Active detuning of inductively coupled surface coils

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Introduction: Inductive coupling is an RF probe design technique in which the probe consists of two coils coupled by their mutual inductance, without direct electrical connection between them[1]. One common design using inductive coupling uses a surface receive coil and a coaxial matching coil. The receive coil is tuned to the Larmor frequency, and matching is controlled by adjusting the distance between the two coils. The absence of physical connections to the receive coil makes such a design especially suitable for implanted coils or for coils made from superconducting materials.

Using a receive-only surface coil with a separate transmit volume coil combines the advantages of the volume coil's homogeneous field with the high sensitivity of a surface coil. One difficulty in using inductively coupled coils in this manner has been the challenge of decoupling the receive coil from the transmit coil. Several methods for decoupling have been proposed, including using transmit coils with orthogonal B1 fields, passive detuning using crossed diodes, Q-spoiling using Josephson junctions, and optical detuning with photodiodes. All of these methods have their shortcomings. Here we introduce a method for active detuning of inductively coupled coils. This method uses pin diodes to introduce a strongly coupled second resonance that detunes the receive coil, analogous to detuning techniques commonly in use for conventional receive-only surface coils[2].

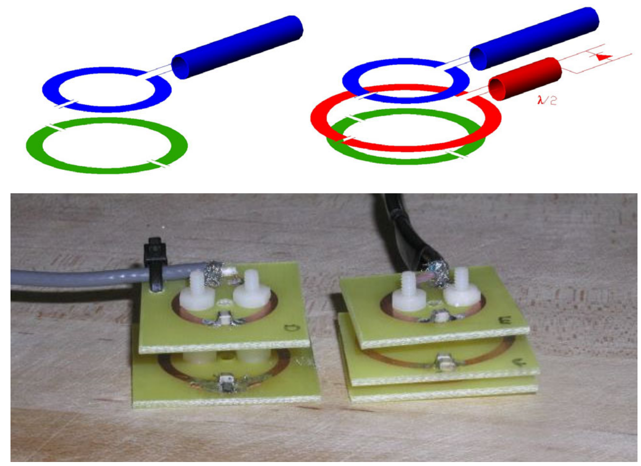

Figure 1 Inductively coupled surface coils, without (left) and with (right) detuning coil.

Methods: Several one-inch diameter receive coils were constructed and compared. The coils included an inductively coupled coil with no detuning elements, an inductively coupled coil with crossed diodes for passive detuning, a capacitively coupled coil with pin diode detuning, and an actively detuned inductively coupled coil. For active detuning we have introduced a third detuning coil between the matching and receive coils (figure 1). Forward biasing a pin diode at the end of a half-wavelength cable resonates the detuning coil at the Larmor frequency, and inductive coupling between the receive and detuning coils shifts the resonance of both coils.

Coils were tested on the bench and in a Siemen's Allegra 3T scanner. A 12-inch diameter detunable birdcage coil was used as the transmit coil. An HP4395A network analyzer was used to tune the coils and to measure the degree of coupling between transmit and receive coils. In the scanner, a spin echo sequence with a flip angle of 180 degrees, TR = 3000 ms, TE = 18 ms, 0.2 x 0.2 mm inplane resolution, 0.4 mm slice thickness, and a 256 x 256 matrix was used to evaluate the coils' performance.

Results: S21 measurements with the transmit birdcage coil on port 1 and the inductively coupled coil was on port 2 indicated that the addition of the detuning coil reduced the coupling between transmit and receive coils by more than 30 dB. Figure 2 shows images of a uniform phantom taken with the birdcage transmit and different receive coils. The image taken with the tuned receive coil displays severe artifacts due to variations in flip angle caused by the receive coil's B1 field. Adding the detuning coil removes the artifacts and produces an image with comparable quality to those taken with a conventional actively detuned capacitively coupled coil or a passively detuned inductively coupled coil. Figure 3 shows a 3D-VIBE image of a middle proximal interphalangeal joint taken with an actively detuned inductively coupled surface receive coil and birdcage transmit coil, with TR = 20 ms, TE = 4.34 ms, 0.5 mm thick slices, 4 averages, 192 x 256 matrix, 0.26 x 0.26 inplane resolution, total acquisition time = 7 minutes.

Conclusions: Inductively coupled coils with active detuning perform as well as or better than conventional coils with similar geometry. This technique requires no physical connections or additional components to be added to the receive coil. These coils are simpler to tune and match than capacitively coupled coils and should be considered whenever either style could be used.

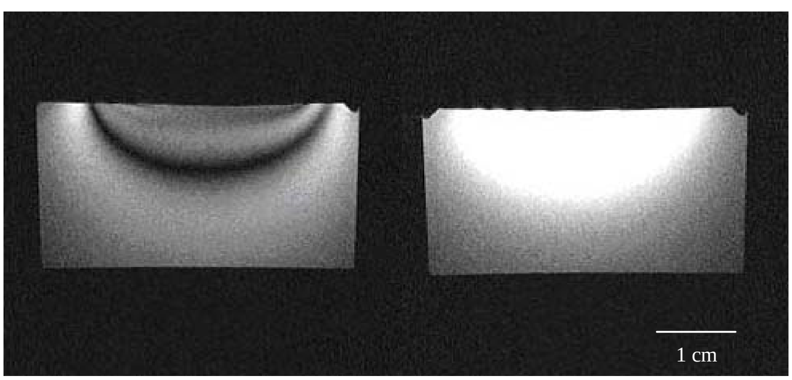

Figure 2 Spin-echo images of a uniform phantom and inductively coupled receive coils, without (left) and with (right) active detuning.

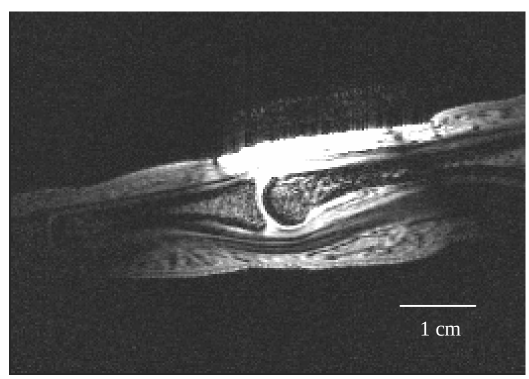

Figure 3 3D-VIBE image of a finger joint taken with inductively coupled surface coil and cylindrical volume transmit.

[1] P.L. Kuhns *et al*, "Inductive Coupling and Tuning in NMR Probes; Applications," J. Magn. Reson. **78**, 69-76 (1988).
[2] W.A. Edelstein *et al*, "Electronic Decoupling of Surface-Coil Receivers for NMR Imaging and Spectroscopy," J. Magn. Reson. **67**, 156-161 (1986).