A 16-element coil array optimized for multi-dimensionally accelerated parallel brain imaging using multi-oblique imaging planes

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INTRODUCTION

Parallel imaging strategies (1,2) are becoming the principal tool for accelerated clinical MR imaging. The competing constraints between (i) available baseline signal-noise-ratio (SNR), (ii) noise amplification (g-factor) and (iii) achievable acceleration factor (R) represent a fundamental challenge for clinical parallel imaging applications. The use of multi-dimensional coil arrays consisting of large numbers of elements can improve SNR and hold the promise to reduce noise amplification which requires tailored coil configurations for different applications. This study is aiming at the design of a 16 channel head coil customized for multidimensional parallel imaging brain applications using multi-oblique imaging planes. The coil arrays performance was examined (i) in phantom studies and (ii) in volunteer studies using high spatial resolution anatomical T_1 weighted imaging together with multi-dimensional net acceleration factors of up to 16 (R=4x4).

MATERIAL AND METHODS

The layout of the sixteen loops was selected such that the optimum geometry factor is obtained for all the three directions X, Y and Z. In order to get low geometry factor values for all directions the number of loops was maximized for both the tangential and axial direction. In consequence the coil consists of four sets of 4 loops in the axial direction, 4 loops in the tangential direction resulting in a total number of 16 coil elements as illustrated by the schematic drawing (Fig 1a) and by a picture of the final array design (Fig. 1b). The geometrical dimensions of all coil elements are shown in the drawing in Fig 1.

The decoupling of the individual loops was accomplished using (i) overlap to reduce coupling between direct neighbors in the SI direction, (<-15 dB), (ii) transformers between next to nearest neighbors in the axial direction (<-10 dB), diagonally coupled elements (<-25 dB), nearest neighbors in the tangential direction (<-25 dB). Low input impedance preamps (3.5Ω) were applied to further reduce the coupling. Separation was applied along the in the AP/RL direction. Baluns were applied on all 16 coaxial cables to prevent cable modes.

A T_1 weighted 3D gradient echo sequence was implemented for bi-dimensional parallel imaging (3) using 1 mm isotropic spatial resolution. The generalized encoding matrix algorithm (GEM) was applied for the reconstruction of the accelerated images (4).

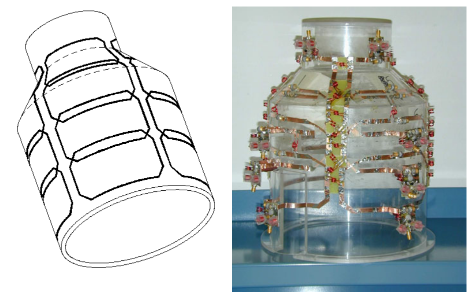

Figure 1. Final design of the 16 Channel head coil showing the layout of the 16 loops, 4 in the AP/RL direction and 4 in the SI direction.

RESULTS

After the design of the coil was finalized, g-factor maps were obtained using a series of different net acceleration factors for all three cardinal planes. The g-factor maps obtained for the sagittal plane are identical to those derived from the coronal plane due to the symmetry in the coil design. Axial slices were acquired for different locations relative to the SI center of the coil without any noticeable difference in the g-factor maps. The average values of the g-factor are close to 1 for both the sagittal and axial plane as demonstrated in Figure 2 and summarized in Table 1, whereby R = 2, 2.67 and 3 indicate the acceleration along each phase encoding direction leading to a total acceleration factor of 4, 7.13 and 9. The peak g-factor values occur in the axial slice close to the boundary of the phantom that are not of much concern.

	Sagittal Plane				Axial Plane	
R	Mean (SI)	Maximum (SI)	Mean (AP/RL)	Maximum (AP/RL)	Mean (AP/RL)	Maximum (AP/RL)
2	1.02	1.08	1.00	1.04	1.03	2.40
2.67	1.07	1.51	1.07	1.58	1.20	5.68
3	1.13	1.89	1.16	1.88	1.35	7.28

Table 1. Mean and maximum g-factor values obtained for the sagittal and axial plane.

