3-D FDTD Simulations of Ground-Penetrating-Radar Scenarios

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For the purpose of assisting the subsequent designs of high-performance Ground-Penetrating-Radar (GPR) hardware and detection algorithms, the versatility of the three-dimensional (3-D) finite-difference time-domain (FDTD) method to model arbitrarily inhomogeneous geometries is exploited to simulate realistic ground-penetrating-radar (GPR) scenarios. The borders of the FDTD computational domain are terminated by perfectly matched layer (PML) absorbing boundary condition (ABC) designed for layered media. The PML ABC is also used to simulate the physical absorbers mounted inside the GPR unit, around the antenna feed structures, in order to reduce the resonance effects.

The ground is modeled with unprecedented detail including large numbers of randomly distributed heterogeneities placed in a background of arbitrary permittivity and conductivity. The heterogeneities encompass both embedded scatterers and surface holes, which model the surface roughness. The decay of the waves in relation to the conductivity of the ground is demonstrated. The detectability of the buried targets is investigated with respect to the operating frequency of the GPR, the background conductivity of the ground, the density of the conducting inhomogeneities in the ground, and the surface roughness. The buried targets are modeled by conducting and dielectric prisms and disks with arbitrary permittivity, conductivity, and shape. In addition, a novel transmitter-receiver-transmitter (TRT) configuration will be presented as a means of filtering the transmitter-receiver direct coupling and surface-scattering signals.

Simulations of a detection system employing multiple (two) GPR units will also be presented. It will be shown how this new system enhances the detection process by illuminating and covering a broader footprint on the ground. Moreover, it will also be shown that, a system with multiple GPR units can provide information on the position of the target in the transverse axis that is perpendicular to the direction of the GPR movement, in addition to the longitudinal position in the axis of movement. At a given time, only one of the two transmitters operate and the two receivers record the signals they observe. By alternatively operating two transmitters and recording two signals for each operation, the GPR system provides four signals at each discrete GPR location. By comparing the relative amplitudes of these four signals, it will be motivated that it may be possible to detect the transverse position of the buried target. The longitudinal position of the target in the direction of the GPR movement can be extracted from the largest scattered signals observed in a B-scan measurement. Therefore, using a multiple-GPR system, extraction of the target location knowledge by performing a B-scan measurement will be illustrated.