Parallel, Explicit, and PWTD-Enhanced Time Domain Volume Integral Equation Solver

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Time domain volume integral equations (TDVIEs) are useful for analyzing transient scattering from inhomogeneous dielectric objects in applications as varied as photonics, optoelectronics, and bioelectromagnetics. TDVIEs typically are solved by implicit marching-on-in-time (MOT) schemes [N. T. Gres et al., *Radio Sci.*, 36, 379-386, 2001], requiring the solution of a system of equations at each and every time step. To reduce the computational cost associated with such schemes, [A. Al-Jarro et al., *IEEE Trans. Antennas Propagat.*, 60, 5203-5215, 2012] introduced an explicit MOT-TDVIE method that uses a predictor-corrector technique to stably update field values throughout the scatterer. By leveraging memory-efficient nodal spatial discretization and scalable parallelization schemes [A. Al-Jarro et al., in *28th Int. Rev. Progress Appl. Computat. Electromagn.*, 2012], this solver has been successfully applied to the analysis of scattering phenomena involving 0.5 million spatial unknowns.

In this work, we further advance the capability of the above TDVIE solver through acceleration via a recently developed parallel implementation of the plane wave time domain (PWTD) algorithm [Y. Liu et al., in *URSI Digest*, 2012]. Interestingly, the PWTD scheme required for accelerating the TDVIE is quite different from that required for enhancing time domain surface integral equation (TDSIE) solvers [Shanker et al., *IEEE Trans. Antennas Propagat.*, 51, 628-641, 2003]. Rather than rapidly evaluating electric fields due to past currents, here the PWTD scheme accelerates the computation of magnetic vector potentials due to source electric flux densities. Interactions between far-field groups are evaluated by decomposing vector potentials into their three Cartesian components that are propagated independently using a scalar PWTD scheme; electric fields are computed from the potentials using a simple finite difference scheme. Interactions between near-field groups remain accounted for by the direct predictor-corrector scheme. This parallel PWTD-enhanced TDVIE solver has been used to analyze transient scattering from a layered dielectric sphere involving 20 million spatial unknowns, a record for time domain integral equation solvers. The accuracy and stability of the PWTD-accelerated TDVIE solver are verified by comparing electric field intensities and wideband RCS data with analytic results. The solver's real-world applicability will be demonstrated via simulation of scattering from red blood cells.