ABSTRACT

In this dissertation a fast integral equation method, termed IE-FFT, is developed, analyzed and applied to solve electromagnetic (EM) scattering problems. The methodology is developed for the Method of Moments (MoM) solution of the Electric Field Integral Equation (EFIE) on electrically large Perfect Electric Conducting (PEC) structures. Similar to other Fast Fourier Transform (FFT) based algorithms, IE-FFT uses a Cartesian grid to drastically decrease memory storage and speed up the matrix-vector multiplication, when used with iterative solvers. The IE-FFT algorithm employs two discretizations, one for the unknown current on an unstructured triangular mesh and the other on a uniform Cartesian grid for interpolating the Green's function. The uniform interpolation of the Green's function allows the fast computation of well-separated MoM interaction terms with the aid of a global FFT. Nevertheless, the coupling between near-interaction terms should be adequately corrected. The major contribution of this dissertation lays on the Lagrangian interpolation of the Green's function. This not only allows simple and efficient algorithmic implementation, but also naturally suggests a rigorous error analysis and tight error bounds of the algorithm. The efficiency of the method is based on the Toeplitz structure of the interpolated Green's function. Therefore, it is applicable on both asymptotically-smooth and oscillatory kernels arisen in static and wave propagation problems, respectively. Through the electromagnetic wave scattering from a PEC sphere, the complexity of the IE-FFT algorithm is found to scale as $O\left(N^{1.5}\right)$ and $O\left(N^{1.5}\log N\right)$ for memory and CPU time, respectively. More accurate integration of weakly singular integrals for EFIE formulation is proposed. Subsequently the proposed

integration improves the robustness and the accuracy of the EFIE greatly. Furthermore, the IE-FFT algorithm can be directly applied to Finite Element Method-Boundary Element Method (FEM-BEM) for solving the boundary integral equation. Finally, multi-regions are analyzed by Domain Decomposition-Finite Element Method (DD-FEM) combining with the IE-FFT algorithm.