Dipole Matched Filter with SWIFT

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Background: There is renewed interest in capturing information from the local macroscopic magnetic field in MRI, especially with the increasing availability of higher field systems. Phase contrast imaging techniques (1), positive contrast sequences for visualizing iron oxide nano-particles (2), as well susceptibility weighted imaging (3) all have a component of sensitivity to local magnetic field perturbations.

Purpose: We are interested in extracting information about the presence of a local dipole field in an MRI dataset. There has been much work on sequence-based, post-processing-based and combination methods to detect dipole fields such as the approach of Mills and Ahrens (4). An important subset of this effort has been focused on obtaining "positive" contrast (3) from paramagnetic contrast agents such as iron oxide nano-particles (5)

Methods: We have implemented the combination of the SWIFT sequence (6) on a Varian Inova console utilizing vnmrj "classic" software. SWIFT has very short excitation to acquisition delay, in this case 4 µs. There is no time for intra-voxel dephasing so that signal is preserved as long as the frequency shift or T_2^* broadened linewidth stays within the acquisition bandwidth.

We combine this with the post-processing-based of a multiplicative or "matched" (7) filter in K-space. The filter is the secular dipole field pattern (8). The filter in K-space has the advantage of being scale invariant (it is a function of angle only, not radius). It also has "high pass" property of suppressing a uniform background signal, in other words the "dc" spatial frequency response is zero. The filter function in k-space is: $\Lambda(\theta) = [3\cos^2(\theta) - 1]/2,$

where θ is the polar angle with B_0 as the axis (see figure 1). Experiments were conducted on a 4 T human magnet system using a quadrature single breast coil (9). In addition we use an in-house system integrated Echotek (Mercury Computer Systems) based IF digital receiver system (*10*). We developed in-house signal processing and image reconstruction applications utilizing Matlab (Mathworks), "ifort" fortran (Intel) and LabVIEW G (National Instruments).

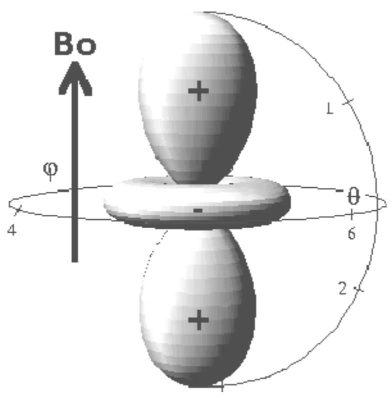

Figure 1 Secular dipole pattern in k-space. Complex k-space data is multiplied by this real valued 3D angular only function.

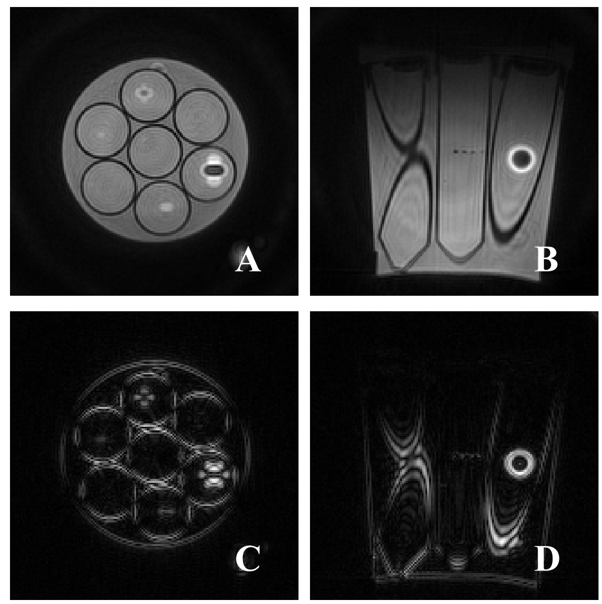

Figure 2: Ti ball-bearing phantom with plastic mesh (when visible) in 50mL centrifuge tubes containing agar gel.

Results: Phantom data at 4 T are shown in figure 2. Figure 2 A-B shows a 62.5 kHz SWIFT image with 96,000 radial views (8 min) and 4 deg nominal flip. The complex image is presented in magnitude mode. The phantom consists of 7 centrifuge tubes (50 mL) containing 1% Agar gel. In addition some of the tubes contain Ti ball bearings, which due to their spherical shape and material homogeneity form an ideal dipole field pattern outside their volume. The tubes are submerged in water in a 500mL tapered cylindrical plastic container. Some of the tubes also contain a horizontal patch of plastic mesh. By comparing figues 2 A and B to the filtered dataset in figures 2 C and D it is clearly seen that the uniform signal from Agar and water is suppressed. Locations of the dipole artifact are greatly enhanced relative to the background, and their size is slightly increased. The simple and easy to implement approach works with non-SWIFT sequences as well, with reduced signal at the center of the dipole area.

Conclusion: The combination of SWIFT and a secular dipole amplitude filter in k-space (dipole matched filter) is a novel way to obtain positive contrast from local dipole field perturbations in MRI.

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