Self-Resonant, Implantable, Radio Frequency Circuits for *in vivo* Magnetic Resonance (MR) Imaging & Spectroscopy

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Introduction

The miniaturization of radio frequency resonators provides increased signal-to-noise ratio (SNR) per unit volume in MR [1,2]. Several groups have demonstrated the utility of microresonators in ex vivo MR microscopy [3,4] and in vivo MR microscopy should benefit as well. If these implantable microresonators are self-resonant at the operating frequency of the MR scanner, they can be coupled inductively with an external radio frequency coil [5,6]. The implanted microresonators then can operate in an entirely wireless mode, which provides ease of use and eliminates the risk of infection associated with implants with invasive, connecting wires.

Experimental Methods

Spiral microcoils were designed, fabricated and tested at Dartmouth College and Micrometrics Inc. For a given number of spiral turns, inductance was estimated from previous experience and characterization of inductors with 50-μm trace width and 50-μm inter-trace separation. Capacitance was estimated to achieve resonance at the proton Larmor frequencies of our MR scanners. Self-resonant circuits were fabricated using photolithographic techniques. Beam lead capacitors were soldered onto contact pads to achieve resonance.

Results and Discussion

11.75 T: A slab of PDMS was hollowed out; the microresonator was placed in this hollowed space ,and the recess was filled with 2% agarose gel. The construct was placed proximate to a 1-mm Bruker RF transceiver microcoil for imaging. Images were acquired using a 3D FLASH sequence. SNR from gel proximate to the microresonator was 2.94 times higher than that from the surrounding agarose.

21.1 T: The microresonator was glued to a piece of acetate film and inserted into a 1-cm NMR tube filled with 2% agarose. The tube was placed into a 1-cm Bruker RF coil for imaging. For SNR measurement, images were acquired using a 2D FLASH sequence. SNR from the gel proximate to the microresonator (SNR = 26.4±8.2) was 2.1 times higher than that from the surrounding agarose (SNR=12.6±1.5). Sensitivity profiles were acquired with a 2-mm loop coil placed adjacent to a disk of agarose containing the microresonator, with optimized tip calibration. Signal-to-axial distance plot showed the expected profile of signal drop-off with axial distance. Using a setup that would be applied to *in vivo* pre-clinical imaging with an external transmit surface coil, 3D FLASH images (20-μm isotropic resolution) also demonstrate that signal originated from the resonator instead of susceptibility distortions.

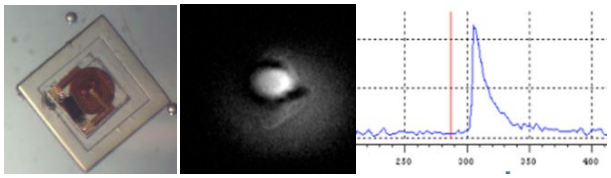

Figure 1: A self-resonant circuit, with microcoil and capacitor, integrated with a cell-encapsulating microcapsule (left). The circuit was inductively coupled to an external RF microcoil. MR image of agarose gel phantom showing signal enhancement proximate to the inductively coupled microcoil (middle). A sensitivity profile showing signal drop-off with axial distance from coil.

Conclusion

We successfully demonstrated increased sensitivity in signal detection using a self-resonant microresonator. We are in the process of extending our studies to demonstrate *in vivo* imaging of small implanted cellular clusters.

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References

[1] Peck, T.L., *et al.,* J Magn Reson, **108B,** 114–124 (1995).
[2] Eroglu, S., *et al.,* Concepts in Magn Reson Imag B, **17B(1),** 1-10 (2003).
[3] Aguayo, J.B., *et al.,* Nature, **322,** 190–191 (1986).
[4] Gimi, B., *et al.,* Concepts in Magn Reson Imag B, **18B(1),** 1-8 (2003).
[5] Wirth, E.D. 3rd, *et al.,* Magn Reson Med., **30(5),** 626-33 (1993).
[6] Volland, N.A., *et al.,* Magn Reson Med., **63(4),** 998-1006 (2010).