A 6-element Array for Parallel Wrist Imaging at 3 Tesla

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Introduction

Parallel imaging is known for providing performance gains while requiring dedicated receiver coil arrays. Since imaging performance is known to improve with the number of independent coils in the array, we have designed and built a versatile 6-element array of miniature coils to take advantage of improved SNR as well as SENSE[1] acceleration in the wrist region. Comparable commercial coils with 6 channels are currently not available.

Coil Construction and Characterization

Imaging of small regions such as the wrist using an array of coils requires that each coil be physically small to maximize signal strength and localization while being located as close as possible to the imaging region. Based on the average dimensions of the human wrist and desired field of view, the shape of each coil loop was chosen to be a 3.5×7cm rectangle (Fig. 1). This allows the 6 coils to be distributed tightly around the wrist in a hexagonal arrangement. Each rectangular loop was connected to a high-impedance, low-noise preamplifier through a matching network to minimize the effects of inductive coupling[2] and achieve optimal noise figure[3].

The coils' individual noise performance was characterized by imaging a large aqueous phantom with a single coil. All images were acquired on a Philips Intera 3T system. Measurements of SNR under different loading conditions initially suggested that the sample noise is a minor contribution to the overall noise, as is expected given the coils' limited field of view. This noise regime was subsequently confirmed by the significant improvements observed when the coil loop or both coil loop and preamplifier were cooled by liquid nitrogen, resulting in 15% and 23% gains in SNR, respectively. Test bench measurements showed that the liquid nitrogen did not alter the electrical operation of the circuit. While accurate temperature measurements could not be obtained easily within the imaging bore, the temperature of the loop was near the altitude-adjusted nitrogen boiling point (−190°C) while that of the preamplifier was approximately −50°C. Unfortunately, using even the best room-temperature electronics it is unlikely that similar improvements in noise performance can be achieved. Noise from the electronics could thus become a fundamental limitation in arrays of a large number of small coils.

Image Acquisition and Analysis

Images of a wrist-shaped phantom were acquired to test the parallel imaging performance of the coil system. Results (Fig. 2) indicate that the coils are sufficiently decoupled and spatially unique to enable high reduction factors ranging up to the maximum value of 6 for 2D reduction. High-resolution transverse images of a volunteer's wrist were acquired using the following parameters (GRE): 384×310 matrix, FOV 70×70mm^2, T_E 6.9ms, T_R 16.8ms, 5mm slice thickness, 182×228µm in-plane resolution, scan time 160s. Full Fourier, as well as SENSE-reconstructed images are shown in Fig. 3, confirming the array's favorable parallel imaging performance as previously assessed in vitro. High SNR and uniformity are also illustrated by the sagittal image shown in Fig. 4. The parameters for this image were 256×256 matrix, FOV 100×100mm^2, TE 3.7ms, TR 7.3ms, 5mm-thick slice, 390×390µm in-plane resolution, scan time 30s.

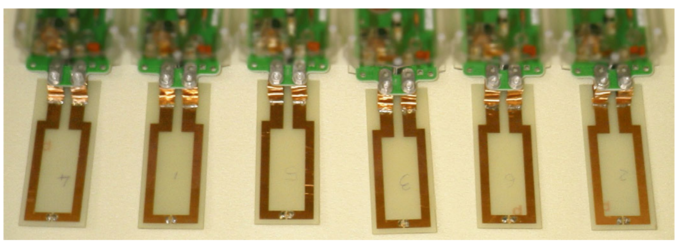

Figure 1: uninsulated wrist coil array

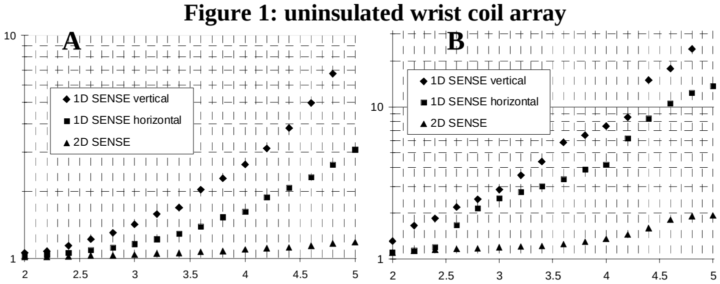

Figure 2: mean (A) and maximum (B) geometry factor, g, as a function of reduction factor, R

Conclusion

We have shown that an array of tightly-arranged, preamplifier-decoupled small coils is not only feasible but offers excellent image uniformity and SNR. In the wrist area, in particular, these benefits permit imaging with very high resolution. Using parallel imaging, the SNR advantage can be readily traded for scan speed, leading to clinically acceptable scan times. Experiments in cryogenic conditions suggest that significant further improvements in SNR could be achieved with a cooling mechanism.

References

1. Pruessmann et al. MRM 42:952-962, 1999 2. Roemer et al. MRM 16, 192-225, 1990 3. Leussler et al. Proc. ISMRM 11 (2003) p.2370

Acknowledgements

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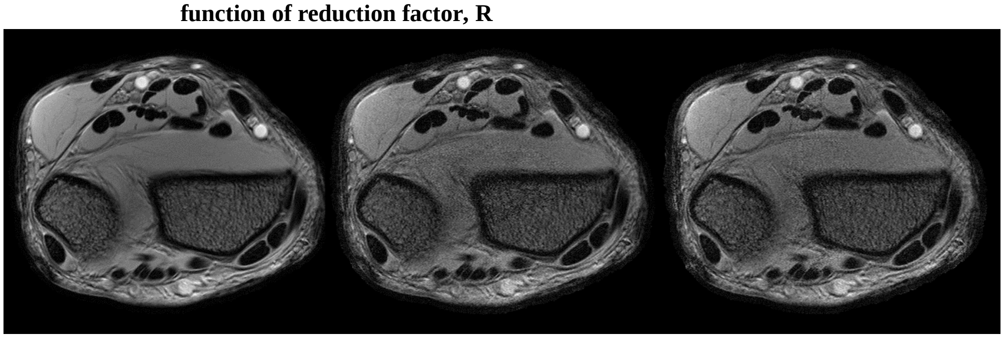

Figure 3: Full Fourier (left), SENSE×3 (1D reduction, middle), SENSE×6 (2D reduction, right) transverse images of the wrist

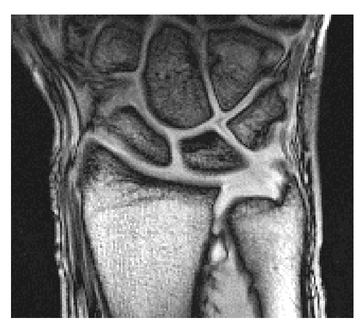

Figure 4: Full Fourier sagittal wrist image