# Signal Processing and Image Reconstruction for SWIFT

**C. A. Corum[1], S. Moeller[1], D. Idiyatullin[1], and M. Garwood[1]**
[1]CMRR, University of Minnesota, Minneapolis, MN, United States

**Background**

SWIFT (*1*) (SWeep Imaging with Fourier Transform) is a novel imaging sequence utilizing frequency-swept pulse excitation with nearly simultaneous signal acquisition in the time between pulse elements. SWIFT utilizes the correlation method(*2, 3*) which removes phase differences due to the time of excitation and produces FID data as if the spins were simultaneously excited by a short duration pulse.

We present in detail the evolving SWIFT signal processing and reconstruction chain.

**Methods**

We implemented signal processing and image reconstruction software for SWIFT imaging in Matlab and LabVIEW. SWIFT data was acquired using native transmit and receive on our Varian INOVA console and 4 T 90 cm bore Oxford magnet with Siemens Sonata gradients. We also acquired data with a separate IF digital receiver(*4*) which removes the need for phase cycling in the acquisition and allowed higher acquisition bandwidths.

**Results**

The SWIFT signal processing chain is summarized in table 1.

We acquired SWIFT images at rates of over 100 views per second at 31.25 kHz acquisition bandwidth and 200 views per second at 62.5 kHz in 3d radial view ordering mode. This is with very smooth and quiet utilization of the gradients. In fact on our 4T scanner, ear protection would not be necessary.

Figure 1 shows reconstructed phantom images with and without selected post-processing steps turned on. LabVIEW based gridding was accomplished in a 256x256x256 array, with width 2.5 Kaiser-Bessel kernel having β=3.38 and taking about 120 seconds for 4000 views on a Linux OS high performance PC. The post-processing steps: chopping to remove the edge regions of projections where correlation amplifies noise; separate post-correlation dc estimation in the time domain; and zeroing of the imaginary component of projections before retransformation into k-space and gridding, have significant impact on the SNR and subjective image quality.

**Table 1** - SWIFT signal processing chain

| Frequency (Projection) Domain | | Time (k-space) Domain |
|---|---|---|
| | | acquire raw data |
| | ← | |
| divide by pulse profile* | | |
| constant and linear phase correction | | |
| (optional view dependent correction) | | |
| zero Im component** | | |
| | → | |
| | | optional constant and linear phase correction*** |
| | | (optional view dependent correction) |
| | | dc offset correction**** |
| | | optional filtering (Hanning, etc.) |
| | | optional fat water separation(*5*) |
| | | optional k=0 phase and/or amplitude consistency(*6*) |
| | ← | |
| un-jittering | | |
| chopping/filtering of edges | | |
| | → | |
| | | gridding reconstruction(*7, 8*) |

* this is the frequency domain equivalent of correlation(*2, 3*)
** usually not activated until all other phase corrections have been determined
*** this can correct for off resonance errors
**** in place of or in addition to the pre-correlation Varian offset correction, may not be needed with 4 step phase cycle

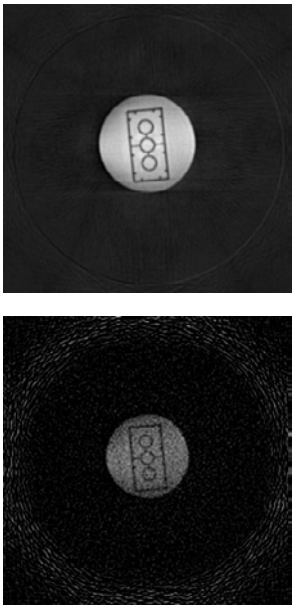

**Figure 1** - 31kHz SWIFT images of a toy plastic brick in Gd doped water FOV=30cn
a) – Reconstructed image using complete signal chain, SNR 60
b) – Reconstructed image without chopping, dc, or zero Im, SNR 6

**Conclusion**

Due to a number of factors, including use of the correlation method, correction or amelioration of RF transmit and receive hardware limitations, and fundamental NMR physics considerations due to the nearly simultaneous transmit and reception of the spin signal, SWIFT has unique signal processing requirements as compared to standard MRI sequences. Use of our signal processing chain significantly improves SNR and image quality for reconstruction of SWIFT data. We gratefully acknowledge support by NIH Grants 5R01CA092004 and 5P41RR008079, and the Keck Foundation.

**References**

1. D. Idiyatullin, C. Corum, J.-Y. Park, M. Garwood, *Journal of Magnetic Resonance* (2006).
2. H. Nilgens, M. Thelen, J. Paff, P. Blumler, B. Blumich, *Magn Reson Imaging* **14**, 857 (1996).
3. J. Dadok, R. F. Sprecher, *Journal of Magnetic Resonance (1969)* **13**, 243 (February, 1974).
4. P. Andersen *et al.*, paper presented at the Proc. Int. Soc. Magnetic Resonance Medicine 1996.
5. M. I. Altbach *et al.*, *Medical Imaging, IEEE Transactions on* **20**, 1156 (November, 2001).
6. A. F. Gmitro, A. L. Alexander, *MAGNETIC RESONANCE IN MEDICINE* **29**, 835 (June, 1993).
7. P. J. Beatty, D. G. Nishimura, J. M. Pauly, *Medical Imaging, IEEE Transactions on* **24**, 799 (June, 2005).
8. J. I. Jackson, C. H. Meyer, D. G. Nishimura, A. Macovski, *IEEE TRANSACTIONS ON MEDICAL IMAGING* **10**, 473 (1991).