Compressive Sensing in Radar Imaging of Subsurface and Through-the-Wall Targets

Ahmad Hoorfar [1]* and Wenji Zhang [2]
(1) Antenna Research Laboratory, ECE Dept, Villanova University, Villanova, PA 19085
(2) Checkpoint Systems, Inc, NJ 08086

Through-the-wall radar imaging (TWRI) and ground penetrating radar (GPR) technologies have become of increasing importance in many civilian and defense applications, such as in detection, imaging, and identification of targets behind multi-layer or multiple walls, non-destructive testing of concrete slabs or walls' interior structures, detection and imaging of improvised explosive devices (IEDs), and detection of human in earthquake, avalanche, firefighting, or other rescue missions. In general, to achieve high imaging resolution a long aperture is synthesized with an ultra-wideband transmitted signal. This becomes impractical and costly in many realistic situations, and it is therefore important to reduce the data volume in TWRI or GPR applications, as it accelerates processing and, subsequently, allows prompt actionable intelligence. In recent years, to meet these objectives many research groups have applied various forms of sparse data reconstruction and Compressive Sensing (CS) techniques to TWRI and GPR to reconstruct a radar signal from far fewer non-adaptive measurements. Most of the reported CS works, however, are for targets behind single-layer walls and assume known wall parameters.

In this presentation we give an overview of our recent works on a general CS-based approach for radar imaging of targets behind single or multilayered walls. Our approach, which is applicable to both multi-input multi-output (MIMO) radar and SAR, fully accounts for all the wall effects through the use of the layered media Green's functions in forming the images of targets behind walls. The approach is also easily applicable to the imaging of a wall's interior structure or GPR imaging of subsurface objects using an efficient evaluation of Green's function of a half-space lossy dielectric medium. The sparseness of the target space is then exploited through the use of CS to achieve a less cluttered and high resolution image with far fewer antennas and/or frequency point measurements. In addition, we discuss the application of total variance minimization (TVM) to the above generalized Green's function based approach. TVM is based on the minimizing the gradient magnitude of the image and can result in better edge preservation and shape reconstruction than standard L1-minimization based CS. Finally, any successful imaging of targets in TWRI requires an accurate estimation of the wall parameters. The resulting sparse reconstruction of the objective function, however, is multimodal and non-convex, thus not lending itself to the standard L1 minimization. We discuss the use of nature-inspired optimization techniques to overcome such limitations in estimation of wall parameters under limited bandwidth and/or randomly selected frequency points. Details of the formulation for the above cases together with numerical examples for various wall-target and GPR scenarios for both SAR and MMIO radar cases will be given in the presentation.