Parallel Imaging performance for densely spaced coils in phase arrays at ultra high field strength

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Objective

The objective of this study was to experimentally examine parallel imaging performance (in this case specifically SENSE encoding[1]) as a function of increasing number of individual coils in the human head at 7 Tesla using parallel arrays with 4, 8, 16 and a 32 elements, with the specific goals of evaluating i) impact of coil design on reduction factors, ii) the maximal reduction factors that can be practically attained for human head imaging at 7 T and iii) the convergence of the reduction factors towards a theoretical maximum.

Background

Parallel imaging strategies allow sub-sampling of the k-space that would otherwise be required to generate an image, but at a loss of signal-to-noise-ratio (SNR). This SNR loss can be compensated by inherent SNR increases available at high magnetic fields. Reciprocally, parallel imaging strategies alleviates some of the problems encountered at high magnetic fields such as power deposition and image distortion and/or blurring in rapid imaging methods that are essential for applications such as fMRI where high fields provide improved contrast-to-noise ratio (CNR). It is, therefore, of great interest in high field applications to determine maximal reduction factors that can be attained by use of parallel imaging and the number of coils that are needed to attain them. For parallel imaging applications, the deterioration of SNR in undersampled data reflects not only $\sqrt{R}$, where R is the reduction factor, but also the ability of the coil array to separate pixels superimposed by aliasing. The latter is described by the geometry factor (g-factor) [1]. The g-factor can be used to evaluate the performance of different coil designs. At any field strength, the g-factor is expected increase with increasing reduction factor R and, for a given g-factor, the possible R value that can be attained is expected to approach a limit irrespective of large increases in the number of coils used. This behavior would define the performance that can practically be attainable at a given field strength. In this work, we have examined these issues experimentally for the human brain at 7 Tesla using multi-element coil arrays going up to as high as 32 elements.

Methods and Materials

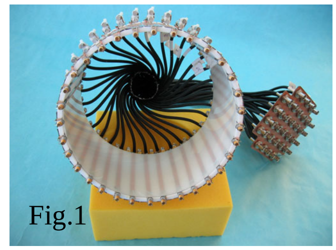

Fig.1

Imaging experiments were performed on a 7 Tesla Magnet (Magnex Scientific, UK). We utilized a single RF amplifier (CPC, Brentwood, NY) and split the RF power 4, 8 16 and 32-ways respectively utilizing a transmit-receive transmission line head-coil arrays [2] with radially distributed, identical transmission line elements as described in [3]. The coils used ¼" or ½" wide copper conductor strips and decoupling capacitors between neighboring transmission line elements. The transmit phase increments for each channel were adjusted for optimal image homogeneity. T/R switches with low insertion loss of 0.2dB in each transmit path blocked transmitter noise during reception and enabled the used of low noise preamplifier's. *The full FOV was set to closely match the volunteers head in the imaging slice*. For the sensitivity calibration 336x256 images were acquired in an axial plane, with a standard gradient recalled sequence (TR/TE: 16ms/5ms, flip angle: 10 degrees, slice thickness 5 mm, 1 acquisition per phase encoding step (i.e. NT=1)). A separate but identical full k-space data obtained subsequently were "undersampled" by post processing to generate data with different reduction factors. Two different types of experiments were performed. In one case, 16 element arrays were constructed using different strip width (¼" or ½") and strip to ground spacing ((¼" or ½") and were evaluated. In the second case a single, circular 23cm i.d. cylindrical 32 element coil array (Fig 1) was used; by examining the data only from equidistant 4, 8, or 16 of the 32 elements as well as the entire 32 elements, g-factor vs. R (along 1 dimension only) was calculated as a function of the number of elements. 2 dimensional reductions were also evaluated for 16 channel data obtained from the 32 element coil.

Discussion and Results

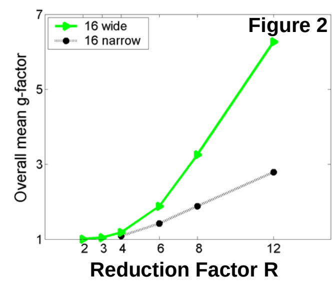

Figure 2

Despite the rather spatially extensive sensitivity profiles for each coil and consequently large overlap among adjacent coils at this field strength, the conductor width and substrate thickness was found to impact attainable g-factors for a given R (1 dimension) for human brain imaging at 7 Tesla (330 MHz). This is demonstrated for two different 16 element coil in Fig.2 where conductor and substrate thickness were different by a factor 2. The 32 element coil had the narrower element dimensions corresponding to the better performance in Figure 2. Using this 32 element coil (Fig.1) as 4, 8, 16 and 32 channel array overall mean g-factor was calculated as a function of R along one dimension and the number elements and were fitted to a polynomial function (Figure 3a); Figure 3b shows R vs. the number elements for fixed overall mean g-factors (g-factor =1.4 and 1.2) . These data show that the largest gains in parallel imaging performance is going from 4 to 8; however, there were still significant, albeit progressively smaller, gains with 16 and even 32 elements.

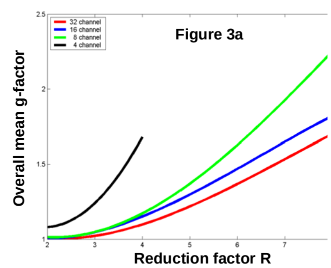

Figure 3a

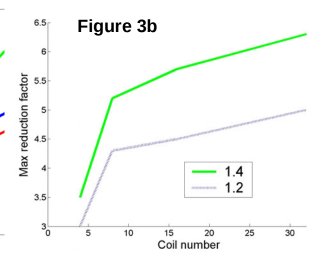

Figure 3b

The g-factors for 2-dimensional under sampling were also calculated. In addition to the usual mean g-values, also the g-values as a function of aliasing are reported. The results are tabulated for a 16 element array (1/4" conductor strips). Corresponding reconstructed images are illustrated in Figure 4.Note that this fig also includes 1x6 reduction factor image from an 8 element coil for a comparison.

	2x2	*2x3*	*2x4*	*3x4*
Overall Average	1.02	1.06	1.16	1.18
Average g-factor /degree of aliasing	1.07 /3	1.11 /4	1.18 /6	1.22 /7
Average in Center	1.00	1.04	1.18	1.22

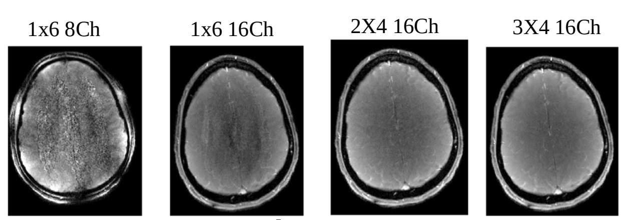

Figure 4

CONCLUSIONS: It is concluded that gains in R can be realized even up to 32 element coils in human head imaging at 7Tesla, and R of 5 to 6 in 1-dimension and 8 to 12 in 2-dimension can be attained with good SNR and acceptable g-factors.

Acknowledgment

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References

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