Radar Implementation of Compressive Sensing: RICS Project Overview

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Abstract— **The interest and use of Compressive Sensing (CS) techniques in radar applications are growing very rapidly. The project Radar Implementation of CS (RICS) is the answer to the European Defense Agency (EDA) invitation to tender 12.R&T.OP.270, which has been awarded to a consortium which conjugates both representatives from industry and academia, having deep experience in this field. Indeed, the proponent consortium involves SELEX ES (as leader), Consorzio Nazionale Inter-universitario per le Telecomunicazioni – CNIT (partner) and Fraunhofer Institute for High Frequency physics and Radar techniques – FHR (partner). In this article we present an overview of the results obtained in this project highlighting the more significant issues found an the approach that has been taken in order to understand where CS can be applied in the RF Sensors domain.**

Keywords - Compressive Sensing, Radar, Receiver, Antenna Synthesis, DOA, SAR and I-SAR.

I. Project Summary

RICS is focused on the application of CS theory to radar topics by investigating and developing CS-based solutions in different real world user cases. The main objective is to justify clearly in what kind of applications Compressive Sensing may be used to provide an acceptable performance with a substantial benefit in terms of savings in determined parameters. The project aims simultaneously at providing a clear picture of the state of the art of CS as applied to radar, and a common framework of reference in terms of definitions and basic theory needed to establish as much as possible common interfaces among the considered applications. Among the RICS areas of investigation there are those briefly described in the following paragraphs.

Radar receiver chain: Multifunctional wide-band radars open a considerable gap with the actual Analog-to-Digital Converters (ADC) devices. Conversion speeds that are twice the signal's maximal frequency component have become more and more difficult to obtain. Recently, several "sampling-reconstruction" strategies have been proposed, exploiting the CS theory for sampling and recovering sparse signals at a much lower rate than Nyquist one. The aim is to eliminate the conventional RF to IF conversion stage (typical in the demodulation scheme) that does not need a frequency agile stable local oscillator. Hence, this makes possible to eliminate a substantial analog section and the need of large band pass ADC, obtaining a significant reduction in the hardware complexity, dimensions, costs as well as higher flexibility and reconfigurability.

SAR imaging and SAR tomography: Another class of problems which makes profit from the condition of sparsity in the quantity to be determined is the area of Synthetic Aperture Radar Imaging, both regarding SAR and Inverse SAR.

In particular, two possible interesting applications of CS have been already developed for the case of SAR imaging. In the first one, the expected compressibility characteristics of the reflectivity (the unknown function) are exploited in order to simplify the acquisition process or to improve the resolution. A second application is concerned instead with 'SAR tomography' (3D SAR), where the system is able to get additional information about the contents of each reflectivity cell by exploiting multiple passages of the satellite on the same area. The spacing amongst the different trajectories (baselines) is not regularly spaced. As a consequence, elevation focusing within each range-azimuth pixel of the reflectivity is not possible by usual Fourier analysis, while the goal naturally lends itself to the exploitation of CS. In fact, the 3-D reflectivity function is expected to be sparse with respect to the elevation coordinate, while the non regular spacing in the acquisition allows to get some "poor mutual coherence property", thus ensuring the success of CS based procedures where traditional approaches will fail.

Active and passive ISAR: ISAR applications seem to be particularly well suited to the consideration of CS techniques, as the ISAR image is composed by a number of dominant scatterers much smaller than the number of grids in the image domain. In fact, ISAR processing can take advantage from CS in several ways. First, a reduction of the received data can be accomplished because of the capability to successfully deal with under sampled data. In a dual fashion, a resolution enhancement in delay time and Doppler domains can be achieved when using the usual sampling rate. Finally, the possibility to use data that are not complete along the time and/or frequency domains is also worth to be mentioned. Notably, the different applications can be extended in a conceptually easy fashion to the case of passive ISAR systems, i.e., situations wherein opportunity signals are used for imaging. In this case, the geographical sparsity of the emitters of opportunity can also be faced by making use of CS.

Sparse or random radar antennas: In antenna array synthesis, assuming one is looking for a sparse array (i.e., the positioning of the elements in the antenna aperture is arbitrary), the problem can be formulated as the definition of the sparse array geometry (and the relative element excitations) such as to realize a given far field pattern. The main advantage relies in the possibility of using a number of transmitting/receiving elements much lower than in usual architectures, with substantial savings in costs. The synthesis problem, that is naturally sparse in the spatial domain, is other candidate to be addressed in a straightforward manner through CS-based approaches.

Directions of arrival estimation: Another considered application, related to the RF Sensors, and still concerned with Fourier like relationships amongst the unknowns and the data, is the problem of estimating the directions of arrival (DoA) of signals by means of an array of antennas. In this case, the data are the voltages measured at the output of the array elements, while the unknowns are the amplitudes and phases of the plane waves impinging on the antenna from the different directions of the space. Supposing the solid angle surrounding the antenna is discretized with a fine grid, the unknown signal vector one is looking for turns out being sparse, since relatively few incoming signals are generally expected. Accordingly, the CS seems to be suitable resolution strategy for DoA estimation problems, but this has to be demonstrated

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