# Wireless Control of an Implantable Coil System for MRI/S

B.L. Beck (UF, AMRIS); B.S. Letzen (UF, Biochemistry); R. Bashirullah (UF, Electrical and Computer Engineering); T.H. Mareci (UF, Biochemistry)

## Introduction

Type-I diabetes sufferers live a near normal life through daily insulin injections, but they are greatly affected by a changed lifestyle and can only delay major health consequences induced by diabetes [1,2]. An alternative solution is the development of tissue engineered pancreatic constructs monitored by MR via implanted coils [3,4]. These experiments demonstrate excellent potential, but face limited sensitivity, hindering the evaluation of the construct. In addition, detection of multiple biological nuclei, including $^{1}$H,$^{19}$F,$^{31}$P, and $^{13}$C is necessary for complete characterization of the construct. Multiple-resonant coils require additional components or create degenerate modes that limit the Signal-to-Noise Ratio (SNR). We propose a multiple-frequency solution involving a "single resonant" approach, where an array of varactors is remotely switched, via a microcontroller embedded within a microchip, to resonate with the inherent inductance of the coil (Fig. 1). The focus of this work is to build a proof-of-concept prototype before developing the entire micro fabricated integrated chip system.

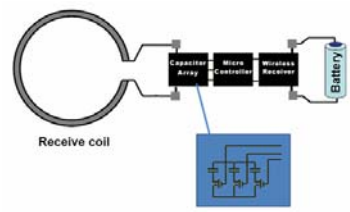


Figure 1. Conceptual diagram: wireless, implantable microchip and MR coil.

## Experimental

The prototype design was built to mimic the function of the above concept at 11.1T for the detection of 4 MRI/S nuclei: $^{1}$H, $^{19}$F, $^{31}$P and $^{13}$C. The MR coil was directly connected to a varactor array consisting of three parallel branches, each containing a varactor for variable tuning. The first branch contained only a varactor, the second and third branches each a varactor and PIN diode switch controlled by a FET. The supporting circuitry consisted of a controller (Atmega168) and a wireless receiver (a small antenna, bandpass filters, and envelope detectors). Based on input from the wireless receiver, the controller generated 2 outputs: (1) the appropriate data stream to the multiple-output DAC generating an analog voltage for the varactors, and (2) a digital voltage for FETs to select the appropriate array branch to be activated. To select an MR frequency, the user sent an rf signal at the MR frequency of interest, which was detected by the small antenna and input into the prototype circuitry.

## Results and Discussion

The assembled working prototype is shown in Figure 2 (a), along with a close-up of the capacitor array (Fig. 2b). Figure 2 (c)-(f) displays plots taken from the network analyzer when each of the four frequencies is requested wirelessly, showing successful frequency selection.

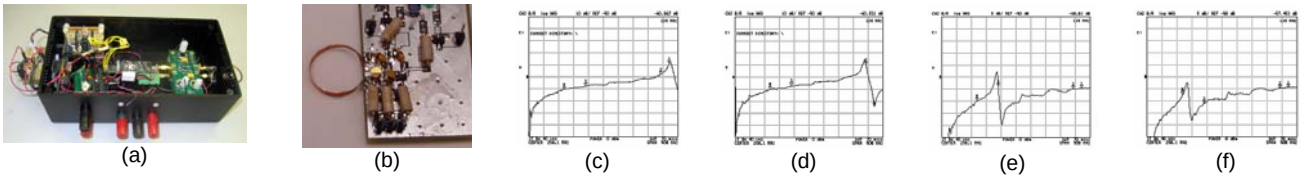


Figure 2. (a) working prototype, (b) close-up of the capacitor array and MR coil, and (c)-(f) Network analyzer measurements of the MR coil switched to four frequencies available at 11.1 T; (c) 470 MHz (1H), (d) 442 MHz (19F), (e) 190 MHz (31P), and (f) 118 MHz (13C).

## Conclusions

The prototype enables automatic tuning to any frequency through simple input from the MR console. It demonstrated function at 11.1 Tesla for 4 frequencies 470 MHz (1H), 442 MHz (19F), 190 MHz (31P) and 118 MHz (13C). The prototype presented herein shows promise in allowing a flexible design that can be adapted to any targeted MR frequency.

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## References

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