A Penalty Method for Multidomain Pseudospectral Time-Domain (PSTD) Algorithm

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The pseudospectral time-domain (PSTD) method has demonstrated significant advantages over the finite difference time-domain (FDTD) method due to its less sampling density and higher-order accuracy. However, traditional pseudospectral methods with a fixed global distribution of grid points suffer from an intensive computational burden and severe time-step (Δt) restriction when solving problems with strong internal inhomogeneities. This leads to the need for development of multidomain approaches.

Previously, we have implemented the 3-D multidomain PSTD algorithm built on a 3-D hexahedral mesh accurately conformal to the problem geometry. The multidomain strategy allows for a flexible treatment of strongly localized features and avoids the intensive operations on the global domain. We have shown the versatility of the multidomain PSTD method for the simulation of inhomogeneous and conductive media (G. Zhao and Q. H. Liu, *IEEE Microwave Wireless Compon. Lett.*, in press).

In spite of its flexibility, the multidomain scheme requires an extra computational step, namely subdomain patching, to reconcile the field values at the interface of nonoverlapping subdomains. To this end, the characteristic and physical boundary conditions have been developed for the multidomain PSTD algorithm. However, none of these techniques naturally guarantees that the updated fields at the interface still satisfy the original Maxwell's differential equations. Besides, the sequence of patching is dependent on the indexing of subdomains, which can incur singularity problems at the locations of edge and corner, resulting in a potential accuracy and stability degradation. Therefore, a stable and accurate patching technique is called for to bring the advantage of the PSTD method into full play.

The penalty method (J. Hesthaven and D. Gottlieb, *SIAM J. Sci. Comput.*, **17**, 579-612, 1996) seeks for the compromise between the boundary conditions and the equation itself by weakly enforcing the boundary conditions as a penalty term to the equation. This approach has been proved to be asymptotically stable, and has been successfully applied to the finite element method. In this work, we apply the penalty method to our previously developed multidomain PSTD algorithm, to achieve a stable and accurate interface patching technique. This will increase the robustness of the PSTD method, and further broaden its application areas.