Integrated Coil-Setup for Multiple-Channel Transmit Applications at 200MHz

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Introduction: The principles of parallel RF-excitation with an array of transmit coils [1, 2] and the possibility to reduce B1 inhomogeneities with Transmit SENSE [3] have recently been published. The described experiments were performed with arrays of transmit coils driven sequentially with one transmitter and subsequent numerical combination showed the theoretically predicted excitation pattern. The impracticality to drive the coil setup in a mode with nearly homogenous transmit field $B1^{(+)}$ resulting in strong $B1^{(+)}$ variations restricted these experiments to using only gradient echo sequences. All these studies were limited by the lack of suitable hardware to perform really simultaneous transmission on multiple channels. So-called B1 shimming by adjusting the amplitudes and phases of individual transmit coils according to numerical calculations was introduced last year [4]. This study has shown that the adjustment of $B1^{(+)}$ by setting different phases and amplitudes allows to provide a desired excitation pattern. Numerical RF-field simulations were needed to pre-calculate the RF-sensitivity distributions for controlling the transmit field $B1^{(+)}$ in objects. The present study depicts a novel RF-coil setup and electronics which overcome the mentioned hardware limitations and demonstrates the practical feasibility of Transmit SENSE in experiments with simultaneous, individual transmission of specific RF-waveforms on up to three channels.

Methods: All measurements were performed on a 4.7T, 40cm BioSpec-system (Bruker BioSpin MRI GmbH, Ettlingen, Germany) equipped with four independent transmit channels (1x 1kW, 3x 0.3kW) capable of generating four independent RF pulses with individual sequence timing, pulse shape, frequency, phase and amplitude. Additional pin diode driving units were integrated in the system comprising 4 driving channels for actively decoupling the individual coils.

A novel coil setup was developed specially designed for multiple-channel transmission experiments. This setup (Figure 1) consists of two individual coils: a so-called CSA-Array [5] with three actively decoupled elements and an actively decoupled birdcage-type resonator, the so-called body coil. The CSA-array is mounted on a FR4 cylindrical former with an inner diameter of 72mm. The three array elements with a width of 2.5 cm and a length of 8 cm each are mounted symmetrically on the cylindrical former re 120° sectors. All elements are equipped with an active decoupling circuit and are switched simultaneously by the same active decoupling pulse. The unloaded and loaded Q-values were measured as 240 and 180, respectively. All array elements where pre-matched and pre–tuned for the intended loading. The array elements are decoupled with a minimum S12 of -18dB. This CSA-Array coil with an outer diameter of 112mm was inserted into the body coil with an inner diameter of 197mm and an outer diameter of 255mm. The active decoupling of both coils ensures the individual coils to be decoupled with a minimum S12 of -28dB by appropriately detuning one coil with respect to the resonance frequency of 200MHz. The coil setup was loaded with a spherical phantom of 6 cm diameter filled with T1-doped saline water solution (ε=76 and δ=0.2S/m). For the practical realization of Transmit SENSE a transmit coil array with spatially varying $B1^{(+)}$ sensitivity profiles is essential. In addition, for detection a coil with homogenous sensitivity profiles is preferred, in particular to enable slice selective refocusing. Both requirements are very well fulfilled with the above described coil-setup. A Spin-Echo sequence with a 2D selective pulse and slice selective refocusing was used for Transmit SENSE image acquisition.

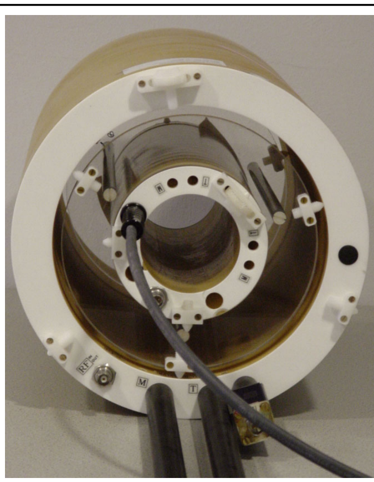

Figure 1

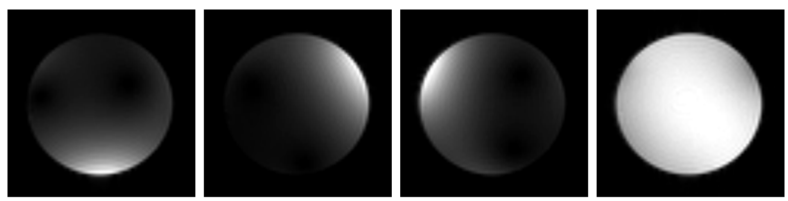

Figure 2 a-d

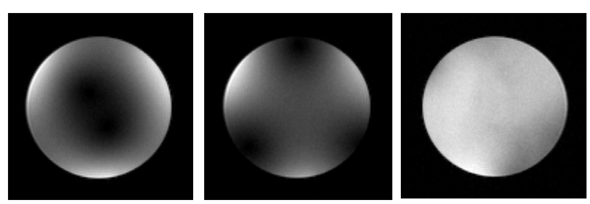

Figure 3 a-c

Results: The images in Figure 2 show the transmit profiles of the individual array elements and the body coil. The sensitivity profiles of the array elements (Figure 2a-c) show a good rotational symmetry by 120° and a well-suited spatial variation of the transmit field. In comparison the rather homogenous $B1^{(+)}$ field as measured for the body coil is presented in Figure 2d. These field profiles are the basis for the calculation of the complex sensitivity maps required for Transmit SENSE. Various dependencies of the excitation pattern from different driving parameters of the array elements are demonstrated in Figure 3. Figure 3a shows the excitation pattern generated by the array-elements when driven with the same phase and amplitude. Otherwise, when driving the array elements with the same amplitude and a phase shift of 120° between neighbouring elements a relatively small region with rather homogenous transmit field could be observed in the centre of the phantom. When applying the Transmit SENSE technique a significant increase of the transmit field homogeneity could be observed. The excitation pattern shown in Figure 3c has been obtained from the CSA-array when driving the array elements with the individual RF-pulses which had been pre-calculated using the complex sensitivity maps.

Discussion and conclusions: The presented coil-setup and additional electronics provide an appropriate hardware solution for Transmit SENSE with real simultaneous RF-transmission by multiple array elements on independent channels. Adjusting the $B1^{(+)}$ field by means of the Transmit SENSE techniques provides a significant improvement of the RF-transmit field homogeneity compared to the RF-field distributions which can be generated by simple superposition of the individual array element $B1^{(+)}$ fields with various phase settings.

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