Slotted end-ring volume coil for small animal Magnetic Resonance Imaging at 7T

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Introduction. The development of transceiver volume coils for high field MRI is still a very dynamic field of investigation and development. A volume coil based on the high frequency cavity resonator [1] is presented in this paper for whole-body MRI of rodents at 7 Tesla (proton frequency: 299.47 MHz). This coil design has been previously tested on phantoms at 170 MHz (4T for protons) with standard spin echo sequences [2]. The encouraging results obtained with this coil design motivated us to develop a whole-body coil for rodents (in a) at higher magnetic field MRI. The coil design with slotted end-rings presented here is a variant of the coil above and was developed to work at 300 MHz. This coil design operates in the transceiver mode and was designed for small biological samples. A popular birdcage coil was constructed in order to compare their performances. Phantom and rat images proved the viability of this coil design for high field MRI applications.

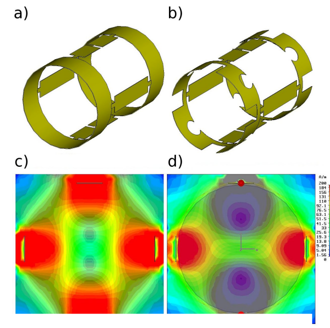

Figure 1. Birdcage (a) and slotted end-ring (b) coils. (c) & (d) are their corresponding magnetic fields.

Methods. To study the behaviour of the magnetic field of the coils, numerous simulations were performed using CST Microwave Studio (CST America, MA, USA). Simulations were carried out at 300 MHz (proton resonant frequency at 7 T). A variant of the high frequency cavity resonator prototype was developed with 4 circular slots on each end-ring of the coil and 4 legs. The coils were made out of copper strips and mounted on an acrylic cylinder. The coil length was 12 cm with 6 cm diameter and the circular slots had 2 cm diameter. Additionally, a birdcage coil was built with similar dimensions and the same number of legs. All coil prototypes were operated in the transceiver mode and quadrature driven. Two 50Ohm-coax cables were attached to the coil to transmit/receive the MR signal from the scanner. The coil design was tuned to 299.47 MHz using 6 fixed-value capacitors (3.9pF) evenly distributed and two non-magnetic trimmers (1-15pF) for fine tuning. 50 Ohm-matching was done with two variable capacitors (1-15pF), too. Quality factors of the slotted end-ring coil for the unloaded and loaded cases were approximately 101 and 45, respectively. To test the validity of this coil, a cylindrical saline-solution phantom (6cm diameter and 14.5cm length) was used to generate images using ~~a~~ standard gradient 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 = 4.11 ms, TR = 530.70 ms, FOV = 80 cm x 80 cm, matrix size = 256 x 256, slice thickness = 2 mm, NEX = 3. 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 = 2 mm, NEX = 10.

Results and discussion. Numerical simulations of the magnetic field (B_1) of the coils were conducted and the results are shown in Fig. 1. Both coil designs show a similar magnetic field pattern, and the slotted end-ring coil is able to produce a higher magnetic field compared to the birdcage coil magnetic field. The axial phantom image shown in Fig. 2 demonstrates a high SNR for the slotted end-ring coil and a fairly good uniformity. From the image data, profiles along the diameter were performed for both coil designs and shown in Fig. 3. An important SNR increase can be appreciated for the slotted-end-ring coil for the same acquisition parameters. While the SNR is increased, uniformity is diminished as commonly found when developing MRI coils. However, a useful SNR increment can be achieved with a reasonably good uniformity. Finally, rat images were also acquired using the parameters above and shown in Fig. 4. Images confirmed the viability of this volume coil and its compatibility with high field imagers and standard gradient echo sequences. The improvement on the coil performance of the slotted end-ring coil offers an alternative coil design to the traditional birdcage coil for MRI applications at high fields. Thus, these preliminary results make this coil design a good candidate for MRI and MRS applications of high magnetic fields. It still remains to investigate how this coil design compares against the TEM and microstrip coils.

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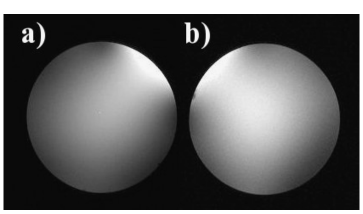

Figure 2. Phantom images acquired with the slotted end-ring coil.

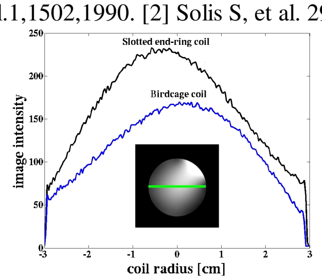

Figure 3. Comparison plots of uniformity for both coil designs.

Figure 4. Rat image acquired with the slotted end-ring coil.