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Experimental 3D Microwave Imaging of Magnetic Targets using Discontinuous Galerkin Contrast Source Inversion and a Two-Stage Reconstruction Technique

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1 Extended Abstract

While microwave imaging (MWI) for biomedical applications continues to make steady progress as a prospective clinical modality, a promising research trajectory has recently emerged involving the use of contrast enhancement with magnetic nanoparticles (MNPs) [1, 2]. While reconstructed profiles of the complex relative permittivity (ε_r) yield important anatomical information of biological targets, the addition of MNPs accumulating preferentially in metabolically-active tissue could allow the relative magnetic permeability (μ_r) to play an important role in the future cancer diagnostic capabilities of this technology. A fully parallelized 3D implementation of Contrast Source Inversion using the Discontinuous Galerkin Method (DGM-CSI), a fast and robust imaging algorithm supporting the use of inhomogeneous backgrounds with high-order expansions over coarse meshes, has been successfully used to reconstruct synthetic targets with pathologically high values of magnetic permeability in the past [3]. However, the algorithm has not hitherto been subjected to rigorous testing on realistic models of MNP-laden breast tumours or used on experimental 3D data, which is demonstrated herein.

To accurately accomplish these reconstructions when contending with the inherently low-magnitude magnetic signals from physiologically achievable MNP concentrations, a two-stage reconstruction procedure [4] must be employed. Based on the physical observation that the strong dielectric signal of underlying tissue can be elegantly separated from the MNPs' magnetic response through the use of a weak external static magnetic field [1], the complex relative permittivity can be independently reconstructed and used as an inhomogeneous background in DGM-CSI for the subsequent inversion of magnetic permeability. We demonstrate the capabilities of the two-stage procedure to first reconstruct the complex permittivity profile, and subsequently the MNP-enhanced magnetic profile, for both synthetic and simple experimental target configurations within a semi-resonant breast imaging chamber capable of both electric and magnetic field measurements [5].

References

[1] G. Bellizzi, O. M. Bucci, and I. Catapano, "Microwave cancer imaging exploiting magnetic nanoparticles as contrast agent," *IEEE Transactions on Biomedical Engineering*, **58**(9), 2011, pp. 2528-2536.

[2] O. M. Bucci, *et al.*, "Experimental framework for magnetic nanoparticles enhanced breast cancer microwave imaging," *IEEE Access*, **5**, 2017, pp. 16332-16340.

[3] K. Brown, *et al.*, "3D microwave imaging using the time-harmonic discontinuous Galerkin method - contrast source inversion," *USNC-URSI Radio Science Meeting, San Diego, California, July 9-14*, 2017.

[4] C. Kaye, I. Jeffrey, and J. LoVetri, "Two-stage reconstruction of complex dielectric permittivity and magnetic permeability for biomedical microwave imaging employing magnetic contrast agents," *The 4th Advanced Electromagnetics Symposium (AES 2016), Malaga, Spain, July 25-28, 2016 Proceedings*, 2016, pp. 40-42.

[5] K. Nemez, A. Baran, M. Asefi, and J. LoVetri, "Modeling error and calibration techniques for a faceted metallic chamber for magnetic field microwave imaging," *IEEE Transactions on Microwave Theory and Techniques* **65**(11), 2017, pp. 4347-4356.