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Modeling of Antenna Effects for Characterization of Cylindrically Layered Structures

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The characterization of structures starting from measurements of the scattered electromagnetic field is becoming important in many applications, ranging from geophysics to biomedical engineering [1, 2]. To this end, an inverse problem should be solved, where the unknowns are represented by some properties of the inspected targets. Two main classes of solution techniques can be identified. Quantitative methods aim at reconstructing the full distribution of the dielectric properties (e.g., dielectric permittivity, electric conductivity) of the structure under test, whereas qualitative strategies usually provide only a set of particular properties of the target (e.g., shape and location). In both cases, to obtain a good characterization of the properties of the structure, the measurement system plays a crucial role, as well as its proper modeling inside the inversion procedure. In particular, the interactions between the radiating/receiving elements (i.e., the antennas) and the structure under test cannot be neglected if a quantitative inversion is needed, and even the simpler qualitative techniques can benefit from a correct modeling of such effects. To give an example, in buried objects detection, the uncompensated antenna-soil interactions may completely mask the scattered field from the underground targets, which represents the useful information for inversion purposes.

In [3, 4] a closed-form radar equation is presented to model radar antennas and inherently account for the antenna-medium interactions. The radar equation applies to both far-field and near-field conditions. The antenna is described using a set of source and receiver points and global, complex reflection and transmission coefficients that are frequency dependent. The radar equation was combined to Green's functions describing three-dimensional wave propagation in planar layered media. The high level of accuracy of the model to reproduce actual radar data permits full-wave inversion for retrieving the electromagnetic properties of the media under test.

In this study, we tested the radar equation for wave propagation in cylindrically layered media, for which closed-form Green's functions also exist. This approach is particularly appropriate to address various situations where the body under examination presents a cylindrical cross section with several layers characterized by different dielectric properties, such as trunks, columns, pipes, or biological bodies.

References

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