Preconditioned Parallel MLFMA Solution of Metamaterial Structures

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Since metamaterials display unusual electromagnetic properties, their accurate electromagnetic modeling via integral-equation formulations becomes an important issue. The metamaterial structures considered in this study consist of split-ring resonators (SRRs) and thin wires arrays (TWAs), which exhibit double-negative properties. These structures have open surface geometries that require the use of electric-field integral equation (EFIE) for their electromagnetic modeling. In order to have a better understanding of the scattering and transmission properties of these metamaterial structures, we model and solve large numbers of SRR inclusions. Consequently, we need to solve large computational problems, and the acceleration power of the multilevel fast multipole algorithm (MLFMA) becomes essential. Since MLFMA employs an iterative solver, solution of large problems requires the reduction of number of iterations. Unfortunately, EFIE formulation tends to increase the number of iterations. Other integral-equation formulations producing better conditioned matrix equations, such as the combined-field integral equation (CFIE), are not applicable to open geometries. Therefore, effective strategies for the preconditioning of the iterative MLFMA solution should be developed.

In this talk, we consider the use of both exact and approximate inverses of sparse matrices containing electromagnetic near-field interactions of various strengths as preconditioners. For this purpose, incomplete LU (ILU) preconditioners and sparse approximate inverse (SAI) preconditioners are employed. By accelerating the convergence of the iterations in MLFMA, solutions of large metamaterial structures are targeted without resorting to simplifications involving homogenization, periodicity, and symmetry. Hence, the interactions of electromagnetic fields with large, albeit finite, SRR and TWA structures are modeled.

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