Mapping Phase Changes in MR Signal Due to Current Injection into Hydrogel Phantoms

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Introduction: Magnetic resonance electrical impedance tomography (MREIT) can be used to image the current density distribution, due to the injection of external current within a conductive object, by mapping the changes in the signal phase resulting from the induced magnetic field perturbation in the direction of the static magnetic field [1]. Therefore this technique can provide insight into the mechanisms of electrical stimulation and improve the success of therapies like, deep brain stimulation (DBS) and transcranial direct current stimulation (TDCS). Common injection current ratings, on the order of milli-amperes, translate to a field change in the order of nano-to-pico Tesla. Hence the sensitivity of the imaging system to these small fields is limited by the signal-to-noise ratio. In this study, we characterized the phase and magnetic field changes observable at 4.7 T due to current injection through a wire placed in a 15 mL hydrogel phantom (see Figure 1) using multiple current ratings, as well as changing the number of averages during the data acquisition.

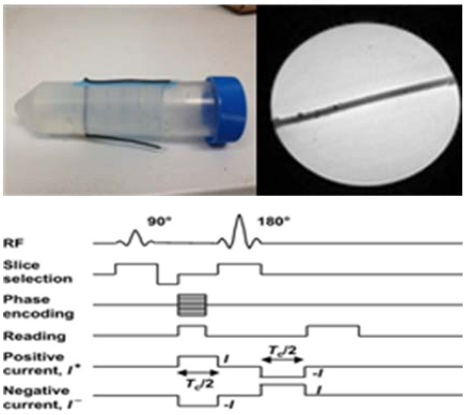

Figure 1; Top row shows a sample and its magnitude image. Bottom diagram is the MREIT pulse sequence.

Experimental: The data was acquired with a spin-echo pulse sequence and a bi-polar current-pulse pair (see Figure 1), centered on the refocusing RF pulse, using a volume transmit-receive coil in a 4.7 T Agilent magnet system. The top row of images in Figure 1 shows the sample used for the data acquisition along with a spin echo image. The bottom diagram in Figure 1 shows the pulse sequence used for the data acquisition. Simulations of the phantom were performed of the using the Biot-Savart law and compared to the experimental measurements. Identical currents of opposite polarities were used during the acquisitions and the resulting datasets were complex divided in order to obtain a greater sensitivity to the phase change.

Results and Discussion: The top row of images in Figure 2 shows the results for a 200 uA current injection and the bottom row shows the results for a 400 uA current injection. The first column of images is the result from the complex division of images acquired with positive and negative current (see Figure 1), the second column is the respective plots along the red line in the images in the first column, and the third column in the simulation of the expected phase along the red line. The measured phase changes are in good agreement with the simulated values.

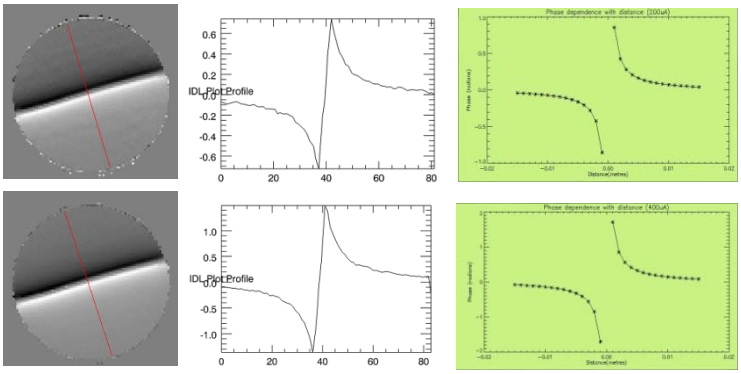

Figure 2: Images (left colume), measured phase (center column) and simulated phase (right column for 200 uA (top row) and 400 uA (bottom row) injected current.

Conclusions: This study demonstrates that we can detect phase changes due to very small injected currents in the 4.7 T magnet system. We plan to perform measurements using a gap in the wire in the center of this phantom with various gap lengths and current ratings. This will provide a phantom to suitably model experiments performed in vivo with implanted electrodes.

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References:

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