High Field Parallel Imaging in Rats

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Introduction: Animal model studies often require imaging large numbers of animals in order to establish statistical significance e.g. when evaluating a new treatment. Partially parallel imaging (PPI) with phased array coils permits scan-time reduction, allowing significant increase of animal throughput with acceptable signal-to-noise ratio (SNR) penalty. Resolution enhancement, artefact suppression and SAR reduction are additional benefits from PPI application [1]. Furthermore, partially parallel MRI benefits from high field strengths due to the higher SNR obtained and the concomitant wavelength effects [2].

The PPI procedure, however, reduces the SNR of the final image by at least $R^{1/2}$, where R is the acceleration factor for a given SENSE acquisition. These SNR losses are due to decreased temporal noise averaging and non-unitary transformations inherent in PPI reconstructions [1].

Methods: A 4.7 T, 40 cm bore, BIOSPEC® 4-channel system (Bruker BioSpin MRI GmbH, Ettlingen, Germany) was used with a novel rat head 4-element coil array (displayed in figure 1), optimally designed for high field strengths, with special attention given to the effects of inductive coupling and dielectric resonances.

The array was designed with four overlapping elements with a size of 15 mm in diameter. Special attention was also paid to the optimisation of the performance of the single loops which results in an unloaded Q-value of $Q_{ul}=220$. Screening of the electrical and parasitic electrical fields yields a loaded Q-value of $Q_l=140$. All loops are isolated by enhanced geometrical decoupling. This results in a mutual isolation of the elements of approximately -20 dB in the loaded coil. The isolation was additionally improved to more than -30 dB using Bruker-built low-input-impedance preamps with approximately **zero** Ohm input impedance, a noise figure < 0.5 and a gain of 27 dB. All loops are matched to 50 Ω with a **balanced** feeding. The optimised cable length of the feeding guarantees the $\lambda/4$ transformation needed for preamp decoupling. The phased array coil operates as receive only coil in combination with a standard, actively decoupled transmit coil. During the transmission the array loops are actively decoupled by a parallel decoupling circuit. The moulded coil cover fits perfectly to a standard animal bed for rats and integrates the whole electronics.

Adult female Fisher rats were anaesthetised with an isoflurane gas mix. Standard spin echo images were acquired with TR 3.5 s, TE 18.3 ms, FOV 3 cm, slice thickness 1.5 mm and a 256^2 matrix. A standard GRAPPA (**G**ene**R**alized **A**utocalibrating **P**artially **P**arallel **A**cquisitions) [3] algorithm was implemented in MATLAB (The MathWorks Inc., Natick, MA, USA) and used for image reconstruction.

Results: Figure 2 shows coronal images acquired with the individual elements of the coil array while figure 3 shows a sum-of-squares combination of these images. Figure 4 displays images acquired with 24 reference lines and acceleration factors 2 and 3 respectively. Those images were reconstructed using the GRAPPA algorithm. The scan time for a fully sampled image of 14 m 52 s reduces to 8 m 7 s for acceleration factor 2 and to 5 m 54 s for factor 3. Finally, Figure 5 shows a sum-of-squares combination of axial images (the axial images were acquired using a RARE-sequence). A SNR comparison of the phased array coil to a standard quadrature rat brain coil shows an increase of the SNR in the combined images of about 45% for the central region of the rat brain. This evaluation was done by using a standard spin echo sequence (parameters see above) and a cylindrical loading phantom equivalent to the load of a rat head. A SNR evaluation in vivo shows approximately the same SNR improvement.

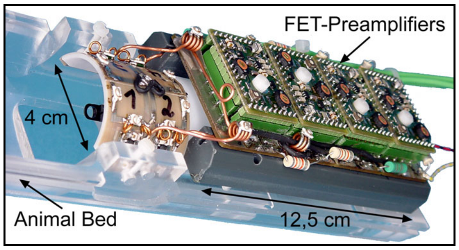

Figure 1

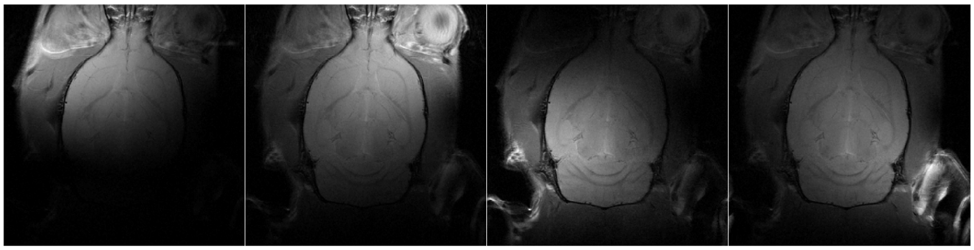

Figure 2

Figure 3

Figure 4

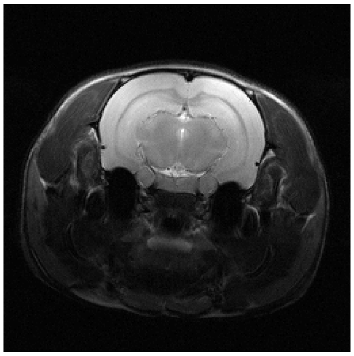

Figure 5

Discussion and conclusions: The images acquired with acceleration factor 2 show very good quality (they are, in fact, flawless). When using acceleration factor 3 some minor backfolding artefacts from the sample interfaces occur in the brain region. Contrarily to first expectations, the signal-to-noise ratio is almost maintained in the images with acceleration factors 2 and 3 compared to the image without acceleration. This is due to the fact that the additional reference lines in central k-space contribute considerably to the signal.

Furthermore the axial image indicates that the penetration depth obtained with the whole array (here approx. 11 mm; measured from additionally acquired phantom images) is considerably larger than the radius of a single array element (approx. 7.5 mm) which has already been mentioned by Sodickson et al. [4].

The study shows that partially parallel imaging has been successfully implemented for in vivo rat imaging. Animal MRI applications such as high-resolution functional brain imaging, white matter fibre-tracking and dynamic cardiac and perfusion imaging with unprecedented temporal resolution will benefit significantly from the implementation of parallel animal MRI.

References: [1] K. P. Pruessmann et al., Mag. Reson. Med. 42:952-962 (1999); [2] F. Wiesinger et. al., abstract 447, Proc. ESMRMB 2002; [3] M. Griswold et al., Mag. Reson. Med. 47:1202-1210 (2002); [4] D. K. Sodickson et al., abstract 469, Proc. Intl. Soc. Mag. Reson. Med. 11 (2003).