A Time-Domain Hybrid Finite Difference/Finite Element Method for Anisotropic Materials

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Hybrid methods have been studied extensively with isotropic materials (A. Mororchio and R. Mittra, IEEE Micro. Guided Wave Letter, 8, 93-95, 1998) and have shown promise in improving the efficient and accuracy over the use of a single computational method. With the recent interest in the study of meta-materials for potential applications, numerical methods will have to handle the tensor nature of these material properties coupling additional fields for the update equation. The additional coupling increases the computational cost of the numerical simulation, and boundary conditions have to carefully account for the coupled fields. To combat these challenges, we propose a hybridized method that utilizes the strengths of the finite difference time domain (FDTD) method and finite element time domain (FETD) method to efficiently and accurately model the phenomena of anisotropic materials.

The FDTD method is a computationally simple but fast and powerful method used in many electromagnetic simulations; however, its solution accuracy decreases when applied to complex geometries due to using non-conforming meshes. On the other hand, the FETD method models complex geometries very accuracy since it uses meshes conformed to the geometry, but compared to the finite difference method, it's more computationally intensive, requiring a matrix solution for every time step. To utilize the strengths of each method in our proposed hybrid method, an explicit FDTD method is applied in electrically large domains with simple geometries, and an implicit TDFE method will be applied in regions of complex geometries. Pyramidal elements will be used to bridge the transition region between the finite difference and finite element meshes.

Also, we propose a new method to properly enforce the PEC boundary conditions within anisotropic materials. Since the stencil of an FDTD Yee cell within an anisotropic material extends beyond a single cell, fields located a half-cell away from PEC surfaces cannot be properly updated since they rely on fields that may not exist. To solve this problem, we developed a hybridized boundary condition for block geometries. The fields located half-cell away from the PEC are updated using an implicit FETD update, and the fields one cell away from the PEC are updated with both an implicit FETD and 2nd-order explicit FDTD update so that field information can be communicated between the two methods.