Efficient 3-D Ground Penetrating Radar Simulation with Spiral Antennas and Buried Objects

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In the simulation of ground penetrating radar detection of buried objects such as landmines, one often needs to model the detailed structure of the transmitting and receiving antennas as well as the buried objects. Of particular interest are compact GPR systems with spiral antennas which were designed to operate at an optimal efficiency with a limited dimension. Unfortunately, such antennas may have fine structures well below the wavelength of the transmitted microwaves. Such small structures require fine spatial discretization, and thus a small time step size in the finite-difference time-domain (FDTD) method. This restriction arises because the Courant-Friedrich-Levy (CFL) conditions limits the maximum time-step to minimum cell size in a computational domain. Recently, an unconditionally stable three-dimensional alternating direction implicit (ADI) scheme was investigated. The successful implementation of this scheme has the potential to impact the application of FDTD to the problems where very fine mesh is required over the large geometric area.

For the ADI-FDTD to be applicable to the practical electromagnetic problems, an efficient absorbing boundary condition must be derived to maintain unconditional stability. In this work, a well-posed perfectly matched layer (PML) medium in a non-split form based on the coordinate-stretching technique is applied to the three-dimensional (3-D) ADI-FDTD method. Under this well-posed PML absorbing boundary condition, the ADI-FDTD method remains unconditionally stable. To validate this new method, we compare the ADI-FDTD and the regular FDTD methods for large-scale simulations of ground penetrating radar (GPR) measurements of landmines.