An parallel-transmit, parallel-receive coil for routine scanning on a 7T head-only scanner

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Purpose. Design challenges exist when attempting to develop to a transmit/receive coil for head-only, ultra high field scanners. Limited radial space, due to the narrow bore, imposes tight geometrical constraints on the design of the coil that can affect coil performance. Further accommodations must be made to ensure the coil is practical for patient studies and routine scanning. In this study, an 8-channel transmit coil and 32-channel receive coil (Fig. 1) were designed and constructed to fit inside a 7T head-only scanner that could accommodate an RF coil with a maximum outer diameter of 32 cm. The transmit and receive coils were integrated into one former and the anterior and posterior sections were split into two sections to facilitate patient positioning. A large opening was incorporated into the anterior of the coil for patient comfort and for the presentation of visual stimuli during functional studies.

Methods. The 32-channel receive coil was constructed on a polycarbonate former mimicking the shape of the head. The multi-loop design was modeled after the soccer-ball geometry[1], and the anterior and posterior halves were overlapped to ensure optimal decoupling between adjacent elements. Due to the lack of radial space, the low-input-impedance preamplifiers were mounted in a box at the superior aspect of the coil (outside the transmit field) and were connected to receive elements with nλ/2 cables (~33 cm). Preamplifiers were secured to boards, in groups of eight, which could be rotated to allow access during coil construction. The transmit coil was separated from the receive coil by approximately 1 cm at its nearest location. While effort was made to route receive cables along the virtual grounds of the surrounding transmit elements, each receive cable had two integrated lattice baluns to reduce common-mode currents induced by the transmit field. Two parallel-resonant active-detuning circuits were incorporated into each element: one on the loop itself and one on the mounting board of the preamplifier. The additional detuning circuit was required due to the tight coupling of the transmit coil. A matching network, passive detuning network, bias-T, and fuse were also located on or near the mounting board of the preamplifier.

The transmit coil consisted of eight overlapping elements (13.0 × 23.4 cm [width × height]) on a quasi-elliptical polycarbonate former. The anterior-most element was bridged across a central gap left for the presentation of visual stimuli—these bridges were at a larger diameter than other elements to place them outside the subject's line-of-sight. Elements were tuned to 297 MHz and matched to 50 Ω using the ratio of parallel-to-series capacitance. Wire jumpers on the element legs were bent to adjust the overlap between adjacent elements and optimize decoupling. Each element had two parallel-resonant circuits for active detuning during receive, and choke baluns were placed on the input of each transmit element to prevent common-mode currents. The anterior and posterior halves were electrically connected, through coaxial pins and receptacles, by breaking two diametrically opposed elements. Full-wave electromagnetic simulations of the transmit coil were performed to determine safe operating-limits for human scanning

Whole-brain MP2RAGE images with 750-μm isotropic resolution were acquired to assess image quality (matrix: 320 × 320 × 208, TE/TR: 2.0/6000 ms, TI1/TI2: 800/2700 ms, BW: 240 Hz/pixel, flip angles: 4°/5°, R: 3 (A-P), reference lines: 24, partial Fourier encoding: 6/8 (A-P) and 6/8 (H-F), acquisition time: 9 min 38 s).

Results. The minimum and mean S_{12} between adjacent receive coils was -12 dB and -17 dB, respectively. The necessity of cables between the receive elements and the preamplifiers could have hindered preamplifier decoupling; however, by using low-loss cables and lattice baluns, preamplifier decoupling of an isolated element was still -25 dB. Active detuning was better than -40 dB with the addition of a second active-detuning circuit on the coil loop. The *Q*-ratio of an isolated element was 5.8, thereby indicating body-noise dominance was achieved. The multiple lattice baluns in the receive cables were successful at rejecting common-mode currents and reducing coupling between receive coils—the mean and maximum noise correlation between receive elements was 3.4% and 25%, respectively.

The transmit coil had a minimum and mean S_{12} of -12 dB and -23 dB, respectively. SAR simulations (Fig. 2) showed the local-to-global SAR ratio for a CP mode to be 4.0. The transmit reference voltage was 109 V per channel for a CP mode. B_1^+ non-uniformities caused by the asymmetric split former could be compensated by adjusting the magnitude and phase of individual transmitters; this resulted in the transmit field being uniform to 30% across the brain (to the inferior aspect of cerebellum). The efficiency and uniformity of the transmit coil allowed for MP2RAGE images with uniform contrast into the cervical spine (Fig. 3).

Conclusions. It is possible to create a multi-transmit, multi-receive RF coil that adheres to the restrictive space requirements of a head-only 7T scanner, while still being practical for routine scanning. Design modifications can be made to limit the interaction between the transmit and receive coils, despite their close proximity.

References. [1] Wiggins et al. MRM 2006; 56: 216-223.

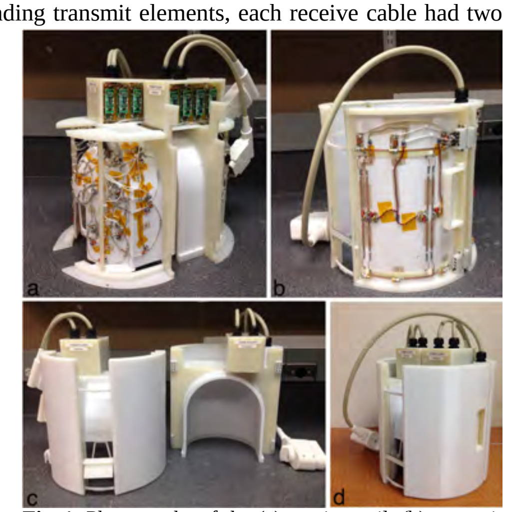

Fig. 1. Photographs of the (a) receive coil, (b) transmit coil, and (c,d) the combined coil with covers.

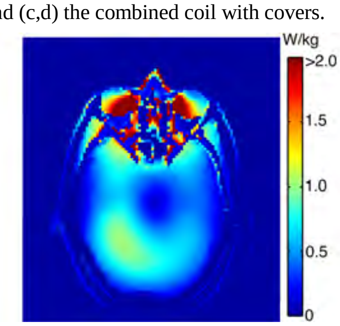

Fig. 2. Local SAR map of the transmit coil.

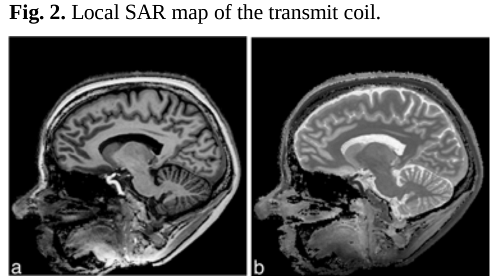

Fig. 3. (a) 750-μm-isotropic MP2RAGE image and (b) corresponding T_1 map.