B1+ and Coupling Variability of Transmit Head Coils and Arrays for Ultra-High Field MRI: Simulation Studies and Experiments

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Introduction: Benchmark studies of SNR comparison of available RF coils have been done by [1] for 3T. At 7T however, the prevalent variable inhomogeneties of spin excitation and E-field distribution between different subjects can cause severe image artifacts and consequently lack of safety assurance. In this work using 7T experiments and EM simulations, we present a quantified study that systematically examines the consistency of B_1^+ field and coupling in phantoms with different load contents of a decoupled 8-loop (D-8L), a birdcage (BC) and a 4-ch. Tic Tac Toe (TTT) volume coils.

Methods: 7 plastic bottles 300cc each and total volume of 2.1 Liters were configured as shown in Fig. 1. The phantoms were filled with different saline solutions doped with CuSO4 (σ =0.46 to .76 S/m, ε_r =80) and 50% ethanol doped with saline (σ =0.44 S/m, ε_r =50). The spatially varying estimate of $|B_1^+|$ field were obtained using a 3 RF pulses α-α-β stimulated echo (STE) sequence, with 32 incremental voltages. The STE intensity is proportional to $\sin^2(\alpha)$. Read out images of 32 incremental voltages were fit with a $\sin^2$ function with two parameters amplitude and frequency coefficients: Intensity = x1*Sin (x2*pi*voltage)*Sin (x2*pi*voltage). The x2 frequency parameter is proportional to $|B_1^+|$ field. The following parameters were used for the STEAM sequence: *TR* =15 *msec*, *TR effective*=4sec, *TE* = 8.5 *msec*, *FOV* =25 *cm*, resolution 64x64, number of slices 8, slice thickness 8 *mm*, receiver bandwidth 510 *Hz*. The RF simulations were done using FDTD method and the coupling parameters were measured using a network analyzer.

Results and Discussion: The mean percentage deviation of $|B_1^+|$ estimated from the fit to a $\sin^2$ function for cases 'f, g, and j' from the homogeneous base the case 'a' are shown in Fig. 1. The mean percentage variation of B_1^+ for the TTT coil is consistently lower than the decoupled 8-loop and birdcage coils (see Fig. 1). The significant relative invariance in the B_1^+ field for the TTT coil is due to minimal coupling changes between its 4-ports. Adjacent ports (with base value of -8 dB) showed 6-8% change in its coupling, while the opposite ports (with base value of -3.3dB) showed 0.1-1.2% change in coupling for cases a through. The phantom aggregates with different liquid/gel, possessed RF properties that were similar to white matter, grey matter, muscle, fat, or cerebrospinal fluid. The B_1^+ maps/coupling have been verified with FDTD simulations as shown in Fig. 2. The presented results demonstrate the consistency of the spin excitation field in different types of RF coils at 7T.
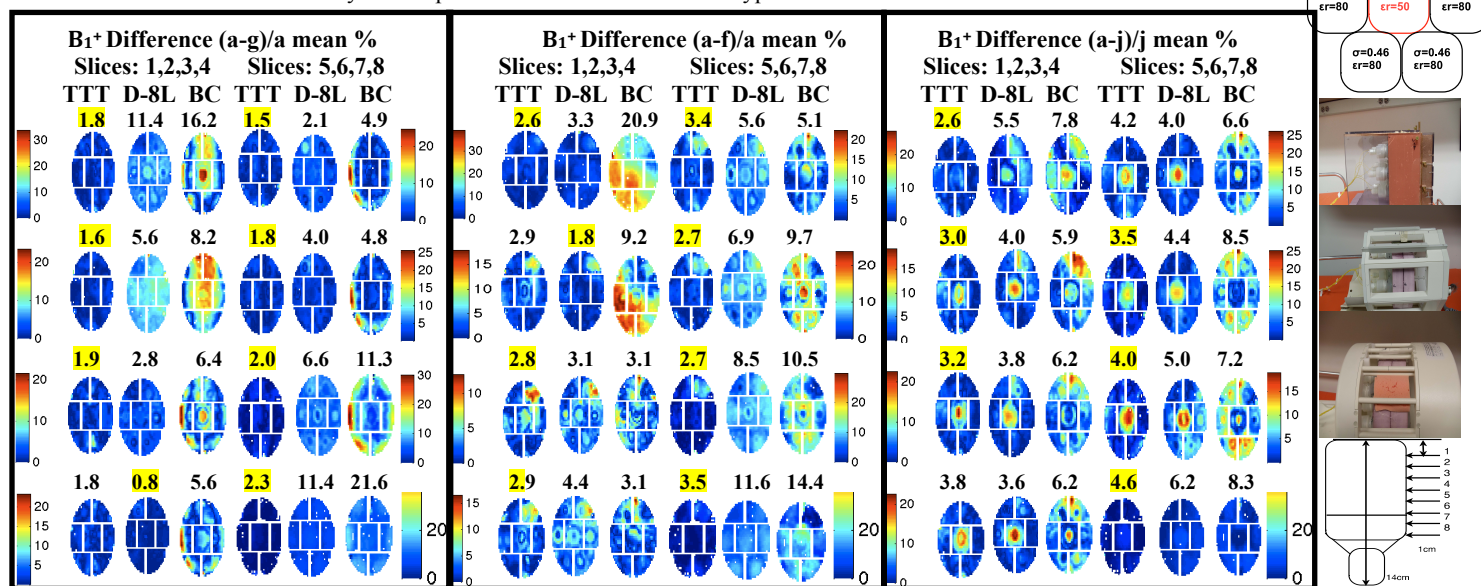

