Coil Performance vs. Preamplifier Location in the MR Phased Array

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Introduction

The location of preamplifiers (preamps) in a MR phased array is critical to image quality, RF stability, and patient ergonomics. There are many reasons to place the preamps as close as possible to the coil elements. This close proximity of the preamp to the coil limits coil cross talk, simplifies the system hardware, and enables the use of small diameter, high loss coaxial cables after the preamp to enhance patient ergonomics. In contrast, remote preamps allow the field of view (FOV) of the coil to be free of clutter, which can cause signal to noise ratio (SNR) loss and stability problems. It is also easier to construct RF coil arrays with remote preamps. In order to understand the advantages or disadvantages of these two approaches, two coil arrays (each of them containing ten coils) were constructed and tuned to 64MHz. One of the arrays contained the preamps on the coils, and the other one off the coils. The performance of the two arrays was compared in phantom imaging experiments.

Methods

The two coil arrays were constructed using individual circular elements of 7.6cm diameter, with the copper trace width of 5mm. Figure 1 shows a picture of the two arrays. Due to the channel limitations of the system available for data collection, only eight of the ten elements were used in each array for data collection. The printed circuit board material was .8mm FR4, with .07mm thick copper. Small cylindrical shielded baluns (1.2cm x 1.8cm) were used on each array. Standard preamps were used for the remote preamp scenario, with an average gain figure of 28dB, and an average noise figure of .3dB. Custom preamplifiers, with dimensions of 3cm x 1.7cm x .7cm, with a typical average gain figure of 26dB and a noise figure of .25dB were used for the preamp on the coil case. The coils were carefully overlapped with each other to obtain zero mutual coupling with each coil's nearest neighbors. Both arrays were cabled identically with low loss *Teflon* coaxial cable. Two single coils with preamps on and off the coil were also constructed to verify single coil data. For the remote preamp scenario, the balun was placed as close to the coil element as possible. For the preamp on the coil scenario, the preamps were placed as close to the element as possible, between the coil element and the balun. The arrays were evaluated with a 1.5 Tesla MR Scanner (GE Healthcare, Waukesha, WI).

The phantoms used for SNR measurements were constructed by filling a rectangular polycarbonate container with $CuSO_4$ and Na-doped water (1g/l, and 2g/l respectively). SNR measurements were obtained using identical protocols on each array. Axial and sagittal images were collected on each array, with two imaging planes acquired in each case (one at the center of the array, and one 5cm superior to the center of the array).

Results

The sagittal images obtained with the single coil setups (with the preamps on and off the coil) showed no discernable difference in SNR. Figure 2 shows a graph of the image SNR for the single coil case, in sagittal orientation. The images acquired with the two arrays (in both sagittal and axial orientation) showed a SNR advantage of up to 20% for the case of the remote preamps. Figure 3 shows a graph of the SNR of signals coming from each coil out of the two coil arrays, as a function of coil number. The SNR of the images with the preamps on the coil did not exceed the SNR of the images with the preamps off the coil in any imaging plane.

Discussion

In our experiments, remote preamps proved to be advantageous, resulting in increased image SNR. This is not unexpected, as active or passive elements that are inside the FOV of a RF coil can couple to the coil, and decrease coil performance. System hardware requirements and patient ergonomics, however, are important, and clearly not ideal in the remote preamp case. As channel count increases, remote preamps may become a significant problem due to their sheer space requirements (in and around the scanner).

A possible compromise approach may be offered by a hybrid scenario, in which one could place preamps on the coil, along the edge of the coil array, but away from the FOV, and match cable wavelengths to the coil elements. Smaller preamp footprint technology that is currently emerging should also help improve performance, by reducing coupling of the preamps to the array elements.

References: P.B. Roemer, W.A. Edelstein, C.E. Hayes, S.P. Sousa and O.M. Mueller, The NMR phased array, *Magn.Reson.Med.***16**(1990), pp192–225.

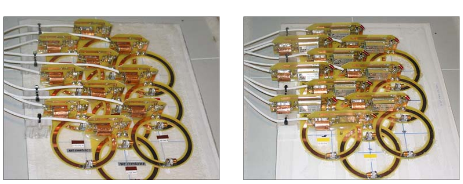

Figure 1: Coil arrays with remote preamps (a) and preamps on coil (b)

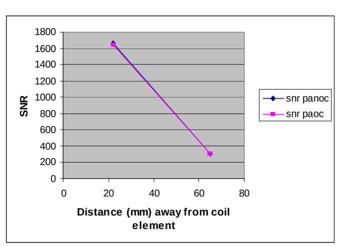

Figure 2: SNR of the single coils

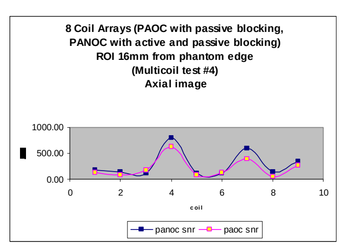

Figure 3: Phased arrays SNR