Three Dimensional Conformal Alternating Direction Implicit Finite-Difference Time-Domain Solver (C-ADI-FDTD)

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Introduction and Objectives

One drawback of the conventional FDTD method is that the smallest spatial step limits the maximal stable time step. Therefore, spatially highly overdiscretized electromagnetic simulations are generally inefficient. To increase the time step, implicit time integration schemes, which are unconditionally stable, can be used. In 3-D the alternating direction implicit (ADI) FDTD method is an numerically efficient possibility. On the other hand, conformal PEC FDTD models, reducing staircasing errors, may get a time step reduction to obtain the best accuracy. Therefore, the unconditional stability of the ADI-FDTD algorithm is very attractive for conformal simulations, because in contrast to C-FDTD no time step reduction is needed to benefit the most from geometrical details. The objectives of this study thus were the development and implementation of a conformal ADI-FDTD solver in 3-D.

Method

All implementations and comparisons were performed within the framework of the 3-D EM TCAD platform SEMCAD X. In contrast to published C-FDTD schemes, the C-ADI-FDTD model presented here uses the conventional ADI-FDTD algorithm but with locally modified update coefficients (no splitting of curl coefficients). Therefore, the original ADI-FDTD update equations are used, while the coefficients calculation is conformally enhanced. Instead of the well known C-FDTD schemes, a new conformal PEC model using modified but conventional update coefficients was adapted to the ADI-FDTD method. The conformal coefficients incorporate the reduction of electric edge lengths and the reduction of the area of the magnetic flux to profit the most from geometrical details. The conformal dielectric model uses effective electromagnetic properties calculated in the area perpendicular to the dielectric edge. In detail, arithmetic averaging weighted with the conformal area fraction defines the effective electromagnetic properties.

Results and Discussion

Aside from canonical benchmarks, complex CAD based electromagnetic engineering problems have demonstrated the suitability and benefits of the presented C-ADI-FDTD method compared to the conventional FDTD method. Since the ADI-FDTD scheme decreases accuracy with increasing overtuning of the conventional timestep, a tradeoff between speed and accuracy has to be taken into account. However, the developed C-ADI-FDTD method allows the effective computation of complex CAD derived configurations, in particular for overdiscretized models, which would require unacceptable runtime requirements using conventional FDTD. Furthermore, the proposed conformal ADI-FDTD scheme has neither an impact on the memory consumption nor on the speed compared to the conventional ADI-FDTD method, since both use the conventional ADI-FDTD update equations. Therefore, the C-ADI-FDTD method improves the accuracy of simulation results without deficiencies and should be always favored over the ADI-FDTD method.