Le Bastard of the Cerema.

Professor Laurent Ferro-Famill is presently one the heads of the Remote Sensing, Localisation and Propagation department at IETR. His current activities of research and education are centered in the topics of digital electronics, microwave theory and radar imaging with emphasis in radar polarimetry and radar interferometry. His research covers a wide spectrum of areas such as radar signal processing and focusing (SAR, ISAR, STAP), 3-D imaging and polarimetric SAR tomography and Pol-inSAR, radar polarimetry theory, and multi-dimensional radar signal processing, with applications to natural environment remote sensing and object characterization, segmentation and classification, EM modeling, and physical parameter retrieval. Moreover, he is also Adjunct Professor at the Tromso University, Norway.

Professor Yide Wang is a researcher in the laboratory IETR. His research area is about the application of signal processing techniques in various fields such as radar (spectral analysis for characterizing a high resolution radar target; radar signature for SAR imaging) and telecommunications (array signal processing, source localization, beamforming, and modeling). Moreover, he was the director of STIM, one of the doctoral schools of the region Pays de La Loire from 2008 to 2011. From 2011, he is the director of research of Polytech Nantes. He is also in charge of international relations with China in Polytech Nantes, an engineer school at the University of Nantes.

Cédric Le Bastard is a researcher at the Cerema, and has received his Ph. D. degree in signal processing and electronics about the improvement of the pavement survey with GPR by super and high resolution techniques. His current research interests are radar and signal processing such as time delay estimation, spectral analysis, deconvolution techniques and machine learning methods. Moreover, he is interested in nondestructive testing and evaluation techniques as well as intelligent transportation systems.

About the work  The electromagnetic (EM) response of an environment contains a very important amount of information, related to the geo-physical characteristics of the medium under observation, and may be used to perform a wide range of applications, like nondestructive testing [1], 3-D imaging [2], traffic monitoring [3]. Such high-level objectives generally require multi-dimensional EM measurements, operated with different modes of diversity. Adapted multivariate signal processing techniques are then required to extract the useful part of the acquired information and to derive relevant, accurate and robust parameters, which may be combined for a given purpose. Modern applications
generally require acquisitions performed over a short period of time and at high spatial resolution. Synthetic aperture signal processing, based on the coherent combination of signals acquired with spatial diversity, is a natural solution meeting both requirements. Spatial diversity may be generated through the motion of the measuring radar system (SAR) or of the observed medium (ISAR) [4, 5].

In the last years, several works are dedicated to the development of imaging systems either based on dedicated sensor array [6] or using a specific array, operated under a MIMO (Multiple Input Multiple Output) configuration.

Some ongoing studies are being led at the IETR, on 3-D high-resolution SAR system development and applications [7], MIMO SAR imaging [8], DOA-DOD estimation [9] which combine digital communications techniques, radar imaging and specific applications like tomography. The aim of this thesis is to develop advanced signal processing techniques and to design a 3D imaging system for the characterization of environments. Further objectives, such as traffic management or nondestructive testing and evaluation, could be considered.

During this study, a MIMO-DOA-DOD system configuration will be investigated through theoretical studies, simulation and measurements: first using narrowband signals (2-D imaging), then considering wideband waveforms (3-D imaging) and finally in the frame of an ISAR application for moving object imaging. The proposed PhD work is the following:

1. Comprehensive bibliography on signal processing principles and techniques, related to
   - MIMO arrays and their applications,
   - waveform design for specific applications such as the detection and the estimation of the associated DOA and DOD of the environment. This list may be expanded depending on the thesis requirements.
2. Design, simulation and experimentation of a 1D antenna array
   - having MIMO capabilities,
   - adapted to DOA-DOD estimation techniques,
   - operating in SAR/ISAR 1-D imaging mode
3. Extension of the above 1D configuration to the 2D configuration and assessment of the corresponding 2D imaging performance.
4. Proposition of a 3D imaging sensor combining the 2D system with specific waveforms in order to improve the imaging performance through range resolution.
5. Conclusion about these developments.

Références


