Patch Antenna in Comparison to and in Combination with a Volume Coil for Excitation at 7T: Whole-brain B1 shimming and Consequent SAR

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Introduction: Traditionally, volume coils and arrays are used to produce the B_1 field for nuclear excitation, producing RF fields that travel into the region of interest in a roughly radial direction [1, 2]. Recently, a new approach of intentionally using the MRI system bore (with a diameter of 60cm or more) to carry a wave traveling along the axis of the bore at frequencies above about 300 MHz was shown to be feasible [3]. Here we use numerical models to perform comparison and combination of these two different approaches for producing a homogeneous B_1 field in the human brain and examine the resulting SAR levels.

Method: We simulated a human body [4] within a 60cm-diameter system bore along with a TEM-type [1] volume coil centered about the head and with a large circularly-polarized patch antenna at the end of the bore (Fig. 1). Fields were calculated from each of two orthogonal channels for both of these coils, making a total of 4 transmit channels. Use of only two channels on a body coil in this fashion has produced promising results in body imaging at 3T [5]. Field calculations were performed at 300 MHz using commercially-available software (xFDTD; Remcom, Inc., State College, PA). Using optimization routines, we determined the combination of magnitude and phase for the channels in each antenna alone, and also for both together, that could produce the most homogeneous excitation throughout the brain volume. The optimization was performed using routines coded in Matlab (The Mathworks, Natick, MA).

Results: Fig. 2 shows the optimal distribution of the transverse magnetization (M_t, equal to the sine of the flip angle) in the brain for the patch antenna and volume coil separately and together before (top) and after (bottom) RF shimming at 300MHz. Results before shimming within brain for the antennas separately are similar to those seen in experiment for a patch antenna compared to a head-sized volume coil [6]. Because the target excitation in this work is a 90 degree pulse, by our method the best achievable M_t at each location would be 1. Table 1 shows the mean and standard deviation of M_t in the brain, maximum one-cell and average SAR in the head before and after optimized excitation with each of the antennas individually and with the patch antenna and volume coil combined. The most homogeneous (highest mean and lowest standard deviation) occurs when all antennas are used simultaneously. This case also has the lowest average and maximum local SAR.

Discussions: As shown in Fig. 2 and Table 1, although an antenna at the end of the bore producing fields that travel to the subject primarily in the axial direction provide an alternative excitation method, by themselves they do not necessarily produce more homogeneous excitation patterns or lower SAR than a conventional volume coil – at least within the brain volume. When used in combination with the volume coil, however, excitations more homogeneous than achievable with either antenna alone can result. In order to fully evaluate benefits of these different approaches alone and in combination with each other it will also be necessary to perform optimization including consideration of the SAR, and with more independent channels in the body array. It is anticipated that with more variables (channels) available in the optimization will also provide the most flexibility in homogeneity and SAR. Future work will also examine relative advantages of different approaches considering other parts of the anatomy, such as heart, prostate, and knee.

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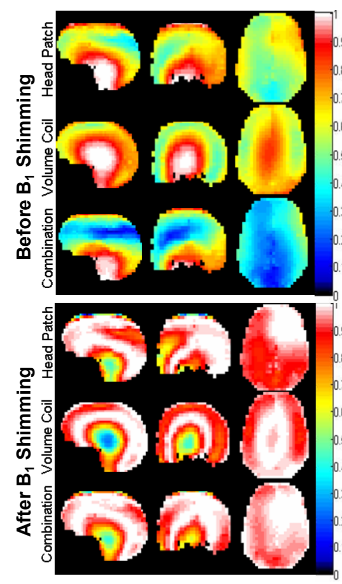

Figure 2 Distribution of M_t (or sine of the flip angle) before (top) and after (bottom) B_1 shimming throughout the brain for the patch antenna (first row), volume coil (second row), and combination of both (third row).

Table 1 Comparison of Mean $|M_t|$, Standard Devitation of $|M_t|$, avg. SAR in the head, and max one-cell SAR after B_1 shimming for the head patch, volume coil, and combination of them

	Head Patch	Volume Coil	Combination
Mean $\|M_t\|$	0.90160	0.90386	0.92567
SD of $\|M_t\|$	0.13121	0.12477	0.10283
Head-Avg. SAR (W/Kg)	0.10475	0.09167	0.06973
Max 1-cell SAR (W/Kg)	1.1384	1.4862	0.74549

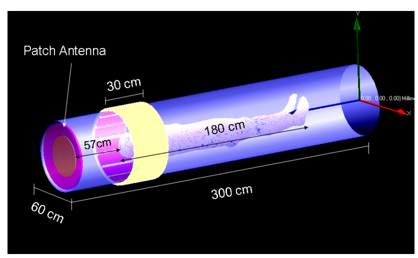

Figure 1 Model used for Numerical simulations.