A Twisted Loop Coil for High Field MRI

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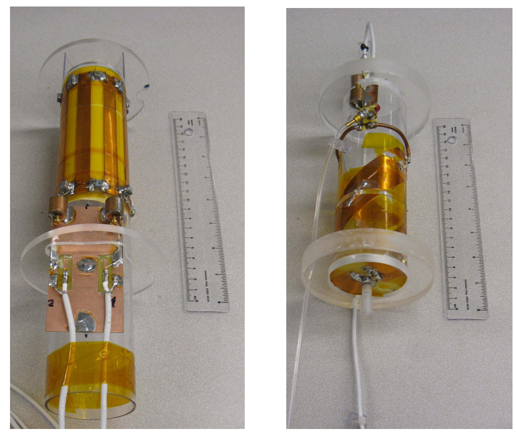
Introduction: The RF coil is a key element for MR imaging of small animals at high field. Previous work has shown that homogenous excitation is possible along the z-direction with orthogonal double solenoids at 4.7T [1]. However, this method requires very low capacitor values at higher fields such as 7T due to the large inductance of the solenoid. This effect increases with the diameter of the solenoid for larger animals and makes coil tuning difficult.

Birdcage coils have the advantage of increased signal to noise ratio (SNR) and homogenous excitation due to quadrature detection. However, the design and tuning of a birdcage coil is time consuming and the matching can be a challenge compared to a standard loop coil. Planar loop coils, on the other hand, are easy to construct, but have an inhomogeneous excitation profile over a cylindrical volume. To overcome the excitation profile disadvantage of a simple loop coil while maintaining low inductance, a twisted loop coil wound around a cylindrical tube was built. This coil was compared to an identically sized birdcage coil on a small-bore 7T Bruker animal system.

Materials and Methods: A birdcage coil and a twisted loop coil were constructed for a Bruker 7T animal system (Figure 1). Both coils had the same effective length of 130 mm and an inner diameter of 54 mm. The coils were positioned inside a removable RF shield with an outside diameter of 114.3 mm and a length of 290 mm. The use of the RF shield permitted both coils to be tuned on the bench without a frequency shift once positioned in the magnet.

A 125 ml bottle filled with $NaCl_2$ (2 g/l) and $CuSO_4$ (1 g/l) solution, was used for testing. Using this phantom, the high-pass birdcage was tuned with a total capacitance of 7.4 pF distributed around the end rings. The isolation between I and Q was measured to be -20.3 dB with a HP 8751A network analyzer. The twisted loop coil required 1.5 pF total capacitance for resonance. A matching of better than -20 dB was achieved for both coils on the phantom.

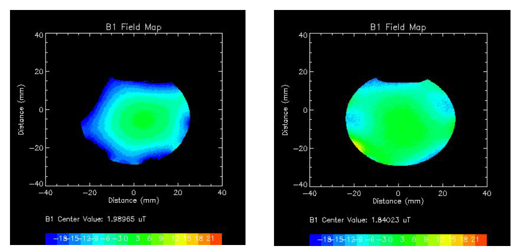
Imaging experiments were performed with a Bruker 7 Tesla system using Paravision 4.0 software. B1 maps were calculated from a 45-degree and a 90-degree gradient echo pulse sequence with a FOV of 64 mm x 64 mm, TR: 100 ms, TE: 6 ms, bandwidth of 50 kHz, NEX 8, and a Matrix size of 256 x 256. SNR comparison between the two designs was performed with a 2 ms Hermite RF pulse on a single slice at isocenter with a Matrix size of 256 x 256 and a 69.4 kHz bandwidth. *In vivo* imaging experiments were performed with the twisted loop on a mouse using a gradient echo sequence.



a) ***b)***
Figure 1*: a) Birdcage coil and b) twisted loop coil.*

Results: Figure 2 shows the B1 map results for the birdcage and the twisted loop coil. The B1 birdcage profile (Figure 2a) is highest in the center and decreases towards the outside. Overall, the birdcage profile is homogenous with low variations in B1 as expected for this type of coil. The signal drop-out at the top of the phantom is due to an air bubble. The twisted loop coil shows a homogenous region in the center which extends further towards the edge of the coil. The profile does vary slightly around the cylindrical coil wall. The minor increase in field at the bottom left of the coil is due to a coil conductor.

SNR was calculated using Bruker's SNR measurement tool. With the phantom described above an SNR of 134 was measured for the birdcage and a SNR of 90 for the twisted loop on an axial slice at isocenter. Multi-slice axial *in vivo* head images of a mouse are shown in Figure 3.



a) ***b)***
Figure 2*: B1 color map with 3 % steps of a) birdcage coil and of b) twisted loop coil.*

Conclusion: The decreased SNR observed with the twisted loop design is consistent with the lack of quadrature. However, a homogenous excitation field similar to that of a birdcage was achieved with the novel coil design. The twisted loop coil design has the advantage of easy tuning because of the characteristics of a single loop coil. It also required fewer capacitors to construct. We found that the design required more baluns than a birdcage to block cable currents, although not more than expected for a high field loop coil. Our design made the coil accessible from only one side, because of the return path in the x-y plane.

Further research will be conducted using a quadrature twisted coil to simultaneously gain the advantage of homogenous excitation of this design and the increased SNR of a quadrature coil.

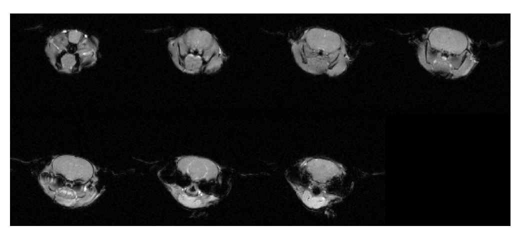


Figure 3*: In-vivo mouse gradient echo images (FOV 32 mm x 32 mm, TE: 3.1 ms, TR: 200 ms, bandwidth 55.5 kHz, NEX 8, Matrix 128 x 128).*

References:
[1] Kurpad K.N. ISMRM 20, 2011, 1818