Alternating Impedance Element for 7T Multi-Channel Transceive Coil

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Objective:

RF field uniformity is a problem when imaging large volumes at 7T. In this investigation, we aim to mitigate this problem through coil element design.

Background:

The development and advancement of multi-channel transceiver coils has provided a means for signal transmission and reception at high magnetic fields[1-3]. The multi-channel volume coil can be comprised of an array of transmission line elements that are mutually decoupled and operated as independent coils in typically multiple-channel transmit and receive configurations. In these arrays, microstrip lines have been successfully implemented as magnetic field propagating elements[4]. However, in-homogeneities at high fields demand the further development of these coils. The inherent nature of the microstrip transmission line[5], B1+ distribution peaking at the center of the resonant line, needs to be homogenized or 'flattened' along the z-direction of the coil without suppressing B1+.

To flatten the B1+ field along z-direction, a multi-section alternating impedance microstrip circuit is investigated. The widths of the signal line are varied to produce an alternating low-high impedance configuration. Imaging and simulation results obtained with these coils at 7T for phantoms and in the head are presented.

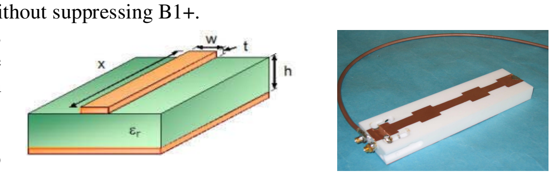

Fig 1**a)** microstrip transmission line **b)** one alternating impedance coil element

Concept:

A standard diagram for a microstrip line is shown in Figure 1. A capacitively loaded microstrip transmission line produces a standing wave with a current distribution peaking at the center of the line. There is a sharp drop-off of B1+ signal at the feed point and the terminating port of the coil compared to the middle of the resonant element (Fig 2a). This dropoff in the z-direction leads to insufficient B1+ at the top and bottom of the brain when designing head coils. To produce uniform B1+ in the z-direction, the signal line can be altered into equal length discrete segments by alternating the signal line widths in a thick-thin manner (Fig. 1b). By slightly varying the impedance along the line element, the current peak is broadened (Fig 2b).

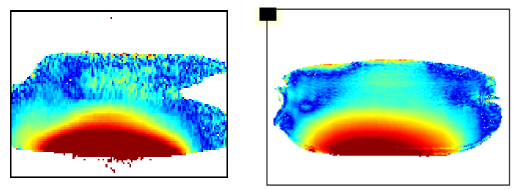

Fig 2) Experimental 7T Sagittal B1+ map for **a)** microstrip **b)** alternating impedance with 100 mM NaCl phantom

Methods:

An eight-channel transceiver array **(Fig. 5c)** was built. Each element was comprised of a low loss Teflon substrate (permittivity of 2.08) with height (h) and length (x) of 1.90 cm and 14.0 cm, respectively. The conductor widths (w) were alternated at 1.02 cm and 1.90 cm for the alternating impedance elements (4 thick and 3 thin sections). The elements were attached to a circular polytetrafluoroethylene (PTFE) plate 25.4 cm in diameter and 14.0 cm in length (x). Each element was individually tuned to 297 MHz (7 T) with decoupling capacitors between elements to achieve nearest neighbor decoupling[6], and matched to a 50-Ω, coaxial cable. Experiments were performed on a 7 T (ω_o = 297 MHz) magnet (Magnex Scientific, UK) interfaced to a Siemens console.

Numerical Maxwell solutions of the 8 channel transceiver arrays were calculated about a saline phantom (Er =80, conductivity =0.9)[7] using XFDTD version 6.3 (Remcom Inc., State College, PA). The widths along the strip were 1.02-cm and 1.90-cm wide for the alternating impedance coil and 1.90-cm for the microstrip coil. Each channel was simulated individually and later combined by using the principle of superposition into an 8 channel circular configuration by Matlab (v7.5). The available B1+ power for each coil was used to normalize each respective coil element.

