Resistively Coupled Interventional Device Visualization

G. C. Scott[1], W. Overall[1], J. Santos[1], J. Pauly[1]
[1]Electrical Engineering, Stanford University, Stanford, California, United States

Introduction: MRI guided interventions require some form of device visualization. Passive methods such as susceptibility markers and passive resonators have provided one approach. Active techniques have been based on micro-coil and loopless dipole structures in which microcoax carries the distal reception signal to a receive coil port. Both methods usually require substantial re-engineering of catheter devices. We propose that guide wire and RF ablation electrode devices can act as active receiver elements using resistive coupling and minimal device modifications. We demonstrate feasibility at 1.5T and in vivo at 0.5T.

Theory & Methods: Our approach uses the electrode probe concept[1] in which tissue forms a part of the signal path. If one passes an RF current between electrodes, RF magnetic fields would be created. Conversely, according to reciprocity, these same RF fields will create signal sensitivity. Noise will be determined by the resistance between the device and ground pad. In all tests, an external ground pad provided the RF signal return path (Fig. 1).

The active device (RF ablation electrode or guidewire) was connected to a receive coil signal port via a DC blocking capacitor, shunt diode and simple impedance matching circuit. The leveen ablation electrode tests were performed on a GE 1.5T Signa scanner using fast spin echo sequences. No modifications were made to the electrode. All .035 nitinol guide wire tests were performed at 0.5 T on a GE SP double donut interventional scanner. FSE testing was performed using the phantom grounds of Fig. 1. Approximately 2mm of the coating were stripped from the guide wire tip to reduce impedance to the saline, 20mm were stripped 500mm from the tip to allow impedance matching network connection. The guide wire test was then repeated in vivo on a rabbit using fast spin echo and real time imaging pulse sequences. The return pad was placed on the abdomen.

Results: Figure 2 shows a Boston Scientific Leveen RF ablation electrode when connected as a receiver at 1.5T. Substantial signal exists along the shaft where RF current would be confined. Phase images in both the coronal and axial planes show phase sensitivity that match the expected RF magnetic field directions in the rotating frame. These sensitivity maps could be used to include these devices as a phased array element in a SENSE reconstruction. Figure 3 shows the FSE guidewire reception as the wire is advanced from the introducer sheath. The wire tip has a signal void where field vectors destructively interfere. In Fig. 4, body coil and guidewire reception are demonstrated in vivo in a rabbit aorta. Real time images showed a similar reception profile but with lower SNR.

Discussion & Conclusions: Any interventional device capable of conducting RF current will in turn create receiver sensitivity. However the return path and ground pad location will modify sensitivity. RF safety must also be considered since conductors may couple with body coil excitation. We have demonstrated that this can be mostly eliminated with single and array surface coil excitation[2]. With these modifications a wide array of interventional devices could provide new active visualization options for MRI.

Figure 1: The Leveen RF ablation electrode (left). Copper taped exterior to the phantom provides the ground pad RF return path (center). A spin echo surface coil image shows the deployed ablation electrode (right).

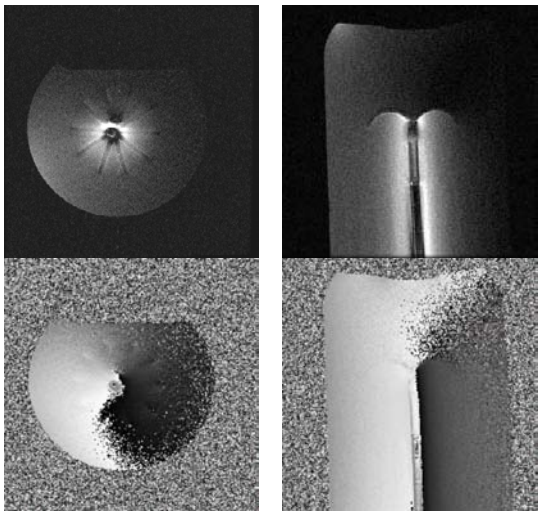

Figure 2: Ablation electrode receiver tests at 1.5T. These fast spin echo magnitude and phase images show the electrode sensitivity when connected to the receiver coil port of the scanner. The electrode is colinear with Bo in these scans.

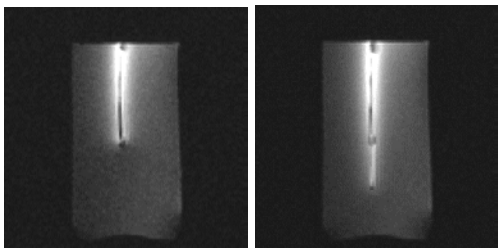

Figure 3: Nitinol guide wire connected as a receiver coil element at 0.5 T. The wire tip coincides with a catheter sheath tip (left) and is inserted an extra inch (right). The wire is orthogonal to Bo.

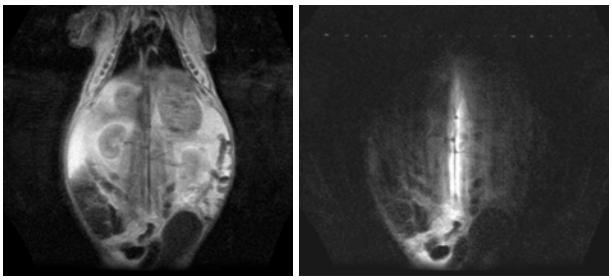

Figure 4: Left: In vivo FSE image of a rabbit with body coil reception at 0.5T. Right: In vivo FSE image of rabbit using guide wire receiver connection. The return electrode pad was placed on the rabbit stomach.

References:

[1] G. Scott et al, Proc 8th ISMRM. 1377, 2000.
[2] Venook et al, ISMRM MRI Safety Workshop , 2005.