A Wavelet-Based PWTD Algorithm-Accelerated Time Domain Surface Integral Equation Solver

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The multilevel plane-wave time-domain (PWTD) algorithm allows for fast and accurate analysis of transient scattering from, and radiation by, electrically large and complex structures. When used in tandem with marching-on-in-time (MOT)-based surface integral equation (SIE) solvers, it reduces the computational and memory costs of transient analysis from $O(N_t N_s^2)$ and $O(N_s^2)$ to $O(N_t N_s \log^2 N_s)$ and $O(N_s^{1.5})$, respectively, where N_t and N_s denote the number of temporal and spatial unknowns (Ergin et al., *IEEE Trans. Antennas Mag.*, 41, 39-52, 1999). In the past, PWTD-accelerated MOT-SIE solvers have been applied to transient problems involving half million spatial unknowns (Shanker et al., *IEEE Trans. Antennas Propag.*, 51, 628-641, 2003). Recently, a scalable parallel PWTD-accelerated MOT-SIE solver that leverages a hiearchical parallelization strategy has been developed and successfully applied to the transient problems involving ten million spatial unknowns (Liu et. al., in *URSI Digest*, 2013). We further enhanced the capabilities of this solver by implementing a compression scheme based on local cosine wavelet bases (LCBs) that exploits the sparsity in the temporal dimension (Liu et. al., in *URSI Digest*, 2014). Specifically, the LCB compression scheme was used to reduce the memory requirement of the PWTD ray data and computational cost of operations in the PWTD translation stage.

In this study, we extend our previous work by implementing an LCB compression scheme for *all* PWTD stages. In other words, all operations required in all PWTD stages are performed in the wavelet domain with reduced computational cost (compared to traditional PWTD-accelerated MOT-SIE solvers). (i) Outgoing/incoming rays of parent/child groups are constructed/projected by spherical interpolation/filtering of the LCB coefficients obtained from those of child/parent groups. (ii) Local shifting operations are performed by multiplying LCB coefficients with shifting matrices expressed in the wavelet domain. (iii) The translation operation is carried out by coupling LCB coefficients of the incoming and outgoing rays using translation matrices expressed in the wavelet domain. The computational cost and memory requirement of the proposed LCB-enhanced PWTD-accelerated MOT-SIE solver are theoretically proven and numerically validated to be $O(N_s^{1.5})$ and $O(N_s \log N_s)$ when analyzing transient scattering from many practical quasi-planar objects. The efficiency and accuracy of the proposed solver are demonstrated through its application to some very large scale scattering problems.