Microstrip TEM Coil Optimization at 7T

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Introduction:

Efficient high-frequency RF coils are needed to realize the gains of ultra-high field MR imaging. Transverse electromagnetic (TEM) resonators[1] which use microstrip elements, have provided a solution. To further advance this technology the design parameters of these coils and the transmission line elements comprising them have been identified and investigated with the aim of generating more efficient coils with higher B_1 field gains[2]. Specifically substrate thickness (h), signal line width (w), and shield sidewall depth (s) were varied on microstrip designs to achieve desired B_1 fields at 7T (300MHz). Simulations of eight channel TEM coils incorporating these optimized microstrip elements were then used to analyze B_1 field plots for strength, penetration, and decoupling potentials of different coil configurations.

Fig 1. Microstrip parameters: S = sidewalls h = height w = signal line width

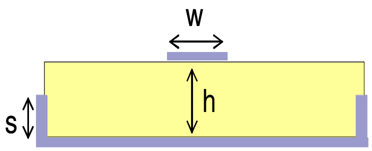


Fig 2. 8-element TEM coil with conductive sidewalls

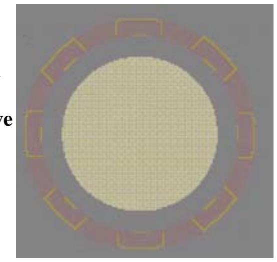
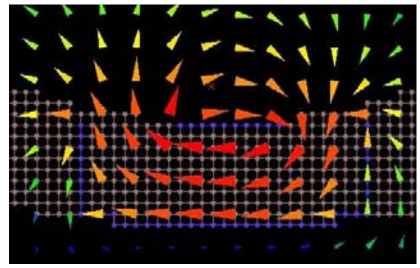


Fig 3. Magnetic field vector plot for a microstrip transmission line with conductive sidewalls



Methods:

To model and compare theoretical B_1 magnitude field patterns at 300 MHz, numerical Maxwell solutions of microstrip-based (**Fig. 1**) volume coils were obtained using XFDTD (Remcom Inc., State College, PA). A volume coil with an inner diameter of 9"and length of 6.25" was used as a standard for the coil with a 7" diameter saline sphere phantom (conductivity = 0.9 and permittivity =78)[3] placed in the center of the coil (**Fig. 2**). Different signal line widths (0.5" and 0.75") and substrate heights (0.5", 0.75", and 1.0") are analyzed for B_1 performance. Performances of the TEM coils were compared to width dimensions of 0.5" for the signal strip and 2.0" for ground width[4]. Shield segment sidewalls of different heights were investigated for shaping the B_1 field toward the center of the coil and facilitating inter-element decoupling, (**Fig. 3**) Specifically, sidewalls of 50%, 75%, and 100% substrate thickness were tested (**Fig 1**). All elements were driven independently and tuned to 298 MHz. To compare the performance of the 8 element TEM coil, the magnitude of B_1 fields were normalized to input powers for evaluation of B_1 gain as a function of power of the respective coil configurations.

Results:

An eight channel coil with element substrate thicknesses of 0.75" and signal line width of 0.5" produced the strongest B1 field magnitude in the center of the coil (**Fig. 5**). The magnitude difference when changing the substrate height from 0.5" to 0.75" and to 1.0" while keeping the width at 0.5" can be seen in **Figs. 4-6**. The 0.75" substrate in **Fig. 5** produced a 30% increase in B_1 magnitude at the center of the coil compared to the 0.5" in **Fig. 4** and 1" in **Fig. 6.**

Using a signal line width of 0.75" and substrate thickness of 0.75" as a standard, the effect of the conductive sidewalls were analyzed. The percentage increase in the B_1 field magnitudes of coil models with sidewalls (50%, 75%, 100%) compared to coils with no sidewalls are shown in **Figs. 7-9**. The 50% sidewall model shows a ~10% increase in B_1 magnitude over most of the coil's field of view, compared to a coil whose elements have no sidewalls. The coil with full sidewalls (100%) shows significant B_1 increase in the periphery of the coil, as well as an approximately 13% increase in the center coil. The full sidewalled elements are also better shielded from neighboring elements in the coil, and better shielded from the magnet bore environment as seen in **Fig 9**.

Conclusions

Improvements to the TEM resonator were made by adjusting the substrate thickness, and introducing conductive sidewalls. In the first case study, a 30% increase in B_1 magnitude at the center of the coil is seen with substrate thickness of 0.75" compared to the 0.5" and 1.0" substrate cases while keeping the signal line widths at 0.5". Introducing shield sidewalls to the dielectric substrate sections promoted a stronger B_1 field in the coil periphery and improved decoupling between the multi-channel elements compared to a conventional microstrip volume coil.

1. Vaughan J.T. et al. Magn Reson Med 1994; 32: 206-218
2. Bogdanov G. et al. ISMRM pg.422; 2004
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   Air Force material command, Al/OE-TR- 1996- 0037; 1996.
4. Adriany, A. et al. Magn Reson Med 2004: 53:434-445

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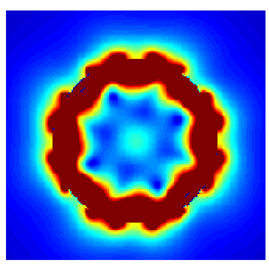

Fig. 4 w= 0.5", h=0.5" Magnitude plot

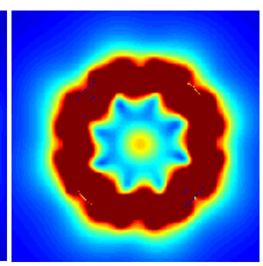

Fig. 5 w=0.5", h=0.75" Magnitude plot

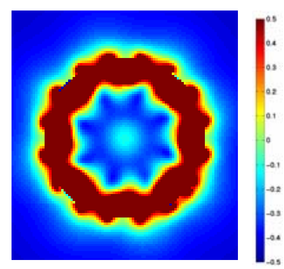

Fig. 6 w =0.5", h = 1" Magnitude plot

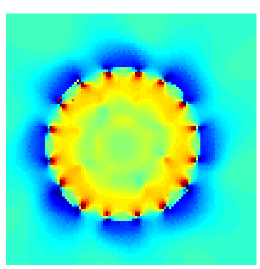

Fig. 7 50% sidewalls vs. no sidewalls

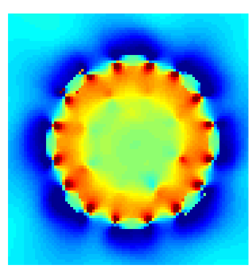

Fig. 8 75% sidewalls vs. no sidewalls

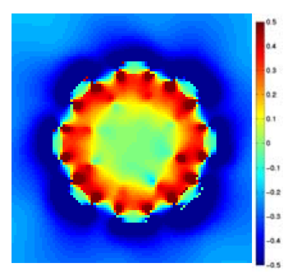

Fig. 9 100% sidewalls vs. no sidewalls