FMM Solution of Large Three-Dimensional Electromagnetics Problems with Arbitrary Surface Triangulations

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Large-scale problems of computational electromagnetics are very challenging because the sizes of the problems that can be solved are limited by computational resources. Despite the difficulties involved, the solution of these problems usually offer valuable results that are immediately useful in real-life applications.

The fast multipole method (FMM) enables the solution of larger problems with existing computational resources by reducing the computational complexity and the memory requirement of the solution without sacrificing the accuracy. This is achieved by replacing the matrix-vector multiplications of $O(N^2)$ complexity by a faster equivalent of $O(N^{1.5})$ complexity in each iteration of an iterative scheme. Some versions of the FMM have complexities that are even lower than $O(N^{1.5})$ per iteration. A direct solution would require $O(N^3)$ operations.

In this work, three-dimensional problems with complicated surface geometries are modelled by flat triangular patches. Electric-field integral equation is solved on an arbitrary mesh of flat triangles by using piecewise linear basis functions defined on triangular domains (due to Rao, Wilton, and Glisson). Triangulations of complicated surfaces are obtained using a commercially available mesh generator, which is integrated with our fast solver. Uniform and nonuniform mesh densities are employed and the outcomes will be compared on the basis of how well the boundary conditions are satisfied on the conducting surfaces of some canonical geometries.

FMM solutions of several electromagnetic problems involving complicated and canonical geometries (sphere, patch, rectangular prism, cylinder, cone, pyramid, etc.) will be presented and compared to analytical results and numerical results in the literature, when available. In order to compare the accuracy and the efficiency of the FMM solution, two reference solutions, namely, a direct solution and an iterative solution (employing ordinary matrix-vector multiplications) of the matrix equation obtained with the method-of-moments (MoM) discretization, are obtained. Computation times and memory requirements of all three methods will be compared.