Simulation Tool for 3T/7T Subject-Specific Multi-Transmission Applications without RF Measurements

T. S. Ibrahim[1], L. Tang[2], and Y-K. Hue[3]
[1]University of Pittsburgh, Pittsburgh, PA, United States, [2]University of Oklahoma, [3]University of Pittsburgh

INTRODUCTION:

Previous electrodynamic numerical modeling efforts have demonstrated the ability to predict the transmit (B_1^+) field and the receive (B_1^-) fields produced/received by RF coils as well as coil/array's coupling matrix. Significant doubts remain however if such modeling techniques can directly aid in performing a complete multi-transmission (B_1 shimming (1-3) or transmit SENSE (4-6)) experiments at 3T and 7T. In this work we present a modeling mechanism that can accurately perform subject-specific B_1 shimming and account for local/global SARs (without performing RF field measurements.) This model is capable of 1) maximizing the intensity of the B_1^+ field in an ROI, 2) homogenizing the distribution of the B_1^+ field in an ROI, 3) minimizing the average/local SARs over the whole load. The technique was successfully tested on 3T and 7T whole-body systems equipped with multi-Tx (8-channel) array excitation systems and using both *coupled and decoupled* transmit arrays.

METHODS:

The electrodynamic modeling approach has an excitation/reception mechanism that accurately resembles the electromagnetic interactions at the locations where the feeding meets the transmit arrays. Since the excitation mechanism is independent of the transmit array geometry, the accuracy of the scheme is not dependant on the geometry/physics of transmit array used. Depending on the properties of the transmit array, numerically producing B_1 field distributions from all the elements of the transmit array require few (2-8) hours on a single-CPU computer. The manipulation of the RF fields in order to achieve a targeted excitation profile (both B_1^+ as well as local/average SAR) only require few (≤5) minutes for as many as 16 amplitudes and 16 phases using Matlab on a standard desktop.

We have successfully experimentally tested the proposed B_1 shimming scheme on variety of multi-transmit RF arrays (coupled TEM transmit arrays at 7T) and un-coupled loop arrays at 3T and phantoms (spherical and cylindrical phantoms with different loading properties). The presented sample results were obtained at 7T using a 4-port (coupled) TEM transmit array and at 3T using an 8-port (decoupled) loop transmit array.

RESULTS:

Figures 1 and 2 present B_1^+ shimming using RF simulated fields and without RF measurements for 3T (1) and 7T (2), respectively. The 7T focused and homogenous 3D B_1^+ shimming was achieved with successful minimization of 1) local SARs, 2) global SARs, and 3) the variation in the B_1^+ field distribution in the denoted ROI. The 3.9 μT represent maximum B_1^+ intensity (in ROIs denoted in the 3D figures as cylinders with 7/8in in radius 1in in height) instantaneously below 8 Watts per Kg per 1 gm. The experimental/simulated coefficient of variation of the B_1^+ distribution in the targeted ROIs = 0.099/0.098 resembling highly homogenous excitation field. The average SAR associated with 8 Watts per Kg per 1 gm local SAR was approximately 2 Watts per Kg. The mean B_1^+ intensity in the targeted region of interest was improved by at least 5 folds over standard 4-port quadrature operation.

The results show excellent correlation between the experiment and simulation.

Acknowledgements: NIH R01EB, Siemens, ADRC

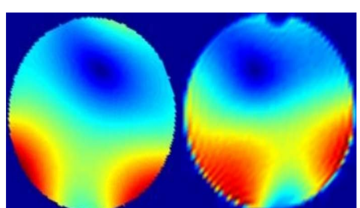
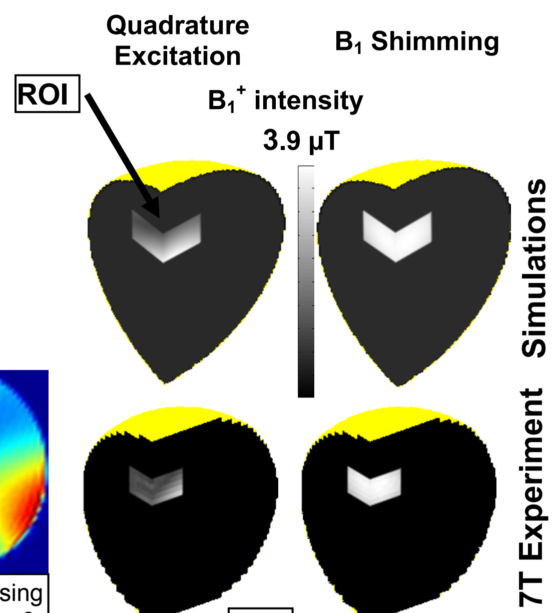


Fig. 2: **3T** B_1^+ shimming using RF simulation fields and 8-channel decoupled loop Tx/Rx array. As the quadrature excitation mode excited fairly uniform B_1^+, a more distinctive pattern was intentionally excited (simulation: left and experiment: right.)



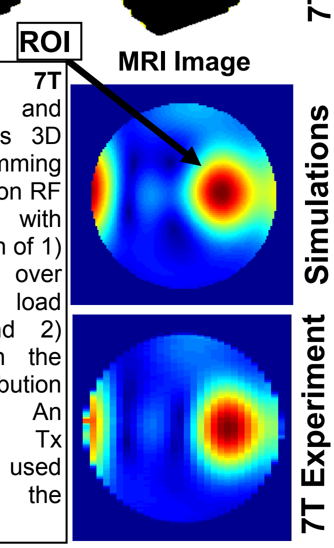


Fig. 2: **7T** focused and homogenous 3D B_1^+ shimming fully based on RF simulations with minimization of 1) local SARs over the whole load volume and 2) variation in the B_1^+ distribution inside ROI. An 8-channel Tx Array was used in the experiment.

References:

1. Hoult DI. J Magn Reson Imaging 2000;12(1):46-67.
2. Ibrahim TS, et al. Magn Reson Imaging 2000;733-742.
3. DelaBarre L, et al. ISMRM 2006 May; Seattle. p 2619.
4. Katscher U, et al. Ieee TMI 2004;23(4):520-525.
5. Setsompop K, et al. Magn Reson Med 2006; 1163-1171.
6. Zhu Y. ISMRM 2006 May; Seattle. p 599.