Simulation of Realistic Three-Dimensional GPR Scenarios Using the FDTD Method

Levent Gürel and Uğur Oğuz
Department of Electrical and Electronics Engineering
Bilkent University
TR-06533 Bilkent, Ankara, Turkey
E-mail: lgurel@ee.bilkent.edu.tr

One of the objectives of performing ground-penetrating radar (GPR) simulations is to assist the development of detection algorithms used in practical GPR systems. These detection algorithms, which are used to discriminate the effects of targets and other inhomogeneities embedded in the ground, are indispensable to GPR systems. However, most of the simulation efforts reported in the literature employ homogeneous ground models. These simulation results cannot be used to compare or evaluate the performances of detection algorithms, since a real GPR system will never face the easy task of detecting a target buried in homogeneous ground. In this work, the results of simulations involving more realistic ground models are presented.

A variety of numerical modeling techniques have been developed for the purpose of simulating and understanding GPR systems. Among these techniques, the finite-difference time-domain (FDTD) method has been the most popular one, due to its versatility in solving problems involving arbitrarily complicated inhomogeneities. In this work, small scatterers with a wide range of sizes and permittivity and conductivity values are randomly placed in a dielectric and lossy half-space in order to obtain realistic ground models. Moreover, the surface-roughness feature of the ground is modeled by placing many small scatterers at the ground-air interface. For example, by choosing the permittivity, permeability, and the conductivity values of these surface scatterers identical to those of the air, small holes on the ground are modeled.

The power and flexibility of the FDTD method is combined with the accuracy of the perfectly matched layers (PML) absorbing boundary conditions (ABCs) to simulate realistic GPR scenarios. The PML regions, surrounding the FDTD computational domain, are designed in a layered manner in order to match both the ground and air regions and the interface between them. The PML absorbers are employed not only to terminate the computational domain, but also to simulate the physical absorbers commonly used inside the shielding walls of practical GPRs to avoid large reflections from the inner walls. The transmitter and the receiver are usually isolated using perfectly-conducting (PEC) walls. These shielding walls enclosing the two antennas form a partially open chamber, in which the electromagnetic fields can resonate. As a solution, the inner faces of the PEC walls are coated with absorbers, which can be modeled, among other means, using PML ABCs. This reduces the coupling from the transmitter to the receiver in the GPR system.

Suggested Topics: Ground-penetrating radars, subsurface scattering, electromagnetic scattering, FDTD applications, computational techniques.