A New Microstrip Resonator Coil for Imaging Rhesus Monkeys

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Synopsis

The microstrip volume coil design has been successful in small animal (rat and marmoset) imaging applications at 4.7T, and has recently been scaled to operate at 11.7T [1]. In this paper we discuss the scaling of this coil concept to larger sizes, suitable for rhesus monkey head imaging at 4.7T. It is demonstrated that such coils of larger dimensions are feasible and provide satisfactory performance. In addition, the previously developed optimization strategy [2] is employed and the resulting field homogeneity allows imaging very close to the coil strips.

Methods

Prior to construction, the rhesus coil was simulated and optimized using the multi-conductor transmission line (MTL) model. This model treats the strips and shield as a coupled transmission line system, and allows estimating the unloaded quality factor, filling factor and field homogeneity of TEM-type coils. The details of the MTL model are discussed in reference [3].

Simulation Results

The investigated rhesus coil has a 133mm inner diameter, 178mm outer diameter and 152mm length, which is significantly larger than the rat coil of 72mm ID, 105mm OD and 102mm length. The outer diameter was selected as large as possible and the inner diameter as small as possible to optimize the coil efficiency (SNR).

The MTL model has shown a 65.3% relative strip width (22.8mm actual width) to be optimal for this 12-strip coil. Specifically, this strip width optimizes the transversal B_1 field homogeneity in quadrature mode, while at the same time insuring close to optimal efficiency and wide frequency separation between the primary and parasitic resonant modes.

Twelve strips were selected for this resonator as a tradeoff between efficiency, transversal B_1 homogeneity and practical factors. The MTL model predicts that coil efficiency drops slightly as the number of strips increases, while the transversal B_1 homogeneity improves. In practical terms, increasing the number of strips requires more components and complicates the assembly and tuning procedure. Table 1 details the homogeneous B_1 region diameters predicted by the model. A homogeneous region diameter of 92.5% of ID in quadrature mode is more than sufficient in this application and the 77.5% of ID in linear mode is marginally acceptable (the field visualization in seen in Figure 1). An 8-strip coil carries a risk of greater field inhomogeneity due to imperfect tuning, and the 16-strip coil would be unnecessarily complex to build and tune. An additional reason for ruling out the 8-strip coil is that its wide strips and shield segments might interfere with gradient switching.

Coil Construction

The prototype rhesus coil in Figure 2 was constructed on a polycarbonate former with wall thickness of 3.2mm. The adhesive copper strips are installed on the inner surface of the former, while a matching set of shield segments is installed on the outer surface. The shield segments are connected near the ends of the coil using capacitors. The two printed circuit boards attached to the endplates of the former contain the strip terminating capacitors, matching circuits, connectors and active detuning circuits. Two capacitors are used in parallel per strip termination to improve quality factor and reduce parasitic inductance.

Imaging Results

The prototype coil was installed on a custom rhesus restrainer (not shown) and tested on an anesthetized animal. Imaging was performed on a 4.7T Bruker spectrometer with a 40cm bore and a 26cm 4G/cm gradient set at the Center for Comparative Neuroimaging in Worcester, MA. Figure 3 presents the results in the linear-driven connection, while Figure 4 presents the quadrature-driven result. The anatomical images in Figure 3 were acquired using the RARE sequence with TR=4.1s, TE=92ms, 8 echoes, 5 averages, 256x256 matrix, 12 cm FOV, and 2 mm slice thickness. The quadrature images in Figure 4 used RARE with TR= 3s, TE= 58ms, 8 echoes, 8 averages, 256x256 matrix, 12 cm FOV, and 2 mm slice thickness. Good field homogeneity is observed even though the upper portion of the head nearly touched the coil strips, as evidenced by the pattern of dark and light areas in the upper skin region on the linear image. The quadrature images show no inhomogeneity even close to the strips.

Conclusions

The microstrip resonator coil design has been successfully scaled to image rhesus monkeys. The MTL model based optimization strategy allowed nearly perfect transverse field homogeneity even in the immediate vicinity of the strips as well as optimized RF performance.

References

[1] Fisher T, Bogdanov G, Ludwig R. "An RF microstrip resonator for imaging at 11.7T." 11th ISMRM, 2003.

