A Hybrid PSTD/FDTD Method for Multiscale Problems

Mei Chai*, Tian Xiao, Gang Zhao, and Qing H. Liu
Department of Electrical and Computer Engineering
Duke University
Durham, North Carolina 27708
Email: mchai@ee.duke.edu, qhliu@ee.duke.edu

Realistic electromagnetic problems are often multiscale, where electrically coarse structures (i.e., structure details comparable or larger than a typical wavelength) exist at one extreme, and electrically fine structures (i.e., structure details much smaller than a typical wavelength) exist at the other extreme. In such problems, we need to use high sampling density in order to capture the geometrical details of electrically fine structures. Obviously, if a uniform grid is used such as in the conventional FDTD method, a large number of grid points will be wasted in the electrically coarse domains, causing unnecessary computational expenses. On the other hand, if a non-uniform grid is used, a method with high-order accuracy need to be applied in the electrically coarse domains in order to obtain accurate result efficiently.

To solve this multiscale problem, in 2005 we developed a hybrid technique combining the pseudospectral time-domain (PSTD) method with a version of FDTD method to optimize the grid distribution in the computational domain (M. Chai et al., 2005 URSI Meeting Abstract, Washington, DC, July 2005). Specifically, the alternating direction implicit (ADI) conformal FDTD (ADI-CFDTD) method is developed to preserve the second-order accuracy with unconditional stability in domains with electrically fine structures; the PSTD method is used to model electrically coarse domains with spetral accuracy.

In this work, we further extend this hybrid technique to combine the PSTD method with two versions of advanced FDTD methods, i.e., the ADI-CFDTD and CFDTD methods for full 3D problems. Both CFDTD and ADI-CFDTD methods are second-order accurate in spatial discretization; the former is ideal for the intermediate scale where the geometrical feature size is approximately between 1/20 of a wavelength to about one wavelength, while the latter is ideal for the fine scale below the intermediate scale, and the PSTD method is ideal for the coarse scale above the intermediate scale. Such a hybrid method is close to being optimal in terms of its accuracy and efficiency. Numerical results will be shown to demonstrate the effectiveness of this hybrid PSTD/FDTD method.