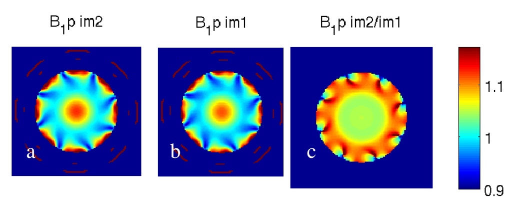

Fig 3) 8 channel B1+ simulation for **a)** alternating impedance element **b)** for microstrip **c)** ratio of alternating vs. microstrip

Results:

The B1+ axial simulations show the 8 channel alternating impedance element coil performing 7-10% better in the center of the coil (Fig. 3) while the E-fields are 10-15% less than the traditional microstrip coil indicating that the new design would have significantly lower SAR results. Imaging performance was evaluated using TSE (Resolution = 0.39 / 0.39 mm, TR/TE = 6000.00 / 84.00 ms, nominal flip angle = 130.00 deg, thk = 5.00 mm) to acquire coronal and sagittal slices (**Figures 5a, b)**. The images demonstrate good penetration and coverage. The images are homogeneous, especially, in the sagittal plane illustrating the uniformity of the new design.

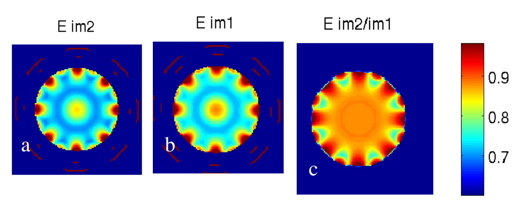

Fig 4) 8 channel E-field simulation for **a)** alternating impedance **b)** microstrip **c)** ratio of alternating vs. microstrip

Conclusions:

A novel alternating impedance element coil is introduced for high field imaging. The coil demonstrated uniform images of the head when altering the traditional microstrip line. Images acquired demonstrate homogeneity and a flattened profile. Simulations indicate higher B1+ and less E-field in the field of view when compared to the standard microstrip design. Alternating impedances in signal lines in multi-channel transceiver coils appear to be a good strategy in overcoming B1+ field fall-off and SAR limitations in high field MRI.

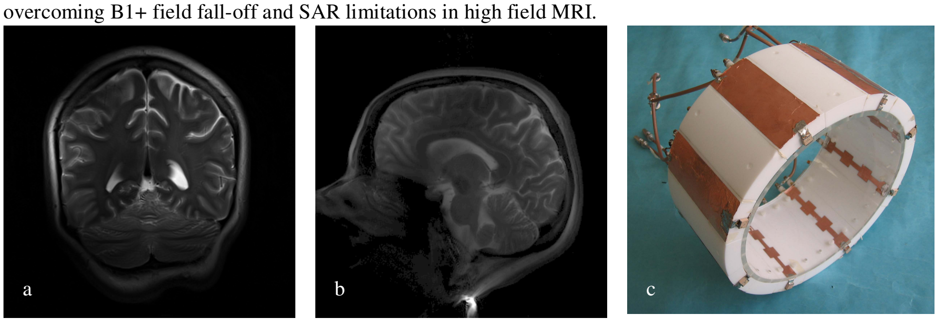

Fig 5) TSE images (TR/TE=6000.00/84 ms) **a)** coronal **b)** sagittal **c)** 8 ch. alternating impedance coil

References:[1] Roemer PB, et al. Magn Reson Med 1990 ; 16: 192-225,[2]Vaughan J.T. et al. Magn Reson Med 1994; 32: 206-218, [3]Lee RF, et al. *Magn Reson Med* 2001; **45**: 673-683 [4] Adriany,G. et al. Magn Reson Med 2005; 53(2): 434-445, [5] Wheeler H. *IEEE Trans Microwave Theory Tech* 1977; **25**: 631-647 [6]Wang, J. Proc. 4th ISMRM p.1434 (1996) [7] Gabriel C. Brooks Air Force Base, TX: Air Force material command, Al/OE-TR- 1996- 0037.

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