

A localized 16-channel linear planar array for 3T human brain imaging

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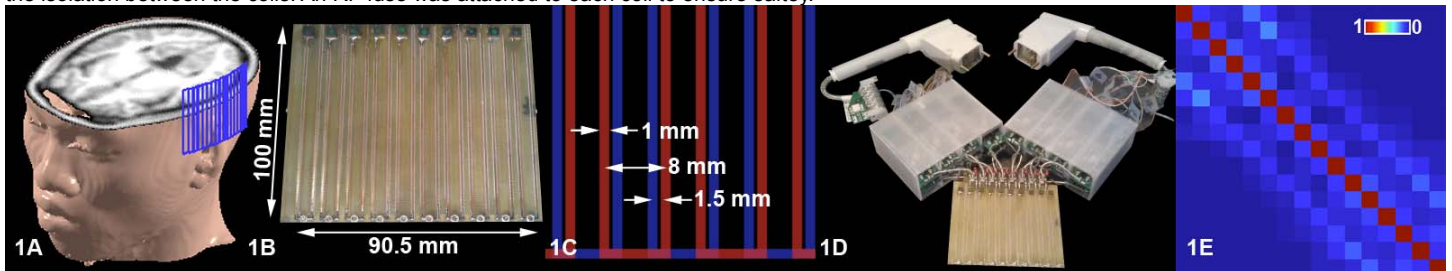
Introduction

Independent of reconstruction algorithms, parallel MRI (pMRI) aiming at spatiotemporal resolution enhancement critically depends on the spatial information among a coil array [1]. Previously, sixteen-channel coil arrays have been developed for volumetric head imaging at 3T [2, 3] and 7T [4], breast imaging [5], and airway imaging [6]. Yet, to our knowledge, there was no dedicated 16-channel array designed for localized brain imaging. When coil elements are arranged linearly, it has been suggested that an image can be acquired in a single echo [7]. However if the size of the RF coil is too small, the depth of the detection sensitivity becomes limited.

Here we develop a 16-channel linear planar coil array for 3T localized brain MRI. Specifically, the design aims at two features: 1) a small coil element and a large total area in order to ensure simultaneous high sensitivity and sufficient detection depth. 2) The array elements are arranged linearly for the optimal 1D pMRI acquisition. Experimental results show that this planar array provides good isolation among coils and high sensitivity in the temporal lobe using 4-fold accelerated acquisitions. Potentially the coil may also be used for other localized brain areas in neuroscientific and clinical applications.

Material and Methods

The 16-channel planar array was designed to cover a total area of $9.05 \times 10 \text{ cm}^2$ using 16 rectangular RF coils arranged linearly (Figure 1A). Each RF coil was $10 \times 0.8 \text{ cm}$ and tuned to 123.25 MHz with 2 distributed capacitors. The coil was routed automatically with 1mm wire width using FR4 circuit board (thickness=1.6mm, 18um double copper layer, NYPCB corp.). The RF coils were distributed over two sides of a circuit board (8 at each side; Figure 1B). In order to reduce the mutual inductance between two neighboring coils at the opposite side of the circuit board, coils were overlapped by 1.5 mm (between the next red/blue coils in Figure 1C). At each side of the circuit board, eight coils were connected to eight pre-amplifiers located a two-stack pre-amplifier module (Figure 1D). These low-noise pre-amplifiers (Stark Contrast, Erlangen, Germany) with 7+j20 input impedance and 26 dB gain can further improve the isolation between the coils. An RF fuse was attached to each coil to ensure safety.



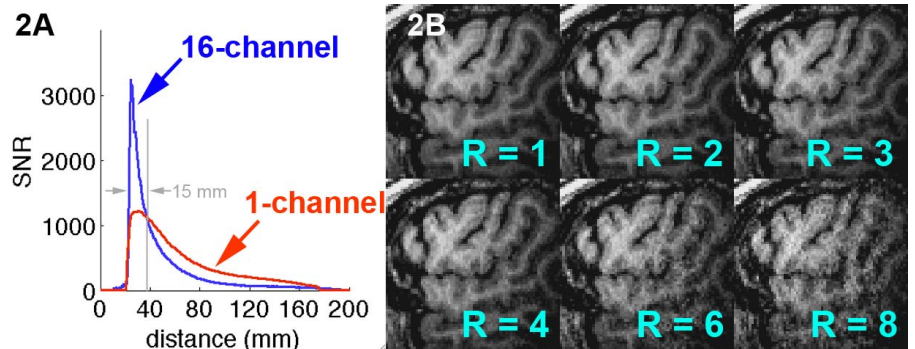
Data were acquired on a 3T MRI scanner (Tim Trio, Siemens, Erlangen, Germany). For SNR comparison, a spherical phantom was measured using the 16-channel planar array and a 1-channel planar coil with the same coverage area. We used the turbo-spin echo (TSE) sequence with the following parameters: TR/TE=3000/12ms, Slice thickness=5mm, FOV=20×20cm², image matrix=256×256. The noise covariance matrix was calculated using data collected without RF excitation. T1-weighted images were measured using a MPRAGE sequence (TR=2530 ms, TE=3.03 ms, TI=1100 ms, Flip angle = 7°, slices = 192, slice thickness=1 mm, FOV=256 mm). The fully gradient encoded data were accelerated numerically to demonstrate the performance of this 16-channel linear planar coil array in 2x, 3x, 4x, 6x, and 8x accelerations.

Results

Figure 1E shows the noise correlation matrix of the array. The average/max/min noise correlation values between the nearest neighboring coils were 0.14/0.18/0.11. The average/max/min noise correlation values between the next nearest neighboring coils were 0.07/0.16/0.01.

Figure 2A shows the SNR profiles of the 16-channel linear planar array and 1-channel RF coil of the same size. As expected, the 16-channel arrays has a higher SNR close to scalp, potentially due to a smaller RF coil element. At the brain areas deeper than 15 mm, the SNR of single channel RF coil preceded that of the 16-channel array. At around 50 mm from the scalp, the 16-channel array has approximately 60% SNR of the 1-channel RF coil.

Figure 2B shows un-accelerated (R=1) and accelerated (R=2, 3, 4, 6, and 8) images of an ROI close to the auditory cortex in a sagittal slice. Note that image SNR degraded gradually as the acceleration rate (R) increased. At R=4, we still observed nice white/gray matter with an acceptable SNR.



Discussion

The development of this linear planar array aims to provide high quality small-FOV accelerated brain MRI. Our preliminary results show that this array has independent information among channels. Yet the depth sensitivity becomes a necessary trade-off for the pMRI spatiotemporal resolution enhancement. We demonstrated unaccelerated and accelerated anatomical images of 1 mm resolution. Further array optimization includes (i) material/width of the RF coil to increase the ratio between unloaded vs. loaded quality factor, (ii) a curved planar structure to tailor to the geometry of the head, (iii) a mechanical housing for easy usage. Functional MRI studies aiming at sub-millimeter resolution will be attempted using this linear array shortly.

References

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