A 16-channel rat-body array coil with an integrated birdcage transmitter at 7T

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Introduction:
In the recent years routine MR imaging at high fields on animals using standard routine imaging protocols gained more and more importance. In this context the introduction of parallel imaging capabilities for biological and genomic research on small animals and the use of RF coil-arrays is essential for high resolution images and a cost-efficient high throughput. The basic requirements for the introduction of RF coil-arrays are suitably designed multi-channel coils. Numerical RF-field simulations are essential to pre-calculate the RF-sensitivity distributions and parallel imaging capabilities for an optimized RF coil-array. With this study we present a novel 16 channel array-coil including a transmitter coil for investigations on rats which is optimized for rat abdominal imaging. We have carefully compared this new designed coil with a standard quadrature birdcage coil owning the same physical dimensions. This novel RF coil-array is an alternative coil design for rat whole-body applications including all the advantages of parallel imaging.

Methods:
All measurements were performed on a 7T, 30cm ClinScan-system (Bruker BioSpin MRI GmbH, Ettlingen, Germany) equipped with 16 receiver channels. The number and the distribution of the array coil-elements were optimized by numerical calculations performed with CST MWS (CST, Darmstadt, Germany). The optimal number and arrangement of the receiver-coils was determined under the consideration of a high SNR in the centre of the coil, a low g-factor up to an acceleration factor of 3 and a maximum of 16 receiver channels. The sensitivity of the array-coil increases with an increased number of coil-elements (figure 1). This explains the choice of minimum 8 coils surrounding the volume of interest (VOI). The calculation of the g-factors maps with an 8x2 array results in values ranging between 1.04 (acc.-factor of 2) to 2.85 (acc.-factor of 4). The various, systematic simulations led to the decision to design a receiver-array with 8x2 surface coils (two rings with 8 coils in z-direction).

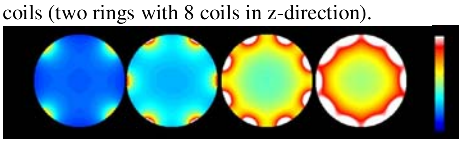

FIG.1.Normalized B-field with increasing nr. of coils (4,6,8 and 10)

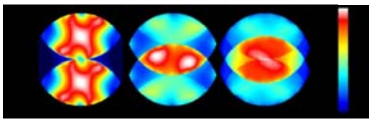

FIG.2. G-factor simulation with 2x8 array

The coil consists of 16 receiver-coils including the whole decoupling electronics, phase shifters, preamplifiers and a quadrature driven transmitter coil. The receiver coils were placed on a 60mm Ø GRP tube. Every single coil is decoupled from the seven neighbour coils by using geometrical (overlap) or transformer decoupling. The remaining eight coils are decoupled by their geometrical arrangement with a value of min. -18dB, when the load consisted of a rat. The Q-value was measured to a value of about 45 for loaded conditions. All receiver-coils are actively decoupled during transmission and arranged in four independent groups. They can be activated and deactivated for choosing different combinations of regions during reception (head, foot, anterior, posterior).The receive-signals are amplified with 16 built-in low-impedance preamplifiers (R_{input}=2.6 Ω, NF=0.7 dB, gain 27 dB). An insulating network that reduces the coil-coupling by additional 6dB was designed. The array-coil elements are surrounded by an integrated quadrature driven birdcage transmit-resonator (inner diameter: 90mm, length: 150mm) with eight rungs, so that the B_1-field is almost homogeneous in the VOI. This resonator is equipped with an active decoupling network for optimal decoupling from the receive-elements of the array. The coil array was matched and tuned stationary for a medium-sized rat-body. For comparing the SNR at the MRI-system a phantom (ε=76 and δ=2.2S/m) which is equivalent to this load was used.

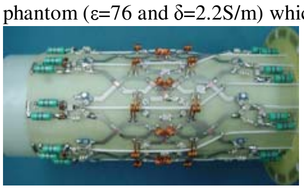

FIG.3. receive surface coils

FIG.4. 16 channel coil

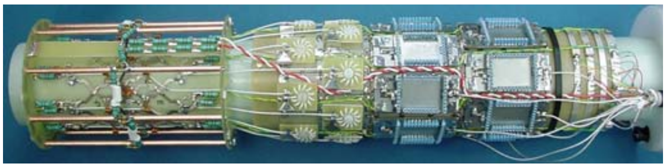

FIG.5. inner assembly of the coil

Results:
The SNR of the array-coil was compared to the quadrature resonator of the same physical dimensions. It shows an improvement of the SNR of the 16-channel coil in the center of a transversal slice by a factor of 1.1. That value increases to a factor of 2.5 regarding the periphery of the VOI. The coil also shows good results when accelerated imaging techniques are used. The coil can be used up to a acceleration-factor of 3 without limitations by imaging artefacts (figure 7, in-vivo axial images of a rat at a factor of 1 above left to 4 bottom right). First application results also indicate a good imaging quality for abdominal imaging on rats (figure8.).

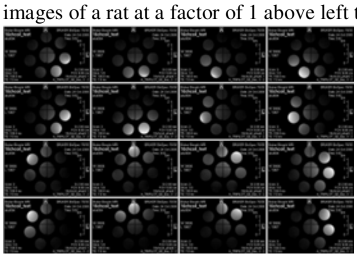

FIG.6. 16 uncombined phantom images

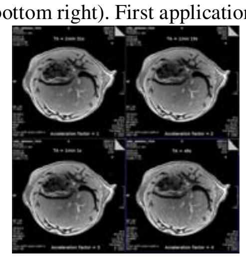

FIG.7. liver imaging with acc. factor1 to 4

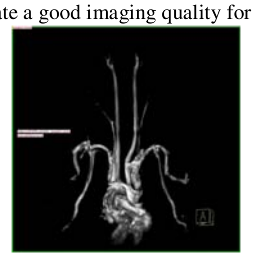

FIG.8. PC angiography of rat carotids

Conclusion:
A novel and optimized phased array-coil with 16 receive channels and improved SNR was developed and will be introduced as a new series-coil for rat whole-body applications. Together with a multi-channel MRI-system, all advantages of parallel imaging techniques on small animals can be utilised, e.g. rats can be examined in shorter times by using accelerated 2D/3D imaging. In the future, the basic concept will be extended to other field strengths (e.g. 9.4T). For applications like rat head and mouse whole-body imaging, it will be adapted to other inner diameters.

References:
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