Time Domain Integral Equation Solver for Planar Structures in Layered Media

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Numerical methods for analyzing transient electromagnetic interactions with objects residing in open multilayered media are critical in applications ranging from remote sensing to biomedical imaging and electronic design. Unfortunately, time domain integral equation (TDIE) methods are computationally costly when applied in this area. Their high computational cost primarily stems from the need to calculate time domain Green's functions (TDGFs) for sources residing in a layered background and subsequently convolving them with source temporal signatures. In the past, many approaches for calculating TDGFs have been proposed; examples include Cagniard-de-Hoop techniques (L. Cagniard, McGraw-Hill, 1962), schemes leveraging discrete leaky and surface wave modes expansions (G. W. Hanson, A. B. Yakovlev and J. Hao, IEEE Trans. AP, 51, 146-159, 2003), frequency to time domain Fourier transform methods (L. Tsang, C-J Ong, C-C Huang, and V. Jandhyala, IEEE Trans. AP, 51, 1559-1571, 2003), and complex-time methods (Ghaffari-Miab et al., EABE, 36, 1116-1124, 2012). Unfortunately, these approaches suffer from one or more of the following drawbacks: they are difficult to apply to multilayered configurations, computationally expensive, and cumbersome to implement and/or incorporate into TDIE solvers.

In this work, we use a finite difference time domain scheme to convolve TDGFs for horizontal electric dipoles above a planar multilayer substrate with temporal interpolators. Vector and scalar potential contributions to this convolution satisfy scalar time domain wave equations that are solved following the imposition of proper boundary conditions and application of appropriate singularity extraction techniques. Following their computation, the potentials are compressed and stored in a manner that facilitates their subsequent use in a TDIE solver. The proposed method can be considered the extension of (A.C. Cangellaris, and V.I. Okhmatovski, IEEE Trans. MTT, 48, 12, 2225-2232, 2000) to the time domain and unbounded structures. The proposed method suffers from none of the drawbacks of the aforementioned techniques for computing TDGFs for sources in layered media and TDIE solvers using it compete favorably with finite difference/element time domain or "broadband" frequency domain integral equation methods. Moreover, TDIE solvers using this TDGF representation can be easily accelerated using time domain adaptive integral methods (TD-AIM). In this work, the above technique for computing the convolution of TDGFs with temporal interpolators is employed in a recently developed TDIE solver that uses divergence-conforming spatial and non-causal, distance-dependent, and variable-order shifted B-Spline temporal interpolators to expand currents on horizontal metal traces and patches that reside on a substrate-backed ground plane. Numerical results that demonstrate the applicability of the technique to the analysis of various microwave structures will be reported at the conference.