# RF Gated Wireless Power Transfer System

Kelly Byron[1], Pascal Stang[2], Shreyas Vasanawala[3], John Pauly[1], and Greig Scott[1]
[1]*Electrical Engineering, Stanford University, Stanford, CA, United States,* [2]*Procyon Engineering, CA, United States,* [3]*Radiology, Stanford University, Stanford, California, United States*

**Introduction:** Wireless patient coils [1] promise improved work-flow and reduced setup times if this technology can be realized. Battery operation is possible but will limit magnet time by the finite storage energy. Wireless power transfer (WPT), using inductively coupled resonant coils to transmit and receive power at a particular frequency, would be a desirable feature. It would also be useful to send a pilot tone as a phase reference or as a sync at the beginning of each receive cycle to transmit data accurately. The goal of the WPT system shown in Figure 1, which is a modified version of the system first proposed in [2], is to deliver sufficient power inside an MRI bore with minimal RF interactions, and minimal added SAR to the patient. We present both MRI and bench-top tests detailing the capabilities and limits of this system, and options for gated WPT.

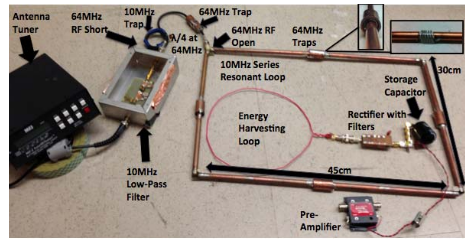


**Figure 1**: Complete wireless power transfer test setup.

**Methods:** We constructed a 45x30cm drive loop incorporating 64 MHz traps and tuned for series resonance at 10 MHz. Power harvesting was accomplished by a one turn, 20cm diameter flexible pickup loop, tuned to 10MHz with a parallel resonant capacitor to maximize efficiency for the reasonably large load presented by the preamplifier [3]. As an alternative to rectifier shielding, we added the option of gating WPT off in the RX window by adding an electronic switch at the input of the WPT transmit power amplifier. A 10mF capacitor was added at the output of the rectifier to maintain the required power level while the system was gated on and off, after being initially charged to about 10V. The switch was controlled by a signal coming from a Medusa module.

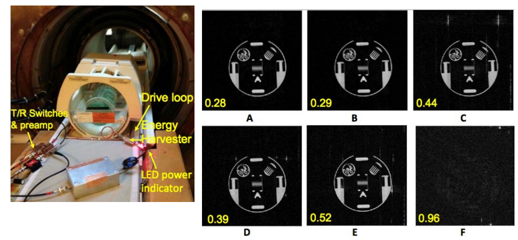


**Figure 2:** Test setup and image results inside an MRI bore with RMS background noise numbers given for A: WPT off, B: RFPA 5W, no harvester, C: RFPA 25W, no harvester, D: Small harvester, 130Ω load, E: Large harvester, 130Ω load, F: Small harvester powered preamp.

**Results:** Our drive loop was designed for embedding inside a patient table. With our pickup loop about 2.5cm above our drive loop, we are able to achieve an efficiency of about 11.5% with a 160Ω load. With this efficiency we could transmit about 87W to receive 10W, which is enough to power an array of preamplifiers. The discrepancy between drive and pickup loop areas contributes to inefficient conversion. Figure 2 shows the initial MRI testing with a loaded head coil, where we continuously transmitted power during the scan. With no harvesting, transmit powers up to about 5-7W had minimal impact on image quality (2b), although at higher power levels, more image artifacts appear (2c). This is acceptable for impressing sync/clock signals. With harvesting by a 6 cm or 25cm pickup, background image noise degrades, even wiping out the image when powering the preamplifier. Figure 3 shows the noise spectrum at the output of a preamplifier when connected to a loaded MRI coil. Diode rectifier back-emission on the receiver side generates harmonics in 10MHz increments. Smaller sidebands about 1-2MHz away from these harmonics likely result from our LC low-pass filter being terminated with our drive loop, which does not provide a 50Ω load. This results in an undamped filter response and low frequency noise peaking, which is up-converted by diode rectifier mixing action and is difficult to shield. Because of this interference, it is desirable to gate the WPT system off during the MRI receive window while continuing to power the preamplifier with a storage capacitor. Bench-test results of the gated WPT option are shown in Figure 4, where we are using a Medusa module to re-transmit pre-acquired k-space image data and compare the recovered image quality. Looking at the intensity of a line of pixels through the center of the image, we can see a slight increase in the variance when the preamplifier is being wirelessly powered, but it is a very minor difference.

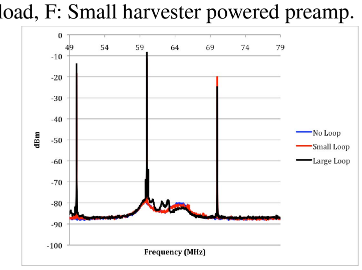


**Figure 3:** Noise response of a preamp with large & small harvester.

**Discussion & Conclusions:** Harmonics and mixing caused by the diode rectifier on the receiver side cause noise issues that are difficult to filter, partially because of the uncertain impedance terminating the transmit filter. WPT RF gating is the simplest option to mitigate this interference, and bench tests indicate high quality SNR imaging is achievable with WPT in a 1.5T scanner. Even without RF gating and no harvesting, 10MHz tone transmission for sync-clocks causes minimal image quality impact up to a 5-7W transmission threshold. Future work will include MRI testing and efficiency enhancement.

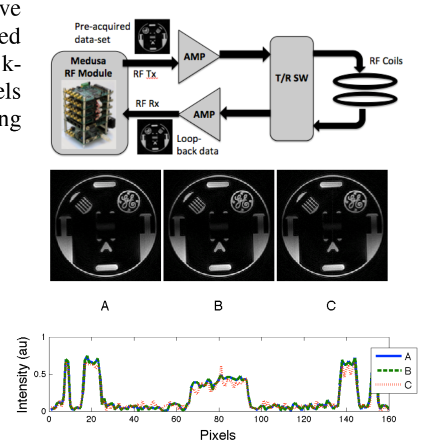


**Figure 4:** Synthetic loop-back MR image quality with A: WPT off, B: WPT on and the preamplifier battery powered, C: WPT powering the preamplifier.

**References:**
1. 0. Heid, M. Vester, P. Cork, P. Hulbert, and D. W. Huish, Cutting the Cord-Wireless Coils for MRI. Proc. Intl. Sco. Mag. Reson. Med. 17 (2009).
2. K. Byron, C. Ellenor, F. Rob, S. Vasanawala, J. Pauly, and G. Scott, MRI Compatible Wireless Power Transfer System. Proc. Intl. Sco. Mag. Reson. Med. 22 (2014).
3. Z.N. Low, R.A. Chinga, R. Tseng, and J. Lin, Design and Test of a High-Power High-Efficiency Loosely Coupled Planar Wireless Power Transfer System. IEEE Trans. on Ind. Elec. 56.6 (2009).

**Acknowledgments:** GE Healthcare research support, NIH grants R01EB008108, P01CA159992, R01EB019241.