ABSTRACT

It is well known that the scope and application of numerically-rigorous techniques for full-wave electromagnetic characterization is limited to problems of moderate electrical size and simplified complexity. These limitations stem from the vast computational resources required by numerical methods such as finite element method (FEM), boundary element method (BEM) or finite difference method (FDM). During the last decade a number of fast and memory efficient numerical algorithms such as Multigrid methods and the Fast Multipole Algorithm (FMA), have been proposed to further reduce storage and computational requirements of full-wave methods.

In this dissertation an alternative proposition will be presented, that is a fast and efficient Domain Decomposition (DD) methodology, appropriately tailored for the solution of time-harmonic Maxwell's equations. The DD method proposed here is a non-conforming one, namely it allows for different mesh on either side of domain interface. This not only relaxes and speeds up automatic mesh generation algorithms, but at the same time opens the road of efficient and robust adaptive field computations. The DD technique is based on a divide-and-conquer philosophy. Instead of tackling a large and complex problem directly (as a whole), it divides the computational domain into smaller, possibly repetitive, and easier to solve partitions called domains. Such domains can be solved with a variety of numerical methods, e.g. finite elements, boundary elements, etc.

The algorithm proceeds iteratively by appropriately communicating information across domains and ultimately reaching the solution for the original (whole) problem.

A detailed presentation of the proposed DD method for electromagnetic problems will be given, along with a novel methodology called "cement" finite elements, for the coupling of domains with non-matching meshes. In addition, a variant of the Finite Element Tearing and Interconnecting (FETI) sub-structuring algorithm will be introduced. Numerical results for a number of challenging real-life engineering electromagnetic applications, ranging from large antenna arrays to novel engineered materials, photonic crystals, and large object scattering, will be given. As a result of this research, complex problems with upwards of 50 to 900 million finite element unknowns have been solved on personal computers without the need of parallelization. Finally, further applications of the cement and DD methods on infinite periodic problems without periodic meshing and a very promising DD based FEM-BEM hybrid are also proposed and studied.