A Parallel Wavelet-Enhanced PWTD Algorithm for Analyzing Transient Scattering from Electrically Very Large PEC Targets

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The computational complexity and memory requirements of classically formulated marching-on-in-time (MOT)-based surface integral equation (SIE) solvers scale as $O(N_t N_s^2)$ and $O(N_s^2)$, respectively; here N_t and N_s denote the number of temporal and spatial degrees of freedom of the current density. The multilevel plane wave time domain (PWTD) algorithm, viz., the time domain counterpart of the multilevel fast multipole method, reduces these costs to $O(N_t N_s \log^2 N_s)$ and $O(N_s^{1.5})$ (Ergin et al., *IEEE Trans. Antennas Mag.*, 41, 39-52, 1999). Previously, PWTD-accelerated MOT-SIE solvers have been used to analyze transient scattering from perfect electrically conducting (PEC) and homogeneous dielectric objects discretized in terms of a million spatial unknowns (Shanker et al., *IEEE Trans. Antennas Propag.*, 51, 628-641, 2003). More recently, an efficient parallelized solver that employs an advanced hierarchical and provably scalable spatial, angular, and temporal load partitioning strategy has been developed to analyze transient scattering problems that involve ten million spatial unknowns (Liu et. al., in *URSI Digest*, 2013).

In this work, the efficiency of the abovementioned solver is further enhanced by employing local cosine wavelet compression along the temporal dimension (Coifman et. al., *Comptes Rendus de l'Academie des Sciences, Paris, Serie I,* 312, 259-261, 1991). Local cosine wavelet bases (LCBs) consist of localized, quasi-bandlimited, and orthonormal cosine-like functions that are well-suited to represent many (naturally occurring/engineering) high frequency plane wave pulses in a multiresolution framework. As a result, they permit a memory reduction in PWTD solvers by only storing wavelet coefficients with magnitudes that exceed a prescribed threshold. Furthermore, the computational cost of the PWTD translation operation can be reduced by coupling the wavelet coefficients of incoming and outgoing plane waves using translation matrices expressed directly in the wavelet domain. These matrices tend to be very sparse due to the narrowband nature of the LCBs and hence can be calculated efficiently on-the-fly; once calculated they can be re-used due to the translational invariance of the translation operator. To date we have achieved one order of magnitude reductions in memory and computational cost by leveraging LCBs. We note that this scheme complicates the parallelization of the PWTD kernel and requires judicious rearrangement of the computation and communication tasks. The proposed solver will be used to solve very large transient scattering problems well beyond those reported in our previous work.