Fast Time Domain Integral Equation Solver for Simulation of Propagation of Wide-band Pulses through Dispersive Media

E. Bleszynski, M. Bleszynski, and T. Jaroszewicz
Monopole Research, Thousand Oaks, USA

We present recent results on the analytical formulation and representative applications of the fast time domain integral equations specially tailored to problems interaction of wideband pulses with dispersive media. The algorithm takes advantage of the the block-triangular and block Toeplitz structures of impedance matrix in temporal indices, and of the Toeplitz structure of far-field component of the impedance matrix in spatial indices, hence allowing for the simultaneous compression in space and time. Furthermore, since the algorithm relies only on the translational invariance of the Green function, its computational cost is independent of the degree of dispersion of medium. An additional advantage of the method is its applicability to problems involving Green functions given in either tabulated or analytic forms.

An important practical element of the underlying time-domain integral formulation is that instead of using the customary integral equation operators involving the Green function and its derivatives, we construct effective integral equation operators equal to (i) the Fourier transform of the dispersive medium Green function, (ii) the Fourier transform of the product of the dispersive medium Green function with the inverse of dielectric permittivity.

Some of the most recent enhancements of our time-domain capabilities include numerically efficient modeling of specific time-localized waveforms, such as linear combinations of hermite polynomials. There is a need for such particular solver numerical capability in the context of several current and future medical and military potential applications. We derived compact analytical expressions for the projections (on spatial and temporal basis functions) of the incident wave represented as a superposition of hermite polynomials. A particular example of practical interest belonging to this class of waveforms is the "Mexican hat" wave-form, expressible as a linear superposition of Hermite polynomials up to the second order. We implemented the resulting formulation in the code module generating the incident wave projection on Rao-Glisson-Wilton (RWG) basis functions defined on triangular patches, and on pulse or band-limited (approximate prolate spheroidal) temporal basis functions.

We present numerical results for scattering on an arbitrarily sharped homogeneous dielectric body of a "conductive Debye" material, in which the electric permittivity is given by the Debye formula with an added conductivity term. The computations are carried out using a surface-integral equation formulation, involving matrix elements of free-space and dispersive dielectric Green functions. We evaluate the matrix elements of the dispersive medium Green function by means of integration in the complex frequency plane. We discuss some aspects of numerical quadrature in evaluation of integrals along branch cuts with singular (but integrable) behavior of branch-cut discontinuities.

We show validation results for a dielectric sphere, for which we compare scattered pulse shapes obtained from our time-domain integral equations with those synthesized using Mie solutions.

*This work is supported by the AFOSR grant F49620-01-0504.