7-channel half-cylinder shaped transmit coil with 32-channel receiver array for multipurpose head imaging at 7T

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Purpose Head images at 7T are typically obtained with a cylindrical volume coil. Although high B_1^+ is reached in the center of the head with this type of coil, the B_1^+ efficiency in the periphery is much lower. As a result, certain regions of the head are hard to image due to insufficient B_1^+, or sequences such as TSE are limited by SAR restrictions. A solution to insufficient B_1^+ is a multi-transmit coil, where by phase and amplitude shimming the B_1^+ can be increased in the region of interest while the SAR is maintained within its limits. Here we extend the advantages afforded by multi-transmit coils with an open half-cylinder shaped coil design. With this design a large field of view is open to the subject, allowing not only for improved B_1^+ efficiency, but also for imaging structures that do not fit in a birdcage coil or for improved access to the subject.

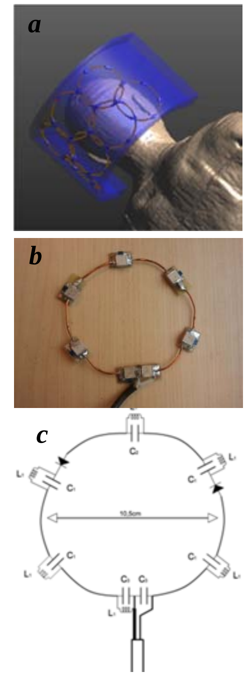

Fig 1: Simulation model (top), construction (middle) and schematic (bottom) of the transmit coils.

Methods Coil design: The housing of the coil consists of 2 concentric half cylinders manufactured from perspex of 5 mm thickness. The inner half-cylinder has an inner diameter of 250 mm, the outer half-cylinder was separated from the inner part by 2 cm. The sides of both half-cylinders were extended with 75 mm perspex for additional support. Seven loop coils were placed on the inner part (Fig 1a). The loop coils (diameter 105 mm) were tuned and matched to 298.2 MHz and 50 Ω. They were geometrically decoupled by an overlap of 15 mm (overlapping as in Fig. 1a). Each loop was made out of six copper wires, separated by capacitors (Fig 1b and 1c, C_1 = 5.6 pF, C_2 = 8.2 pF, C_3 = 15 pF). Detuning of the loops was achieved by placing two diodes in series with the 5.6 pF capacitors. In each loop, choke coils (L = 1000 nH) were placed in parallel with each capacitor to make tuning of the loop possible (Fig 1c). The detune signal of the interface box was used to supply DC current for tuning the loops. The signal was added to the RF signal of the coax cable. Cable traps were placed at the end of the feeding cables. Simulations: Numerical simulations were performed with SEMCAD (Speag, Zurich, Switzerland) to monitor the SAR. MRI Experiments: The coil setup was tested in two configurations; for imaging the cerebellum and mouth area. Two healthy volunteers were scanned with a 7T MR scanner (Philips Healthcare, Cleveland, OH, USA). A flexible high density array of 32 receive coi1s (2 x 1 cm^2 loops) was used for signal reception. For cerebellum imaging, the volunteer rested supine on the half-cylinder coil with the receive coils placed between the head and the transmit coil (Fig 3a). For mouth imaging, the volunteer was scanned in a radiotherapy immobilization mask which was fixed to a base plate (Fig 3c) and the receive coils were placed at the cheeks and secured with foam pads (Fig 3d).

Results Simulations: Fig 2 shows simulation results normalized to 1 W per channel. From the results of the separate channels a shim set was determined that homogenized B_1^+ in the cerebellum. For this shim set the maximum SAR_{10g} was 1.42 W/kg.
Experiments: The RF coupling between the transmit elements was less than -14dB and matching better than -15dB when loaded with the human head. Fig 3b shows a T1-weighted image of the cerebellum obtained after phase shimming (MPRAGE, 1mm isotropic resolution). While a conventionally used 7T birdcage head coil can only provide a relatively low B_1^+ at the cerebellum, sufficient B_1^+ could be obtained with the 7 channel transmit surface array. Fig 3e shows a high resolution T2-weighted (TSE, 0.4x0.62x1.5 mm^3) image of the mouth acquired with the volunteer scanned in a radiotherapy immobilization mask. The immobilization mask setup is not compatible with a standard birdcage coil, but the 7-channel transmit coil fits around it and high resolution images of the mouth could be obtained at 7T.

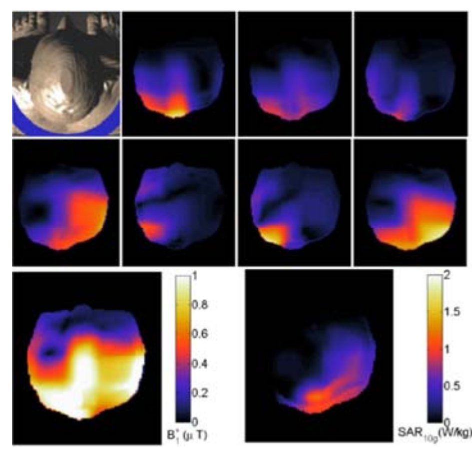

Fig 2: Simulation results normalized to 1 W delivered per channel, transverse slice at the height of the cerebellum. Top two rows: B_1^+ for the 7 separate transmit channels (from left to right and top to bottom). Lower left: B_1^+ combined with a phase combination homogenizing the B_1^+ in the cerebellum. Lower right: SAR_{10g} for this phase combination.

Discussion
Our results show that the half-cylinder coil can be used for imaging areas that typically have low B_1^+, here illustrated for the cerebellum and mouth. Using the flexibility in steering B_1^+ focused to the area of interest, and providing a separate high density receiver coil, maximum SNR and acceleration can be obtained while high flip angle duty cycles can be maintained within SAR guidelines (Fig 2). The coil can be used in combination with a radiotherapy immobilization mask, making 7T scans of the head available for radiotherapy treatment planning. Furthermore, the improved access to the subject with this coil setup can be of benefit for several applications, for instance for increasing the subject's visual field of view for fMRI of the visual cortex.

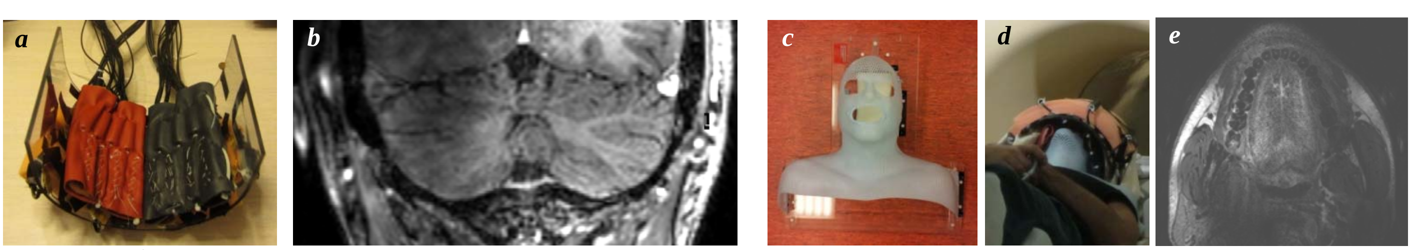

Fig 3: Photos of and MR images obtained with the 7 channel transmit coil merged with a high density 32 channel receiver coil. As can be seen, the half cylinder allows access to the cerebellum and enables 7T MRI while providing an immobilization mask.