Optimizing TEM Transceiver Elements at 7 Tesla

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Objective:

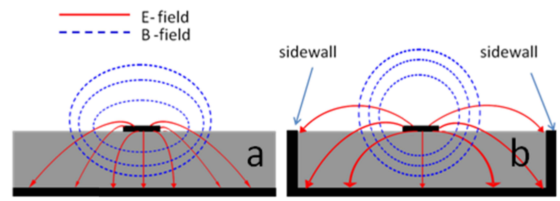
Simulated and experimental investigation of multi-element volume head coils consisting of optimized TEM elements at 7 tesla.

Background:

The microstrip has been a popular coil element of choice in multi-element TEM transceiver arrays [1-4] due to its' bi-directional current path and independent control capabilities. In order to be effective at high magnetic field strengths, multiple microstrip elements must be combined in an array configuration. An important consideration in microstrip design is the ability to control the transmit field propagation in the transaxial plane. In the transaxial plane, the microstrip's magnetic field lines extend past the finite ground planes and hence, mutual coupling becomes a problem as the operating frequency increases. In this abstract, ground plane sidewalls are designed and incorporated as part of the microstrip coil element. Introducing ground sidewalls between microstrip elements can reduce decoupling with neighboring elements, can contain the transmit field near the source, and provide a more efficient coil element.

Concept:

Due to the multi-element coil configurations, controlling field profiles produced by coils has become a necessity. In the case of the microstrip TEM element, extending the ground plane in the transaxial plane in a 'sidewall configuration' modifies the E and B-field produced by the coil as illustrated in Fig 1a-c. Introducing symmetric sidewalls (Fig. 1b) can direct more B_1^+ towards the sample while introducing a single sidewall (Fig. 1c), in essence, tilts the coil and changes the angle of propagation.



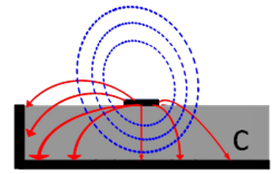


Fig. 1 Transaxial illustration of field vectors for a) microstrip b) microstrip with symmetric sidewalls, and c) microstrip with single sidewall

Methods:

The effect of the ground sidewalls incorporated into the microstrips was investigated numerically in a head and experimentally in a phantom at 7 tesla.

Numerical Maxwell solutions of the 8-channel transceiver arrays were calculated about an anatomically correct human head using XFdtd version 6.5 (Remcom Inc., State College, PA). Each channel was simulated individually and combined in post-processing with B_1^+ geometric phases at the center of the brain to produce a circularly polarized B1+ field by Matlab (version 7.5). All the coils were normalized to 1W input power for comparison purposes.

Three eight-channel transceiver arrays were built. Each element was comprised of a low loss Teflon substrate (εr = 2.08) with height and length of 1.90 cm and 14.0 cm, respectively. The elements were attached to a cylindrical plexi-glass shell 25.4 cm in diameter and 14.0 cm in length. The conductor widths consisted of single 1.2 cm copper foil and 1.2 long copper foils were used as sidewall segments. Each element was individually tuned to 297 MHz (7 T) and matched to a 50-Ω, coaxial cable. No decoupling capacitors were used. Experiments were performed in a 7 T magnet (Magnex Scientific, UK) interfaced to a Siemens console (Siemens HealthCare, Germany). The phantom in experiments was a cylindrical sucrose/saline solution phantom with electric properties of the head (ε_r=58.11 and σ =0.54 (S/m) [5].

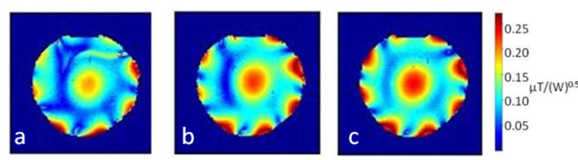


Fig. 2 Experimental B_1^+ maps for 8-element transceiver with a) microstrip b) microstrip with symmetric sidewalls, and c) microstrip with single sidewall elements (central transaxial slice)

Results:

In 7 tesla experiments, in an eight-element transceiver configuration, B_1^+ maps produced an average peak value of 0.235 $\mu T/W^{0.5}$at the center transaxial slice of the phantom for the microstrip with a single sidewall (Fig. 2c), an average peak value of 0.215 $\mu T/W^{0.5}$ for the symmetric sidewalls (Fig. 2b), and an average peak value of 0.188 $\mu T/W^{0.5}$ for the microstrip with no ground sidewalls (Fig. 2a). In eight-element simulations for the three designs incorporating a head, the microstrip with single sidewall once again performed best for peak B_1^+ (0.522 $\mu T/W^{0.5}$) while the symmetric sidewall case produced a peak B_1^+ of 0.450 $\mu T/W^{0.5}$ outperforming the regular microstrip coil for peak B_1^+ (0.376 $\mu T/W^{0.5}$). As expected, the SAR also increased with these designs (Fig. 3d-f) but when a ratio of peak B_1^+ vs. peak 10 gram average SAR was analyzed, the symmetric sidewall (0.713) and no sidewall case (0.725) had similar results while the single sidewall coil had the greatest ratio (0.966).

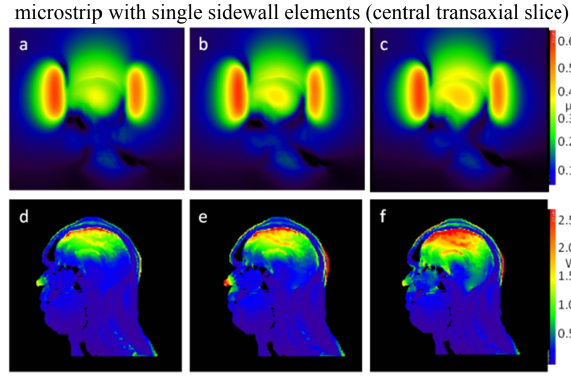


Fig. 3 Eight element microstrip transceiver Remcom simulations with varying ground plane sidewalls for B_1^+ (top row) and SAR (bottom row) a-d) no ground sidewalls, b-e) s = symmetric sidewalls (middle), and c-f) single sidewall

Conclusions:

A new microstrip TEM design is introduced as a means to improve the overall B_1^+ in the sample; ground sidewalls. Two sidewall designs produced greater peak B_1^+ in the center of the phantom experimentally and in the head in simulation. The single sidewall strategy resulted in an even greater peak B_1^+ in the head in simulation when compared to the traditional microstrip element and the symmetric sidewall elements. An increase of 33% is seen in this strategy in peak B_1^+ versus 10 gram SAR ratio when compared to the traditional microstrip element.

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