RF B1 field localization at 9.4T through convex optimization with an iterative method

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Introduction: The impetus of this work originated from the advent of high magnetic field magnetic resonance imaging scanners with B_0 fields of 4T, 7T and 9.4T. These ultrahigh magnetic field systems generally improve the signal to noise ratios. However, B_1 field non-uniformity also occurs due to the increased RF field frequencies when wavelengths in the head become shorter than its size. As interest in multiple channel transmission line coils increases, the control of the amplitude and phase of individual coil elements is required in order to develop desired B_1 field. The choice of the excitation of the coil elements may be determined by convex optimization. Convex optimization is used provides results very fast, when the problem is formulated globally. In addition, convex optimization provides better signal to noise (SNR) ratio when anatomic specific regions are investigated. Although the previous results with convex optimization shows these advantages, problems remain, including high field distribution at the edges and non-homogeneity in suppression region. In this paper, a better approach is demonstrated with an iterative method which makes this method more useful. Simulation results are discussed at 9.4T systems based on the number of elements.

Convex optimization: The primary objective of this study is to increase the signal in a specific target region and decrease the signal and noise in the outside region termed the suppression region. Since B_1^+ is proportional to w which is the linear amplitude and phase of the each generated element, the positively polarized transmit field with w at each element may be written as $\sum B_1^+ w$ for the total field representation. The following are basic convex formulations which satisfy the initial objective,

$$minimize \quad max\left|B_{1,s}^+ w\right| \quad s \in Suppression\ Region, \quad subject\ to \quad B_{1,c}^+ w = 1 \quad c = Center\ of\ Target \qquad [1]$$

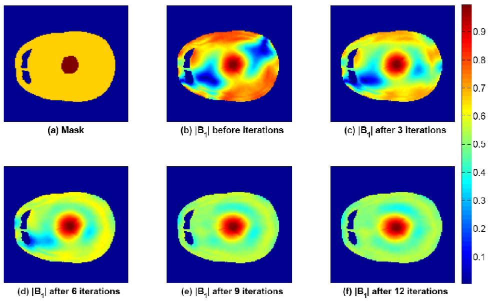
where $B_{1,s}^+$ and $B_{1,c}^+$ represent B_1^+ in the suppression region and at the center of the region of interest (ROI) respectively.

Iterative method: Based on min-max optimization criterion, the selection of $B_{1,s}^+$ is critical to a proper design of w at the given $B_{1,c}^+$ because these vector fields are correlated with each other in terms of the solution of w. The homogeneous coefficient H in the suppression region is defined as $H = \left(\sum_{i=1}^{n}\left|B_{1,i,s}^+ w\right| - M(w)\right)/n$ where $M(w)$ is an absolute mean value of $B_{1,s}^+ w$ and n is the number of pixels in the suppression region. The iterations are performed by comparing the H_{new} of the solution to H_{old} of the previous solution to minimize H by modifying $B_{1,s}^+$.

Simulation results: The results of the localization on FDTD human data at 9.4T are shown in Figure 1 and 2. In these figures, the axial slices of the center of human head model provided by XFDTD are used after manipulating with MATLAB and the 16 channel head coil is excited. Fig. 1 and 2 show an improvement of the homogeneity in the suppression region when the target region (dark brown in Fig. 1(a)) is at center. As shown in Fig. 1(b), this $|B_1|$ distribution comes after solving Eq. [1] based only on the mask in Fig.1 (a). Although the $|B_1|$ field is desirable in the target region, it is not large enough to distinguish it from the noise of the whole region due to a poor homogeneity in the suppression region. To avoid this, the modified $B_{1,s}^+$ from new excitation parameters is applied iteratively. As seen in Fig. 1(b-f), the homogeneity is improved significantly whereas $|B_1|$ on the target remains almost constant. Fig. 3 illustrates the $|B_1|$ field distributions depending on the position of ROI and compares the results from the 16 and 32 channel coil on FDTD phantom model studies. More homogeneous suppression regions in the 32-channel simulations are obtained.

Conclusion: Convex optimization with an iterative method was performed on both the human head and phantom models with operating frequency 400MHz to design coil channel excitation parameters. Although the previous convex optimization without iterations generates large signals in the target region, the poor homogeneity is still problem in the suppression region. By applying the iterative method to the convex optimization, however, more homogeneous B_1 fields are obtained in the suppression region for 9.4T system.

References: (1) Vaughan J et al, MRM 2001:24-60 (2) Vaughan J et al, MRM 2006:1274-1282 (3) Olson C, Master's thesis, University of Minnesota 2007 (4) Van de Mortele P-F et al, MRM 2005:1503-1518 **Acknowledgements:** NIH R01-EB006835, BTRR P41-RR008079, and Keck Foundation.



(a) Mask (b) $|B_1|$ before iterations (c) $|B_1|$ after 3 iterations

(d) $|B_1|$ after 6 iterations (e) $|B_1|$ after 9 iterations (f) $|B_1|$ after 12 iterations

Fig. 1. FDTD human head model results at 9.4T

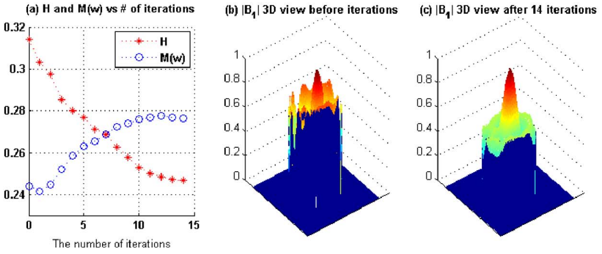


Fig. 2. 3D view before & after iterations

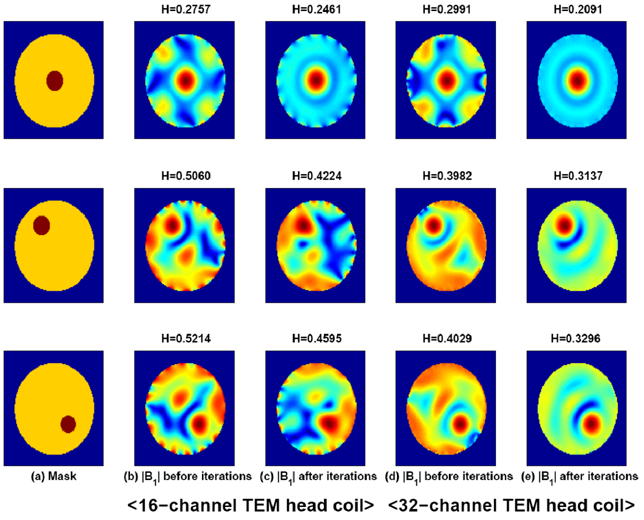


Fig. 3. FDTD results at 9.4T in a phantom model. The 16-channel ((b),(c)) and 32-channel TEM coil ((d),(e)) are driven.