A TSVD Analysis of an Enclosed Array of Multi-Band Patch Antennas for Microwave Breast Imaging

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Quantitative microwave imaging based on inverse scattering shows promise for breast cancer risk assessment, detection, and treatment monitoring due to its low cost, non-ionizing nature, and fully three-dimensional imaging potential. The quality of the microwave image is limited by the quality of the scattering data recorded by the antenna array that surrounds the breast. At the UHF frequencies typically used in microwave inverse scattering algorithms, the target exists within the near field of the antennas, necessitating a departure from established far-field array analysis techniques. An analysis based on truncated singular value decomposition (TSVD) provides a systematic approach to evaluating potential near-field imaging performance as a function of various array design considerations.

A TSVD method of analysis approximates the process of inverting the scattering matrix and makes use of the full field data available in a simulated setting, thereby avoiding any linearizing field approximations (Shea *et al., IEEE Trans. Biomed. Eng.*, 59, 936-945, 2012). Application of a fidelity metric, defined as a normalized inner product between the TSVD estimate and the true object profile (available in a simulated setting), allows the impact of various design considerations to be quantified. The truncation index at which the fidelity peak occurs gives information on the resolution of the available data. This approach decouples the nonlinear inverse scattering problem from the system design problem and has the advantage of avoiding the multiple forward solutions required in an iterative imaging technique such as the distorted Born iterative method, greatly decreasing evaluation time of various designs.

We apply the techniques employed by Shea *et al.* to investigate a realistic antenna array configuration recently proposed for microwave breast imaging (Burfeindt *et al., IEEE Antennas Wireless Propagat. Lett.*, 2012, in press). The array is composed of groundplane-backed miniaturized tri-band (1.6 GHz, 2.2 GHz and 3.0 GHz) patch antennas and provides diversity of scattering frequencies while electrically isolating the imaging region from the external environment. The targets consist of MRI-derived numerical breast phantoms from the UWCEM Numerical Breast Phantom Repository (`http://uwcem.ece.wisc.edu/MRIdatabase/index.html`). The finite-difference time-domain method is used to simulate the array measurements. We evaluate the effect of polarization, antenna location and array configuration on the quality of the received field data. A number of trade-offs are explored: antenna number vs. distance to target, polarization diversity vs. channel performance, and reflect vs. through channel information content.