Patient-Specific Models of Susceptibility-Induced B0 Field Variations in Breast MRI

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Introduction: MRI is an important tool for diagnosing and staging breast cancer. The shape of the breast may result in susceptibility-induced field changes, which can cause artifacts at the air-tissue boundary. The goal of this work is to discover the true source of these artifacts and to see if the field inhomogeneities near the edge of the breast could be modeled based on the breast shape in 3D image datasets. Through simulation of the magnetic susceptibility in three dimensions, we estimated the B_0 distribution. The simulated estimated field map help correct off-resonance effects and may lead to more accurate diagnostic images.

Methods: We used 20 datasets from patient studies following IRB approval from our institution. Images were acquired on a GE 1.5T scanner with an investigational version of the IDEAL-SPGR sequence [1]. IDEAL (iterative decomposition of water and fat with echo symmetry and least-squares estimation) provides separated water, fat and field-map images by acquiring the three images with different phases. In this study, we created a model-based B_0 field map based on magnetic susceptibility using the equation,

$$\Delta B_0(r) = FFT^{-1}\left[B_0\left(\frac{1}{3} - \frac{k_z^2}{|k|^2} FFT[\chi(r)] \right) \right],$$

where $\Delta B_0(r)$ is the distribution of the magnetic field perturbation, B_0 is the static magnetic field, **k** is the Fourier space coordinate, and $\chi(r)$ is the 3D magnetic susceptibility distribution. [2, 3]

For each dataset, we first generated the tissue susceptibility mask, $\chi(r)$ (Figure 1B) by thresholding using the original source image (Figure 1A). After obtaining $\Delta B_0(r)$ using the above equation, linear shims used in the original scan were added to the estimated field map to create the simulated field map (Figure 1C). The simulated field map was then quantitatively compared with the measured field map (Figure 1D) by subtraction, after removing the mean field from both.

Results and Discussion: We drew a line along the modeled (Figure 1C) and measured field maps to measure the difference between the two field traces (Figure 1E). Further agreement of the field traces is shown with different patient studies (Figures 1F, 1G). Within the tissue, the simulated field map closely modeled the inhomogeneities of the actual field map. The empirical model that we developed predicts spatial variations in the magnetic field in the breast based on the shape of the breast. This simulation may provide a model for improved shimming or estimates for unwrapping frequency shifts in phase-based fat-water separation techniques like IDEAL. It also may contribute to understanding what fraction of the field error is due to the lungs versus the outside air.

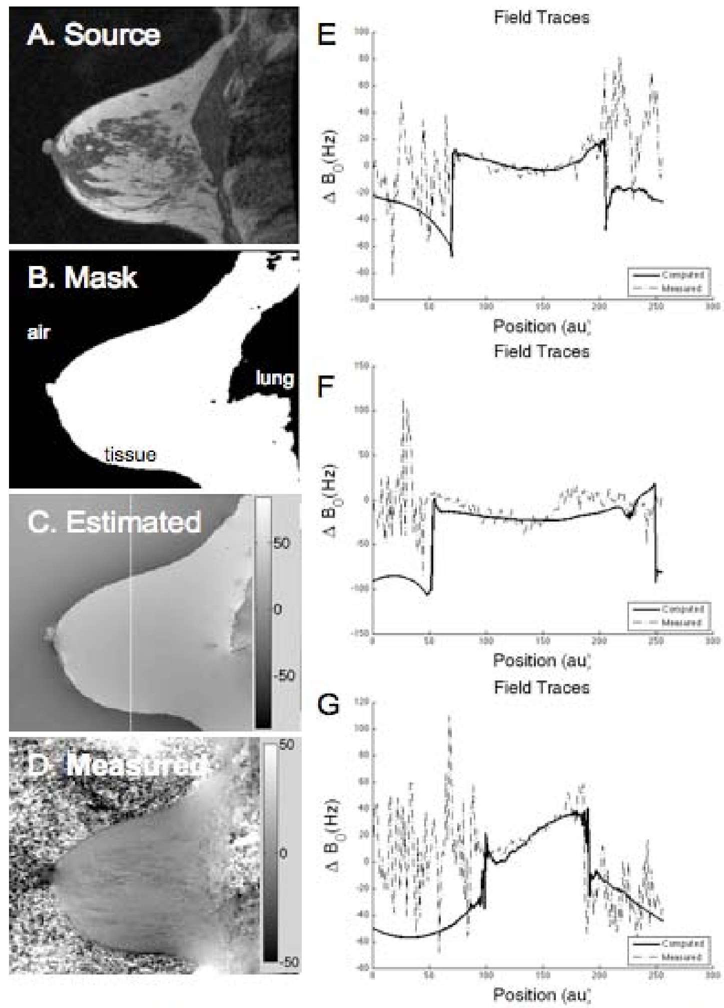

Figure 1. A) Sagittal IDEAL-SPGR image. B) Tissue Susceptibility Mask. C) Estimated Field Map. D) Measured Field Map. E) Field Trace Comparisons from C and D. F-G) Further Field Trace Comparisons

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References

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