

MRI Compatible Wireless Power Transfer System

Kelly Byron¹, Chris Ellenor¹, Fraser Robb², Shreyas Vasanawala³, John Pauly¹, and Greig Scott¹

¹Electrical Engineering, Stanford University, Stanford, California, United States, ²GE Healthcare, California, United States, ³Radiology, Stanford University, Stanford, California, United States

Introduction: In an MRI environment, the addition of a variety of monitoring devices in the bore is becoming more common^{1, 2}, with the added burden of powering these devices. While non-magnetic batteries are an option, the requirement to ensure full charge is a potential nuisance. Another option is wireless power transfer (WPT) using inductively coupled resonant coils to transmit and receive power at a particular frequency. The goal of the WPT system shown in Figure 1 is to deliver power inside an MRI bore with minimal RF interactions. We present our first bench-top tests demonstrating feasibility of this system.

Methods: We constructed a 45x30cm drive loop incorporating 64 MHz traps and tuned for series resonance at 10 MHz. RF power was injected via an automatic antenna tuner (MFJ Enterprises) and a filter with cutoff frequency of 11.12 MHz and an attenuation of 80 dB at the MRI frequency. The 10 MHz filter circuit presents an RF short at 64 MHz. However, the transmit coil feed must appear open at 64 MHz to prevent interaction with the MRI coil. In addition to the traps, a BNC cable cut to a length of $\lambda/4$ at the MRI frequency was connected between the two to transform the impedance. Cable traps were added at 64MHz and \sim 10MHz transmit frequency to the quarter-wavelength cable to further isolate the transmit coil. Power harvesting was accomplished by a 3 turn, 2.25in diameter pickup loop, impedance matched to a target load of 50Ω , with RF rectified by a schottky diode bridge.

Results: Figure 2 shows the output power with varying input frequency for transmit and receive coils tuned to approximately 10MHz and an input power of 10 Watts. The system works only over a very narrow frequency range, with almost no power being received 500kHz away from the tuned frequency. Figure 3 shows the frequency response of an MRI coil through a preamplifier. The signal sensitivity at

the MRI frequency is approximately 85 dB above that of the WPT frequency. The spectrum of the WPT system shows that there are harmonics at 60 and 70 MHz, however these harmonics are about 90-100dBm below the fundamental, as expected from the attenuation in the filter and cable traps. The WPT system also did not change the noise floor of the preamplifier at 64MHz, but it did introduce low-level spurs at intervals of the transmit frequency. As a result the spurs are always at least 4MHz away from the MRI frequency, with no danger of saturating the preamp. For demonstration, we synthesized and did a loop-back MR data transmission to a 64 MHz Rx coil and preamp. Figure 4 shows the image quality with the WPT system off, with it on, and with it supplying the power to the preamplifier. It also shows the intensity across a line of pixels through the center of the image for each case. There is a slight increase in the variance of the intensity of the black regions when the preamplifier is being wirelessly powered, which corresponds to a slight increase in noise, however it is a fairly negligible difference.

Discussion & Conclusions: Harmonics that occur every 10MHz are likely the result of the diode rectifier back-emission on the receiver side. Additional filtering could be added to the receiver side to reduce these harmonics. However, the actual noise floor at the MRI frequency had little change, so even with the harmonics the noise of the image increased only slightly. As a result, our WPT system offers a method of wirelessly delivering power compatible with a 1.5T scanner, and is ready for testing within an MRI.

References:

1. Jekic, M., Ding, Y., Dzwonczyk, R., Burns, P., Raman, S. V. and Simonetti, O. P. (2010), Magnetic field threshold for accurate electrocardiography in the MRI environment. *Magn Reson Med*, 64: 1586–1591. doi: 10.1002/mrm.22419.
2. Foroglou, Nicolas, Amir Zamani, and Peter Black. "Intra-operative MRI (iop-MR) for brain tumour surgery." *British journal of neurosurgery* 23.1 (2009): 14-22.

Acknowledgment: We would like to thank GE Healthcare for their research support. This project is supported by grants R01EB008108 and P01CA159992.

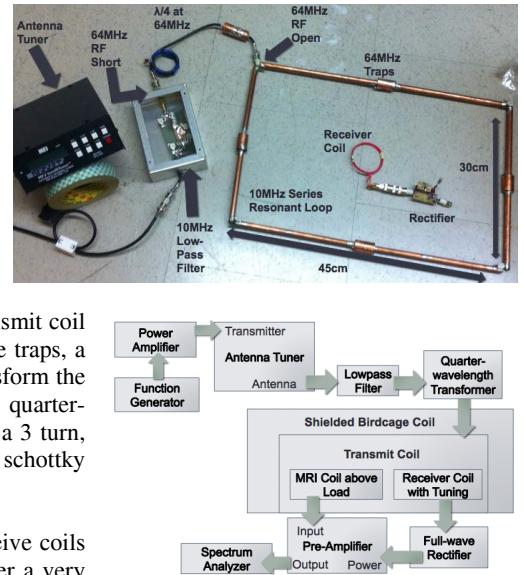


Figure 1: Complete wireless power transfer test setup.

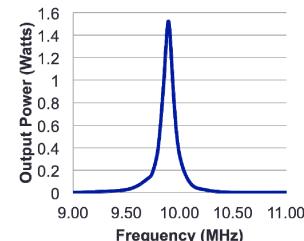


Figure 2: Receiver output power vs. transmit frequency for a 10W input signal.

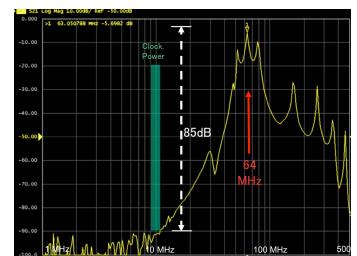


Figure 3: Frequency response of an MRI coil through a preamplifier.

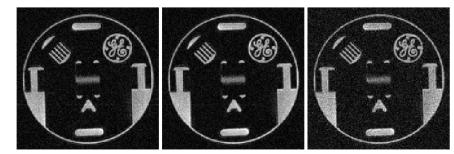


Figure 4: Synthetic loop-back MR image quality with A: the WPT system off, B: the WPT system on and the preamplifier battery powered, C: WPT system powering the preamplifier.