SOME NON-TRADITIONAL APPROACHES TO COMPUTATIONAL ELECTROMAGNETICS FOR SOLVING A CLASS OF REAL-WORLD ANTENNA AND SCATTERING PROBLEMS

R. Mittra, EMC Lab, Penn State University
319 EE East, University Park, PA 16802
rajmittra@ieee.org

Abstract

Computational Electromagnetics (CEM), though well-established, is an extremely active field, as is evident from the number of recent publications and symposium presentations on this topic. It should be noted, however, that the landscape of CEM applications is continuously evolving, as relatively new areas such as nano-photonics and biological sensors appear in the horizon. A quick survey of the literature reveals that in the recent past the primary focus area in CEM has been the solution of 'Large Problems,' typically involving millions if not billions of unknowns. However, it has also been realized that many of the algorithms developed for solving large problems—such as the Fast Multipole Method (FMM)—are restricted in their application primarily to perfectly conducting (PEC) bodies, since these algorithms are so-called "kernel-dependent." Furthermore, a majority of these algorithms utilize iterative methods to solve large problems, because the memory required to store large matrices is well beyond the capability of most available computing platforms, which, in turn, rules out the possibility of using direct solvers to tackle them. While the iterative solvers work fine, and are numerically efficient for well-conditioned problems, they run into difficulties when handling a matrix who condition number is high, unless a suitable preconditioner can be found, which is not an easy task, especially when we are dealing with resonant structures, or when we encounter the ill-conditioning problem that inevitably arises at low frequencies. Even if the frequency is not low, the geometry of the problem may have multiscale features, and this may have serious repercussions, insofar as the convergence behavior of the iteration scheme is concerned. The presence of finite losses may further exacerbate the problem, and unfortunately, no quick-fix is available to alleviate it.

The objective of this paper is to introduce several non-traditional MoM-type formulations designed to alleviate the problems we often encounter in the conventional MoM approach, when solving the new generation of CEM problems involving nano- or multi-scale or geometries, and those involving arbitrary media such as plasmonics. The non-traditional formulations include: (i) bypassing the use of conventional Green's functions for scattering and radiation problems, and utilizing the newly developed Dipole Moment (DM) technique instead; (ii) tackling the low frequency instability problem without using the loop-star basis functions; (iii) employing an alternate formulation for the layered medium that does not utilize the traditional Sommefeld integral approach; (iv) utilizing macro basis functions, also referred to as the Characteristic Basis Functions (CBFs) that help reduce the size of large matrices to the point where one can use direct methods to solve them, and handle multiple right hand sides in an efficient way; (v) hybridizing the DM approach with traditional CEM formulations to solve multiscale problems efficiently; and, (vi) introducing a new CEM formulation in the frequency domain which is both matrix- as well as iteration-free, but which generates the solution by using a recursive update algorithm instead, just as is done in the FDTD leapfrog scheme.

The paper will demonstrate that, when combined with the Characteristic Basis Function Method (CBFM), the proposed algorithms open up new vistas in computational electromagnetics, and enlarge the scope, as well as the range of application of the CEM solvers, to a wide variety of practical and real-world problems.

Acknowledgement: The author is pleased to acknowledge his colleagues at the EMC Lab of Penn State, the EM group at METU, as well as at the Universities of Pisa, Alcala, Ovieda, and Eindhoven, who have been very helpful in the development of the DM- and CBF-based methods mentioned herein.