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[3] Bogdanov G, Ludwig R. Magn Reson Med 2002;47:579-593.

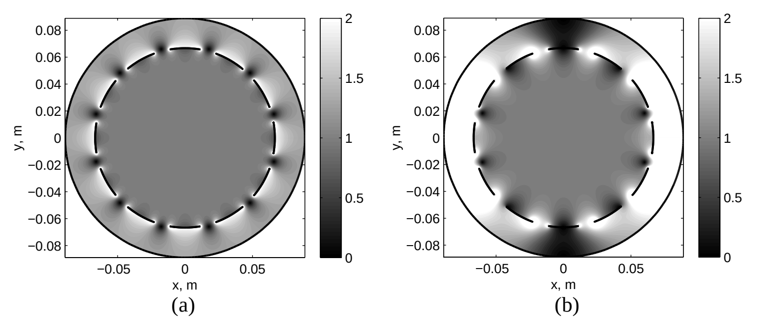

Figure 1. Simulated cross-sectional view of B_1 field: (a) quadrature, (b) linear.

Table 1. Simulated homogeneous B_1 region diameters.

# strips	Linear ±1dB B_1 diameter	Quad ±1dB B_1 diameter
8	65.5% of ID	88.9% of ID
12	77.5% of ID	92.5% of ID
16	83.3% of ID	94.3% of ID

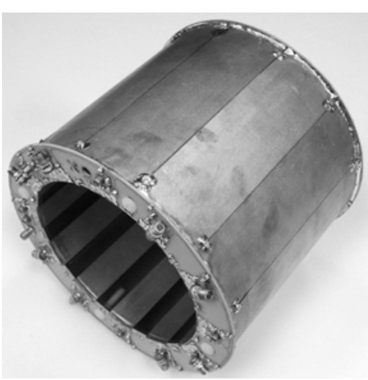

Figure 2. Rhesus coil prototype.

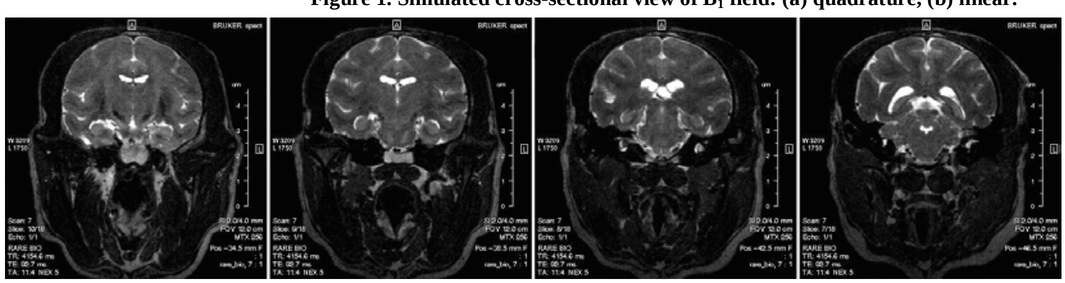

Figure 3. Rhesus images obtained using the linear-driven coil prototype.

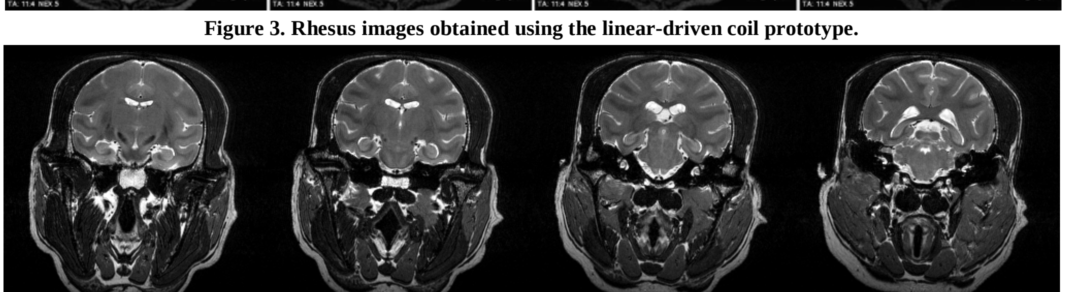

Figure 4. Rhesus images obtained using the quadrature-driven coil prototype.