Arrays of Birdcage Coils for Imaging Multiple Samples

Steven M. WRIGHT[1], Mary MCDOUGALL[2], David G. BROWN[3], John HAZLE[4]
[1]Texas A&M University, Engineering, TAMU Mail Stop 3128, College Station, Texas United States; [2]1006 Val Verde, College Station, TX ; [3]Texas A&M University, Electrical Engineering, MS 3128, College Station, TX USA; [4]University of Texas M.D. Anderson Cancer Center, Department of Diagnostic Radiology, Houston, TX ;

Introduction

Radio-frequency coil arrays are widely used in MR imaging, but typically are used to improve the SNR in a single FOV. To our knowledge, the first discussion of using multiple coils in a single MR experiment was directed towards using multiple, independent coils to view separate imaging regions [1]. That work used two counter-rotating-coils that were intrinsically decoupled from each other by way of their design. More recently, investigators have demonstrated the use of multiple, independent coils to enable spectroscopy from multiple samples, improving the efficiency of the experiment in direct proportion to the number of coils [2]. The recent increase in interest in small animal imaging, along with the relatively high-cost of using MRI as a survey procedure has led us to investigate the possibility of using multiple coils to simultaneously and independently image multiple animals. This abstract reports our initial results from several different birdcage coil configurations.

Methods

Modeling: Arrays and single birdcages were modeled using a quasistatic based method of moments program reported which allows the current distribution on the birdcages and the shields to be determined as a function of frequency [3]. Previous experience using this program has shown that the quasistatic approach gives good results in coils this small at 1.5 T and 4.7 T, the field strengths considered in this study.

Measurements: Imaging and bench measurements were used to verify modeling results. Measurements at 1.5 T were performed on a GE Signa scanner at the MD Anderson Cancer Center, and at 4.7 T on the GE/Bruker Omega scanner at the Magnetic Resonance Systems Laboratory at Texas A&M. Bench measurements for SNR were made by measuring the field produced with the coil operating in linear mode and matched to 50 ohms.

Coil Configurations: Several coil configurations were compared. For the effects of shielding on coupling, SNR and homogeneity. The birdcage coils had a 1.36” diameter, 16 legs, and were 2.75” long. A variety of shields were investigated, three are reported here: A 2” diameter, 5” long cylindrical shield, a 6”x6” flat plate between two coils spaced by 2” (center to center) and a corner shield formed from two 5x5x6” plates.

Results

Mode spectrums for a single birdcage coil, as well as for two and four coils separated by 2” (center-to-center) are shown in Figure 1, showing only the first two modes for clarity. Only one coil was excited in each case. The coupling between the birdcages is clearly evident in the mode splitting. The imaging mode for the four coil array splits into six modes, clearly demonstrating the need for shielding. Several shielding configurations were tested to minimize coupling without adversely affecting SNR. The results are shown in Figure 2 and Table 1. The first approach was simply to use two cylindrical shields. Due to the close spacing required to image multiple animals in the existing gradients, a closely spaced shield was used, with a 2” diameter. While this eliminated coupling, SNR in the individual coils was decreased approximately 50% due to shield losses in the closely spaced shield. Measured and calculated results were in excellent agreement. As an alternative, a single 6”x6” plate was used to isolate two coils. The coils were spaced by 2” as before, with the plate between them. Isolation was excellent. Relative SNR and frequency shift information is included in Table 1. The plate prevents coupling between the coils while having relatively little affect on the SNR, and a small frequency shift.

In order to allow four animals to be imaged simultaneously, a shield composed of two plates was considered to allow four coils on a 2” grid to isolated by a horizontal and vertical 5”x5” plates. SNR was reduced by a somewhat larger amount than with the two coil configuration with a single plate. Importantly, no mode splitting was evident when using either the plate or corner shield.

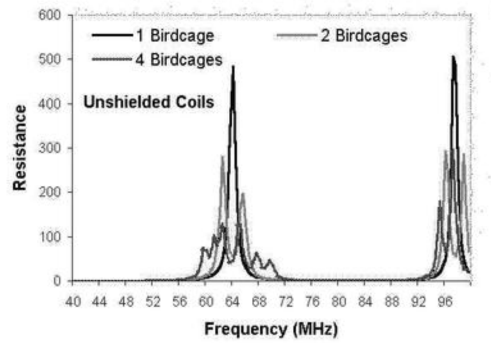

Figure 1. Mode Spectrum of unshielded coil arrays. Only the first two modes are shown for clarity.

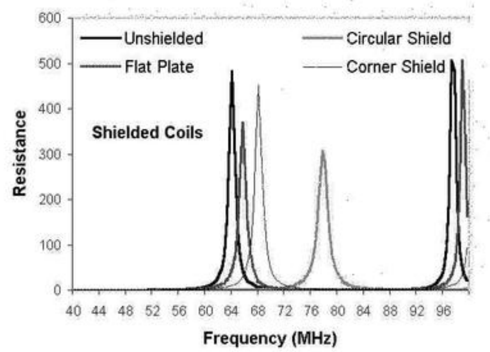

Figure 2. First two modes of the shielded arrays.

	Calculated		Measured	
	Δf (%)	SNR	Δf (%)	SNR
Unshielded	0.0	1.0	0.0	1.0
Circular Shield	21.5	0.54	21	0.53
Flat Shield	2.6	0.90	2.2	0.97
Corner Shield	3.3	0.84	5.8	0.97

Table 1. Relative SNR and frequency shift for different shields.

Discussion

Multiple birdcage coils can be operated in close proximity without significant SNR loss or coupling, but proper shield design is critical. This will allow an improved SNR as compared to using a birdcage coil large enough to accomodate all four animals, and potentially allows much greater flexibility. Depending on the application, one could extend this to arrays of eight birdcages and potentially even more. The planar and corner shields decrease copper losses while effectively preventing coupling between coils. Other coil configurations, such as shielded solenoids or TEM resonators [4], were not examined. Solenoids, while well-suited for multi-sample spectroscopy with small samples, are not convenient for small animal imaging and do not have the homogeneity of a birdcage coil. A four coil TEM resonator array would be an interesting extension worth investigating.

References

[1] Hyde, J. S., et al. J.Magn.Reson., vol. 70 pp. 512-517, 1987.
[2] Li, Y., Wolters, A. M., Malawey, P. V., Sweedler, J. V., and Webb, A. G., Anal.Chem., Nov 1;71, no. 21, pp. 4815-4820, Nov.1999.
[3] Wright, S. M. and Porter, J. R., Proc., 2nd Ann.Mtg., Soc. Magn. Reson. p. 1131. 1994.
[4] Vaughan, J. T., et al., Magn Reson.Med., vol. 1994 Aug;32, no. 2, pp. 206-218, Aug.1994.