A Study on the Sensitivity of DORT Method to Noise and Parameter Perturbations

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The *decomposition of the time-reversal operator* (DORT under its French acronym) [C. Prada and M. Fink (1994), *Wave Motion*, 20, 151-163], [H. Tortel, G. Micolau, and M. Saillard (1999), *J. Electromagn. Waves Appl.*, 13, 687–719], [G. Micolau and M. Saillard (2003), *Radio Sci.*, 38, 3, 1–12] is a method first introduced in acoustics that exploits the time-reversal (TR) invariance of the wave equations for detection and selective localization of well-resolved scatterers in inhomogeneous media. DORT utilizes the eigenvalues and associated eigenvectors of the TR operator (TRO) of a TR antenna array (TRA) to achieve selective focusing on desired scatterers in inhomogeneous and possibly random media. However, when strong inhomogeneities are present in the intervening medium, TRO eigenvalues that correspond to background clutter may be on the order of those associated to embedded scatterers (strong clutter). In such cases, it is highly desirable to distinguish the subspace of eigenvectors that correspond to the embedded scatterers (signal subspace) from that of background clutter (noise subspace). For this end, we investigate the effects of different kinds of external perturbations on each of these subspaces and seek to determine possible criteria to distinguish signal and noise subspaces in the strong clutter regime. We first assess the sensitivity and stability of the DORT method against *additive noise* in the system (data perturbation). Then, we investigate the stability against TRA location (boundary conditions), where we backpropagate eigenvectors obtained at a specific location from slightly different TRA locations (model perturbations). We study the behavior of the TRO singular values and the TRA signal correlation at different locations. We use the obtained focusing stability and correlations of the received signals to distinguish and classify a particular eigenvalue in strong clutter conditions.

We employ ultrawideband signals and limited aspect TRA configurations. Impenetrable point-like scatterers embedded in background random media are considered. The random medium models are based on inhomogeneous soil models with spatially fluctuating random permittivities having Gaussian distributed variances and correlation functions. The TRO is obtained explicitly using finite-difference time-domain (FDTD) simulations.