SNR and parallel imaging performance of a 32-channel array for human brain imaging at 7 Tesla

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Introduction: Multi-channel coil arrays [1] have led to substantial sensitivity and resolution improvements in MRI of human brain. These benefits generally increase with the number of coil elements but levels off at large element counts. Another advantage of increased array size is increased parallel imaging (PI) performance. Here, actual data from a 32-channel array at 7 T were compared with a simulation of the array and with numerically derived coils with lower element counts to investigate these two aspects.

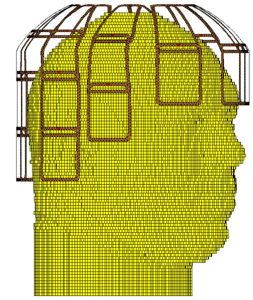

Figure 1: Coil element layout.

Methods: The 32 channel array was designed in cooperation with, and built by, Nova Medical (Wilmington, MA) [2]. It consists of a 4-by-5 grid of elements in the posterior half, and 5 columns with respectively 3, 2, 2, 2 and 3 elements in the anterior half (see Fig. 1). Coil columns (perpendicular to z) are gapped (gap size is 30% of element width), whereas elements in a column (in the z-direction) overlap to avoid signal dropouts. Finite element simulations of this coil layout were also performed [3]. Image- and noise-data were acquired on normal volunteers (n=2) on a 7 T GE scanner (120×96; twelve 1-mm slices; 9 mm gap; 225×180×111 mm^3 coverage). Since comparisons between different coil designs are difficult, acquired coil data were numerically combined as described earlier [4] to yield a 15-, a 10-, two 8-, two 5-, two 2- and a 1-element coil. Note that such combinations suffer from more component noise than actual arrays that consist of less (larger) elements. SNR over the entire brain and a central 15×15×21 mm^3 region were evaluated, as well as the average g-factor (over whole brain) for 20 different PI acceleration rates. Since the scanner is currently equipped with only 16 receivers, image data were acquired in two groups of 16, and coil noise data in 6 different groups of 16 to allow complete coil noise correlation assessment. (All 32 elements were connected to pre-amplifiers at all times).

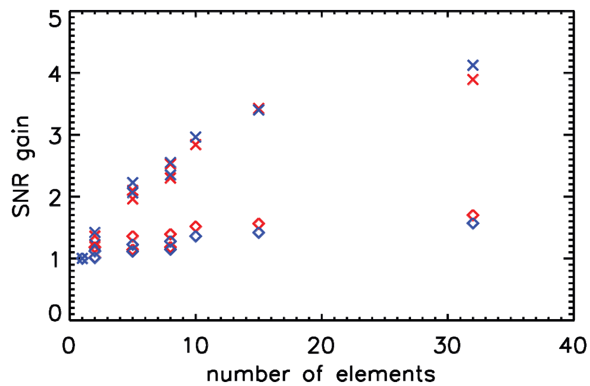

Figure 2: SNR gain as a function of the number of coil elements, averaged over the entire brain (×) and in the center (◊) for the two volunteers (color).

Results & Discussion: Fig. 2 shows SNR (relative to 1-channel) as a function of the number of elements. SNR in the center remains relatively constant, but improves about a factor of 4 on average over the brain for 32 independent channels. Note however that the gain from 15 to 32 channels is only 19%, demonstrating that SNR gain levels off when many elements are used.

Fig. 3 shows the average PI g-factor in the head. Multi-dimensional acceleration outperforms a similar overall rate in 1D, and acceleration in the largest dimension (AP>LR>SI) performs best. Up to ~6-fold acceleration can be achieved with a mean PI penalty of <~20%. This corresponded very well to the simulated array's PI performance; the correlation coefficient of the mean g-factor for the 20 acceleration rates is 0.93 when compared to the actual array.

Table 1 compares the mean g-factor for the numerically-combined 10- and 15-channel array with the 32-channel array, which outperforms the smaller arrays in all cases, most notably for R>3. (The 10-channel array performs especially poorly for $R_{SI}\neq1$ since it consists of only a single row of elements.)

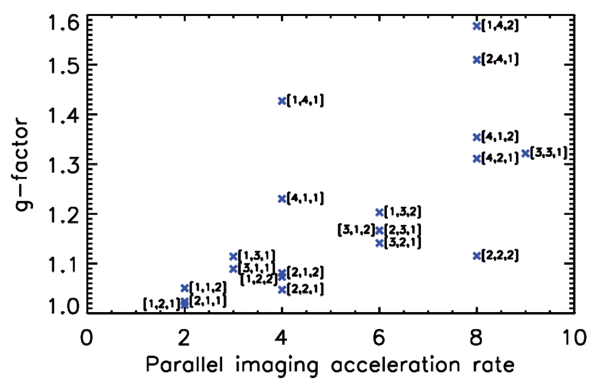

Figure 3: Average (first over brain, then volunteers) g-factor for 20 different PI acceleration rates for the 32-channel coil. Labels at the right of each symbol indicate acceleration in the AP, LR and SI direction as [R_{AP},R_{LR},R_{SI}]. (Except [1,2,1], [1,2,2] and [3,1,2], placed left of symbol due to space constraints).

Conclusion: The high-performance 32-channel array yields approximately 4-fold SNR gain compared to a similarly sized single-channel coil and up to 6-fold PI acceleration can be achieved with minor PI penalty. A large number of elements is particularly advantageous for image acceleration, while benefits for average SNR start to level off.

References: [1] MagnResonMed 16 1990 p. 192; [2] ISMRM 2007, p. 242; [3] ISMRM 2007, p. 1008; [4] MagnResonMed 51 2004, p. 22

channels	average g-factor (for rate [R_{AP},R_{LR},R_{SI}])											
	[2,1,1]	[1,2,1]	[1,1,2]	[3,1,1]	[1,3,1]	[2,2,1]	[2,1,2]	[1,2,2]	[3,2,1]	[2,3,1]	[3,1,2]	[1,3,2]
32	1.02	1.02	1.05	1.09	1.11	1.05	1.08	1.07	1.14	1.17	1.17	1.20
15	1.03	1.02	1.16	1.11	1.15	1.06	1.21	1.20	1.20	1.23	1.35	1.41
10	1.03	1.03	1.96	1.13	1.18	1.08	2.19	2.53	1.29	1.32	2.90	3.95

Table 1: Average g-factor for the actual 32- and numerically-combined 15- and 10-channel arrays. In the 10-channel array the coils in each row are combined. The 15-element coil is similar, but the elements in the occipital half consist of two rows of 5 elements.