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Recent Advances in the Cylindrical-Wave Approach for Electromagnetic Scattering by Subsurface Targets

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The Cylindrical-Wave Approach (CWA) rigorously solves, in the spectral domain, the electromagnetic forward scattering by a finite set of buried two-dimensional perfectly-conducting or dielectric objects. In this technique, the field scattered by underground objects is represented in terms of a superposition of cylindrical waves. Use is made of the plane-wave spectrum to take into account the interaction of such waves with the planar interface between air and soil, and between different layers eventually present in the ground.

In this work we present the progress we recently made to improve the method. In particular, we introduced rough perturbations in the interfaces between different media, in order to model the typical unevenness of real surfaces. Moreover, we faced the fundamental problem of losses in the ground: this improvement is of significant importance in remote sensing applications, since real soils have often complex permittivity and conductivity, and sometimes also a complex permeability.

The rough deviations on the interface between air and soil have been dealt with by means of the Small Perturbation Method. Reflection and transmission coefficients have been evaluated in a first order approximation, and the fields involved in the scattering problem have been expressed as the sum of a zero-order (unperturbed) solution, relevant to the basic case of flat surface, and first-order perturbation terms, associated to the surface roughness. Numerical results for a circular, perfectly-conducting or dielectric, cylinder buried under an interface with sinusoidal profile, are presented. They have been obtained through an exact evaluation of the spectral integrals, giving results both in near- and far-field regions.

As far as the ground losses are concerned, a convergent closed-form representation of the angular spectrum of a cylindrical wave in a generic lossy medium is presented. To obtain this spectrum, the canonical Sommerfeld representation of the first-kind Hankel function of integer order has been used; its integration path has been modified to ensure the convergence of the integral for complex values of the wavenumber. Some numerical examples are reported and the limits of the representation are derived in terms of complex spatial frequency.

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