A Low-Power, Offline Prescreen to Detect and Suppress Dangerous Currents

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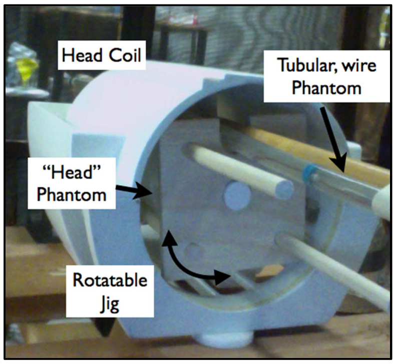

Figure 1 - Experimental Setup

Purpose. Patients with long wire implants such as pacemaker leads or deep brain stimulators are generally prohibited from undergoing MRI due to risk of RF heating and resulting tissue damage. We report progress in developing an "offline" prescreening technique (i.e. outside the scanner environment) through which dangerous electromagnetic interactions between implants and imaging fields can be identified without exposing the patient to danger.

Using only an RF drive coil and a network analyzer, ultra-low power impedance measurements take advantage of information from a range of frequencies to identify dangerous interactions, and prescribe imaging modes which can minimize these interactions. This may be more broadly applicable to imaging during interventions or of patients with other metallic implants.

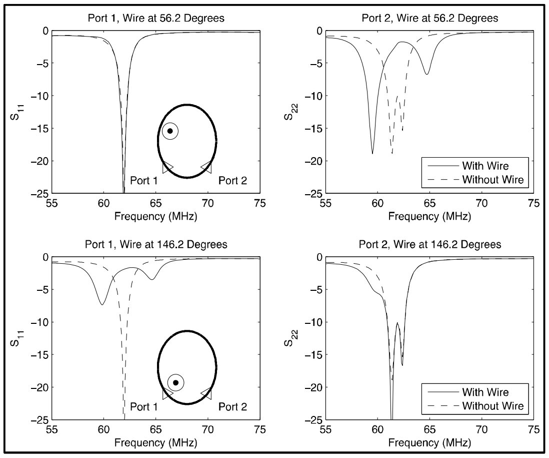

Figure 2 - Spectra of reflection coefficients for two positions of the wire phantom, for each drive port.

Methods. We use a modified birdcage coil with dual drive ports, used previously to study reverse polarization imaging [1]. The two drive ports of the birdcage coil are located 90 degrees apart, allowing generation of arbitrary polarizations using a two-channel transmit system controlled by a Medusa MR console. Shown in Figure 1, a rotatable phantom was constructed comprising a 2m, wire-containing tubular phantom and a 4 liter cylindrical "head" phantom, all with saline solution.

A first set of measurements was performed <u>outside</u> the MR suite. A network analyzer (Agilent E5071C, Santa Clara) measured the two-port S-parameters of the drive ports for different azimuthal positions of the wire phantom, in the range of 55 – 75 MHz. In a second experiment, we tested the transferability of the prescreening results to the scanner environment. We moved the apparatus to a GE 1.5 T Signa scanner, where the impedance of the birdcage coil is measured using directional couplers in the RF chain. The wire phantom is not moved in this experiment, but a toroidal physical current sensor is affixed to a portion of the wire extending out of the tube. Impedance parameters and current are recorded while the load is probed with a 30 ms, < 100mW pulse wherein the imaging field is linearly polarized and is rotated through an angle of 2π.

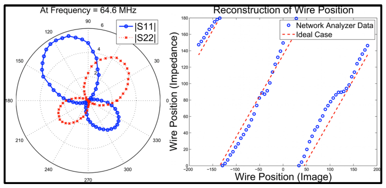

Figure 3 - Impedance parameters for different angular locations of the wire phantom (left), and inferred and actual phantom positions (right)

Results. Figure 2 shows the dramatic distortion of the coil impedance spectrum caused by the presence of a resonant conductor, an unambiguous indication of a resonant, dangerous coupling with the wire. The impedance spectra also provide information as to the potential for mitigation of these dangerous currents. Spectra are shown for two wire locations, and in each case one port of the coil is unperturbed, while the other is severely distorted. This corresponds to the wire being placed in the E = 0 plane of either driving port, since each port drives a linearly polarized field. If the coil impedance is monitored at a well-chosen frequency, this impedance will increase or decrease monotonically with coupling, and the relative coupling of each port can be known. With this information it is possible to configure the coil in a "safe" scanning mode where the E = 0 plane can be co-located with the wire. Shown in Figure 3, we demonstrate this by locating the angular position of the wire using only impedance measurements.

Figure 4 shows the results of the second experiment, in which a fixed wire phantom is probed by a varying linearly polarized imaging field within the scanner. The result clearly shows the expected modulation of the induced current, and also shows the excellent correlation with measured impedance parameters.

Discussion and Conclusions. The key concept is the creation of an independent means of detecting resonant conducting structures in the body. Detection using pickup coil perturbations has been demonstrated in [2], but an important difference in this work is the unambiguous detection of resonance, and the addition of the significant ability to prescribe polarization states for subsequent scans. It has been shown previously [3] that dangerous heating in implants can be significantly reduced through the use of such appropriately chosen imaging fields. We believe this result is generalizable, and fits within the framework of work done on parallel transmit arrays.

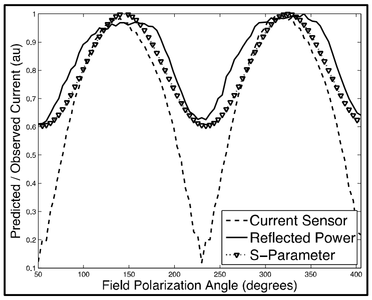

Figure 4 - Validation in MR scanner - impedance parameters can be used to predict and null current

References. [1] Overall WR, et. al. MRM. 2010;64:823-833. [2] Graesslein I, et. al. ISMRM. 2009;17:4793. [3] Eryaman Y, et. al. MRM. 2011;65:1305-1313. NIH Grant Support: R01EB008108, R33CA118276, R21EB007715, P01CA159992.