# Three-Dimensional Electromagnetic Modeling of Various GPR Problems

**Levent Gürel and Uğur Oğuz**
Department of Electrical and Electronics Engineering
Bilkent University
Bilkent, Ankara, Turkey
(lgurel@bilkent.edu.tr, uoguztr@yahoo.com)

Full-wave electromagnetic analysis of ground-penetrating-radar (GPR) problems will be reported. The versatility of the three-dimensional (3-D) finite-difference time-domain (FDTD) method to model arbitrarily inhomogeneous geometries is exploited to simulate realistic GPR scenarios for the purpose of assisting the subsequent designs of high-performance GPR hardware and software. 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 dipole antennas.

The ground is modeled as a heterogeneous dielectric half space with arbitrary background 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.

Even though the emphasis of this paper is on the capabilities of the simulation, rather than the detection, some fundamental methods of filtering the transmitter-receiver coupling and surface-scattering signals will also be briefly exemplified. In this context, a novel transmitter-receiver-transmitter (TRT) configuration will be presented. In this configuration, the GPR consists of two transmitters and a receiver. The receiving antenna is located in the middle of the two identical transmitters, which are fed 180° out of phase. This configuration implies the existence of a symmetry plane in the middle of two transmitters and causes the cancellation of the direct signals coupled from the transmitters at the receiver location. The antenna polarizations and their separations are arbitrary. The TRT-configured GPR model is optimized in terms of the scattered energy observed at the receiver by varying the antenna separation. The performances of the TRT-configured GPRs above heterogeneous ground models are investigated.

Finally, simulations of a detection system employing multiple (two) GPR units will be given. 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.

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| Names of the Authors: | Levent Gürel and Uğur Oğuz |
| Affiliation: | Bilkent University |
| Address: | Department of Electrical and Electronics Engineering<br>Bilkent University<br>Bilkent, Ankara, Turkey |
| Phone: | +90-312-290 2096 |
| Fax: | +90-312-290 2439 |
| E-mail: | lgurel@bilkent.edu.tr |
| Corresponding Author: | Levent Gürel |