Design of a coil array for mouse imaging at 14.1 T

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Introduction: The "phased array" concept in MRI refers to simultaneously acquiring and subsequently combining data from a number of closely positioned MRI receiving coils [1]. This can be used to increase the SNR over a large field-of-view due to the high sensitivity of the small individual coils, or to increase the speed of imaging through partial parallel acquisition (PPA), which utilizes the inherent spatial information of the coils [2-4]. Although phased array technology is now standard for clinical applications, the extension to very high field vertical, small bore magnets used for microimaging has not been demonstrated. Here, we describe a probe consisting of a large transmit surface coil and four phased array receive coils, designed for operation at 600 MHz within a 45 mm clear-bore magnet for studies of mouse spinal cord.

Method: Minimizing the interaction between coils is essential to phased array probe designs. There are a number of ways to minimize crosstalk, including optimum overlapping, using low input-impedance amplifiers [1], capacitive or inductive decoupling networks [5], or additional mutual inductance [6]. It is difficult to build preamplifiers with very low input-impedance at 600 MHz, and to integrate these within the probe given space limitations. Therefore, the phased array was designed to have an input impedance of 50Ω, and variable capacitors were used to minimize coupling between arrayed coil pairs without introducing significant loss. Figure 1 shows the circuit diagram of a single coil pair with decoupling capacitors and a vector analysis of the decoupling mechanism. Non-magnetic varactors were used for transmit/receive switches between coil sections, due to their minimal junction capacitance and simple control circuit, compared to PIN and Schottky diodes. Varactors were also used as tuning capacitors for the coil array because of their low loss and small physical size. The bias voltages used by the varactors were controlled by a TTL output on the Varian Inova 600 console.

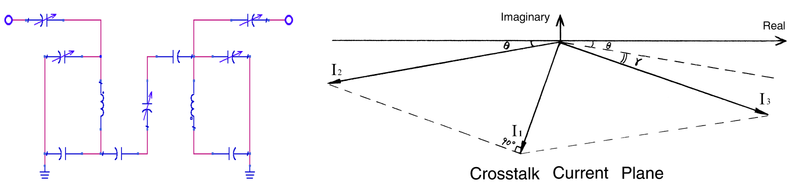

Figure 1. (left) Circuit diagram of a coil pair. Each coil is impedance matched to 50Ω in a balanced configuration. The decoupling branch consists of two fixed-value and one variable capacitor. (right) Vector analysis of decoupling mechanism. I_2 is the crosstalk current due to mutual inductance between coils; I_3 is the current introduced by the decoupling capacitors; I_1 is the minimized total crosstalk current by using this method. θ is the loss angle of a loaded sample coil and γ is the loss angle of the decoupling capacitors.

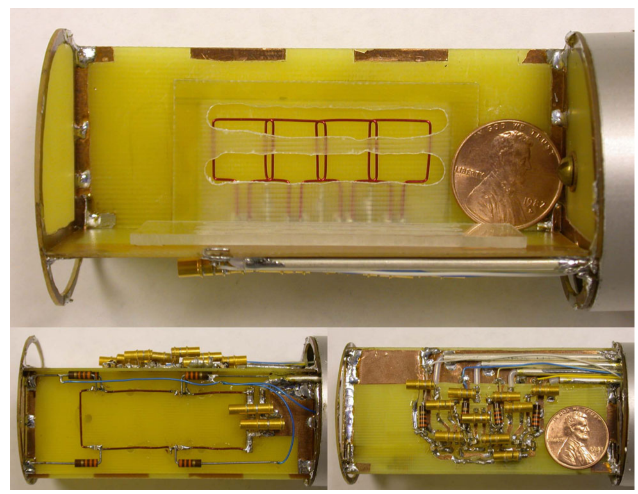

Figure 2. Photographs of the probe head. (top) 4 arrayed receive coils. Each coil is 10 × 10 mm; the total length of the array is 36 mm. (bottom left) Transmit coil and its tuning and matching circuit. (bottom right) Tuning, matching and decoupling circuit for the receive coil array.

Results: Coupling between receive coil pairs was -23 to –42 dB, and between transmit and receive coils –17 to –23 dB. MRI experiments were performed on an adult mouse with a 2D gradient-echo sequence. Data matrix 1024x256, TE 5 ms, TR 1s, slice thickness 250 μm, in-plane resolution 60 x 30 μm, data acquisition time 8 minutes. Figure 3 shows the reconstructed 2D image using a sum-of-squares method.

Conclusion: MRI microscopy can be improved using phased array technology at high field. Preliminary results have shown that effective decoupling can be achieved using a capacitor network. Future work will use PPA applications for mouse cardiac imaging.

References: [1] P. B. Roemer, et al., MRM, 16, 192, 1990. [2] D. K. Sodickson, et al., MRM, 38, 591, 1997. [3] K. P. Pruessmann, et al., MRM, 42, 952, 1999. [4] M. A. Griswold, et al., MRM, 47, 1202, 2002. [5] J. Lian, et al., US Patent, 5,840,969. [6] R. F. Lee, et al., MRM, 48, 203, 2002.

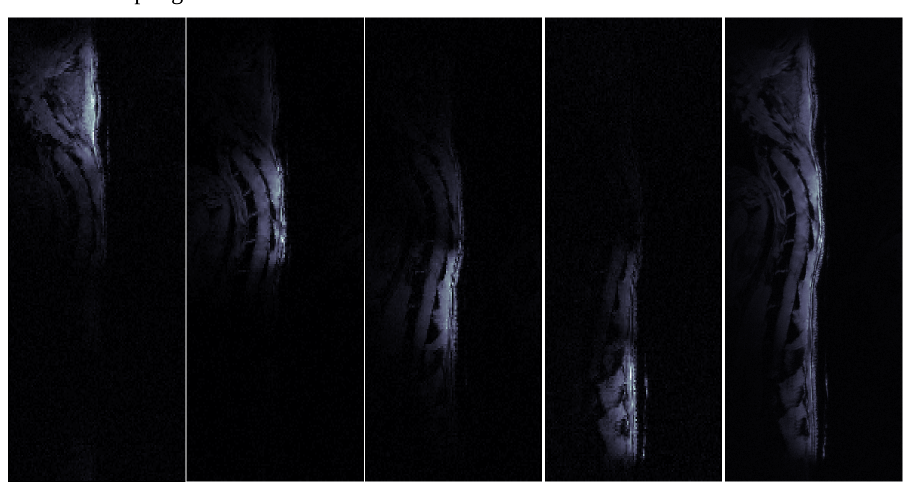

Figure 3. MR images of a spinal cord of an adult mouse. (left four images) Images acquired using 4 individual arrayed coils. (right) Reconstructed image using a sum of squares algorithm.