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Advanced Three-Dimensional Implementation for GPR Imaging of Buried Targets

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Ground penetrating radar (GPR) is a well-established nondestructive technique, widely used for subsurface surveys in a large number of applications, such as geology, archaeology, environmental and planetary investigations, etc. [1]. In standard GPR surveys, the post-processing procedure of the numerical/experimental raw data is typically developed by assuming the illumination mechanism as generated by ideal sources [1]. By means of suitable implementations of electromagnetic CAD tools, an imaging procedure has recently been developed in order to accurately model the radiation pattern of real antennas in 2-D conditions, by assuming a translational invariance of the domain under investigation [2]. In such cases, the relevant linear tomographic approach has a scalar nature, thus providing a 2-D reconstruction of illuminated objects just on a cross section [2].

By advancing in the microwave imaging theory [3], [4] that extends the canonical 2-D analysis, we propose here a tomographic algorithm which is capable to account for the vector nature of the scattering equation in the presence of targets, considering the 3-D features of the radiation pattern of directional antennas. We then focus on the possible improvements achievable when the 3-D inverse scattering approach is used. The solution exploits multi-frequency GPR synthetic data, whereas the inverse problem is linearized through the Born approximation and regularized by means of a singular value decomposition scheme. The adjoint operator of the discretized scattering equation is considered as well in the numerical solution [1].

By implementing a full-wave setup representing the 3-D scenarios under test [4], it has been possible to simulate the spatial distribution of the incident and scattered fields in the presence of canonical buried targets for both ideal and realistic radiating elements, gathering the field at a ground interface over an investigated 3-D region. To this aim, a directional Vivaldi antenna has been chosen as transmitting/receiving element; a number of tests has been performed accounting for both metallic and dielectric buried targets, and collecting the various components of the scattered field.

This type of analysis represents a fundamental step to assess the improvements achievable when the 3-D shape of the illuminating antenna pattern is considered in the inversion process, as well as to investigate on the potentialities provided by the processing of the vector field components scattered in the presence of hidden objects.

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