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Numerical Modelling of Ground Penetrating Radar Antennas

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Numerical methods are needed in order to solve Maxwell's equations in complicated and realistic problems. Over the years a number of numerical methods have been developed to do so. Amongst them the most popular are the finite element, finite difference implicit techniques, frequency domain solution of Helmontz equation, the method of moments, transmission line matrix method. However, the finite-difference time-domain method (FDTD) is considered to be one of the most attractive choice basically because of its simplicity, speed and accuracy. FDTD first introduced in 1966 by Kane Yee. Since then, FDTD has been established and developed to be a very rigorous and well defined numerical method for solving Maxwell's equations. The order characteristics, accuracy and limitations are rigorously and mathematically defined. This makes FDTD reliable and easy to use.
Numerical modelling of Ground Penetrating Radar (GPR) is a very useful tool which can be used in order to give us insight into the scattering mechanisms and can also be used as an alternative approach to aid data interpretation. Numerical modelling has been used in a wide range of GPR applications including archeology, geophysics, forensic, landmine detection etc. In engineering, some applications of numerical modelling include the estimation of the effectiveness of GPR to detect voids in bridges, to detect metal bars in concrete, to estimate shielding effectiveness etc. The main challenges in numerical modelling of GPR for engineering applications are A) the implementation of the dielectric properties of the media (soils, concrete etc.) in a realistic way, B) the implementation of the geometry of the media (soils inhomogeneities, rough surface, vegetation, concrete features like fractures and rock fragments etc.) and C) the detailed modelling of the antenna units.
The main focus of this work (which is part of the COST Action TU1208) is the accurate and realistic implementation of GPR antenna units into the FDTD model. Accurate models based on general characteristics of the commercial antennas GSSI 1.5 GHz and MALA 1.2 GHz have been already incorporated in GprMax, a free software which solves Maxwell's equation using a second order in space and time FDTD algorithm. This work presents the implementation of horn antennas with different parameters as well as ridged horn antennas into this FDTD model and their effectiveness is tested in realistic modelled situations. Accurate models of soils and concrete are used to test and compare different antenna units. Stochastic methods are used in order to realistically simulate the geometrical characteristics of the medium. Regarding the dielectric properties, Debye approximations are incorporated in order to simulate realistically the dielectric properties of the medium on the frequency range of interest.