A 16-Channel Conformal Transceive Coil for 7-T Neuroimaging

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Introduction

Transmit/receive arrays have been developed to mitigate RF inhomogeneities at high field and to increase SNR. The majority of these designs consist of an array of surface coils or transmission line elements on a cylindrical former. The cylindrical geometry increases transmit uniformity, due to the large distance from the head, while sacrificing transmit efficiency and receive sensitivity. Conformal designs have the potential to increase transmit efficiency (and decrease SAR), while at the same time increasing SNR. A 16-channel transmit/receive coil is presented that conforms to the shape of the head. The decoupling scheme allows for coil elements to have arbitrary shape, size, and location: this flexibility allows coil elements to be both electrically and physically independent—a desired characteristic for parallel imaging. The increased receive sensitivity of the conformal design, coupled with the reduced radiation losses achieved with the individually shielded design (1), creates high SNR.

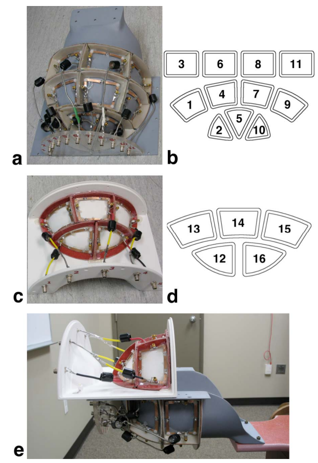

Fig. 1. Conformal transmit/ receive coil and planar schematics of coil layout.

Methods

The coil consisted of 16 independently driven transmit/receive channels located on two detachable halves of a head-shaped former (Fig. 1). Each element was curved to conform to the former and the shape chosen to maximize orthogonality of the B_1 field to the B_0 field. Elements were decoupled using circumferential shields around each element that extended orthogonally from the former. Electrically isolated copper-mesh shields encompassed each coil element at approximately 5-9 mm from the element and were 1.9- to 2.5-cm high. Elements were raised above the former by 5.1 mm. These distances were empirically determined to increase SNR, while retaining high isolation between elements.

The RF coil was tested in a Varian 7-T MRI system. Transmit fields were mapped using the method presented by Van de Moortele et al. (2). The required transmit amplitudes and phases for transmit shimming were then calculated to provide maximum transmit efficiency over a 3D ROI covering the entire brain. Two-dimensional multislice gradient-echo images were acquired to measure SNR. The signal was normalized by the standard deviation of pixels in a noise-only scan. To demonstrate the parallel imaging performance, fully sampled gradient echo images were acquired and under-sampling of k-space was performed during post-processing. Two-dimensional geometry-factor maps were then calculated using the SENSE method (3).

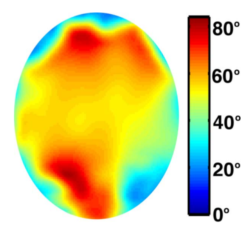

Fig. 2. Axial flip-angle map. The flip-angle map has been smoothed, interpolated, and cropped for display.

Results

The mean loaded and unloaded Q values of the coil elements were 145 ± 30 and 250 ± 60, respectively, resulting in Q ratios (Q_U/Q_L) of 1.3-2.4. The high isolation between coil elements (27 ± 10 dB) increased the effectiveness of RF shimming and allowed for a normalized transmit-field uniformity (std/mean) of 43% over the brain. A representative axial slice of a 3D flip-angle map is shown in Fig. 2. The tight coupling of coil elements to the head reduced the absorbed power during RF transmission (331-µs pulse for a 90° flip angle with a 1-kW hard pulse). During reception, the close proximity of the elements to the head increased SNR in the periphery of the brain, most notably at the top of the head (Fig. 3). The achievable SNR is demonstrated in a slice of a T_2^*-weighted multislice gradient-echo acquisition (Fig. 4). For accelerated imaging, sensitivity profiles of each element are localized beneath their respective shield, resulting in low geometry factors (Fig. 5).

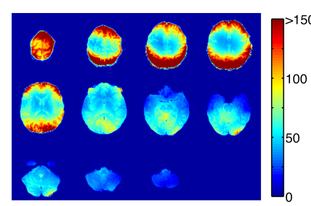

Fig. 3. SNR maps. Matrix: 96 x 96, FOV: 19.2 x 19.2 cm, thk: 2 mm, TE/TR: 2.8/ 2000 ms, BW: 83 kHz.

Discussion

The individually shielded decoupling scheme allowed coil elements to be of arbitrary shape and size and allowed the most efficient use of space on the two-part former. Circumferential shielding around the elements of the conformal coil localized receive sensitivities to below the plane of the shield and created a more rapid decrease in receive sensitivity than an unshielded coil. This caused the SNR to be high in the cortex, while also decreasing the g-factor and the degree of aliasing during SENSE reconstruction. The conformal geometry still achieved sufficient transmit uniformity over the brain. The combination of high cortical SNR and excellent parallel imaging performance make this coil particularly well-suited to functional MRI.

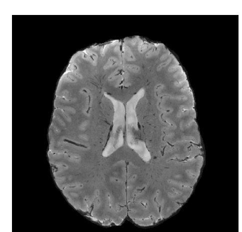

Fig. 4. T_2^*-weighted multislice gradient-echo. Matrix: 384 x 384, FOV: 19.2 x 19.2 cm, N_{slices}: 25, thk: 1 mm, TE/TR: 16/1000 ms, BW: 15 kHz.

References

1. Gilbert et al. MRM 2010; DOI: 10.1002/mrm.22574.
2. Van de Moortele PF et al. Proc. 17th Annual Meeting ISMRM, Honolulu, Hawaii, 2009. p 366.
3. Pruessmann KP et al. MRM 1999; 42:952-962.

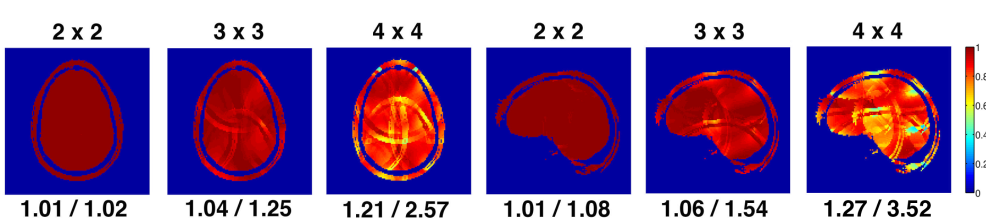

Fig. 5. Inverse g-factor maps. Mean/maximum g-factors are provided below the corresponding map. Matrix: 128x128, FOV: 25.0x25.0 cm, BW: 89 kHz.