FDTD Modelling of Electrically Thin Frequency Dependent Layers in Large-Scale Electromagnetic Problems

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The computational cost is one of the major concerns of the standard finite-difference time-domain (FDTD) method based on a uniformly spaced orthogonal Cartesian lattice when it is employed to solve large-scale electromagnetic problems. To ensure numerical accuracy, the FDTD cell size has to be determined based on the size of the smallest object within the FDTD space. This spatial constraint causes very fine meshing of the entire FDTD space unnecessarily and also leads unreasonably small time step usage under CFL (Courant-Fiedrichs-Lewy) stability condition. Hence, any practical engineering problem containing an electrically small object relatively to a large physical space, especially in the presence of a thin layer in the environment would demand prohibitive computational resources in terms of memory and CPU time. An approach is proposed to permit arbitrarily thin layers to be placed in the FDTD space, without need of reducing the FDTD cell size in proportion. This allows significant reductions of the computational memory and execution time to be achieved, and thus enables us to simulate large-scale electromagnetic problems with a reasonable computational cost.

Several methods have been proposed in the past to handle layers thinner than the FDTD cells. For dielectric or lossy layers, and more recently frequency dependent layers. The proposed method permits more general situations to be addressed, where both the layer and the surrounding background are composed with such frequency dependent media as Debye media. The method relies on applying the integral form of the Maxwell-Ampere equation, and on using the auxiliary differential equation (ADE) technique to advance the E and D fields in the cells traversed by the layer. However, the auxiliary equation used at the regular nodes of the grid is replaced with a set of three auxiliary equations that come from the discontinuity of the D vector in the cells filled with three different frequency dependent media. This results in a set of four equations whose discretised forms allow the four unknowns, i.e. the E field and the three D fields, to be advanced on time in each cell.

In the conference, we will present the implementation of the algorithm and the application to thin layer problems in bioelectromagnetism. Furthermore, we will show the performance of the proposed algorithm by comparing with other approaches in terms of accuracy and computational efficiency.