Eight-channel array coil optimized for functional imaging of awake monkeys at 7T

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Introduction: Functional MRI of awake non-human primates is challenging due to increased demands on image encoding and SNR required for high resolution and the need to mitigate body-motion induced susceptibility distortions. High field strengths and receive-coil arrays can both boost the sensitivity required for smaller voxel sizes, but require dedicated receive coil geometries for accelerated primate imaging studies and for the stresses of the primate and the high-field environment. Furthermore, the penetration of the coil sensitivity must reach into the brain region, which can be far from the scalp due to the thick temporalis muscles. Here we present an 8-channel monkey coil designed to be compatible with a monkey chair and head restraint system. The coil diameter was chosen as a trade-off between element count (which in part determines the acceleration capabilities of the array) and penetration. Our larger element sizes allowed whole-brain coverage and required that the array be mounted on a single plastic former, which also provided additional mechanical stability compare to dual paddle designs [1]. With this array we were able to acquire temporally stable, BOLD-weighted EPI data at 7T with 0.75 mm and 0.5 mm isotropic voxel sizes and increased image SNR compared with similar coil designs for 3T and 7T.

Methods: The array (Fig. 1) consists of eight elements made of 16 AWG wire loops [2], 5.5 cm in diameter, with four equally-spaced capacitors. A lattice balun with a PIN diode provides matching and detunes each element during transmit. The preamp decoupling is achieved with lumped-element phase shifters, allowing the preamps to be placed close to the coil elements, which reduces cable currents. In addition to this, cable traps are placed behind the preamps. A local detunable single-loop transmit coil 17 cm in diameter is used for excitation.

The elements are laid out on an ABS plastic former fabricated with a 3D printer, and positioned to surround the brain fully while not obstructing the head post system or the visual stimulation. To accommodate different head sizes and positions, the array is slightly flexible while still maintaining sufficient coil decoupling. The array, transmit coil and preamp housing are mounted to the monkey chair.

Array noise covariance and SNR maps for the axial slices were computed following the methods of Kellman & McVeigh [3]. While comparing SNR maps between arrays across field strengths, same-sized transmit coils were used. To evaluate the coil for high resolution FMRI we acquired whole-brain EPI data (at 0.75 mm isotropic voxel size: TE 20 ms, TR 2000 ms, BW 1488 Hz/pixel, echospacing 83 ms, FA 72°, *R*=*2*; at 0.5 mm isotropic voxel size: TE 26 ms, TR 2260 ms, BW 960 Hz/pixel, echospacing 1.13 ms, FA 90°, *R*=*2*).

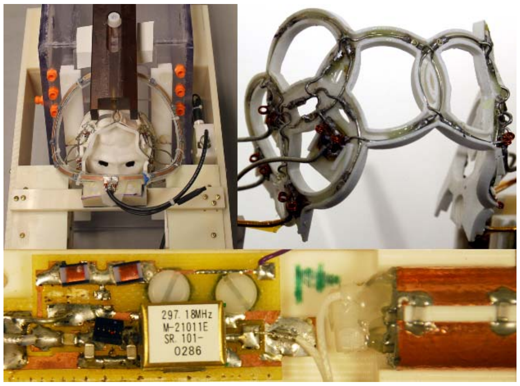

Fig. 1: (top left) Array on monkey chair with plastic monkey model with 17 cm dia. Tx loop shown; (top right) elements laid out on former; (bottom) preamp assembly.

Results: Each element shows a Q unloaded-to-loaded ratio of ~240/60 with a spherical phantom 10 cm in diameter. Loaded S21 between neighboring elements ranges from -18 dB to -12.5 dB. S11 reflections showed the elements tuned and matched to 50 Ohms. Fig. 2 compares the SNR maps and the noise correlation coefficient matrices between the array and different custom-built coils at 7T, and also similarly built arrays at 3T. The results (Table 1) show an increase in SNR by a factor of 3.7 between the 8-channel arrays at 3T and 7T, suggesting contribution from both the field strength and the array design. The off-diagonal matrix values for the noise correlation coefficient averaged to 11.5%. The measured stability of the coil with a spherical agar phantom 10 cm in diameter was 0.42% for peak-to-peak. In an ROI covering the phantom, the SENSE G-factor (*R*=*3*: avg 1.16, Max 2.7; *R*=2: avg 1.07, Max 2.1). Fig. 3 shows EPI images at 0.75 mm and 0.5 mm isotropic resolution with improved temporal stability obtained with high resolution throughout the brain.

Conclusions: The 7T 8-channel monkey coil provides nearly a fourfold increase in overall SNR over the other custom-built arrays. The shot-to-shot stability was good, indicating the coil's utility for functional brain imaging. This design meets the additional demands placed on the coil by the high field strength, the mechanical constraints of the monkey chair and apparatus, the necessity for deeper sensitivity penetration and whole-brain imaging, and the need for small voxel sizes.

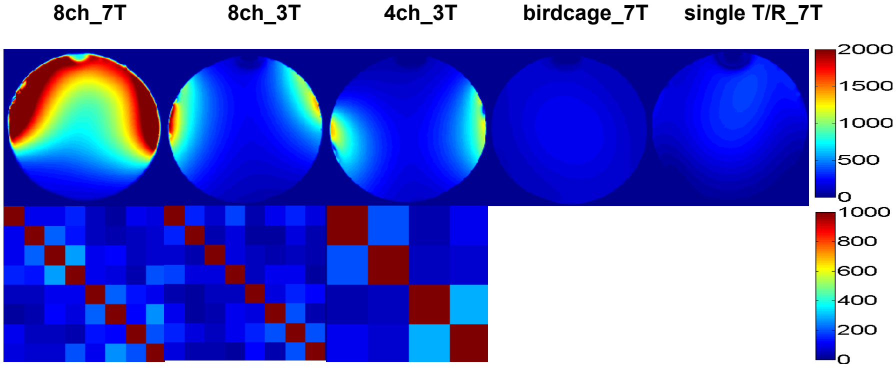

Fig. 2: SNR Maps (top row); noise correlation coefficient matrix (bottom row).

Coil	8Ch 7T	8Ch 3T	4Ch 3T	Birdcage 7T	Single T/R 7T
Average SNR	264	75	61	38	46

Table 1: Average SNR

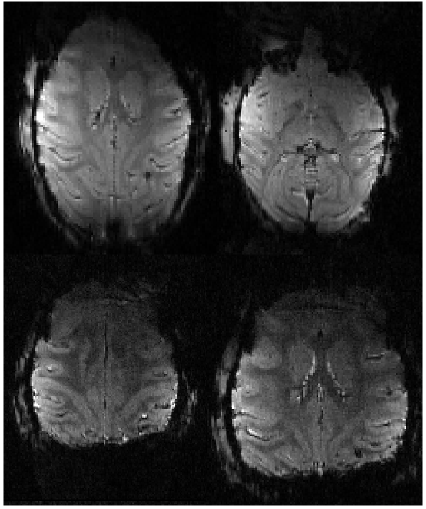

Fig. 3: Example slices from a whole-brain BOLD-weighted single-shot EPI data, with 0.75 mm voxels (top row), and 0.5 mm voxels (bottom row).

References: [1] Kolster *et al.* (2007) *Proc ISMRM*. [2] Wiggins *et al*. (2006) *MRM* 56:216-23. [3] Kellman *et al.* (2005) *MRM*, 54(6):1439-47.

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