A Circularly-Polarized Dual Litz RF Coil for High-Throughput Eight Whole Mouse Head Samples

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Target Audience: Scientists and clinicians with research interests in MRI validation via high throughput *ex vivo* studies

Purpose:

Ex vivo MRI can be very useful for proof of concept studies and experimental validation by acquiring three-dimensional dataset of samples prepared under optimal conditions. It also greatly helps overcome some of the constraints encountered during *in vivo* acquisition. For instance, limitations in scanning time reduce the MRI sensitivity and the anatomical detail while motion artifacts induced by freely breathing anesthetized subjects affect the image quality. In contrast *ex vivo* imaging can benefit from motion-free longer unattended scans thus further pushing the limits of MRI sensitivity while expanding MRI access and usage during off-hour sessions (overnight & week ends). Throughput can also be increased by acquiring simultaneously multiple samples within the same session thus lowering scan costs[1,2]. We previously greatly benefited by the shared coil approach through the simultaneous acquisition of four mouse brain samples placed within a 60-ml syringe[3]. This was achieved with a commercial probe dedicated for mouse body imaging (Doty Scientific, Columbia, SC USA; ID=37-mm; Lenght=42-mm, Accessible Diameter AD=33-mm) that resulted in 3D datasets with sub-millimetric isotropic resolution (<100µm) during overnight scans (less than 10-hours). In this work, we aimed to further increase the throughput under the same overnight sessions by designing a coil and corresponding setup that would accommodate up to eight whole mouse heads. The adopted solution was dictated by the constraint of our single channel MRI installation equipped with a gradient insert with a 60-mm diameter spherical volume (DSV). Furthermore, our design was also driven by the need to use commonly accessible off-the shelf supplies and ease of sample preparation. We considered a 12-rung probe design stretching along the z-direction (ID=38-mm, L==76-mm, AD=36-mm). After examining various structures, the design of a dual litz structure electrically-fed through the mid-point of the rung resulted in the most electrically balanced coil while maintaining a good homogeneity coverage over the length of the rung.

Methods: ***Coil characterization:*** The quality factor (Q), was systematically measured for each coil tuned at 301 MHz both unloaded (Q_U) and loaded (Q_L) using various sample load with an Agilent E5061B analyzer via a pick up coil. The coil homogeneity was assessed using phantom filled with vegetable oil and using a protocol described by Liu *et al.*[2]. ***MRI:*** All scans were performed on a 7-Telsa 200-mm horizontal bore Magnex Magnex equipped with an actively shielded gradient coil (BFG-150/90-750-S; ID 90-mm, 770-mT/m gradient strength, 100-ms rise time, ±5% field linearity) enabling a 60-mm Diameter Spherical Volume (DSV) interfaced to a Bruker Biospec console.

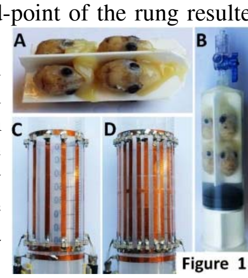

Figure 1

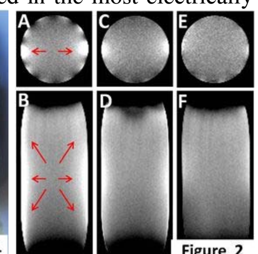

Figure 2

Sample Loading Effect		5mM Gd 10ml syringe	5mM Gd 80ml syringe	8 heads sample
BC	Qu	138	138	138
	QL	135	105	128
	1-QL/Qu	**0.02**	**0.24**	**0.07**
Litz	Qu	140	140	140
	QL	137	112	136
	1-QL/Qu	**0.02**	**0.20**	**0.03**

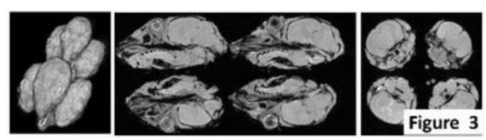

Figure 3

Results and Discussion: Figure 1 depicts the new 8 whole mouse head setup by using A) the syringe plunger where each sample is placed radially in each quadrant and replicated along the z-direction. B) This enables the ease of insertion of the set within the 80-ml syringe immersed in Fomblin to reduce susceptibility artifacts. C&D) are the two 12-rung probe design (ID=38-mm, L==76-mm, AD=36-mm) that we considered based respectively on either a C) traditional birdcage structure[4] (BC) or a D) Litzcage[5] (Litz). Our comparative study confirms that in Figure 2 the C&D) Litz structure expectedly helps better spread the current density along the circumference of the coil resulting in an improved RF B_1 homogeneity and reduction in sample loss compared to the A&B) birdcage. This can be clearly seen by the reduction of hotspots depicted by the red arrows (Fig2). To further improve the RF B_1 profile along the coil length, we examined the effect of a dual litz structure combined with a symmetrical attack in the mid-point of the rung that resulted in E&F) further improving the RF B_1 profile and reduction of the hotspots. Our results clearly demonstrate a significant reduction in hotspots at the vicinity of the rung by enabling a more electrically balanced structure. Table 1 summarizes the testing of the sample losses induced by the two sizes of conductive phantoms filled with 5mM of GdDPTA in water or by the eight whole head setup (Fig. a). The equally nearly unaffected loading effect when using a 10-ml syringe coil centered on either the BC or Litz coils assessed via the sample loss factor ($1-Q_L/Q_U=0.02$) demonstrates the similar RF behavior within their centers. However, the insertion of an 80-ml syringe phantom filling the whole coil volume results in greater sample loss for the BC coil (0.24) and to a lesser extent for the Litz probe (0.20) . These results can be attributed to the larger phantom coverage that includes the hotspots described at the vicinity of the rung reflecting the improved spread of the current density for the Litz structure. Figure 3 illustrate the acquisition of a 3D dataset of the eight whole head sample within the 80-ml syringe setup previously described. Compared to the commercial abdominal mouse imaging coil (Doty Scientific), the resulting SNR loss measured from our eight whole head large structure experienced a ~40% drop while doubling the number of samples acquired at equal imaging time.

Conclusion: Among the various structures we considered and examined, the design of a dual litz structure electrically-fed through the mid-point of the rung resulted by far in the most electrically balanced coil while maintaining a good homogeneity coverage over the length of the rung.

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