Optimal Multiple-element Driving Configuration Depends on Head Geometry, Placement, and Volume of Interest

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INTRODUCTION: Although at low RF frequencies coil design can be performed using field calculations that neglect the presence of the human sample, at high frequencies (above, say, 100MHz) interactions of the RF fields with the sample become significant, resulting in serious obstacles to obtaining uniform images. One method that can be used to gain an advantage in this environment is to adjust the phase and/or magnitude of the separate elements in a transmit/receive coil during transmission (1-3). Here we examine how the phases and magnitudes required for generation of optimally uniform images vary as a function of head geometry, placement of the head in the coil, selection of a volume of interest, and definition of the criteria for a “homogeneous” image.

METHODS: The finite-difference time-domain method was used to model two different heads (5mm resolution) in different locations within 8- and 16-element phased array coils at 300MHz (2). The field produced by each tuned element was calculated and saved. All FDTD calculations were performed with the aid of commercially available software (“xfdtd”; www.remcom.com). Then the results were loaded into a home-built Matlab routine and the phase and/or magnitude of the driving voltage of each element was automatically varied until a configuration yielding an optimally homogeneous image intensity distribution in various volumes of interest were found. Here image intensity is calculated as if parallel acquisition was used, but with full k-space sampling. Image intensity at one location is thus calculated as $|\sin(\gamma\tau\Sigma_N B_N^+)|\ \Sigma_N|B_N^-|$ where B_N^+ and B_N^- are the circularly-polarized components of the RF magnetic field created by element N that rotate with and counter to nuclear precession, respectively, γ is the gyromagnetic ratio, τ is the pulse duration, Σ_N indicates a summation over the N elements of the coil, and pairs of vertical bars indicate that a modulus is to be taken.

RESULTS: A representation of head 1 in the 8-element coil is given in Figure 1. Figure 2 shows the sin(flip angle), receptivity, and signal intensity distributions for head 1 in the 8-element coil at 64 and 300 MHz after optimization. Results indicate that by using parallel imaging methods greater homogeneity may be achievable at high fields due to the combination of centrally enhanced fields during transmission and greater receptivity near elements. Figure 3 shows signal intensity distributions (including weighting for water content) on an axial slice through the brain of two different head models before and after optimization in the 16-element coil array. The driving phases (and magnitudes) in each element required to produce an optimally homogeneous field varied by several degrees (or percent, for magnitudes) depending on which head model was used in optimization, the placement of the model in the coil, the volume of interest defined for optimization, and the mathematical criteria defined for quantitation of homogeneity. Still, use of the phases and/or amplitudes determined to be optimal in one situation would usually result in an improvement from the original (quadrature) configuration in another situation.

DISCUSSION: Due to the difference in required magnitudes and phases to achieve an absolute optimum in one situation (head/placement, volume of interest) it may be important to work towards systems where RF driving amplitudes and phases can be automatically optimized for each experiment, much as the B_0 field is typically automatically shimmed for each experiment.

REFERENCES:

1) Vaughan, et.al. MRM 32:206-218 (1994)
2) Vaughan, US Patent 6,633,161 (2003)
3) Ibrahim et al., MRI 19:1339 (2001)

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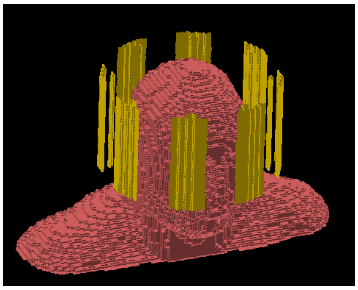

Figure 1: Shaded surface representation of one 3D head model within 8-element coil model.

Figure 4: Linear colorscale used in Figures 2 and 3.

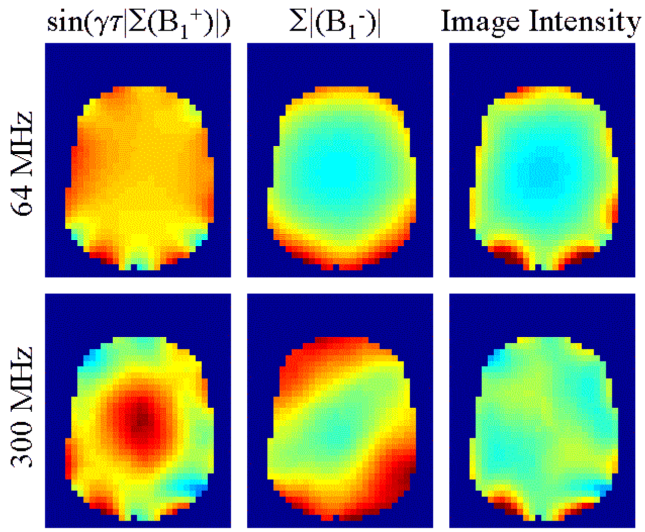

Figure 2: Sin(flip angle) (left), receptivity (center), and signal intensity (right) distributions for head 1 in 8-element coil at 64 and 300 MHz after optimization. Results indicate that greater homogeneity may be achievable at high fields by using parallel imaging methods due to the combination of centrally enhanced fields during transmission and greater receptivity near elements.

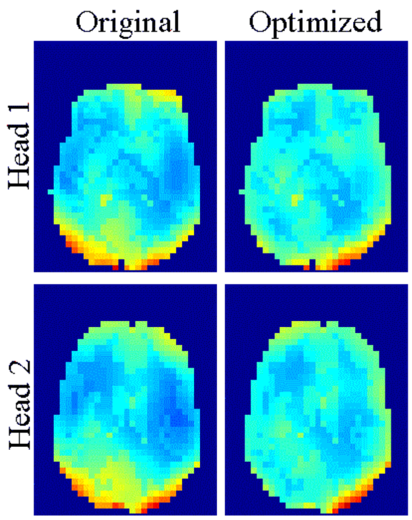

Figure 3: Signal intensity distributions (including weighting for water content) on axial slice through brain of two different head models of differing geometry before (left) and after (right) optimization in the 16-element coil.