Figure 1: **Right**: Longitudinal cross section of the 7- phantom configuration showing the position of slices inside the 7-phantom configuration and pictures of the 7-phantom configuration inside the Tic Tac Toe (TTT), decoupled 8-loop (D-8L) and birdcage (BC) coils. **Top Right** corresponds to the cross-section of the content of the 7-phantom configuration; conductivity σ (S/m) and dielectric constant (ε_r) are indicated inside each compartment. Middle represents B_1^+ Field Difference: original case (always a) - new case / original case. The values above each sub-figure represent the average of the B_1^+ Field Difference across the slice. The highlighted cases represent when one coil consistency-performance outpaces the other two by at least 10%. The middle of the phantom was aligned with the middle of the decoupled 8-loop and birdcage coils. The top of the phantom was ½ in away from the TTT coil elements. Both of these alignments represent actual alignment of the human head inside each coil.
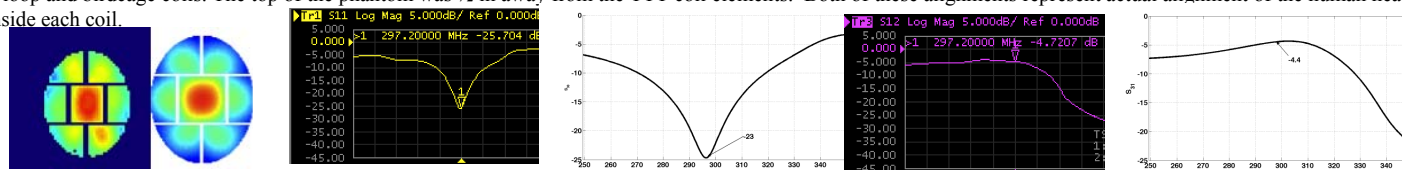

Figure 2: Verification of Experimental Results with FDTD Simulations: S-Params and B_1^+maps. **Coupling change for cases a, f, g &j not shown are: Opposite Coupling changed from base value of -3.3dB by 0.1-1.2%, while adjacent coupling changed from a base value of -8dB by 6-8%.**

References: [1] R. Mekle et.al, "MRM Vol 21 Pages 53-61.