Dipole filtering, decomposition and quantification with 3D radial acquisition

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TARGET AUDIENCE Radiologists, technologists, and researchers interested in microcalcifications, microbleeds, magnetic nanoparticles, and other magnetic field perturbing pathology, tissues, and exogenous materials.

PURPOSE Develop and test MRI acquisition and post processing for identification and quantification of dipole induced field changes in tissues.

INTRODUCTION Normal tissue boundaries, pathologies and exogenous materials introduced into the body produce localized changes to the magnetic field. Many MRI methods have been developed to detect these changes, most recently susceptibility weighted imaging [1] and quantitative susceptibility mapping [2,3]. For many tissues, pathologies, and exogenous contrast agents of interest (such as magnetic nanoparticles), quantification is desirable and full mapping of the susceptibility or other electrical properties is not yet practical. An intermediate approach may be useful.

METHODS We combine a modified phase based dipole matched filter [4,5] to count dipole sources in the field of view with model based dipole source decomposition [6] of the phase offsets in 3D radial sampled data. Due to the spherical polar symmetry of the secular dipole field [7], the dipole source decomposition is most conveniently carried out using decimated radial k-space (3d → 1d projection) data before image reconstruction.

We first acquired phantom images of Ti BBs imbedded in agar gel using the SWIFT sequence [8-10]. Dipole matched filtering highlights regions best described by dipolar field variation and suppresses regions not possessing dipolar variation of the field. Thresholding is then used to estimate the number of dipole sources to use in the decomposition. In this initial proof of principle a singular value decomposition is carried out in matlab using 512 projections.

RESULTS Phantom results are shown in **Figure 1.** 6 Ti ball bearings (Bbs) of known diameter are imbedded in 50 mL centrifuge tubes. The center tube has only a plastic mesh to give texture similar to blood vessels. Some Bbs have a mesh as well. Magnitude, phase, and dipole match are shown. Starting at one o'clock position and moving clockwise the relative strengths are: *1.00, 1.31, 2.72. 1.01, 1.41, 2.07*. Correponding BB diameters are *2.38, 3.18, 4.76, 2.38, 3.18* and *3.97 mm*. Ratio of strength (normalized singular value) to BB diameter cubed is: *0.134, 0.130, 0.144, 0.131, 0.156, 0.163*. This ratio should remain stable for accurate quantification, however the volume of the BB itself could attenuate the phase signal weighting

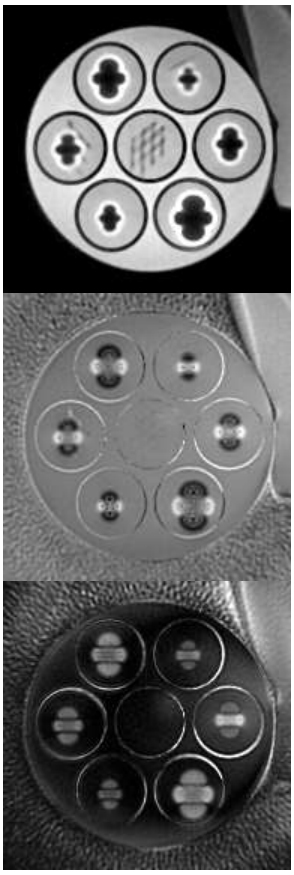

Figure 1: Phantom

DISCUSSION The SWIFT sequence combines excitation (frequency-swept RF pulse), spatial encoding (readout gradient), and acquisition into one multiplexed time interval. SWIFT excites signal at high bandwidth and receives after a very short dead time (4 μs) and so is highly robust against signal loss due to off-resonance effects and eddy currents. SWIFT detects field perturbations from dipole sources within the field of view without signal loss [11] which is a highly desirable feature. The radial acquisition scheme of the SWIFT sequence also allows quantification of dipolar sources to be done in the natural spherical coordinate system, which is highly computationally efficient.

CONCLUSION Dipole decomposition using SWIFT is a promising method to detect and quantify dipolar field sources corresponding for MRI.

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