Low Coupling With Low g Factor Using Venetian-Blind Arrays

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Introduction: While spatially separating coils within an MRI receiver-coil array has been shown to improve SNR for parallel imaging [1-2], recent many-channel parallel-imaging arrays [3-6] have followed an overlapped design to minimize coupling between nearest neighbors. Even in these designs, however, coupling between more distant neighbors remains, which can result in significant detuning of coils for large arrays. An alternative to overlapping coils is to tilt them on edge at a shallow angle to eliminate the mutual inductance between neighbors. It is anticipated that underlapped, tilted coils will exhibit some degradation in baseline SNR relative to overlapped coils. The purpose of this study was to determine whether this effect is compensated by improvements in *g* factor and the lower overall coupling of tilted arrays.

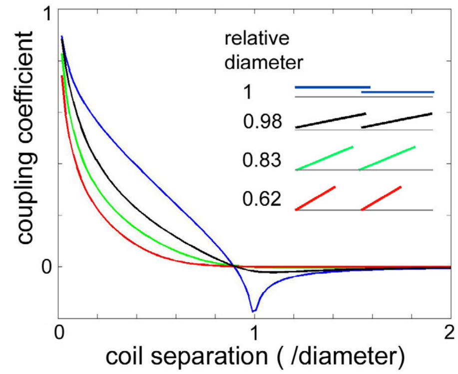

Fig 1. Coupling for flat and tilted coils, as function of coil separation (relative to flat-coil diameter).

Methods: Simulations were performed using MATLAB (MathWorks, Natick, MA) for linear arrays of 5 coils laid out in an A/P plane, with coils running along the L/R direction. The field strength was assumed to be 1.5 T (dielectric effects were ignored). Vector potentials and magnetic fields were calculated for each coil of the array and used to calculate baseline SNR, mutual inductance, noise-resistance matrix, *g* factor, conditioning, and accelerated SNR over coronal planes at various depths. These simulations were applied to a number of different arrays, all of which had the same overall spatial extent. These arrays included one with nearest neighbors overlapped to give zero mutual inductance, one underlapped by an amount which maximized the accelerated (x4) SNR at a depth of one coil diameter, and one similar to the previous one, but with each coil tilted on its right edge like a Venetian blind by an amount which zeroed the mutual inductance between nearest neighbors.

An array of five 8-cm square coils was assembled to test predictions of the simulations. A rectangular $CuSO_4$ salt-loading phantom was constructed which loaded the coils by the same amount as a typical human torso. The coils were arrayed in the L/R direction on the phantom, and gradient-echo images were acquired from a number of axial and coronal planes. 16 images were acquired from each location, and SNR at each pixel was calculated by taking the average and standard deviation of image intensity across images. Measurements were made for overlapped coils and for underlapped coils tilted in the L/R direction by an amount that nulled the mutual inductance between nearest neighbors. For tilted coils the input capacitors were retuned to match the loaded impedance to 50 Ω.

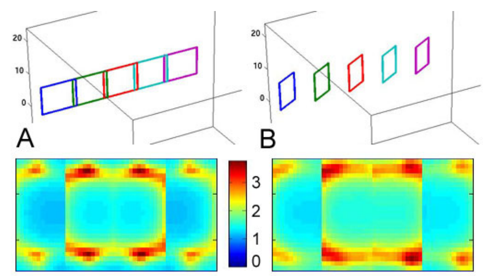

Fig 2. *g* maps for coronal plane for (A) overlapped, and (B) underlapped, tilted coils.

Results: Simulations (Fig. 1) showed that while overlapped coils (blue curve) had no coupling at a separation of ~0.9 diameters, the tilted coils (black, green, red) were decoupled over a much wider range of coil spacing. Figure 2 shows simulated *g*-factor maps for 4-fold acceleration in a coronal plane at a depth of one coil diameter for (A) overlapped and (B) underlapped and tilted coils. The average *g* factor was 1.76 for overlapped and 1.73 for tilted coils. Both average baseline SNR and 4-fold accelerated SNR were within 3% of one another for the two arrays. At a depth of two coil diameters the accelerated SNR of the tilted array was identical to that of the overlapped array. Average measured SNR for 4-fold accelerated images from the phantom experiments showed the tilted array within 7% of the overlapped array at a depth of one coil diameter, and slightly better than the overlapped array at a depth of 2 diameters.

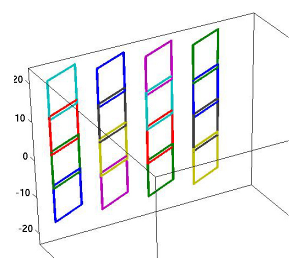

Fig 3. 2D array overlapped in S/I and tilted in L/R

Discussion: The wider "no-coupling" zone for tilted arrays predicted by simulations (Fig. 1) was also experienced in practice; unlike overlapped arrays, tilted arrays assembled under monitoring with a vector impedance meter showed little effect as new coils were added to the array. While there appeared to be little difference in SNR between overlapped and tilted arrays, tilted arrays may be useful because of the relative ease of construction arising from the essential independence of each coil in the array. This takes on more importance for dense 2D arrays, where aggregate coupling from non-nearest neighbors can be substantial. Early modeling of this case (e.g. Fig 3) shows promise.

References:

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