An Eight-channel 3D-segmented RF Coil for Parallel Transmission at 3T

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Introduction: Local excitation [1] in combination with Transmit SENSE [2] can be applied efficiently to compensate for wave propagation effects or to excite arbitrarily shaped patterns. Transmit SENSE requires RF coils with multiple independent transmit elements to excite the desired spatial patterns. Recently, multi-channel transmit RF coils have been presented, which are 2D-segmented in circumferential direction [3-6]. This work describes the implementation and operation of a decoupled eight-element RF coil segmented in 3D, e.g. also the z-direction. This allows e.g. to accelerate spatially selective RF pulses in arbitrary spatial directions using the non-uniform profiles of the magnetic field B_1 of the RF-coil.

Methods: The eight-element coil was designed to perform head imaging at 3T. The transmit elements of the coil, designed as TEM elements, were mounted equidistantly in the RF screen (∅=36cm, l_{coil}=37.5cm). The TEM elements (l_e=16cm) are placed in two rings consisting of four elements each. The rings overlap by 5cm and are twisted by 45° (Fig.1). This results in a -3dB drop of magnetic field B_1 on the z-axis between the maximum of the field (Fig.1, A) and the field measured centrally over the adjacent element (Fig.1, B). The conductor structure was implemented in copper strips to obtain a good reproducibility of the elements. The resonators were tuned to 127.7MHz and matched to 50Ω using an L-shaped (C_1, C_M) network. A decoupling ring, at the centre of the coil, is used to compensate for mutual coupling. The ring consists of the decoupling inductors L_D. The end-ring is connected to the elements by the capacitors C_D. The elements of the ring, especially the inductors L_D do not contribute to the magnetic field B_1 of the coil. The receive signals are directed to low noise amplifiers using Tx/Rx switches allowing to use the coil for transmission as well as reception. The coil was integrated into a 3T MR system (Achieva, PMS, The Netherlands) equipped with eight transmit/receive channels [7]. MR images were acquired using a TFE sequence. A series of phantom (d=17cm, h=25cm, Fig.2) images (T_R/T_E=8/4ms, voxel size 0.8×0.8×5mm) was acquired from transversal slices placed centrically with respect to the element rings (Fig.1). Furthermore, sagittal images (T_R/T_E=8/4ms, voxel size 1.4×1.4×5mm) were acquired to demonstrate the drop of the B_1 field in z-direction.

Results and Discussion: Fig.3 shows the scattering parameters of the coil. The reflection coefficient S_{nn} of the individual RF channels is better than S_{88} = –14dB. The mutual coupling S_{nm} (n,m = 1 – 8, $m \neq n$) between the coil elements is smaller than –13dB indicating a good separation of the coil's transmit sensitivities. Fig.4 shows the result of the imaging experiments. The transversal images (Fig.4a) demonstrate the circumferential segmentation of the sensitivities. The poor SNR in every second image indicates the z-segmentation, i.e., the corresponding element is outside the imaging plane. Fig.4b shows the z-segmentation of the sensitivities in a sagittal view of the phantom. The image intensity decreases with increasing distance from the element in z-direction (along with the already shown drop in radial direction).

Conclusion: A novel 3D segmented RF coil was developed and integrated into a 3T multi-channel transmit MR system. Initial imaging experiments demonstrate an excellent performance of the coil. The 3D segmented sensitivities of the coil allow to accelerate Transmit SENSE in arbitrary spatial directions.

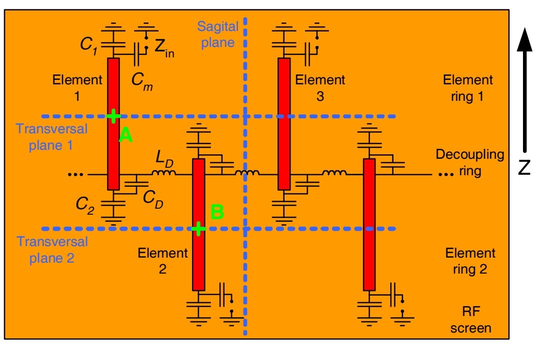

Fig. 1: Sketch of the eight-channel coil. The capacitor C_m is used to match the impedance of each coil to 50Ω. Capacitors C_D and inductors L_D are used to decouple the elements. The TEM element is connected to the RF screen using the capacitors C_1 and C_2.

