

# Controlling induced currents in guidewires using parallel transmit

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**Introduction:** Conductive structures, such as guidewires and implanted device leads, present a safety hazard in MRI. The coupling between these structures and the RF transmit field can result in currents being induced, which can lead to dangerous heating [1, 2]. In previous work [3], it was shown that the magnitude and phase of current induced in a wire depends on the position of the RF coil with respect to the wire. This led us to investigate the feasibility of using parallel transmit with an array of surface coils to excite the imaging volume, without inducing current in a guidewire.

In this work, we show that it is possible to choose parallel transmit coil weightings such that we can control the current induced in a guidewire. Furthermore, we show that only a single transmit mode induces significant current, while the other “null modes” induce low current levels. The null transmit modes are also shown to still provide adequate excitation to visualize the guidewire and surrounding volume.

**Methods:** The experimental setup is shown in Fig. 1. We inserted 30 cm of a 150 cm long copper wire into a saline gel phantom. We arranged four transmit-only 6x3 inch surface coils in a linear array across the top of the phantom, and surrounded the phantom and transmit coils with an eight-channel receive array for imaging.

To measure the coupling between each surface coil and the guidewire, we transmitted a 2-ms hard RF pulse on each coil separately and measured the current induced in the guidewire using an optically-coupled toroidal current sensor [4]. The RF transmit and receive were synchronously controlled by the MEDUSA USB console [5].

The parallel transmit modes are determined by performing a singular value decomposition (SVD) of the matrix consisting of the current sensor measurements. This results in four sets of four complex weights that can be used to scale the RF waveforms on each transmit coil in order to achieve different coupling modes to the guidewire. To test each coupling mode, we then used these weights to scale hard pulses that we transmitted on all coils simultaneously, while measuring the induced current with the sensor.

Finally, we performed B1 mapping to see how the current distribution in the portion of the guidewire located inside the phantom varies when transmitting with the different modes. For each transmit mode, we collected two images (1.5 T, GRE, TE = 6 ms, TR = 600 ms, FOV = 30 cm, matrix size = 256x128, sagittal) and used the double angle method [6] to create a flip angle map.

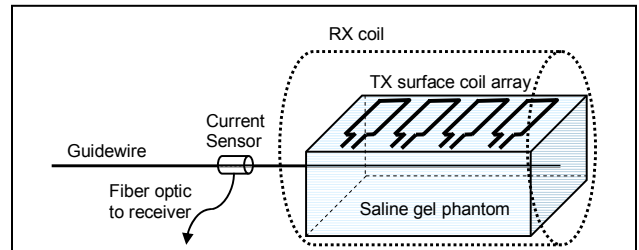
**Results:** From the current sensor measurements in Fig. 2, we see that transmitting with the mode corresponding to the largest singular value of the SVD induces maximal current in the wire, while the remaining three null modes reduce the wire current by more than a factor of 100. These three null modes can be viewed as forming a “coupling nullspace” of excitation patterns, from which any linear combination of excitations would also result in minimal current being induced in the guidewire. We have essentially used up one of the degrees of freedom in our four-element transmit array in order to minimize the current, which leaves us with three remaining degrees of freedom to use for creating safe excitations.

The B1 maps of Fig. 3 show that transmitting with the maximal current mode results in significant perturbation of the background coil sensitivities near the guidewire, while the minimal current mode shows very little perturbation. This verifies that the minimal current mode substantially reduces current in the guidewire, which is in agreement with the current sensor measurements.

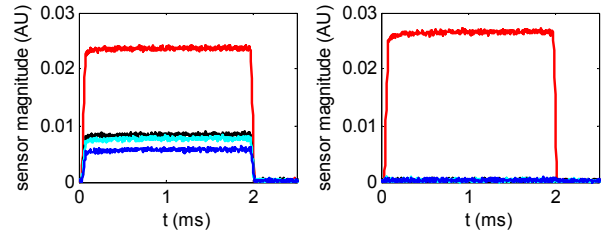
Figure 4 shows two of the images used to create the B1 maps of Fig. 3. Note that the guidewire is visible even in the minimal current case, due to sensitivity enhancement from coupling between the guidewire and the receive array. This illustrates that we can still visualize the guidewire and surrounding volume, without inducing dangerous current levels in the guidewire.

**Discussion and Conclusion:** Parallel transmit excitations that induce minimal current in conductive structures are feasible. The null mode B1 maps show suppressed guidewire coupling, while still creating useful volume excitation. We will be able to use these B1 maps to create excitations that allow the visualization of any particular region of interest. The B1 maps could also be used to derive the absolute current level in the guidewire [7]. The fact that the guidewire remains visible when imaging with the null transmit modes is also promising for visualization during interventional procedures.

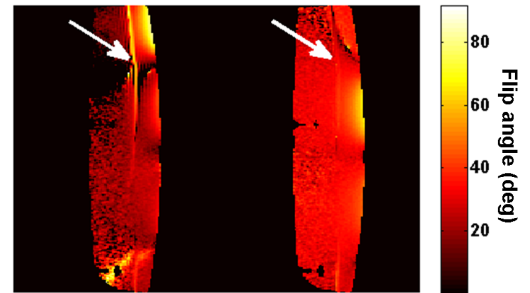
**References:** [1] Nyenhuis et al., IEEE Trans Dev Mat Rel, 5:467-80, 2005. [2] Konings et al., JMRI 12 :79-85, 2000. [3] Etezadi-Amoli et al., Proc 17<sup>th</sup> ISMRM, p4801, 2009. [4] Zanchi et al., Proc 16<sup>th</sup> ISMRM, p897, 2008. [5] Stang et al., Proc 15<sup>th</sup> ISMRM, p925, 2007. [6] Stollberger et al., Proc 7<sup>th</sup> SMRM, p106, 1988. [7] Venook et al., Proc 16<sup>th</sup> ISMRM, p898, 2008. [Acknowledgement: This work partly supported by NIH R01 EB008108, NIH R21 EB007715, NIH R01 EB005307.]



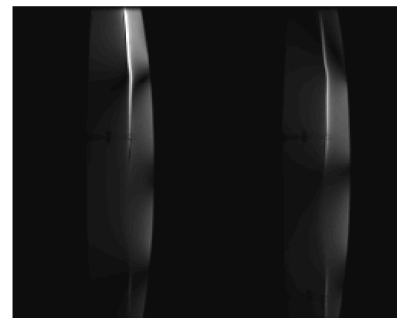
**Figure 1:** Setup for current nulling. The sensor measures current induced on the guidewire by the array of transmit surface coils. A separate receive coil array is used for imaging the phantom volume.



**Figure 2:** Current sensor measurements when transmitting a 2-ms hard pulse on each of the four surface coils separately (left), and when transmitting with the four modes determined via SVD (right). The SVD weightings result in one mode that couples strongly to the guidewire, inducing maximum current (right plot, red line), while the remaining three modes induce minimal current.



**Figure 3:** B1 maps when transmitting with the maximal current RF mode (left) and one of the three minimal current modes (right). In the minimal current mode, the B1 fields near the guidewire show little perturbation from the background coil sensitivities.



**Figure 4:** GRE images corresponding to the B1 maps in Fig. 3. Note that the guidewire can still be visualized in the minimal current case (right), due to local sensitivity enhancement from coupling with the receive array.