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FDTD modelling of the multilayered region of the IFSTTAR geophysical test site and comparison with available experimental data

Santo Prontera and Lara Pajewski
Sapienza University of Rome, Rome, Italy (santo.prontera@uniroma1.it; lara.pajewski@uniroma1.it)

In [1], a wide dataset of ground-penetrating radar (GPR) profiles was presented, recorded on a full-size geophysical test site (Nantes, France); all raw profiles were enclosed to the paper as 'supplementary materials' and are available for download. The geophysical test site reproduces objects and obstacles commonly met in the urban subsurface, in a completely controlled environment; it was especially conceived to allow radar-based measurements. Nowadays the site is used to check, compare and validate various geophysical equipment and methods, as well as for training and demonstration activities. The site is structured into five regions, filled with different materials (silt, limestone, sand, gravel); in four of these regions, several targets are buried (cables, tubes, polystyrene blocks, masonry, and more). The remaining region is a multilayer, with five main layers having thicknesses from 0.6 m to 1.3 m; no targets are buried in this particular region and two vertical holes allow borehole, crosshole, and tomography investigations. The dataset presented in [1] contains almost seventy profiles recorded along eleven parallel lines crossing the test site in the transverse direction; four of these profiles were recorded over the multilayer, by using a GSSI GPR system equipped with ground-coupled 400 MHz and 900 MHz antennas and a MALÅ GPR system equipped with ground-coupled 250 MHz and 500 MHz antennas.
In this work, we present the results of finite-difference time-domain (FDTD) simulations of the multilayered region of the geophysical test site. All necessary information to implement the models was taken from [1] and all simulations were performed by using the open-source simulator gprMax (www.gprmax.com). In a first series of simulations, the environment was modelled in a two-dimensional spatial domain, the GPR transmitting antenna was represented as a line source and the electric field impinging on the receiving antenna was calculated. As is mentioned in [1], the multilayer is the only region that was not geo-localized during the test-site realization, therefore only the theoretical thicknesses of every layer are known; moreover, the permittivity values of the materials haven't been measured, so far. So the multilayer section represents a challenge for GPR specialists, to estimate the real thicknesses and permittivity values of the various layers. We obtained an estimation for such values by matching the results of our FDTD simulations with the available experimental data.
In a second series of simulations, the environment was modelled in a three-dimensional domain; in this case, the GPR transmitting antenna was represented by a hertzian dipole. With these simulations we mainly aimed at investigating how the vertical interfaces between the multilayer and the adjacent silt and sand regions, as well as the presence of the targets embedded in the adjacent regions, affected the measurements recorded over the multilayer.

[1] X. Dérobert and L. Pajewski, "TU1208 Open Database of Radargrams: The Dataset of the IFSTTAR Geophysical Test Site," Remote Sensing 2018, 10, 530; doi:10.3390/rs10040530.