The reduction in the g-factor resulted in an SNR enhancement for higher acceleration factors, which facilitated further scan time reductions without compromising the spatial resolution. Volunteer studies showed performance suitable for accelerated high resolution anatomical imaging using net acceleration factors up to R=9 (3x3). For this net acceleration factor an impractical 11:00 min acquisition time was reduced to 1:13 min while remaining the high spatial resolution. Selected images exhibiting preserved anatomical information and image contrast are shown in Figure 3. Our results also indicate, despite the advantages of the many-element RF brain coil array shown here, that SNR and CNR remain a challenge as very large acceleration factors (R=16 in this case) are explored.

DISCUSSION AND CONCLUSION

A 16-element volume brain coil was developed that affords simultaneous accelerations not only along all three main directions but for multi-oblique imaging planes. Noise amplification maps revealed g factors close to one for all 3 cardinal imaging planes. Accelerated images with a total acceleration factor of up to 9 demonstrated the SNR advantage of two-dimensional accelerations using a dedicated coil array design. Such image quality cannot be obtained with similar one-dimensional net acceleration using a circular array consisting of 16 elements distributed circumferentially since the use of many-element RF coil arrays can alleviate noise amplification to some extent, but electro-dynamic constraints dictate that a fairly rapid degeneration of SNR at high one-dimensional accelerations is inevitable (5).Another drawback of placing many elements in the tangential direction is that the individual elements distributed circumferentially get very narrow and long in size, to cover the entire brain. Such narrow elements tend to become coil noise dominated, depending on the proximity to the patient, the frequency of the coil, and the temperature of the coil. If the individual elements are more of a square or circular in nature, their RF volume penetrates deeper into the patient and therefore is patient noise dominated at higher frequencies and bigger patient distances than a pure tangential/circular array design. In conclusion, further SNR improvements may be expected with the application of three-dimensional accelerations, which are clearly facilitated by the coil design presented here, using non-cartesian k-space trajectories. Consequently, future studies including clinical comparisons are planned with our 16-element brain array.

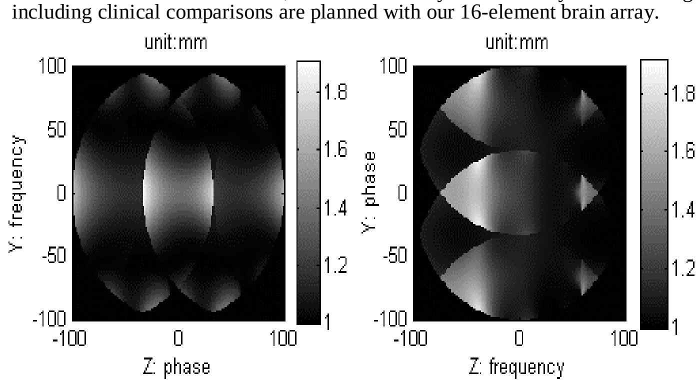

Figure 2. G-factor maps of the sagittal/coronal plane with reduction factor of 3 in each direction.

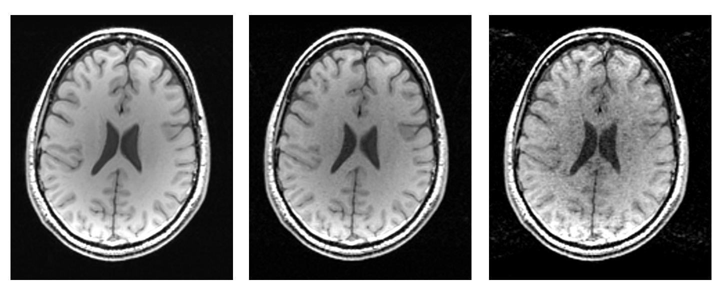

Figure 3. Reformatted axial images, which were acquired with a 3D spoiled gradient echo imaging technique using a) no acceleration (R=1) , and bi-dimensional acceleration with b) R=2x2 and c) R=3x3. The scan time was a) 11:00 min, b) 2:45 min and c) 1:13 min.

References:

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