# Data Hopping and Convergence Criteria for Microwave Imaging

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Microwave Imaging (MWI) techniques have been investigated, over more than 40 years, for a multitude of biomedical, remote sensing, and non-destructive evaluation applications. Quantitative MWI techniques reconstruct electromagnetic properties of a region, or object-of-interest (OI), such as the permittivity and permeability. One class of quantitative MWI methods seek to minimize objective functions that incorporate the error between the electromagnetic scattered field data collected at particular points around the OI with a numerical model that approximates the field at those same locations. The numerical model is a function of a predicted two or three dimensional profile of the electromagnetic parameters of interest. Two such techniques are the Contrast Source Inversion, CSI (P. M. Van Den Berg and R. E. Kleinman, Inverse problems, vol. 13, no. 6, p. 1607, 1997), and the Distorted Born Iterative Methods, DBIM (W. C. Chew and Y. M. Wang, IEEE Trans. Med. Imaging, vol. 9, no. 2, pp. 218-225, 1990). Although many improvements have been made to CSI and DBIM, including the reinterpretation of DBIM as the Gauss-Newton Inversion (GNI) technique (J. De Zaeytijd, *et al.* IEEE Trans. Antennas Propagat., vol. 55, no. 11, pp. 3279-3292, 2007), and a variety of regularization methods have been created, very little research has been published on convergence criteria for these iterative algorithms. Such criteria is not only useful for terminating the algorithm but also provides *hopping points* at which new data can be introduced (*e.g.*, when data at a different frequency is introduced: *frequency-hopping*, or when data obtained using a different immersion medium is utilized).

In this work we take a close look at various criteria that can be used for not only stopping the overall iteration loop but also for providing a systematic way of hopping to new data once a level of convergence has been obtained. We focus on CSI which seeks to minimize a weighted sum of two functionals: the data error, $\|\mathbf{d} - E^s(\chi)\|$ and the domain error, $\|\chi E^i - w + \chi E^s(\chi)\|$. New convergence and hopping criteria are introduced that are based on monitoring the domain error and some statistical properties of the data-error vector, $\mathbf{d} - E^s(\chi)$, throughout the iteration process. Once the statistical properties of the data-error vector are sufficiently close to an appropriately chosen distribution the inversion algorithm is allowed to hop to a different set of data obtained, for example, at another frequency. The inversion result obtained at any step in the process is utilized as prior information after hopping to the subsequent data. This prior information can be introduced in the form of an initial guess or as an inhomogeneous background with respect to which the contrast, $\chi$, is defined. The relative change in the domain error provides a means by which one can terminate the overall minimization algorithm. Results obtained using synthetic and experimental data are examined both in 2D and in 3D. Phantom-based experimental results are obtained via a new breast imaging system that has been developed at the University of Manitoba.