Progress in 3d Imaging at 4 T with SWIFT

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Introduction: SWIFT [1] (SWeep Imaging with Fourier Transform) is a recently introduced radial imaging sequence utilizing gapped frequency-swept pulse excitation[2] and nearly simultaneous signal acquisition in the gaps between pulse elements. We show high-resolution clinical-quality proton-density and modest T_1-weighted images at 31.25 kHz and 62.5 kHz bandwidth in human brain for the first time at 4 T with SWIFT. Unlike most MRI sequences, SWIFT data must be processed to remove phase differences due to the time of excitation in the gapped frequency swept HS1 excitation pulse. We accomplish this by the correlation method[3] which corrects the phase and produces FID data as if the spins were simultaneously excited by a short duration pulse. Because acquisition occurs “inside” the gapped pulse, SWIFT has an intrinsically short dead-time, at present hardware-limited to ~5-15 μs. This provides sensitivity to very fast relaxing spins, similar to that achieved by UTE (Ultra-short TE) sequences[4].

SWIFT utilizes a radial sampling scheme with smoothly updated isotropic spiral[5] (single or interleaved) view ordering. Very little stress is placed on the gradient subsystem and the sequence is extremely quiet, even at short TR and rapid acquisition speeds. The SWIFT sequence is nearly 50dB quieter than 3d Cartesian T_1-weighted FLASH of similar TR and bandwidth on our 4 T scanner. Absolute sound intensity is 55dBb (normal conversation is ~70 dB) compared to 104dB for FLASH. No ear protection is necessary with a SWIFT only MRI session.

Experimental Methods: We have continued to improve performance of SWIFT on our 4 T research MRI scanner (Oxford 90 cm bore magnet, Siemens Sonata 4 gauss/cm gradients, Varian Inova console, vnmrj “classic” interface). For the head imaging we utilize a custom “long” quadrature input-output TEM circularly polarized transceive head coil (TEM head coil) which has very low short T_2 background signal. The SWIFT imaging sequence is currently limited at 4 T to 62.5 kHz bandwidth when using the TEM head coil, due to ring-down and B_1 performance tradeoffs, but has been run at up to 125 kHz bandwidth at 4 T with surface coils.

Results: We show in the Figure(s) three slices from three different 3d SWIFT datasets of adult human heads. While these images contain short T_2 signal, the contrast is dominated by longer T_2 signal. Since the gapped HS1 pulse in SWIFT has an excitation bandwidth from sidebands extending to multiples of the nominal base-bandwidth we suspect some magnetization transfer contrast[6] is introduced as well. Figure A consists of a 4 slice average from a 1.37x1.37x1.37 mm 256x265x256 voxel gridding reconstruction of a 62 kHz, 96,000 unique radial fid view (spoke) dataset. TR was 6.1 ms with 4.1 ms of simultaneous pulse/acquisition time. Total imaging time is 10 min. Filter bandwidth must currently be left wide open (256 kHz HWHM) to minimize overlap of ring-down with the acquisition. Flip angle was nominally 3°. Figure B and C are 31 kHz SWIFT datasets, TR 10.2 ms, 8.2 ms pulse/acquisition time. Total imaging time for each is 17 min, with the same matrix and reconstruction as in Figure A. Figure B is nominal 2° flip angle (proton density) and Figure C is 8° flip (some T_1 weighting).

Currently SWIFT is SAR limited for flip angle and ring-down limited for upper bandwidth at 4 T, and incurs an SNR penalty due to the analog filter. We have begun testing of a 16 channel IF digital receiver[7] and 16 ch TEM element transceive head coil [8] to overcome these limitations and facilitate parallel imaging.

In conclusion we present 4 T head imaging with SWIFT and look forward to further exploring unique contrast mechanisms, applications desiring quiet operation and motion correctability, such as the pediatric imaging community, and other applications where fast quiet T_1 and proton density imaging is required.

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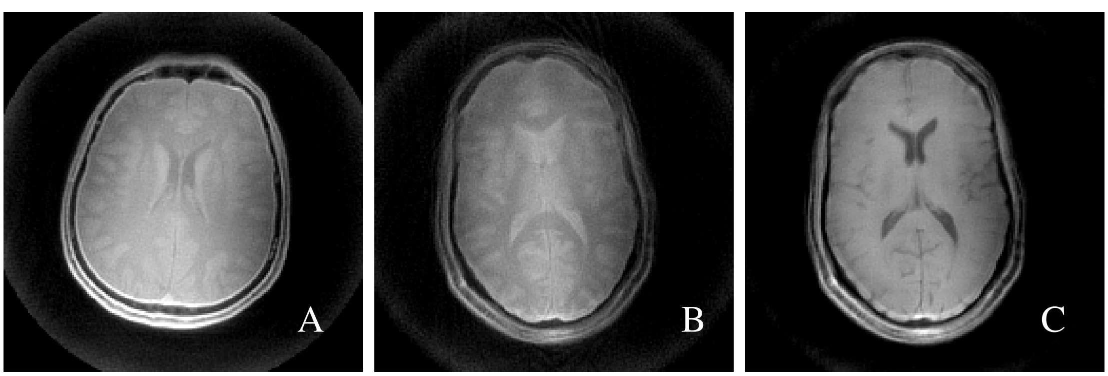

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