Coil Geometry Optimization for Better SNR and Decoupling

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Introduction

The design of RF coil arrays for MRI of small animals requires a meticulous and iterative combination of simulations, implementation and tests to achieve the most satisfactory loop geometry for the coil elements. For small samples at high magnetic fields, the coil noise can dominate [1]. In addition, the available clearance space for the implementation of the coils is quite restricted, imposing significant limitations in the relative positioning of the coil elements to avoid strong mutual coupling. Indeed, in such situations, the standard preamplifier decoupling strategy typically employed in the design of coil arrays for MRI of human subjects may be insufficient to avoid coil-to-coil interactions. The final geometrical shape and the relative positioning of the coil elements may be suboptimal and significantly degrade the theoretically achievable performance of the array. In the present work, we study different coil geometries for improved SNR in MRI of small animals. Three different coil geometries were studied: loops made with circular wires were compared with a circular flat strip and with a cylindrical loop.

Methods

By using the Surface Integral Equation (SIE) method [2] that rigorously solve Maxwell's equations with phantom loading, the Q factor (loaded and unloaded), the B1 field maps and the current distribution of loops with different geometries were evaluated on 300MHz. The sample model consisted of a 40mm spherical object loaded with saline solution. Each coil element consisted of a circular loop of 17.5mm internal diameter. The loop elements consisted of: (a) circular wires with cross-sectional diameters 1mm, 2mm 3mm; (b) a single copper strip 3mm wide; and (c) cylinders of heights 2mm, 4mm, 6mm and 8mm. A lossy capacitance was used in the model for the tuning.

Experimental Evaluation: SNR measurements and the coil-to-coil coupling of four different coil loop pairs were evaluated by MRI experiments in a 7T/30 cm small animal scanner. Each pair of RF coils was mounted over a 40mm spherical sample filled with 0.3% saline solution (figure 1a) with the internal edge of the loops separated by 6mm. The coils were coupled via a 50 Ohms resonant circuit to homemade HEPMT ATF34143 preamplifiers with the following parameters: Zin=1.6 Ohms; S21=17dB; S12=-60dB; NF=0.7dB[4]. As in the simulations, the coil loops were circularly shaped to have a 17.5mm internal diameter. A single wire coil was built using a 1.70mm diameter Ag plated Cu wire. Three cylindrical coils were built using 0.45mm thick Cu foil and heights of 2mm, 4mm, 6mm.

Results

Simulations demonstrated that the 3mm flat strip coil presented the most intense loading by the sample, and the biggest down shift in the resonance frequency due to the dielectric coupling to the sample, as previously reported by Balaban et al [3]. Both for the flat coil and well as for the wire coil, the current was concentrated in its internal diameter, while for the cylindrical coils it was- split in both extremes. As a consequence, the cylindrical coils had an overall stronger B1 field map in regions close to the coil as compared to the circular wire loop coils. This can be seen both from simulations as well as from MRI measurements as shown in figure 1. The SNR obtained along a line from the center of the coil to the center of the sample is shown in Fig. 2. The SNR increases with increasing wire diameter, but it is stronger with the 4mm cylindrical coil. Figure 3 shows the effect of mutual coupling of coil elements for different coils. The coupling was measured from the drop in SNR along a line from the center of the coil to the center of the sample, detected in one coil when both coils are connected. It can be noticed that the cylindrical coil with the highest height provides the best isolation.

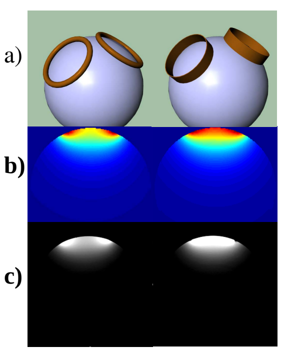

Fig. 1. Coil arrangement (a), B1 filend map simulations (b), MRI image from a saline sample (c).

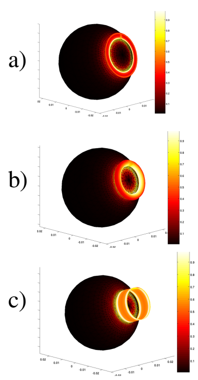

Fig. 2. Current distributions on 3mm flat strip (a), 3mm wire (b) and 8mm cylinder coils (c).

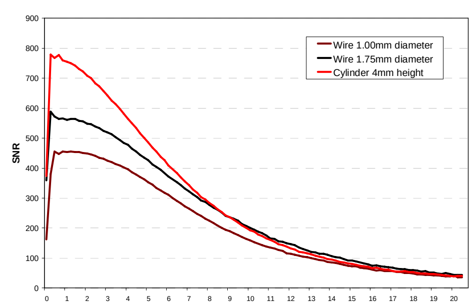

Fig. 3. SNR comparison in a saline sample in the center line of different wires and cylindrical coils.

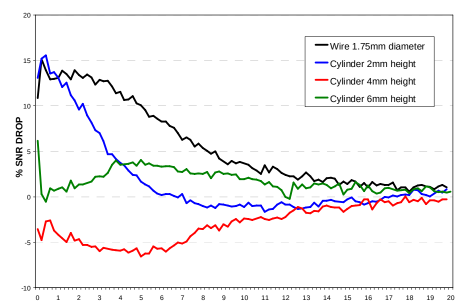

Fig. 4. Coil-to-coil coupling in paired loops. The cylindrical coil with the largest height shows the best isolation.

Conclusions

In comparison to coils made with circular wires, both simulations and MRI measurements shows that cylindrical coils provide a better B1 field map in regions as deep as 6mm from the sample surface. The highest SNR measured from the cylinder shaped coil is about 30% better. In addition, the decoupling between the loops is more satisfactory for the cylindrical coils, with the best isolation obtained in coils with large height.

References

[1] Hoult, D. I. and Lauterbur, P. C. (1979); [2] Wang S et. al, PMB 51:3211-3229(2006). J. Magn Reson. 34:425. [3] Balaban, R. S., Koretsky, A. P., and Katz, L. A., J. Magn Reson. 68:556-560. [4] www.avagotech.com.