Combination of Transmit Array and Parallel Reconstruction Can Yield Homogeneous Images at Very High Frequencies

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INTRODUCTION: RF wavelength and interference effects present significant problems in attempts to achieve uniform signal intensity distributions in high field MRI. Previous studies considering reception with a phased array coil but with no parallel reconstruction techniques showed some improvement when the magnitude and phase of array elements were varied during transmission. Effective parallel imaging reconstruction algorithms use receptivity distributions from different coils to solve for available signal intensity ("spin density") (1), and receptivity distribution ideally does not affect signal intensity distribution on the final image, though SNR becomes a function of location in the final image (2). Here simulations are used to show that very homogeneous images in the human head can be acquired with the combination of these two techniques at frequencies as high as 470 MHz.

METHODS: The finite-difference time-domain method was used to model a human head within a 16-element, elliptical, stripline coil array at 300, 400, and 470 MHz. The field produced by each element was calculated and recorded. Then the results were loaded into home-built Matlab codes and a simple optimization routine was used to vary the magnitudes and phases of the individual coils with the goal of improving homogeneity of the available signal intensity distribution, calculated as

$$|\sin(\gamma\tau\Sigma_n \mathbf{B}_n^+)|$$

where γ is the gyromagnetic ratio, τ is the pulse duration, and the summation of the circularly-polarized vector components $\mathbf{B}^+$ is performed for n=1 to 16 coils in the array. Here it is assumed that due to application of effective parallel imaging reconstruction methods the receptivity distribution of the individual coils will not affect apparent signal intensity distribution on the final image. Calculation of signal intensity is more involved when parallel reconstruction techniques are not applied (3), or when parallel reconstruction techniques are greatly affected by noise or other suboptimal conditions.

RESULTS: A representation of the head model in the 16-element elliptical stripline array is given in Figure 1. Figure 2 shows the available signal intensity distribution in the coil at 300, 400, and 470 MHz before and after optimization. After finding optimal coil magnitudes and phases, the signal intensity distribution is very homogeneous at each frequency.

DISCUSSION: Initial indications are that the combination of transmit phased array coils and application of parallel reconstruction techniques can yield very homogeneous images in the head at very high frequencies. This is another argument for the use of parallel imaging techniques in high field MRI. It has also been shown that parallel imaging techniques themselves will likely become more effective in high field imaging (4). Implementation of such a transmit system may be facilitated in the future with voltage-controlled current sources to force the desired currents in individual elements (5).

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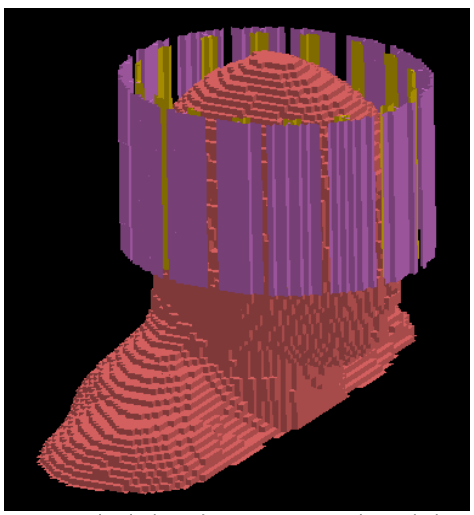

Figure 1: Shaded surface representation of the 3D head model within the 16-element elliptical array.

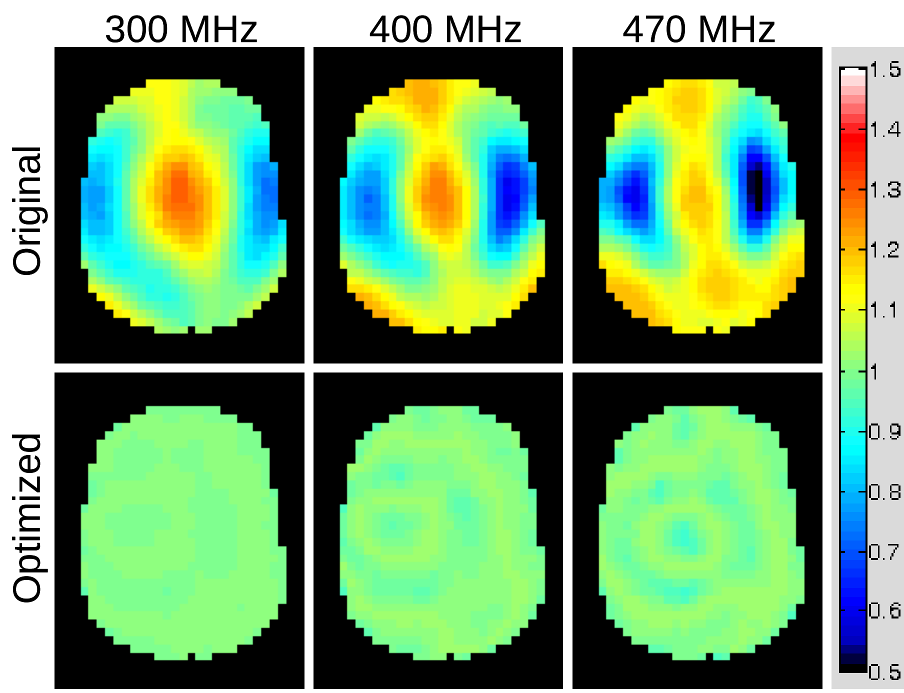

Figure 2: Signal intensity distributions for head in 16-element array at 300, 400, and 470 MHz before and after optimization of homogeneity by variation of magnitude and phase of currents in transmit coils. Scale gives fraction of mean intensity value on plane shown. Even at 470 MHz, all intensity values are within 7% of the mean.