Effect of Shielding on Surface Coil Loops at 7T

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Introduction:

Radiation power loss, or the radiated power of a coil that is not absorbed into the sample, is assumed to be a problem at high field in MRI, as it is known to increase with the frequency (ω) and coil-bounding area (A): RLOSS α A2 * ω4 [1,2]. Various authors suggest that the effects of radiation loss, such as decreased SNR and coil Q, can be mitigated by adding RF shielding to coils used at high field. However, it is also know that shielding can reduce the effectiveness of a coil due to counter-rotating image currents in the shield. We test the effect of shielding on coil performance here, using the most simple case of a single Transmit-Receive (TxRx) coil, to quantitatively compare the benefits of shielding for radiation loss in both transmit and receive at high field. A single surface coil was chosen both because of its simplicity, and because, unshielded, it is the most susceptible to radiation loss because of its open structure at high field.

Methods:

A single rectangular TxRx coil, 80mm in width, with a removable shield placed at a variable height above that, was constructed. This setup was then tested on a 7T scanner (Siemens Medical Solutions, Erlangen Germany) using a cylindrical phantom (length 37cm, diameter 16cm; composition 124g $NiSO_4$ – $6H_2O$ and 2.62g NaCl per 1000g H_2O; Siemens Medical Solutions, Erlangen Germany). The coil contained two variable capacitors for tuning and matching at the to compensate for the effect of the varying shield proximity. Each setup was individually matched and tuned for experimentation.

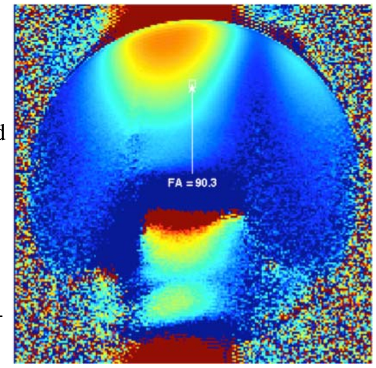

Figure 1:

For each case the quality factor, Q, was measured at the bench using a network analyzer (Agilent Technologies, E5061A) both for the loaded and unloaded case, and the Q ratio was calculated as QRatio = QUnloaded/QLoaded . For each coil to shield distance the excitation was carefully calibrated using a turbo-flash scan with preparation pulse [REF Elodie B1 Scout abstract] such that the flip angle at a depth of 3cm directly under the coil was as specified in the protocol (Figure 1). SNR was measured by acquiring two gradient echo scans in each case (TR/TE/Flip/slice/BW = 500ms/4.07ms/20°/3mm/300, matrix 192x192, FoV 170x170), one with RF excitation and a noise scan with no RF excitation. SNR was also measured with the same parameters but a flip angle of 90°. Raw data was saved and SNR calculated according to the Kellman method [3].

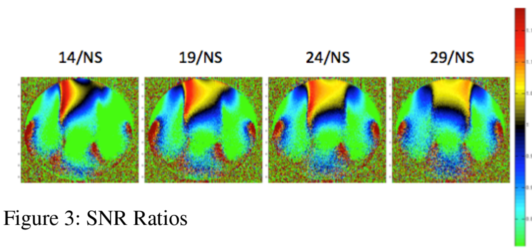

Figure 3: SNR Ratios

Results:

As the shield was moved closer to the coils, it effectively increased both the loaded and unloaded Q values, however, the Q ratio was seen to peak at a coil to shield distance of 24mm. This seems to suggest that shielding near the correct height blocks radiation loss, however when the shield is moved too closely adjacent to the coil it begins to interfere with the coil's function. Along with this, it was also seen that the transmit reference voltage required to obtain a 90° flip angle at the point of interest decreased initially with the addition of the coil, but increased again as the shield was moved too close (Table 1), which also supports this theory.

Table 1:

Shield Height	14mm	19mm	24mm	29mm	None
Qloaded	17.9	14.7	12.8	11.6	8
Qunloaded	28	25.3	22.2	19.8	13.2
QRatio	1.625	1.6918	1.748	1.6983	1.6543
TxRef	92	91	88	87	92

Figure 2 shows the SNR maps of the five shield setups for a flip angle of both 20° and 90°, and the SNR at the point of interest chosen above. The SNR maps were then compared in ratio (shielded coil/unshielded coil) to view performance throughout the phantom (Figure 3).

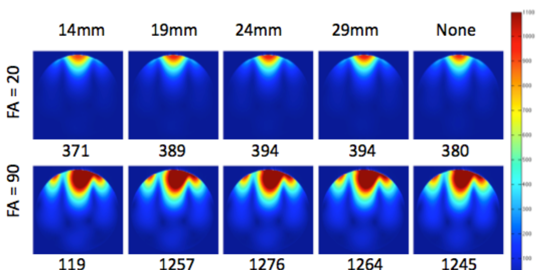

Figure 2: SNR maps. Colorbar ranges from 50 to 1100

In all four shielded coils there was a definitive increase of up to 12% in performance close to the coil itself, including the point of interest. However, in every case there was also a significant decrease of up to 40% in coil performance in the areas of the phantom further from the coil.

Conclusions:

Although the use of a shield for a surface coil can improve both transmit and receive efficiency for regions close to the coil and under the center of the coil, there is always a penalty in efficiency for deeper regions and away from the center of the coil. Whether this is problematic depends on the application, Therefore, it cannot be assumed that decreasing radiation loss in a surface coil by adding a shield will also increase the SNR.

[1] Liu et all. Magn Res Med. 2002 **10** [2] Lee "Principles of Antenna Theory", John Wiley. 1984. [3] Kellman et all. Magn Res Med. 2005 **54** 1439-47