A non-overlapping phased array coil for parallel imaging of the hip at 3.0 T

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Introduction

Higher field strengths, SSFP sequences, and phased array coils can provide the SNR needed for quantitative high resolution imaging of musculoskeletal tissues such as trabecular bone, even in deep-lying regions like the proximal femur[1]. Here we introduce a specialized eight channel phased array coil for parallel imaging of the hip at 3.0 T, allowing the flexibility to acquire more images with the same spatial resolution in the same scan time.

Materials and Methods

A numerical model of SENSE parallel reconstruction (based on a quasi-static EM model) was programmed in Matlab in order to compare potential coil designs for their expected accelerated SNR performance. Due to the dielectric effects at 3.0 T, the simulations were not intended to give truly optimized results, but rather to provide general design guidelines. Based on the simulations, a gapped row of elements encircling the hip was chosen in order to maximize the accelerated SNR performance of the coil by providing highly distinct sensitivity profiles along the AP and RL directions[2]. A schematic of the design is shown in figure 1. Eight rectangular receiver loops were evenly distributed into a single row arrangement in bilateral curved plastic paddles, designed to be positioned above and below the hip and secured by Velcro straps. A capacitive decoupling mesh was installed between adjacent loops to aid in decoupling the individual receivers, and the coaxial connection length was carefully set to one wavelength (a good length to reach the hip) in order to maximize system preamp decoupling. A Kirchoff mesh analysis model predicted the values of decoupling capacitors needed based on bench-measured electrical parameters. Coronal FIESTA-c images of three healthy hips were acquired on a GE 3T scanner using optimized sequence parameters[3] (FOV=12 cm, 512x384, thickness=1.5 mm, TR=8 s, TE=2.32 ms, flip=60°, phase cycles=2, time 6:40) with full phase encoding, and subsequently with variable density undersampling at reduction factors (R) of 2-4 along the RL direction. The images were reconstructed using a GRAPPA-based, customized offline reconstruction in Matlab.

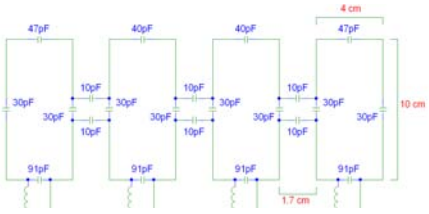

Figure 1 - Schematic showing half of the eight-channel phased array coil

Results and Discussion

The simulations showed significant improvements in parallel imaging performance for our array versus an equivalent non-overlapping design, especially at larger values of R. For example, for rate-3 SENSE in the RL direction, the average g-factor over the sample rose from 1.15 to 1.24, and the peak g-factor increased from 1.49 to 1.85. Although the g-factor analysis does not apply *exactly* to our GRAPPA reconstruction, it remains a critical accelerated coil design criterion. As shown in figure 2, the coil produced images of excellent visual quality using values of R up to 3, despite the reduction in SNR due to the shorter scan time. It is apparent from the images that prohibitively large extra SNR losses (beyond scan time) are not suffered below R=4. A new view of the maximum allowable R in parallel imaging was recently proposed by Breuer et al.[4], who applied principal component analysis (PCA) to coil sensitivity maps in order to determine the largest reasonable R in one or more directions. We have followed this analysis and computed the eigenvalues from the PCA (applied only the RL direction using projection) on some slices from acquired sensitivity maps (figure 3). The cumulative sum of eigenvalues did not reach saturation until R=4-5, suggesting that the coil should be effective for accelerations up to this level. Combining all of these results, we conclude that parallel imaging of the hip along one direction using our array is certainly reasonable up to at least a reduction factor of 3, and possibly up to R=4-5 if the acquisition parameters are adjusted to give more baseline SNR. Thus, a combined application of improved coils and parallel imaging would result in reduced acquisition times, or introduces the possibility of higher resolution imaging, and this is highly significant for the imaging of trabecular structure in osteoporosis or cartilage in osteoarthritis.

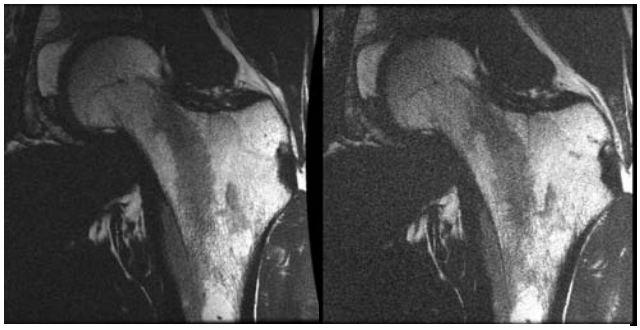

Figure 2a – Fully encoded coronal FIESTA image of hip

Figure 2b – Accelerated (R=3 RL) image of the same slice

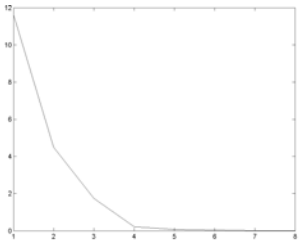

Figure 3 – Eigenvalues from the PCA analysis of coil sensitivity maps for a single example slice

References

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