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Electromagnetic modelling of Ground Penetrating Radar responses to complex targets

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This work deals with the electromagnetic modelling of composite structures for Ground Penetrating Radar (GPR) applications. It was developed within the Short-Term Scientific Mission ECOST-STSM-TU1208-211013-035660, funded by COST Action TU1208 “Civil Engineering Applications of Ground Penetrating Radar”.

The Authors define a set of test concrete structures, hereinafter called cells. The size of each cell is 60 x 100 x 18 cm and the content varies with growing complexity, from a simple cell with few rebars of different diameters embedded in concrete at increasing depths, to a final cell with a quite complicated pattern, including a layer of tendons between two overlying meshes of rebars. Other cells, of intermediate complexity, contain pvc ducts (air filled or hosting rebars), steel objects commonly used in civil engineering (as a pipe, an angle bar, a box section and an u-channel), as well as void and honeycombing defects. One of the cells has a steel mesh embedded in it, overlying two rebars placed diagonally across the comers of the structure. Two cells include a couple of rebars bent into a right angle and placed on top of each other, with a square/round circle lying at the base of the concrete slab. Inspiration for some of these cells is taken from the very interesting experimental work presented in Ref. [1].

For each cell, a subset of models with growing complexity is defined, starting from a simple representation of the cell and ending with a more realistic one. In particular, the model’s complexity increases from the geometrical point of view, as well as in terms of how the constitutive parameters of involved media and GPR antennas are described. Some cells can be simulated in both two and three dimensions; the concrete slab can be approximated as a finite-thickness layer having infinite extension on the transverse plane, thus neglecting how edges affect radargrams, or else its finite size can be fully taken into account. The permittivity of concrete can be defined through a constant real value, or else its frequency-dispersion properties can be taken into account by incorporating into the model Debye approximations. The electromagnetic source can be represented as a simple line of current (in the case of two-dimensional models), a Hertzian dipole, a bow tie antenna, or else, the realistic description of a commercial antenna can be included in the model [2].

Preliminary results for some of the proposed cells are presented, obtained by using GprMax [3], a freeware tool which solves Maxwell’s equations by using a second order in space and time Finite-Difference Time-Domain algorithm. B-Scans and A-Scans are calculated at 1.5 GHz, for the total electric field and for the field back-scattered by targets embedded in the cells.

A detailed description of the structures, together with the relevant numerical results obtained to date, are available for the scientific community on the website of COST Action TU1208, www.GPRadar.eu. Research groups working on the development of electromagnetic forward- and inverse-scattering techniques, as well as on imaging methods, might test and compare the accuracy and applicability of their approaches on the proposed set of scenarios. The aim of this initiative is not that of identifying the best methods, but more properly to indicate the range of reliability of each approach, highlighting its advantages and drawbacks. In the future, the realisation of the proposed concrete cells and the acquisition of GPR experimental data would allow a very effective benchmark for forward and inverse scattering methods.

References

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