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Discontinuous Galerkin JMCFIE-EFIE Formulation for Solving Multi-material Complex Antennas

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The versatility of the Discontinuous Galerkin (DG) method [1, 2] to accurately deal with non-conformal meshes makes it a well-suited approach to address complex, multi-scale problems, greatly simplifying computer-aided-design (CAD) generation and meshing processes. It also facilitates the implementation of domain decomposition (DD) approaches, improving iterative convergence for challenging realistic problems where small geometrical details are combined with large-scale smooth structures [1, 3].

This work presents the combination of the electric current (J) and magnetic current (M) combined field integral equation (JMCFIE) [4] and the electric field integral equation (EFIE) with the DG approach, for the electromagnetic analysis of homogeneous and piecewise homogeneous objects, including perfect electric conductor (PEC) surfaces and dielectric interfaces. With this formulation, the interfaces between different materials can be modeled independently, without the need to attend to any constraint in the multi-region junctions between them. Furthermore, because the JMCFIE includes both tangential and normal (or twisted) equations for the electric and magnetic fields, it leads to a well-posed matrix system.

Properly applying the interior penalty term described in [1], the rather complex treatment at multi-material junctions can be avoided. A novelty of this formulation is that it can address nonconformal junctions using DG between interfaces concerning different regions with different materials, including the combination of PEC and dielectric junctions, where the imposition of normal continuity across the junction becomes particularly tedious and critical for accurate antenna analysis.

We will show the details of the proposed formulation and discuss its capability to solve various realistic antenna cases during the presentation, demonstrating the versatility of this approach in the application of DG techniques for the design of complex dielectric and metamaterial antennas.

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2. Z. Peng, R. Hiptmair, Y. Shao, and B. MacKie-Mason, “Domain decomposition preconditioning for surface integral equations in solving challenging electromagnetic scattering problems,” IEEE Transactions on Antennas and Propagation, vol. 64, no. 1, pp. 210–223, jan 2016.

3. B. MacKie-Mason, A. Greenwood, and Z. Peng, “Adaptive and parallel surface integral equation solvers for very large-scale electromagnetic modeling and simulation,” Progress in Electromagnetics Research, vol. 154, pp. 143–162, 2015.

4. P. Yl¨a-Oijala, M. Taskinen, and S. J¨arvenp¨a¨a, “Surface integral equation formulations for solving electromagnetic scattering problems with iterative methods,” Radio Science, vol. 40, no. 6, p. RS6002, dec 2005.