Magnetic Contrast-Enhanced Microwave Biomedical Imaging using Discontinuous Galerkin Contrast Source Inversion

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Microwave imaging (MWI) continues to steadily progress towards clinical application as a low-cost complementary imaging tool for breast cancer detection and treatment monitoring. Contrast-enhanced MWI is a relatively new extension to the research field which employs exogenous agents to improve resulting reconstructions by artificially accentuating the complex dielectric or magnetic property variation between healthy and cancerous tissues. Although a handful of microwave contrast agent studies have been carried out focusing primarily on modifying the permittivity of the targeted tissue (S.C. Hagness *et al.*, IEEE Trans. BME, 57, 8, 1831–1834, 2010), recent investigations of magnetic nanoparticles (MNP) have been of particular interest, since they augment the magnetic permeability of the region in which they accumulate. As a dearth of magnetic material exists naturally in the human body, MNP-enhanced MWI allows the detection of targeted induced magnetic anomalies within otherwise purely dielectric biological tissues, using the electromagnetic response produced by clusters of retained MNPs (O.M. Bucci *et al.*, IEEE Trans. Biomed. Eng., 58, 9, 2528–2536, 2011). To the authors' knowledge the only published work reporting quantitative images of magnetic polarizability has used synthetic breast data, with inversions based on the truncated singular value decomposition (TSVD) scheme (R. Scapaticci *et al.*, IEEE Trans. Biomed. Eng., 61, 4, 1071–1079, 2014).

A previously described finite element contrast source inversion (FEM-CSI) algorithm (A. Zakaria, C. Gilmore and J. LoVetri, Inverse Probl., 26, 11, Article ID 115010, 2010) was recently extended to both high-order and magnetic materials using a time-harmonic, discontinuous Galerkin formulation of Maxwell's equations (DGM-CSI) (I. Jeffrey *et al.*, 2014 USNC-URSI, 74, 6–11 July 2014). It is based on an earlier dielectric and magnetic, low-order, integral equation CSI formulation (A. Abubakar and P. M. van den Berg, J. Comput. Phys., 195, 1, 236–262, 2004), and supports unstructured discretizations of dielectric, magnetic, and perfectly conducting media, which is ideal for MNP-enhanced targets in open boundary or conductive enclosures. In this work, inversions of synthetic data from models containing inclusions of MNPs at various simulated concentrations are performed to test the algorithm's detection threshold. Reconstructions of experimental data collected from simple 2D targets containing actual dilutions of magnetite MNPs are also investigated, using antenna arrays successfully employed in the past for phantom imaging (C. Gilmore *et al.*, IEEE Antennas Wireless Propag. Lett., 9, 393–396, 2010) and human forearm imaging trials (M. Ostadrahimi *et al.*, IEEE Trans. Microw. Theory Techn., 61, 9, 3424–3434, 2013).