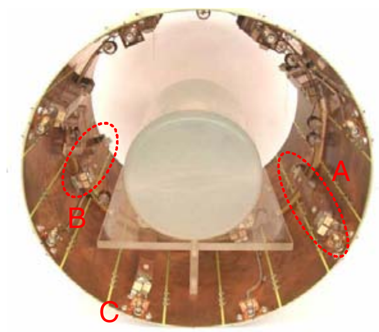

Fig. 2: Image of the transmit/receive head coil loaded with a phantom.
A: an element of the ring 1
B: an element of the ring 2
C: the feeding ports

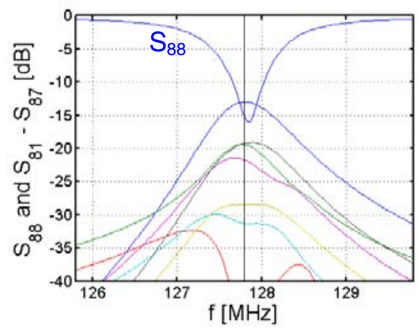

Fig. 3: Scattering parameters S_{nn} and S_{mn} of the coil exemplarily shown for channel eight. The strongest coupling among the elements is –13dB.

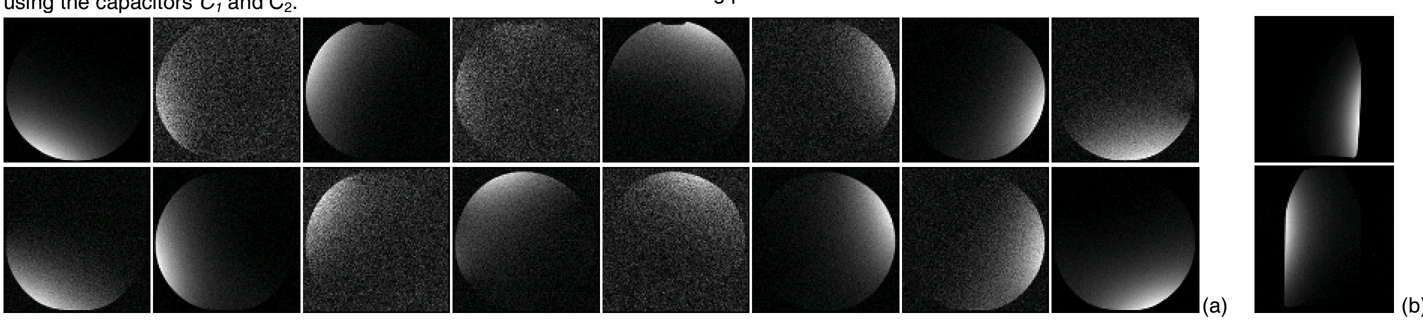

Fig. 4a: Eight single-channel transmit sensitivities of the phantom acquired in transversal planes. The first (second) row shows images acquired in a transversal plane, which is placed in the center of element ring 1 or 2, respectively (see Fig. 1). **4b:** Excitation pattern in a sagittal plane of opposite elements placed up left and down right.

References: [1] Pauly J et al., A k-space analysis of small-tip-angle excitation, JMR 81: 43-56, 1989 [2] Katscher U et al., Transmit SENSE, MRM 49: 144-150, 2003 [3] Junge S et al., Current Sheet Antenna Array, Proc. ISMRM 12: 41, 2004 [4] Alagappan V et al., An 8 Channel Tx Coil for Transmit Sense at 3T, Proc. ISMRM 14: 121, 2006 [5] Snyder C et al. High-Field Transmission Line Arrays for Tx and Rx, Proc ISMRM 14: 421 2006
[6] Vernickel P et al., An Eight Channel Tx/Rx Body Coil for 3T, Proc ISMRM 14: 123, 2006 [7] Graesslin I et al., Whole Body 3T MRI System with Eight Parallel RF Transmission Channels, Proc ISMRM 14: 129, 2006