Extend your conventional animal MRI to a microimaging system

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Introduction
MR microscopy offers great potential to apply anatomical, functional and spectroscopic MRI techniques to small objects or small regions of interest with high SNR. With the Bruker Coil-on-a-Chip technology (Bruker BioSpin AG, Switzerland), highly sensitive microcoils are available on the market for high resolution imaging in NMR spectrometers [1]. In this work, we show that these microcoils can be implanted and used also in a conventional animal MRI system without expensive changes in hardware architecture.

Material and Methods
Implementation and MRI experiments were performed on a 9.4T Bruker BioSpec 94/20 system (Bruker BioSpin, Ettlingen, Germany) equipped with a B-GA12S1 gradient system (max. gradient amplitude: 675 mT/m, slew rate: 4673 T/m/s). The tailor-made probehead is mounted on the standard animal bed sliding system. This allows one to position the inlet containing the microcoil and sample (Fig. 1b) inside the magnet without contact to the vibrating gradient tube. Thus the transfer of vibrations during the experiment to the probe head is avoided. In addition, it includes a complete tune & match network, which can be easily adjusted from outside the magnet (Fig. 1c).
As the typical power consumption of a micro coil is in the order of µW, high transmitter attenuation would be necessary, resulting in very noisy pulse signals. To overcome this problem, microcoils were directly connected to and operated using the Signal Generation Unit (SGU). Hence, no additional amplifier or attenuator was needed within the transmit path. Standard adjustment routines (such as pulse power estimation) have been extended to provide a semiautomatic and quick adjustment of all MRI system settings. Basic imaging sequences (GE and SE) have been modified to improve spatial resolution To demonstrate the successful extension of the conventional MRI system to a microimaging system, GE images of different resolution phantoms were acquired using a planar micro surface coil with a multi-turn spiral (ID 1000 µm, OD 1300 µm, see Fig. 1 a) [2]. In addition, SNR has been compared to results from a conventional mouse quadrate birdcage coil (ID 35 mm).

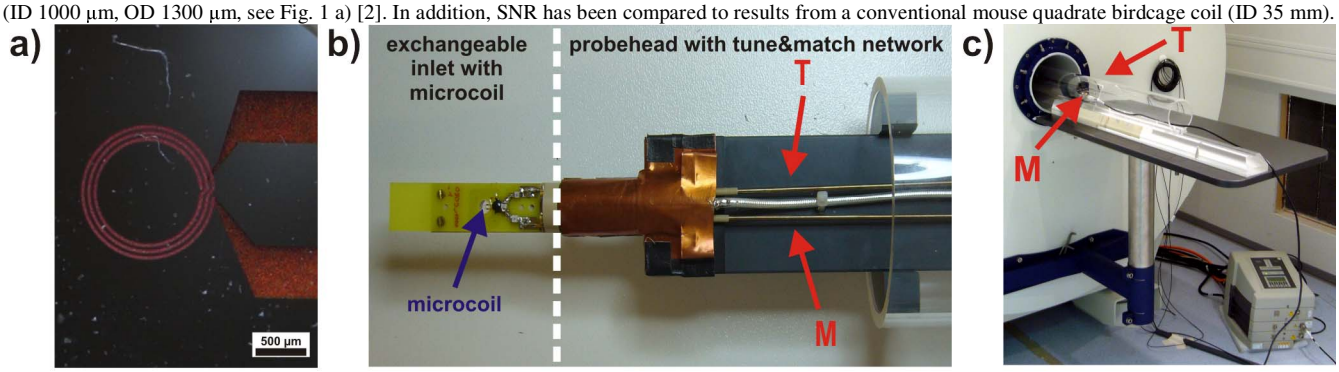

Fig. 1: a) microcoil with 1000 µm ID; b) probehead front end with tune & match network and attached microcoil inlet; c) probehead mounted on sliding system with access to tune & match rods (red arrows) .

Results
Fig. 2 a) shows polystyrene microglobes (OD 100 µm) immersed in water doped with CuSO4 with 10 µm isotropic in plane resolution (3D GE; Matrix: 256x256x64; TR/TE: 300/6.4 ms; FA: 90°; averages: 25; acq. time: 34 h 8 min) A magnification of the dashed area is given in Fig. 2 b). The globes diameter counts 10±1 pixels, corresponding to 100 µm. An image of a SU-8 cylinder with 800 µm outer diameter is shown in Fig. 2 c) (2D GE; Matrix: 256x256; slice thickness: 180 µm; TR/TE: 300/6.6 ms; FA: 90°; averages 10; acq. time: 12 min 48 s). The resulting phantom shape matches well with a circle. Signal cancelation in the upper part of the images (arrow) originates from an adhesive air bubble. Comparison with the standard mouse coil showed a 13.7 times higher SNR in comparison to the 1000 µm ID microcoil. The sensitive volume of the latter was determined to 260 nL.

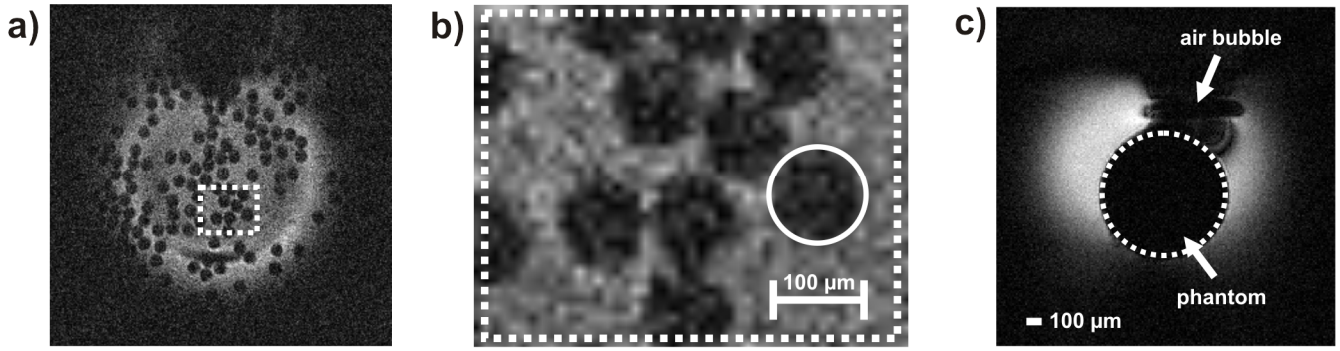

Fig 2: a) microglobes (OD 100 µm), immersed in doped water; b) magnification of the dashed area in a); c) SU-8 cylinder (OD 800 µm), immersed in doped water. The phantom boundaries match with the dashed circle, demonstrating equal resolution in both image directions.

Discussion
Our work showed the successful implementation and application of microcoils in a conventional MRI system. Images with high SNR and high resolution were acquired in an acceptable time. As shown in Fig. 2, even at very high resolution sample geometries were maintained. Besides the specific probehead, which was designed and built for this work, only small changes within the transmit chain and minor modifications of adjustment routines and sequences were necessary to extend a standard MRI to a microimaging system. No additional or expensive hardware was needed. As the coil insert is exchangeable, tailor-made coils such as hand-wound solenoids on thin capillaries can also be used.

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References [1] Weiger et. al., CMR 2008, 33B: 84-93; [2] Massin, JMR 2003; 164:242-255