Experimental Comparison of Array Coil Overlap Strategies for Maximal SNR

T. Charlton[1], A. Maunder[1], B. G. Fallone[1,2], and N. De Zanche[1,2]
[1]Dept. of Oncology, University of Alberta, Edmonton, Alberta, Canada, [2]Dept. of Medical Physics, Cross Cancer Institute, Edmonton, Alberta, Canada

Introduction

Inductive coupling has long been recognized as a source of crosstalk in surface coil arrays, and is traditionally minimized by a combination of coil overlap and preamp decoupling [1]. Recent measurements [2] have shown that coil overlap introduces significantly higher noise correlations compared to gapped coils, but it was unclear whether this translates into differences in SNR of acquired images since both signal and noise coupling depend on a combination of magnetic and electric coupling. In this work we compare the SNR performance of three array designs that use different decoupling strategies.

Methods

Three arrays (Fig. 1) were constructed using 7-mm-wide copper tape and placed on a 36 × 10.5 × 25.7 cm^3 tank filled with a solution of demineralized water, 3.6 g/ℓ NaCl and 1.96 g/ℓ $CuSO_4 \cdot 5H_2O$ for matching to 50 Ω and imaging. Each loop includes a matching and detuning circuit similar to that of Ref. [3] and is connected to a low-input-impedance preamplifier (Philips Healthcare, Cleveland, OH) for preamp decoupling [1] using a λ/2 cable.

The gapped array consists of eight square (7 × 7 cm^2) coils separated by 4 mm gaps for a total size of 14.4 × 29.2 cm^2. The overlapped array was designed to have the same overall width as that of the gapped array (i.e., approximately equal FOV), while individual coil width was determined by minimizing inductive coupling between nearest neighbors resulting in a coil size of 8 × 8 cm^2. Array length was 2.0 cm shorter than the gapped array to avoid unnecessarily large coils that would unfairly lower the SNR. Diagonal coil extensions were used to minimize inductive coupling between diagonal neighbors.

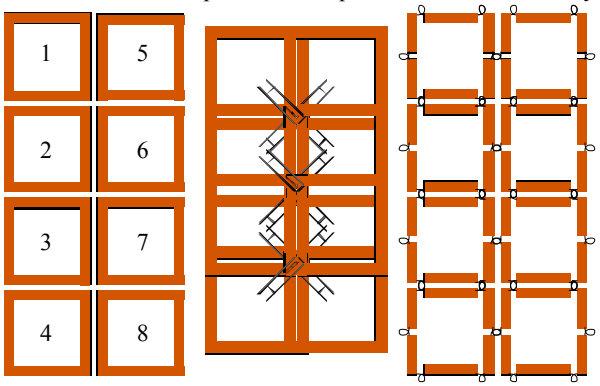

Figure 1: gapped, overlapped, and inductored arrays including channel numbering (capacitors and matching not shown).

The inductored array was geometrically identical to the gapped array but with 2-turn (0.8 mm Cu wire) transformers between nearest neighbors to cancel mutual inductance. Electrical symmetry was preserved by similarly adding 2-turn inductors to the outer sections.

Noise samples and images were acquired on a 3 T Philips Achieva using a standard gradient-echo sequence (256 × 256 matrix, 30 × 30 cm^2 FOV, 10 mm slice thickness, T_R/T_E = 11/2.0 ms). Single-coil images were combined using covariance-weighted root-sum-of-squares [1]; all analysis was performed using MATLAB (The Mathworks, Natick, MA).

Results

The first two rows of Fig. 2 show (left to right) a decrease in SNR and an increase in noise correlation. Left-right asymmetry is due to transmit B_1 inhomogeneity in the large dielectric phantom. Overall the noise covariance matrix (Ψ) also increases (not shown), as described by the product of its eight eigenvalues, i.e., the determinant, |Ψ|. SNRs of the first row multiplied by the relative magnitude of $\sqrt[8]{|\Psi|}$ (respectively 1, 1.18, and 1.24) are shown in the last row of Fig. 2 where the SNR values of all arrays appear equivalent neglecting spatial inhomogeneities due to geometrical differences.

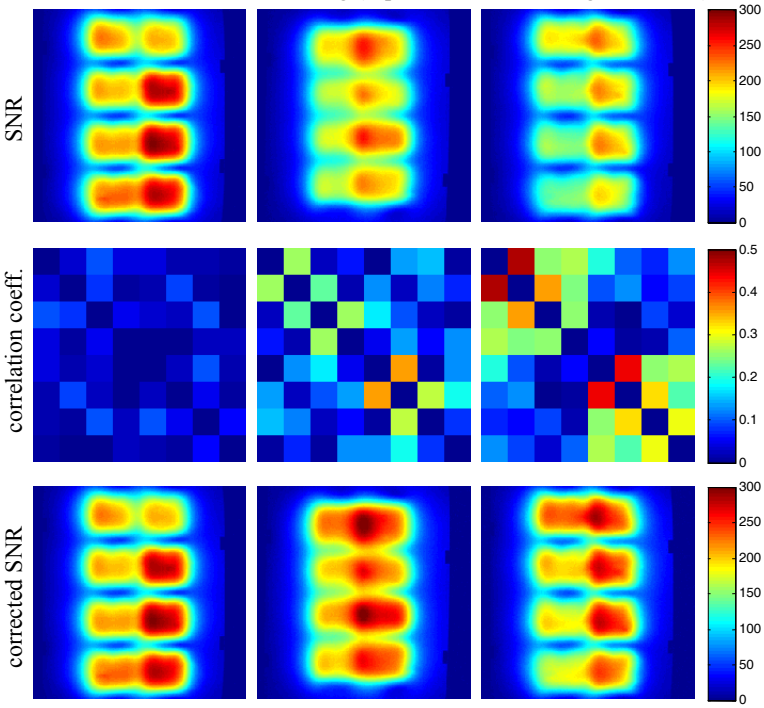

Figure 2: for each of the respective arrays: SNR, correlation coefficient (diagonal zeroed), and SNR corrected for determinant of the covariance matrix

Discussion and Conclusion

We conclude that high noise covariances translate directly to low SNR, and therefore, contrary to the industry-standard overlapped design, the gapped array produces approximately 18% better SNR. This is due to how coil proximity and overlap enhance coupling through mutual resistance, which arises from the electric fields [4]. Preamp decoupling [1] is sufficient to manage inductive coupling in all designs, hence the use of overlap or inductors to null mutual inductance is redundant and, overall, counterproductive. Since a strategy equivalent to preamp decoupling doesn't exist for electric fields the design goal should be to minimize mutual resistance (and noise covariance in general) by gapping the coils (zeros can actually be found with large separations [4,5]) while covering as much of the surface as possible.

References

1. Roemer et al. Magn. Reson. Med. 16(2): 192–225 **2.** De Zanche et al. ISMRM 2008 p.1073 **3.** Barberi et al. Magn. Reson. Med. 43(2): 284–289 **4.** Wright Concepts MR 15(1): 2–14 **5.** King ISMRM 2000 p.1406

Acknowledgements: we acknowledge funding from the Natural Sciences and Engineering Research Council (Canada), Alberta Cancer Research Institute and Canada Foundation for Innovation; we thank Dr. Roger Luechinger for the PATI program used for data transfer and Dr. Nikolai Avdievich for suggesting the inductored array.