Ultrawideband Time-Reversal Imaging Using Space-Frequency Multistatic Data Matrices

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Maxwell's equations in lossless media are invariant under time-reversal (TR), and this can be exploited in various ways to improve detection and localization of targets. In inhomogeneous media, TR techniques are shown to take advantage of multipathing (in a somewhat counterintuitive way) to yield super-resolution, i.e. the ability to resolve scatterers beyond the classical diffraction limit. Additionally, in random media, TR techniques produce statistically stable imaging functionals which depend only on the statistical properties of the intervening (random) media and not on a particular realization.

For most TR-based imaging methods, the TR operator (TRO) obtained from the multistatic data matrix (MDM) plays a fundamental role. The eigenvalue decomposition (EVD) of the TRO forms the basis of the so-called DORT and TR-MUSIC methods. Traditionally, the EVD of the TRO required by both of these methods is carried out using *space-space* MDMs at a single frequency. Ultrawideband (UWB) versions of these methods, viz., time-domain DORT and UWB-MUSIC also utilize space-space MDMs and combine them at multiple frequencies to obtain statistically stable images. However, at each frequency, the eigenvectors carry an arbitrary and frequency-dependent phase from the eigenvalue decomposition. As a result, the time-domain eigenvectors are incoherent and a preprocessing step is necessary to obtain coherent signals.

In this work, we introduce an alternative UWB TR imaging method that avoids this problem. This is achieved by the simultaneous utilization of spatial and UWB frequency data and application of a singular value decomposition (SVD) to *space-frequency* MDMs whose columns and rows correspond to space and frequency components of the received signals, respectively. While the corresponding left singular vectors encode target location in the form of relative phase shifts among array elements, the right singular vectors provide the UWB frequency dependence of the received signals.

These singular vectors are later combined and backpropagated from the TR array antennas to provide a novel UWB TR-based imaging method. We analyze the singular values and vectors obtained for various scattering scenarios involving continuous random media modeled by spatially fluctuating permittivities with Gaussian correlation functions. Additionally, a performance comparison with those of the conventional TR-based imaging methods is also provided. (Ackowledgements: This work was supported in part by NSF and OSC).