7 tesla Localized RF Excitation/Reception Using a Highly Coupled Coil and Without B_1 Measurements

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INTRODUCTION: Transmit-SENSE and B_1-shimming have accelerated the concepts of variable phase/amplitude excitation for hardware development and implementation. Such methods however require knowledge of transmit and receive fields produced by the Tx/Rx Array. These fields are typically obtained using time-consuming B_1 measurements [1-5]. Extracting the receive field is also a challenging experimental problem. In this work using a Tx array exciting a highly coupled-coil, we present an experimental demonstration of a power-controlled, localized, B_1 (both Tx & Rx) shimming without B_1 measurements at 7T.

METHODS: ***Model:*** Utilizing an FDTD model that implements a true coaxial excitation, we have developed an 8-element, half-capped, TEM resonator model (highly-coupled coil) that was tuned to 7T. The simulations at 7T were performed using a 17.5-cm, in diameter, spherical phantom as the load. The dielectric properties of the phantom were assigned to be approximately 80 for the dielectric constant and 0.46 S/m for the conductivity. The simulations utilized a 4-port Tx/Rx configuration where every other coil element was excited and was used in reception as well. As true coaxial excitation was utilized, the precise coupling between the coil elements while the load is present is considered. Therefore, the excitation and reception on the four Tx/Rx ports can be fully manipulated with direct implementation to the experimental settings. ***Experiment:*** The simulated coil design and the phantom were constructed and built to the specifications of the simulations. Figure 1 displays the calculated and experimentally measured ***S*** (***S11, S12, S13***) parameters of the Tx/Rx array. The results (Figure 1) at 297.2 MHz (7T Larmor frequency) demonstrate that the high coupling between the coil elements is between -10dB and -11dB and also demonstrate that coaxial excitation FDTD scheme can predict the ***S*** matrix within ½ dB accuracy.

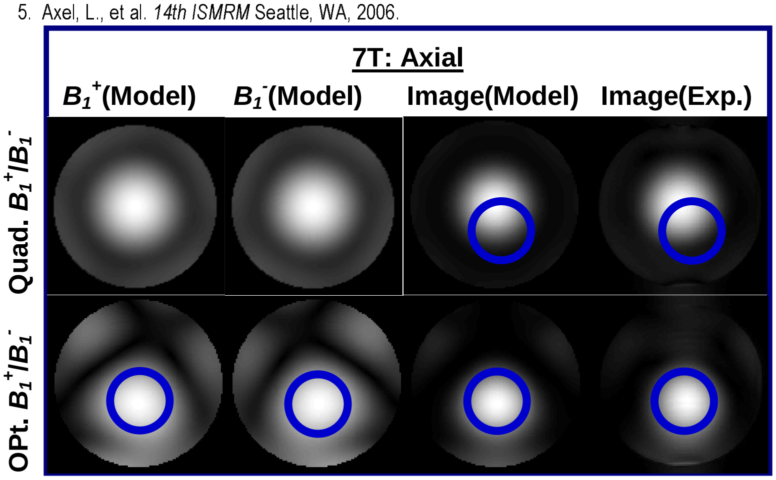
RESULTS: Using modeling, 4-port quadrature excitation/reception was simulated. Additionally, B_1 shimming using variable amplitudes and variable phase shifts (optimized for both the B_1^+ and B_1^- fields) was numerically executed to localize the low flip angle signal, i.e. maximize the mean of $B_1^+ \times B_1^-$ in regions of interest over the mean of $B_1^+ \times B_1^-$ elsewhere in the axial and sagittal planes. The optimization scheme also considered the total RF power entering the coil. Thus in all of the localized excitations, the RF power entering the coil was always kept lower than that utilized for quadrature excitation. To implement B_1 shimming on both excitation/reception, a phased-locked/amplitude controlled Tx array was used. *Without any B_1 measurements*, the phased and amplitudes obtained with modeling were directly implemented on the Tx array.

