Design Guidelines for Utilizing Co-Planar Shielded Loops at 7T

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Introduction

RF shielding of transmit coils helps mitigate undesired electric field effects that intensify at high field strengths. Stray electric fields at 7T may present concerns for both coil stability and patient safety, in terms of increased SAR. Previous research demonstrated the criticality of utilizing an RF shield for 7T surface coils over 10 cm in diameter [1]. Nonetheless, RF coil design requirements may prohibit the use of a true shield or ground plane. An alternate approach involves encircling the coil with an untuned, concentric, co-planar copper loop. Proper utilization of a co-planar shield has been shown by several investigators to mitigate stray electric fields while maintaining sufficient SNR [2-4]. However, without proper design consideration, a co-planar shield may reduce effective B_1 while negligibly improving E-field radiation losses. This abstract presents design guidelines, developed from electromagnetic modeling and verified by bench testing, for utilizing co-planar shields to reduce E-field hotspots, and thus SAR, while maintaining effective RF excitation.

Materials and Methods

Electromagnetic Modeling: Simulations were performed using commercial EM modeling software (XFdtd 7.1, Remcom, Inc., State College, PA). A single loop coil exhibiting the geometry utilized in [4] was meshed to produce a B_1 field in the y-direction, as shown in Figure 1. Both shield width and shield-to-coil spacing were parameterized to create 100 combinations. For operation at 7T, steady-state B and E field data were calculated at 298 MHz. MATLAB was utilized for post-processing. The effective coil sensitivity, $|B_1^+|$, was calculated as the modulus of the B_1 component that rotates in the direction of nuclear precession. As SAR is proportional to the squared electric field modulus, i.e., $|E|^2$, it is desirable to maintain average $|B_1^+|$ while minimizing $|E|^2$. Peak E-field values and average $|B_1^+|$ in the region of interest were determined. Figure 2 illustrates the ratio of $|B_1^+|/|E|^2$, where the larger values exhibit effective $|B_1^+|$ while minimizing local SAR. Fabrication & Bench Measurements: A loop coil matching the modeled geometries, diameter 16 cm, was constructed from industry-standard copper-clad FR-4 PCB and segmented by 11 ceramic capacitors. Two co-planar shields were fabricated to test two divergent modeling results and were individually placed around the coil. $|B_1|$ was evaluated from S_{21} measurements with a pickup loop probe over the unloaded coil, and data compared to simulation results. The model and test coil are shown in Figure 1. Generalization of the guidelines for loop geometries over 10 cm was verified by running simulations and calculations for loops with an inner diameter of 10 cm and 16 cm.

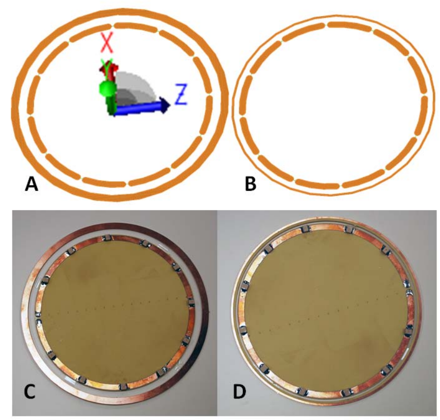

Figure 1: Two software renderings and constructed coils with co-planar shields. **A:** 7mm width shield spaced 8mm from the coil conductor (representing 4.5% coil diameter width and 4.7% diameter spacing). **B:** 2mm width shield spaced 5mm from the coil (1.3% diameter width and 3.2% spacing). **C-D:** corresponding coils used for bench testing, respectively.

Initial Results and Discussion

Simulation results indicated a parameter region with markedly improved field effects, as can been seen in Figure 2. Analysis of E-field results verify low |E| in the region. S_{21} measurements between two cases of shield size/spacing corroborate the differences indicted by simulations. Relative field plots demonstrating agreement between simulations and bench measurements are shown in Figure 3. The results show the proper determination of a co-planar shield can effectively mitigate unwanted field effects.

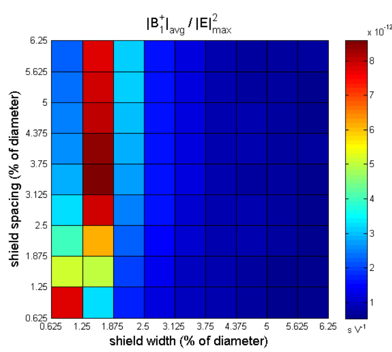

Figure 2: Color-weighted plot illustrating the ratio of $|B_1^+|/|E|^2$. Note the second column shows a parameter region with more desirable improved field effects.

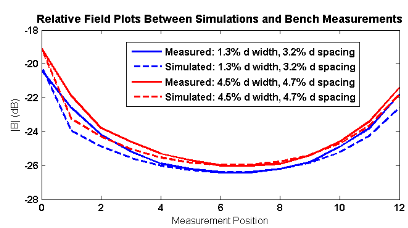

Figure 3: Relative field plots comparing modeling results and bench measurements for |B| across the plane of the unloaded coil plane. The measured and simulated data for each test case largely agrees throughout the coil's excitation region.

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References: [1] G. Adriany et al., Proc. ISMRM 2000, #0563. [2] T. Lanz et al., Proc. ISMRM 2006, #217. [3] M.P. McDougall et al., Proc. ISMRM 2011, #1875. [4] J.V. Rispoli et al., Proc. ISMRM 2012, #2635.