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Electromagnetic simulators for Ground Penetrating Radar applications developed in COST Action TU1208

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Founded in 1971, COST (European COoperation in Science and Technology) is the first and widest European framework for the transnational coordination of research activities. It operates through Actions, science and technology networks with a duration of four years.

The main objective of the COST Action TU1208 “Civil Engineering Applications of Ground Penetrating Radar” (4 April 2013 - 3 October 2017) is to exchange and increase knowledge and experience on Ground-Penetrating Radar (GPR) techniques in civil engineering, whilst promoting in Europe a wider use of this technique. Research activities carried out in TU1208 include all aspects of the GPR technology and methodology: design, realization and testing of radar systems and antennas; development and testing of surveying procedures for the monitoring and inspection of structures; integration of GPR with other non-destructive testing approaches; advancement of electromagnetic-modelling, inversion and data-processing techniques for radargram analysis and interpretation.

GPR radargrams often have no resemblance to the subsurface or structures over which the profiles were recorded. Various factors, including the innate design of the survey equipment and the complexity of electromagnetic propagation in composite scenarios, can disguise complex structures recorded on reflection profiles. Electromagnetic simulators can help to understand how target structures get translated into radargrams. They can show the limitations of GPR technique, highlight its capabilities, and support the user in understanding where and in what environment GPR can be effectively used. Furthermore, electromagnetic modelling can aid the choice of the most proper GPR equipment for a survey, facilitate the interpretation of complex datasets and be used for the design of new antennas. Electromagnetic simulators can be employed to produce synthetic radargrams with the purposes of testing new data-processing, imaging and inversion algorithms, or assess the effectiveness of existing ones. A fast and accurate forward solver can also be used as part of an inverse solver.

This contribution aims at presenting two electromagnetic simulators based on the Finite-Difference Time Domain (FDTD) technique and Boundary Element Method (BEM), for Ground Penetrating Radar applications. These tools have been developed by Members of the COST Action TU1208.

The first simulator is the new open-source version of the software gprMax (www.GPRadar.eu), which employs Yee’s algorithm to solve Maxwell’s equations by using the FDTD method and includes advanced features allowing the accurate analysis of realistic scenarios. For example, a library of antennas is available and these can be directly included in the models. Moreover, it is possible to build heterogeneous media using fractals, as well as objects with rough surfaces. Anisotropic media can be defined and this allows materials such as wood and fibre-reinforced concrete to be accurately modelled. Media with arbitrary frequency-dispersive properties can be also defined and this paves the way to the use of gprMax in new areas, such as the modelling of human tissues. Optimisation of parameters based on Taguchi’s method can be performed: this feature can be useful to optimise material properties based on experimental data, or to design new antennas. Additionally, a freeware and very useful CAD package was developed, conceived to ease the use of gprMax: such tool assists in the creation, modification and analysis of two-dimensional gprMax models and can also be used to plot results.

The second simulator is TWiNS-II: this is free software for the analysis of multiple thin wires in the presence of two media, implementing the Galerkin-Bubnov Indirect BEM; calculations can be undertaken in the frequency or time domain. The time-domain code is focused on the assessment of current distributions along thin wire structures. The configuration that can be analyzed is a set of parallel thin wires placed in free space above a perfect ground, or above a dielectric lossless half-space. The wire array resides in a plane parallel to the interface. Within this basic geometry, the user is allowed to arbitrarily change the number, size and position of wires, their excitation characteristics and the dielectric constant of the half-space. The frequency-domain code can be used for the frequency analysis of the same wire configuration as in the time domain counterpart. In addition, the effects of losses in the ground can be taken into account.

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