32nd URSI GASS, Montreal, 19-26 August 2017

Advances in Sparse Image Reconstruction in Through-the-Wall Radar

Ahmad Hoorfar* and Wenji Zhang
Antenna Research Laboratory, Department of Electrical and Computer Engineering,
Villanova University, Villanova, PA, 19085, USA

Extended Abstract

Over the past decade through-the-wall radar imaging (TWRI) has become of increasing importance in many defense and civilian applications, particularly in such areas as homeland security, law enforcement, firefighting, and earthquake rescue missions. To achieve both wall penetration and high resolution target imaging, most proposed TWRI systems use the frequency range of between 1 and 4GHz to detect and image stationary and/or moving targets behind building walls. In many situations, however, the building's exterior walls induce shadowing effects on targets within the building, resulting in image degradation and errors in geo-locating, or possibly complete masking of targets. The effects become more pronounced for multilayered walls or when the target is behind multiple walls for example a combination of external and interior walls. Furthermore, in most practical situations the imaging of targets should be done in real-time, requiring the development fast data acquisition schemes as well as highly efficient microwave imaging techniques that can fully account for wave propagation through various walls.

The techniques such as Diffraction Tomography (DT), which uses first-order Born approximation together with successive implementations of spatial fast-Fourier transform (FFT) and inverse-FFT (IFFT), have been shown to achieve near real-time and high resolution imaging of targets behind walls when full collected data is available for post processing. Such fast imaging techniques, however, do not address the problem posed by long data acquisition time associated with most TWRI scenarios. Recently to address this problem, assuming a sparse target space, several research groups have proposed the use of Compressive Sensing (CS) to significantly reduce the number of antennas and/or collected frequency points in a TWRI system.

In this presentation we give an overview of our recent works in image reconstruction for both SAR-based and multiple-input multiple-output (MIMO) based through-the-wall systems using Compressive Sensing. In our approach, the wall effects are accurately and efficiently accounted for in the sparse-image reconstruction through the use of approximate expressions for the Green's functions of multi-layered lossy dielectric media. In particular, we will discuss the use of total variation minimization (TVM) and its advantages over the l_1-norm minimization which is often used in the standard radar implementation of CS. The TVM technique minimizes the gradient of the image instead of the image itself, and as a result leads to better shape reconstruction of large through-the-wall targets. It is noteworthy that accurate target detection and imaging in TWRI requires a prior knowledge of the wall parameters, namely dielectric constant, conductivity and thickness of wall layers. Therefore, any CS-based TWRI system in the operational field should also be able to estimate the wall parameters from a limited set of frequency-point measurements collected at a limited number of transmit/receive antennas. The estimation of wall parameters, however, is in general a non-convex, non-linear and multimodal optimization problem, which requires the use of appropriate global optimization techniques. In the presentation, we will discuss, the use stochastic-based Covariance Matrix Adaptation Evolution Strategy (CMA-ES) to accurately estimate the wall parameters from a few measured data points for both single layer as well as multilayered walls. Numerical results for CS-based imaging in various TWRI scenarios will be given in the presentation.