Efficient implicit-explict CN-LF time integration scheme for hybrid FDTD-FETD

Qingtao Sun, Qiang Ren, and Qing Huo Liu*
Duke University, Durham, NC, 27708

Finite different time domain method (FDTD) is widely used for transient electromagnetic field modeling. It shows great computational efficiency by employing central differencing for spatial discretization based on the staggered Cartesian grid and Leap-frog time stepping for temporal discretization. This method avoids matrix operations and presents linear complexity. Thus it has robust adaptability in practical application. One drawback of FDTD is the staircasing error, due to the approximation of irregular structures with the Cartesian grid. Another popular time domain technique is finite element time domain method (FETD), which features great meshing flexibility for fine and complicated structures by employing unstructured tetrahedron element. This method, through a matrix assembly procedure, finally needs to solve a linear system, which involves matrix inversion and can thus become computationally costly, especially for large scale problems. An ideal attempt is to realize hybrid of FDTD and FETD in a way as follows: (1) for smoothly inhomogeneous regions and the perfectly matched layers (PML) in open problems, conventional FDTD is employed to reduce the overall number of unknowns for spatial discretization and improve the computational efficiency with explicit time integration scheme; (2) for fine and complicated structures, FETD is employed to eliminate the staircasing error and meanwhile implicit time integration scheme is used to overcome the CFL constraint. In this way, ideally we can take full advantages of both FDTD and FETD while effectively avoiding their limitations. This idea has attracted considerable attempts, which facilitated the mature of the hybrid method for practical application.

A new efficient implict-explicit time integration scheme is proposed for the hybrid FDTD-FETD method. The proposed scheme employs Leap-frog (LF) time integration for the FDTD region and implicit Crank-Nicolson (CN) time integration for the FETD region, thereby an overall CN-LF time integration scheme is formed for the hybrid method. The proposed implicit-explicit time integration scheme is demonstrated to have a time stability constraint the same as the conventional FDTD. Thus the efficiency of FDTD and the flexibility of FETD are both exploited based on the implicit-explicit time integration scheme. The new scheme will improve the numerical performance of the hybrid FDTD-FETD method when applied to practical cases.