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Efficient Analysis of Structures in Layered Media Using the MPIE Method

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1. Extended Abstract

The accurate, efficient, and robust evaluation of layered media Green's functions (LMGF) is needed for such diverse applications as modeling microstrip antennas and integrated circuit structures, geophysical prospecting and mine safety analysis, metamaterial analysis, and optical waveguide modeling. This paper reviews recent improvements in accelerating the convergence of the Sommerfeld-like integrals of the Michalski mixed-potential Green's function formulation when implementing the Mixed Potential Integral Equation (MPIE) method for the electromagnetic analysis of arbitrary structures in general layered media [1]. These improvements have been extended to uniaxial anisotropic media. Recent enhancements in accelerating the computation of the mixed-potential Green's functions for the more specific case of a half-space problem are also reported. The half-space problem is given special attention because of its importance in applications involving the analysis of structures within or over the earth or ocean, and also for plasmonic problems.

Traditionally, the evaluation of Sommerfeld integrals has been accelerated using Kummer's method, in which "first-order" asymptotic terms are extracted from the various integrands that appear in the Michalski MPIE formulation to accelerate convergence, and then the integrals of these extracted terms are added back in closed or easily-computed forms. We have identified additional "second-order" asymptotic terms in the LMGF spectral integrals for uniaxial anisotropic media for use in Kummer's method to further accelerate the associated Sommerfeld integrals. These not only provide more efficient computation of the Sommerfeld integrals, but also further "regularize" the spectral potentials so they are even smoother than when using only the first-order extraction. This less singular nature of the potentials corresponding to the spectral integrals means that a spatial interpolation of these terms becomes much more efficient and robust, requiring considerably fewer Green's function sample points. This is important when analyzing electrically large structures using the Method of Moments (MoM) with the MPIE method, as entries in the interpolation table need only be evaluated once, and most subsequent Green's function evaluations can then be found simply by interpolation. These new forms in the second-order extraction process also require generalizations of the half-line source potential [2] used to accelerate terms related to vertical currents.

Kummer's method is applied only for observation points in the source layer or adjacent layers, where vertical separations between source and observation points may become vanishingly small, with only algebraic integrand decay rates; for observation and source points separated by at least one layer, it is assumed that the layers are sufficiently thick to grant exponential decay rates. For the case of large transverse separations, further efficiency has also been gained by an extended use of fast Hankel transforms. Additional interpolation data storage efficiency is gained by using a tree-like data storage algorithm.

The efficient evaluation of the MPIE potentials in the classical half-space problem is then examined. The Green's functions and related Sommerfeld integrals are merely special cases of the general layered-medium problem, but are worthy of special consideration. We recently investigated the use of the double-exponential (DE) algorithm to eliminate the Sommerfeld path detours frequently used to mitigate the influence of poles or branch points near or along the integration path. An efficient alternative path is also the steepest-descent path (SDP). The SDP must usually be determined numerically, but its asymptotes can be found analytically and can be used to define alternative paths that also yield good path integral convergence properties. Numerical results will be presented to illustrate the various approaches described.

2. References

1. K. Michalski and D. Zheng, "Electromagnetic scattering and radiation by surfaces of arbitrary shape in layered media. I. theory," *IEEE Trans. Antennas Propagat.*, **38**, 3, March 1990, pp. 335–344, doi: 10.1109/8.52240.

2. F. T. Celepcikay, D. R. Wilton, D. R. Jackson, S. Paulotto, and W. A. Johnson, "Efficient evaluation of half-line source potentials and their derivatives," *IEEE Trans. Antennas Propagat.*, **60**, 12, Dec. 2012, pp. 5834-5842, doi: 10.1109/TAP.2012.2214991.