Figure 2 displays sample images obtained using the constructed coil, the Tx array, and the 7T system, and simulated using the FDTD model for 4-port quadrature and optimized excitation/reception. The circular loops in Figure 2 represent the arbitrary chosen (by the user) regions of interest (many other regions across the volume of phantom were successfully optimized as well.) Note that gradients were used to excite the 3D phantom volume; therefore the localization obtained in the presented images is purely based on RF excitation/reception.

CONCLUSIONS: The preliminary results shown in Figure 2 demonstrate that by properly modeling the load, transmit/receive array, and the excitation/reception scheme, a power-controlled B_1 shimming can be 1) guided through simulations with only a minimum of computational time required (seconds) and 2) efficiently implemented without any B_1 measurements. These developments can pave the way for a fully automatic, subject specific, B_1 homogenization/localization scheme for ultrahigh field human MRI.

REFERENCES:

1. Stollberger, R. and P. Wach, MRM, 1996. **35**(2): p. 246-51.
2. Kroeze, H., et al. *14th ISMRM* Seattle, WA, 2006
3. Daniel, G., et al. *14th ISMRM* Seattle, WA, 2006.
4. Morrell, G. *14th ISMRM* Seattle, WA, 2006
5. Axel, L., et al. *14th ISMRM* Seattle, WA, 2006.



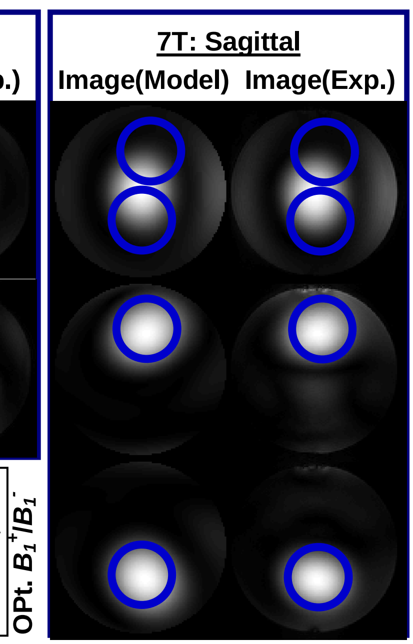


Fig. 2: Calculated B_1^+/B_1^- fields/images and experimental images obtained using a 7T scanner, phase/amplitude-controlled Tx array, and a highly-coupled 4-port Tx/Rx coil. B_1 shimming (on both B_1^+/B_1^-) was based fully on simulations, without any B_1 measurements. Each of the optimizations achieved **2/2.5-to-1 SNR localization** (within the slice of interest) and **40%-46% lower total RF power** compared to quadrature excitation.

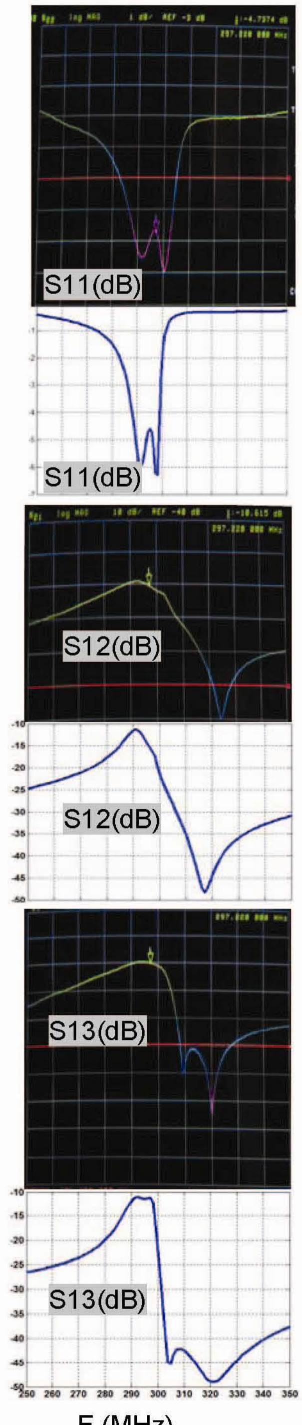


Fig. 1: S parameters measured using a network analyzer and calculated using the FDTD method.