3D Microwave Imaging using the Time-Harmonic Discontinuous Galerkin Method – Contrast Source Inversion

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Over the last 2 decades, experimental Microwave Imaging (MWI) systems have evolved from 2D tomographic systems reconstructing electric properties, to 3D systems reconstructing electric and magnetic properties from electric and magnetic field measurements. Some MWI applications include biomedical imaging, security, and agricultural imaging problems (M. Asefi et al., Comput. Electron. Agric., 119, 2015). To accommodate this wide variety of imaging systems and applications, inversion algorithms such as the Contrast Source Inversion (CSI) method require a flexible forward solver capable of modeling these systems. The time-harmonic Discontinuous Galerkin Method (DGM) forward solver formulated for Maxwell's curl equations offers such flexibility (I. Jeffrey, N. Geddert, K. Brown, PIER, 154, 1-21, 2015).

Herein we present a fully parallel 3D DGM-CSI imaging algorithm. The DGM forward solver can simulate the fields resulting from high-order approximations of permittivity and permeability. The DGM formulation easily handles modeling a variety of imaging system configurations and boundaries (e.g. metallic enclosures) without requiring a numerical Green's function and is capable of representing inhomogeneous backgrounds with high-order expansions. Moreover, using large elements and high-order expansions allows significant flexibility in representing the unknown constitutive parameters. Specifically, DGM-CSI is capable of accurate target reconstruction on coarse meshes without requiring the mesh to line up with the boundaries of the target. An additional feature of this algorithm is the ability to use different expansion orders for the fields, contrasts, and contrast sources. The order of each expansion can also locally vary over each element in the mesh, permitting local image refinement during reconstruction. DGM-CSI results in a flexible imaging algorithm that can be applied to a variety of experimental imaging systems.

In this work we will present the mathematical and implementation details of a fully 3D, distributed parallel, DGM-CSI implementation using PETSc (S. Balay, W. D. Gropp, L. C. McInnes, and B. F. Smith, *Modern Software Tools in Scientific Computing*, 163-202, 1997). The previously mentioned advantages of DGM, including high-order inhomogeneous backgrounds and flexibility in selecting expansion orders for fields and target profiles will be explored within the DGM-CSI framework for both synthetic and experimental 3D imaging problems.