Numerical Analysis of Three-Dimensional Frequency-Selective Structures Using the Multilevel Fast Multipole Algorithm

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We present fast and accurate solutions of electromagnetics problems involving three-dimensional frequency-selective structures, such as metamaterials and photonic crystals. Those structures are usually constructed by periodically arranging unit cells into a host medium and they are useful in many applications, such as electromagnetic filtering, guiding electromagnetic waves, sub-wavelength focusing, invisibility cloaking, and improving the performance of the antennas. Complicated metamaterials and photonic crystals involving metallic and/or dielectric parts are formulated rigorously with the surface integral equations. For accurate solutions, integral equations are discretized by using very small elements with respect to wavelength. Dense matrix equations are constructed by considering the electromagnetic interactions between the discretization elements and testing the boundary conditions. Simulations of realistic structures usually lead to very large matrix equations that can only be solved via fast algorithms. We employ Krylov-subspace methods and solve the problems iteratively, where the matrix-vector multiplications are accelerated by the multilevel fast multipole algorithm (MLFMA). For large-scale structures involving small details with respect to wavelength, MLFMA is further stabilized by using low-frequency techniques. The constructed simulation environment enables the full-wave analysis of complicated and realistic frequency-selective structures discretized with millions of unknowns.

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