Potential gain of a 256 channel head coil at 7T: combined measurements and g-factor calculations

Arjan D. Hendriks[1], Michel G.M. Italiaander[2], Natalia Petridou[1], and Dennis W.J. Klomp[1,2]
[1]*Department of Radiology, University Medical Center Utrecht, Utrecht, Netherlands,* [2]*MR Coils B.V., Drunen, Netherlands*

Introduction

Recently it was demonstrated that UHF MRI combined with high density receiver arrays can facilitate laminar fMRI, bringing neuroimaging of the human brain to a completely new level [1]. A level at which we are closer to the small spatial scale in which the brain is organized. Using the high BOLD sensitivity at 7T combined with uncompromised image accelerations of the high density arrays, fMRI activations can be observed, at close to 0.5 mm isotropic resolution. This can be acquired within functionally relevant scan times (order of sec). However, as the optimal size of the receiver elements at 7T can be as small as 1x2cm (remaining in tissue load dominance; i.e. minimal electronic noise), a 32 channel setup, as commonly available, will provide a limited field of view of the brain. In fact, in order to cover the entire human brain with these receiver elements, close to 256 receivers (Fig. 1) would be required to obtain the full potential of ultra-high resolution fMRI of the human brain at 7T. In this study, while in progress of installing the receivers, we investigated the acceleration performance of a 256 channel high density head coil by measuring the sensitivity profiles (SENSE reference scans) and corresponding g-factor maps.

Figure 1: Concept of the 256 channel receiver coil. The blue squares indicate the size and position of the coil elements. The pre-amplifier boards (green) are stacked behind the head and are small enough to fit inside the transmit coil.

Method

Measurements were performed on a healthy volunteer in a 7 Tesla Achieva system (Philips, Cleveland, OH, USA). Eight different SENSE reference scans were made with 2x16 channel surface coils (MR Coils BV, Drunen, the Netherlands), using a volume headcoil as a transmitter (Nova Medical, MA, USA). The used MR sequence is a SENSE reference scan, with the following properties: 3D FFE acquired interleaved with receiver arrays and volume coil; TE/TR= 1.22/8.0 ms, 2x2x2 mm^3 voxel, 20x20x20 cm^3 FOV, acquisition time= 1 min.

For each SENSE reference scan, the surface coils were shifted to a different part of the head. In this way these 8 shifted reference scans constitute a virtual 256 channel coil. To correct for head displacement in between the reference scans, images acquired for each coil position were aligned to the images of the first position using AFNI. Alignment parameters (rotation & translation) were calculated, using the reconstructed magnitude images from the reference scan, and then applied on the calculated sensitivity matrices per coil position. For comparison, a SENSE reference scan was also made with the standard 32-channel Nova receive array. From the SENSE reference scans, the g-factor (corresponding to noise amplification) was calculated with the following equation from Pruessman et al. [2]:

$$g_\rho = \sqrt{[(S^H\Psi^{-1}S)^{-1}]_{\rho,\rho}\,(S^H\Psi^{-1}S)_{\rho,\rho}}$$

Where S defines the sensitivity matrix (N_{coils} x $N_{folding\_locations}$) and ψ is the N_{coils} x N_{coils} receiver noise matrix. The g-factor was calculated for the same slice of the brain with different acceleration factors.

Results

The g-factor comparison of the standard 32 channel head coil and the virtual 256 channel is in Fig. 2 displayed. The 32 channel head coil shows acceptable g-factors at an acceleration factor of less than 9 (3x3 APxFH). For the virtual 256 channel head coil similar g-factors are obtained at a SENSE factor of 24 (6x4 APxFH).

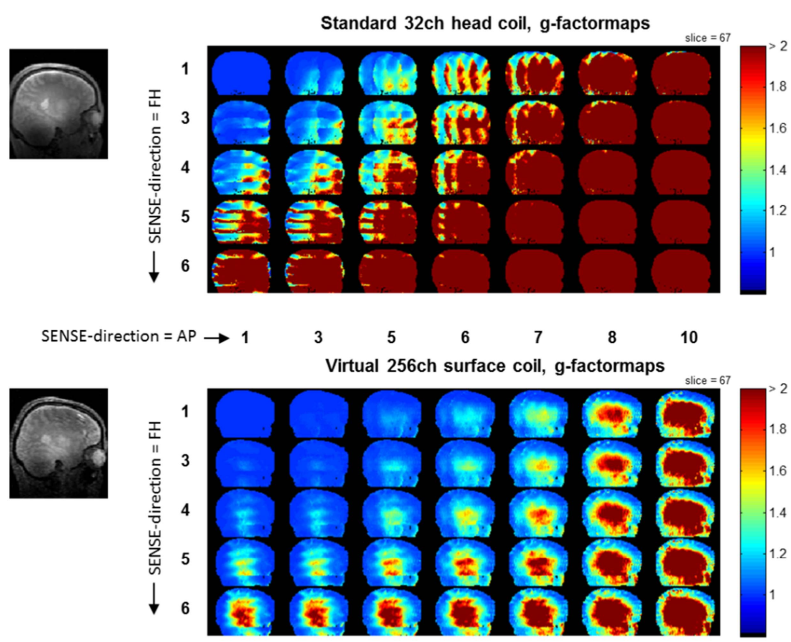

Figure 2: g-factormaps for different SENSE acceleration factors. Shown is the standard 32 channel head coil (up) and the virtual 256 channel surface coil (bottom). The 32 channel head coil shows acceptable g-factors at an acceleration factor of 3x3 (APxFH). The virtual 256 channel surface coil shows similar g-factors at an acceleration factor of 6x4 (APxFH).

Discussion

More than a factor 2 in acceleration performance is expected, when comparing a 256 channel headcoil with a 32 channel headcoil at 7T. Note that the data to obtain the g factor maps is obtained sequentially in time, preventing the inclusion of the full noise correlation matrix. However, it is expected that the dominant noise coupling was already included since at each scan the 32 elements were situated as two dense arrays.

Conclusion

The results show very good g-factor performance for the virtual 256-channel coil, up to an acceleration factor of 6x4. This implies a gain in SNR or acceleration factor. Also, the results suggest that the benefits achieved in spatial/temporal fMRI resolution by using the high-density 32-channel configuration, can be extended to 256-channels with full head coverage.

References: [1] N. Petridou et al. NMR Biomed. 2013; 26: 65–73, *Pushing the limits of high-resolution functional MRI using a simple high-density multi-element coil design.*
[2] K.P. Pruessman et al. Magn Reson Med 1999; 42:952–962, *SENSE: Sensitivity Encoding for Fast MRI*.

Acknowledgement: The Netherlands Organization for Scientific Research (NWO), grant number: ALW-834.14.004