Novel Orthogonal Double Solenoid (ODS) Volume RF Coil for Small Animal Imaging

K. N. Kurpad[1]
[1]Radiology, University of Wisconsin, Madison, WI, United States

Introduction: Solenoids are known to be inherently high SNR coils that also generate highly homogeneous radio frequency magnetic (B_1) fields[1]. The traditional solenoidal coil generates B_1 field that is parallel to the static magnetic (B_0) field. Hence, solenoidal RF coils currently in use for small animal imaging are typically designed for large bore clinical scanners, where the RF coil may be placed with its axis perpendicular to the B_0 field to achieve transverse magnetization[2]. Here, we present a novel variant of the solenoid coil, the Orthogonal Double Solenoid (ODS) coil that generates transverse B_1 field when placed with its axis parallel to the B_0 field in dedicated high field small animal horizontal bore systems. We compare the performance of a linear ODS coil to commercial quadrature birdcage coils.

Theory: The ODS coil consists of two solenoids that are driven in parallel. A schematic coronal view of the ODS coil is shown in figure 1. The component solenoids are represented by the red (coil R) and blue (coil B) lines respectively. As shown, the component loops of the coil B are parallel to each other and form an angle, β (measured clockwise) with the coil axis that is represented by a dashed line. Similarly, the component loops of the coil R are parallel to each other and form an angle, β (measured counter-clockwise) with the coil axis. If coils B and R are wound such that current flows through them in the direction indicated in figure 1, then coil R produces a magnetic field that oscillates along the solid red arrow and coil B produces a magnetic field that oscillates along the solid blue arrow. If time-varying currents at 0^o relative phase are driven in the component coils, then the resultant field will oscillate in a direction orthogonal to the coil axis (figure 2), with amplitude $|B_1| = 2B_{1R}\cos(\beta)$. At β = 45^o, the component solenoids are orthogonal to each other and produce the maximum B_1 field amplitude.

Methods: A linear ODS coil (diameter 63mm) was constructed on a polycarbonate former using copper tape (figure 3). Each component solenoid consisted of 5 turns with consecutive turns spaced 15mm apart. The ODS coil was tuned to series resonance at 199.75 MHz (4.7T) and transformed to the 50Ω system impedance using an impedance transforming lattice balun. The loaded/unloaded Q and the axial phase variation along the coil axis were measured using 2-port (S21) network analyzer measurements.

Imaging experiments were performed in order to compare the performance of the linearly driven ODS coil with quadrature driven commercial rat (diameter=76mm) and mouse (diameter=38mm) birdcage coils. Metrics of comparison were 1) B_1 field homogeneity and 2) SNR. A spherical phantom of diameter 35 mm, filled with 0.3% $CuSO_4$ solution was used for this purpose. A spin echo pulse sequence (TR/TE=250/16.98 ms, FOV=50mm, 256x256, 2mm slice thickness) was used to obtain axial images of the phantom using all 3 coils above. SNR was measured as the ratio of the mean signal intensity within a circular ROI at the center of the phantom to the standard deviation of noise outside the phantom.

Results: The loaded/unloaded Q of the ODS coil was measured to be 97/143, indicating dominance of sample loss. The maximum axial phase variance was measured to be 0.9^o, indicating uniform phase along the length of the solenoid. Homogeneity (L-R and A-P) is indicated in the line profiles in figure 4 and SNR data obtained from the images are tabulated (table 1).

Discussion: The ODS coil shows a drop in B_1 field intensity towards the center of the phantom in the L-R direction. The B_1 field is relatively homogeneous in the A-P direction. This is to be expected in a linear volume coil and is easily corrected by implementing a quadrature drive as in the birdcage coils. The SNR performance of the ODS coil is far superior to the rat birdcage coil, which is of a comparable diameter. This is a surprising result, considering that the birdcage is a quadrature coil. The mouse coil delivers a significantly higher SNR than the ODS coil. However, this is expected, considering the significantly reduced coil diameter and the quadrature drive. In conclusion, the performance of the linear ODS coil is comparable to that of the commercial birdcage coils. Significantly, there is sufficient headroom to further improve the performance of the ODS coil with respect to homogeneity and SNR by implementing a quadrature drive.

References: [1] Hoult D.I *et al*, MRM (1984) 339-353, [2] Lee H-S *et al*, Scanning (2008), v30, 419-425

Acknowledgement: UW Medical School for funding this research

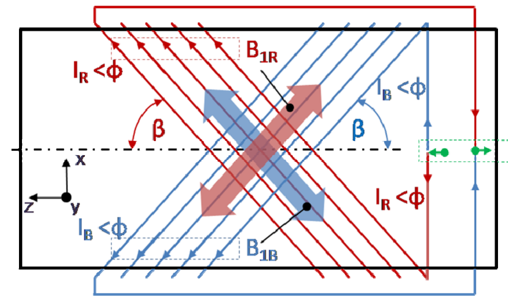

Fig. 1 Schematic coronal view of the ODS coil. Parallel red and blue lines indicate orthogonal windings. Solid red and blue arrows indicate corresponding B_1 field oscillations.

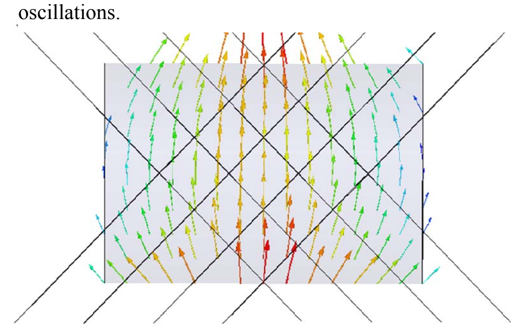

Fig. 2 Vector plot of simulated instantaneous B_1 field. The coronal view shows a resultant transverse B_1 field.

Fig. 3 Picture of ODS coil implementation. (a) View of the matching network and virtual ground points (b) Side-on view showing the orthogonal windings and (c) ODS coil inserted into the shield.

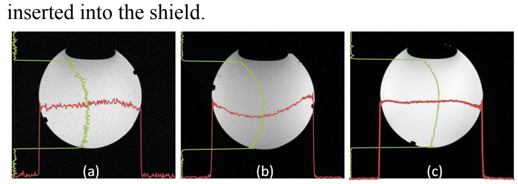

Fig. 4 Spin Echo axial images of a spherical phantom obtained using (a) commercial rat coil, (b) ODS coil and (c) commercial mouse coil. Horizontal and vertical line profiles of homogeneity are shown in red and green respectively.

Table 1 SNR measurements from axial images in Fig. 4.

	Rat coil	ODS coil	Mouse coil
SNR	57.1	116.9	210.7