Contrast in Visualized Currents Using Reverse Polarization and Pre-Spoiling Twister Gradients

Christopher W Ellenor[1], Pascal P Stang[1], John M Pauly[1], and Greig C Scott[1]
[1]*Electrical Engineering, Stanford University, Stanford, CA, United States*

Purpose. The use of reverse polarized imaging fields has been proposed as a low-power method to visualize potentially dangerous currents induced in implanted wires [1]. Furthermore, it has been shown in [2] that the contrast of a reverse polarized signal may be improved by the application of a pre-spoiling twister gradient, taking advantage of the high spatial frequency of the wire image. Though this technique has been shown to be effective in 1.5 T systems, the increasingly inhomogeneous polarization of the RF in higher field systems leaves doubt as to its potential efficacy in these scanners. Contradictory reports have appeared regarding the effectiveness at 3 T [3,4]. In this study we explore how twister gradients may be used either to supplement or replace the reversed polarization technique at 1.5 T, and using numerical methods, attempt to extrapolate our results to higher field systems.

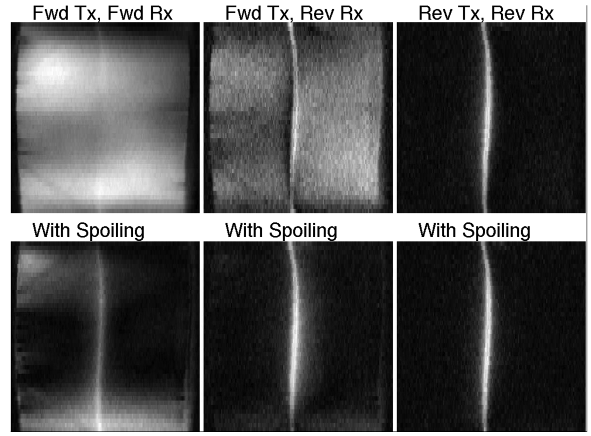

Figure 1 - Images of the wire phantom without (upper) and with (lower) pre-spoiling with a twister gradient

Methods. The first part of our study is a phantom study using a 1.5 T GE Signa Excite scanner, wherein a 16x16x44 cm phantom containing a near-resonant wire in a saline solution is imaged in forward and reverse polarizations, with variable pre-spoiling. The image employs a 2DFT gradient-echo scan with a non-selective slice gradient (i.e. a projection image). The line profile across the wire is measured, and the contrast of the wire feature is evaluated. The contrast is defined as

$$C = (A - BG) / (A + BG)$$

where A is the height of the feature, BG is the background level, and $0 \le C \le 1$. Profile backgrounds are determined by fitting the baseline away from the feature being studied to a second order polynomial (see Figure 2).

For the second part of our study, a numerical model has been constructed in MATLAB and a commercial FDTD numerical modeling package (Remcom, State College, PA), which is used to predict lineshapes observable in an MRI projection image. An 86x86x124 3D mesh is constructed wherein the excitation pattern of the wire system is modeled. In each volume element, the fields produced by both the coil and the wire are summed to produce an excitation of variable phase and amplitude. The fields produced by the coil are assumed to be unaffected by the presence of the wire, and are generated for different drive frequencies using the FDTD software. The field is generated in the simulation by a 16-rung birdcage coil loaded by a head model. Current drivers in each of the rungs, each with variable frequency and phase, allow for the simulation of higher frequency systems, and also reversed polarization. Free parameters in the model include the phase and strength of coupling to the wire, the relative phase of forward and reverse excitation, and background image noise.

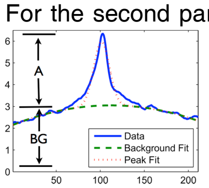

Figure 2 - Curve fitting of peak to determine contrast

Results. Figure 1 shows images of the wire phantom for three different imaging configurations, spoiled and unspoiled. The image using spoiling and no reverse polarization is a clear improvement to the image using only reverse receive, and approaches the reversed transmit and receive image in contrast, shown in the upper right. Figure 2 shows a summary of the contrast data (upper-left), as well as predictions by our numerical model for frequencies corresponding to different values of B_0. For the 1.5 T system, our model predicts contrasts similar to those observed in the experiment.

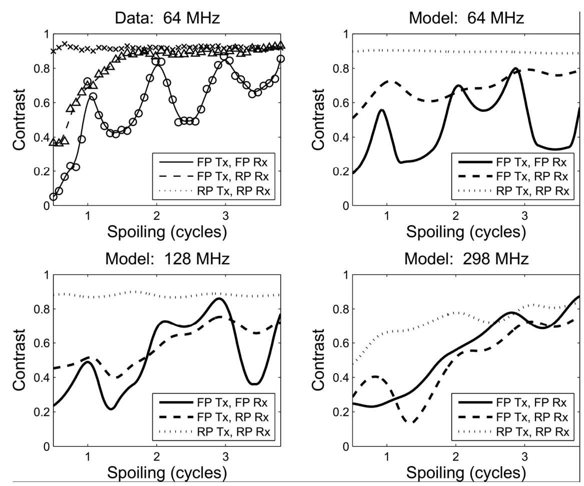

Figure 3 - Line contrast with increasing pre-spoiling for model and experiment

Discussion and Conclusions. We have found experimentally that in a simple system, nearly all of the contrast achieved by reverse-polarization imaging can also be achieved by gradient spoiling. Significantly, excellent contrast can be achieved using forward transmit, producing the same fields as would an imaging scan. Our model shows reasonable agreement with the data in its general features, despite being of slightly different geometry and loaded with a head rather than a phantom. The model results indicate that the reverse polarization technique should be nearly as effective in 3T systems as at 1.5T. In 7T systems, however, the advantage is much reduced. Gradient spoiling remains an effective way to improve contrast, although larger gradients are necessary, owing the higher spatial frequency of phase variations.

References. [1] Overall WR, et. al. MRM.64:823 (2010). [2] Overall WR, et. al. ISMRM. 18:775 (2010). [3] Van de Brink JS, et. al. ISMRM Safety (2010). [4] Celik H, Atalar E, MRM 67:446 (2012) NIH Grant Support: R01EB008108, R33CA118276, R21EB007715, P01CA159992.