A customized coil arrangement for PatLoc imaging inside a 9.4 T MRI spectrometer

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Introduction: Recently, MRI technology has been extended to also include non-linear gradient setups like, e.g., PatLoc [1] or O-space imaging [2]. In combination with the linear gradient coils of a commercial MRI spectrometer, these additional non-linear gradient coils reduce physical space available for imaging. Thus, existing RF coils for transmission and reception cannot be used together with these gradient coils, anymore. In addition, for PatLoc imaging, the ambiguous encoding favours the use of several localized coils, at least for reception purposes (2). For that reason, coil arrays for simultaneous transmission and reception have already been used for PatLoc imaging in small animal systems, with up to eight RF coils in a cylindrical array [3,4]. Here, we present an alternative setup with a custom-built thin-wall volume resonator together with an in-house built thin-wall receive array, both inside a PatLoc gradient coil. These RF coils are adapted to provide maximum imaging space in the region where PatLoc gradients are strongest, i.e., at the periphery of the field of view.

Methods: The setup for PatLoc imaging, already described in [5] has been extended to an actively decoupled eight-leg birdcage coil for transmission, together with an in-house built eight-channel receive array coil. The PatLoc gradient coil prototype (Bruker, Ettlingen, Germany) contains an RF shield restricting available imaging volume to a region with a diameter of 81.5 mm. A thin-wall transmission coil was built for this particular RF shield, allowing further reduction of wall thickness of the chosen high-pass eight-leg birdcage coil. MR experiments with that resonator in transceive mode on a bottle of silicone oil, d = 6 cm, gave an excitation profile that is acceptable for the low number of legs of that birdcage coil. The decoupling of the receive coils in the cylindrical receive array is done in the following way: adjacent coils are decoupled by overlap [6] and next nearest coils, in addition, are inductively decoupled using self-built transformers. Co-simulation with Agilent ADS Momentum and Ansoft HFSS was performed to find values of the mutual inductance between the next nearest coils and to find the optimal shape of the transformer for best decoupling (see ref. [7] for details on co-simulation). Thus, an eight-channel receive array was realized on flexible substrate (35 µm copper, width 1 mm on a 50 µm polyimide foil) which was mounted on a dielectric cylindrical former for good mechanical stability. Each coil in this setup has a size of 25 mm × 25 mm, with 5 mm allowed for overlap. The resonance frequency of each receive coil was adjusted to 400 MHz by an SMD capacitor opposite to the connection points to the coaxial RF cable. Balancing and match to 50 Ohm was done with two SMD capacitors in series. For later use in MR experiments, PIN diodes were added for active detuning of each receive coil, respectively, during transmission of pulses. Figure 1 shows a photo of the coil setup, the coil array, together with the self-built transmission coil and the PatLoc gradient coil prototype. MRI experiments were performed on a Bruker AVANCE III MRI spectrometer, using standard pulse sequences and coil configurations for transmission resonators in combination with either one surface coil or a coil array with up to eight channels.

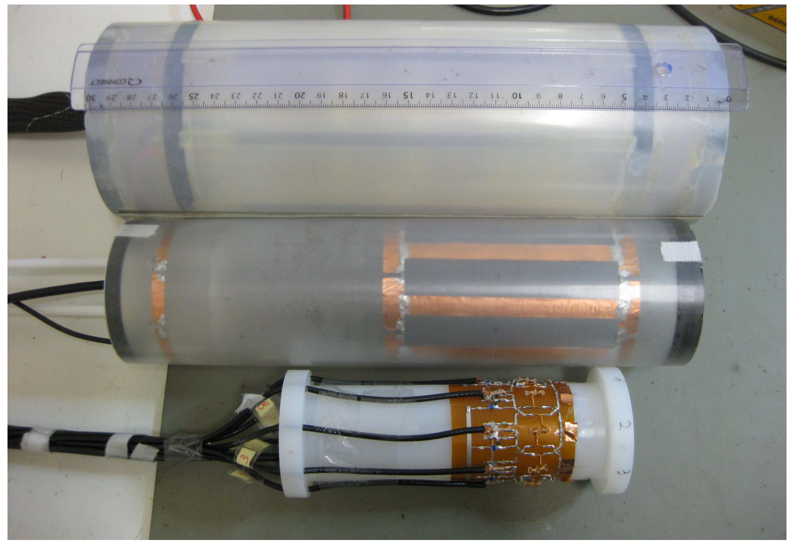

Figure 1: Photo of setup for PatLoc imaging using a concentric arrangement of top: PatLoc gradient coil, middle: eight-leg transmission resonator, bottom: eight-channel receive array coil

Results and Discussion: Bench measurements on a two-port Agilent 4396B network analyzer gave an input reflection coefficient S_{11} of less than -20 dB for all the coils of the array, respectively. Simulation and subsequent measurements of S-parameters revealed an isolation $S_{12} = S_{21}$ between the different coils of the array of better than -20 dB, still without using low noise amplifiers for improved decoupling. Thus, MR experiments even without preamplifiers could be performed. Self-built GaAs amplifiers with low power consumption of only 0.01 Watt became available from the Fraunhofer IAF, Freiburg, Germany [8]. Thus, amplification of signals from eight coils with eight amplifiers in parallel became possible. First results of these experiments are shown in Figure 2 for a phantom of silicone oil inside the receive array, all inside the volume resonator for PatLoc imaging and all inside the PatLoc gradient coil in the magnet.

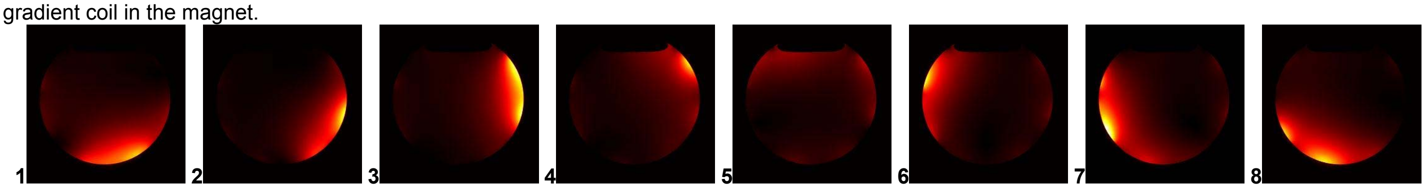

Figure 2: Coil profiles recorded simultaneously with an eight-channel receive array coil inside a volume resonator inside the PatLoc gradient coil.

Good decoupling of receive coils has been observed in accordance to results estimated from bench measurements. Better decoupling of receive coils is expected when additional decoupling is provided by low impedance input in the vicinity of the receive coils of the array. An application to PatLoc imaging of mice is considered.

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Acknowledgements: This work is a part of the INUMAC project supported by the German Federal Ministry of Education and Research, grant #13N9208, and the German Federal Ministry of Education and Research, grant #01EQ0605.