Hybrid Higher Order Techniques for CEM Analysis and Design

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This paper presents our development of novel higher order large-domain computational electromagnetic (CEM) techniques for analysis and design of antennas and microwave devices and systems. The techniques are based on the method of moments (MoM), finite element method (FEM), physical optics (PO), and hybrid approaches and employ unique generalized quadrilateral boundary elements and hexahedral finite elements of arbitrary geometrical orders and arbitrary current and field approximation orders in a hierarchical fashion. This true higher order modeling technology enables using elements that are both electrically large (large-domain approach) and computationally extremely efficient. The reduction in computation costs is by one to two orders of magnitude when compared to low-order (small-domain) techniques and solutions, for the same or better accuracy.

The first group of techniques is aimed for numerical-asymptotic simulations of electrically large structures using the MoM-PO hybridization. Our basic methodology employs higher order divergence-conforming hierarchical polynomial basis functions in the context of the Galerkin method in the MoM region and higher order divergence-conforming interpolatory Chebyshev-type polynomial basis functions in conjunction with a point-matching method in the PO region (M. Djordjević and B. M. Notaroš, IEEE Transactions on Antennas and Propagation, Vol. 53, No. 2, 2005, pp.800-813). Several versions of the method will be discussed, including the recent iterative MoM-PO technique employing multiple reflections between PO currents nested within an overall iterative MoM-PO multiple-reflection process. Techniques to improve orthogonality properties of higher order large-domain hierarchical vector basis functions will also be demonstrated.

The second class of techniques belongs to hybrid FEM-MoM approaches. The solution in the interior region of the problem is based on a higher order FEM for discretizing the curl-curl electric-field vector wave equation (M. M. Ilić and B. M. Notaroš, IEEE Transactions on Microwave Theory and Techniques, Vol.51, No.3, 2003, pp.1026-1033). The solution in the exterior region is based on a higher order MoM formulation for discretizing a set of coupled electric/magnetic field integral equations (EFIE/MFIE) with electric and magnetic surface currents as unknowns (M. Djordjević and B. M. Notaroš, IEEE Transactions on Antennas and Propagation, Vol.52, No.8, 2004, pp.2118-2129). The two methods are coupled at the boundary of the interior (FEM) region via MoM electric surface currents, which are directly related to the boundary conditions required for closing the FEM region.

The applications to be presented include several real-world designs of antennas and metamaterial structures, along with examples of electromagnetic scatterers and microwave devices.