Magnetron volume coil for Magnetic Resonance Imaging of rodents

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Introduction. There is still a great interest to develop volume coils for small-animal MRI. A transceiver volume coil with slotted end-rings and similar to the standard birdcage is proposed in this work. This coil design resembles Mansfield´s cavity resonator [1]. Unlike the traditional birdcage coil, our coil design was formed with two slotted surface coils [2] connected via rungs like the traditional birdcage coil. The coil end-rings were formed with circular slots evenly distributed as shown in Fig. 1. A coil prototype was developed to work at 300 MHz and quadrature driven for rat body imaging. Phantom and rat body images were acquired to prove the viability of this coil design for high field MRI applications.

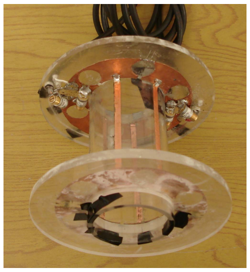

Fig. 1. Photo of coil desgin.

Methods. Numerical simulations were conducted to study the electromagnetic field of this coil design. Simulations were carried out at 300 MHz (proton resonant frequency at 7 T). All numerical computations were performed with the commercial software tool Comsol Multiphysics (COMSOL 3.2, Burlington, MA, USA). A coil prototype comprising 2 end-rings with 6 circular slots each connected via 4 rungs. The coil was made out of copper strips and mounted on an acrylic cylinder shown in Fig. 1. The coil length was 8 cm with 5 cm diameter and the circular slots had 1.5 cm diameter. Since the coil prototype was quadrature driven, two coax cables were attached to one of the end-rings to transmit/receive the MR signal from the imager. Each coax cable was tuned at 299.47 MHz and matched to 50 Ohm using two non-magnetic trimmers (1-15pF). To balance the coil prototype, 2 fixed-value capacitors (0.2pF) were soldered equally spaced to the other end-ring. A trimmer (1-15pF) was also used to decouple the two channels. A birdcage coil with similar dimensions and an equal number of legs was also built for comparison purposes. The Coil quality factors of the magnetron volume coil were approximately 104 and 70 for the unloaded and loaded cases, respectively. To test the validity of this coil, a cylindrical saline-solution phantom (4cm diameter and 9.5cm length) was used to generate images using ~~a~~ standard gradient and spin echo sequences. All imaging experiments were performed on a 7T/21cm Varian imager equipped with DirectDriveTM technology (Varian, Inc, Palo Alto, CA). T1-weighted axial images of a phantom were acquired with the following acquisition parameters, TE = 4.26 ms, TR = 531.60 ms, Flip angle = 20^0, FOV = 100 cm x 100 cm, matrix size = 256 x 256, slice thickness = 1 mm, NEX = 10. The acquisition parameters for T1-weighted images of rats were: TE = 21.89 ms, TR = 1000 ms, FOV = 100 mm x 100 mm, matrix size = 512 x 512, slice thickness = 1

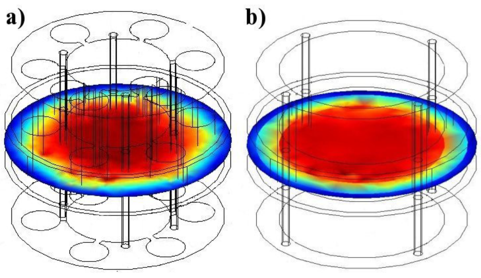

Fig. 2. Magnetic fields Simulations: (a) magnetron and b) birdcage coils.

Results and discusion. The numerical simulations of the B_1 fields for both coils are shown in Fig. 2. An increase in field intensity can be observed from the numerical simulations. Circular slots form small structures with specific inductance and capacitance values. These structures are evenly distributed along the end-rings allowing capacitance and inductance be allocated uniformly. Since both end-rings were orthogonal to the rungs, this allowed us to place all of the capacitors and trimmers away from the region to be imaged. The magnetron volume coil required a low number of fixed-value capacitors: only two were attached to one of the end-rings. 0 & $\pi/2$ channels were fairly easy decoupled by using one single trimmer between them. Axial phantom images were acquired with the coil prototype and shown in Fig. 3. Profiles along the diameter were computed from Fig. 3 image data to compare their homogeneity. A comparison plot of experimental data is depicted in Fig. 4. The magnetron volume coil shows a better uniformity and performance compared to the standard birdcage. The birdcage coil usually requires at least 12 rungs to generate an adequate B_1 homogeneity for large regions of interest, however our coil design only used 4 rungs. Then, the magnetron volume coil shows a better performance than the popular birdcage coil. The size, shape and number of the slots can be easily modified to accommodate more slots if needed. However, the coil performance remains to be studied under these different configurations. Finally, rat body images were acquired and one example is shown in Fig. 5. Thus, these preliminary results make this coil design a good candidate for body rat MRI at high magnetic fields. It still remains to investigate how this coil design compares against the TEM and microstrip coils.

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References. [1] Mansfield P, et al. Meas Sci Technol.1,1502,1990. [2] Solis S, et al. 13 ISMRM,2612,2006.

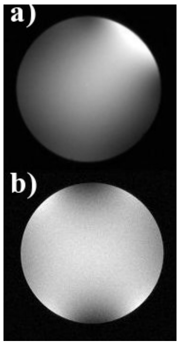
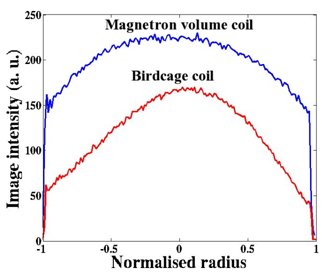


Fig. 3. Phantom images acquired with both the birdcage (a) and magnetron volume (b) coils.

Fig. 4. Comparison uniformity profiles of computed from Fig. 3 images. ➜



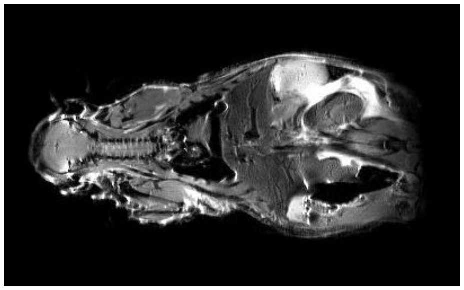


Fig. 5. Rat body image obtained with magnetron volume coil.