A Printed Loop Element with Integrated Capacitors and Co-Planar Shield for 7 Tesla

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INTRODUCTION Shielded RF coils have been investigated since the earliest days of MRI, taking the form of the "Zabel coil" [1] - a shielded transmission line coil, coils over ground planes, and more recently microstrip coils, particularly for use at high-fields [2]. Some authors have stated that RF shields are essential for 7T surface coils over 10 cm in diameter [3], and others have successfully built smaller loops as array elements without using shields [4], consistent with this guideline. This abstract examines the effectiveness of a co-planar shield at 7T. The co-planar shielding configuration may be particularly advantageous in constructing array coils, particularly when paired with coils using the distributed capacitance of dual-sided PC boards.

METHODS Two different shielded surface coils were constructed in order to observe the effectiveness of the shield independently from the effects of using distributed capacitance. A large loop (more sensitive to the effects of shielding) with an i.d. of 14.5 cm and an o.d. of 15.2 cm was constructed on industry standard FR-4 (**Figure 1, left**). Eight gaps were distributed around the coil with appropriate lumped element capacitors inserted to raise the self-resonant frequency. A smaller coil with 9.5cm i.d. and 10.2cm o.d., intended for use as an array element, was printed on dual-sided PC board (Taconic CER-10, ε_r=9.8, 1.27mm thick) (**Figure 1, right**). The equivalent of six segmentation capacitors was integrated into the coil by overlapping traces on the top and bottom at the appropriate angles, as determined by an in-house developed spectral-domain method-of-moments program. For both coils, a co-planar shield was fabricated on the same PC board as the main loop. In each case, the i.d. of the shield was 5mm larger than the o.d. of the main element, and the shield had a tracewidth of 5mm. Matching and tuning was accomplished with a standard balanced configuration across one of the coil breaks and the coax was formed into a resonated wavetrap immediately following the match and tune board.

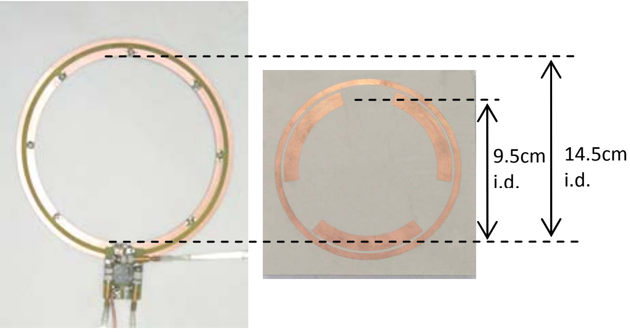

Figure 1. Two shielded loop configurations. (a) 14.5cm i.d. loop coil for observing performance of continuous co-planar shield at 7T. (b) 9.5cm i.d. loop coil with distributed capacitance etched on high dielectric ceramic PCB as a completely planar element

Bench & Imaging Measurements: To assess performance three tests were made: **1)** The loaded and unloaded Q was measured for the shielded coil, the unshielded coil, and, for comparison, the unshielded coil with a ground plane at the recommended distance of 4.5cm spacing for a 10cm coil at 7T [3]. **2)** The reflection coefficient versus frequency of the large coil was measured with and without a shield, loaded and unloaded. To create the "unshielded" case, the shield was actually broken in four places (verified with modeling to be as though unshielded). The segmentation capacitors had to be changed to tune the coil to 298MHz in this case. **3)** Gradient echo images were obtained from the shielded and unshielded 14.5 cm coil on a 7 Tesla scanner. The power required to calibrate the tip angle to 90 degrees was recorded and used as an indication of coil efficiency.

RESULTS Table 1 shows the loaded and unloaded Q for the shielded and unshielded 14.5cm diameter coil as well as the unshielded coil over a large ground plane. The unloaded to loaded Q ratio is 50% higher for the co-planar shielded case. The unloaded to loaded Q ratio with the ground plane was even higher, but the greater flexibility of the co-planar shield may make the co-planar shield advantageous in certain situations. The Q measurement was taken from the 7dB width on the S_{11} response [5-6]. The unshielded coil could not be matched at 298MHz for the loaded case, so the Q measurement was made at 310MHz. The reflec tion coefficients for the shielded and unshielded coils for the loaded and unloaded cases are shown in **Figure 2**, showing the significantly lesser influence of the load on the shielded coil. Finally, to compare the efficiency of the shielded and unshielded 14.5cm coils, each was impedance matched to 50 ohms, and the power required to create a 90 degree tip angle was calibrated. The power requirement was found to be 54% higher with the unshielded coil, consistent with the bench Q measurements.

Table 1. Comparison of Q for shielded and unshielded coils

Coil	Q_{UL}	Q_L	Q_{UL}/Q_L
Unshielded	55	8.3	6.6
Shielded	178	18	9.9
Ground Plane	167	10.8	15.5

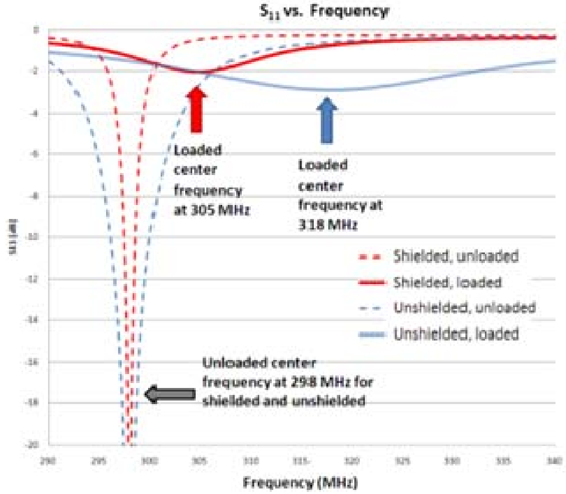

Figure 2. Reflection coefficient curves for co-planar shielded and unshielded coils for loaded and unloaded conditions. The shielded coil is significantly less influenced by the load.

DISCUSSION The need for RF shields increases with high field strengths due to the more prevalent electric field effects. While RF shields certainly aid in ease of impedance matching and decoupling coils due to the decreased loading effects and potentially better 'behaved' electric fields, they can make construction of the coil more difficult, particularly if the coil is to be highly flexible. A co-planar shield greatly simplifies construction, as there is no issue with maintaining spacing to a ground plane. At 7 Tesla it is also relatively easy to obtain enough capacitance through overlaps in dual sided PC boards to also eliminate the lumped element segmenting capacitors. Together, the printed capacitance and co-planar shield enable very simple fabrication of an easily overlapped array element.

REFERENCES: [1] H.J. Zabel et al., Radiology, 165, 1987. [2] G. Adriany et al, MRM 53(2), 2005. [3] G. Adriany et al, Proc. ISMRM, 2000. [4]G.C. Wiggins et al, MRM 54, 2005. [5] T. Lanz, Proc. ISMRM, 2008. [6] R.E. Collins, Field Theory of Guided Waves, IEEE Press, 1991.

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