A whole-brain 8-channel receive-only embedded array for MRI and fMRI of conscious awake marmosets at 7T.

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Target audience:
MR Physicists, Engineers.

Purpose:
The present work describes the development of a whole-brain, 8-channel receive-only surface coil array for MRI/fMRI brain studies in conscious awake marmosets. It has been previously demonstrated [1, 2] that gain in SNR is achieved by integrating coil array elements into the inner surface of restraint helmets used to immobilize the head of the marmosets [3]. However, the use of regular wire as conductor can cause susceptibility artifacts in MR experiments and also could compromises the comfort of the animal during the experiments. To overcome these problems we used here a flexible substrate with copper deposited instead of regular wires, additionally increasing the number of channels to achieve whole brain coverage with high SNR.

Methods:
The 8-element coil array (Fig. 1a) was built using CuFlon (Polyflon Inc., Norwalk, CT, USA) with 2 oz/ft^2 of copper deposited in a 0.25 mm thick PTFE dielectric. This flexible and thin material allowed placing each coil element on the inner surface of the helmet, which was then covered by a 3-mm thick polyurethane foam to provide additional comfort to the animal. The inner diameter of each circular loop is 12.5 mm and the copper width is 1.5 mm. The coil elements were arranged in two frontal rows of 3 elements overlapped in the z direction to cover the pre-frontal and parietal cortices, and one back row of two elements overlapped in the x direction to cover the visual cortex, as shown in Fig. 1b. The coil circuitry consisted of a matching network and a PIN diode controlled blocking circuit for active detuning during transmission. Decoupling was achieved by connecting each element to low input impedance preamplifiers via $\lambda/2$ RF cables. The preamplifiers [4, 5] (Fig. 1c) were designed with input impedance of 1.5 Ω, gain of 32 dB and noise figure < 0.6dB. MR horizontal images from awake marmosets were acquired in a 7T/30 cm USR magnet (Bruker-Biospin, Inc, Ettlingen, Germany) connected to an AVIII console running ParaVision 5.1. To verify coil-to-coil isolation, the noise correlation matrix was measured as well.

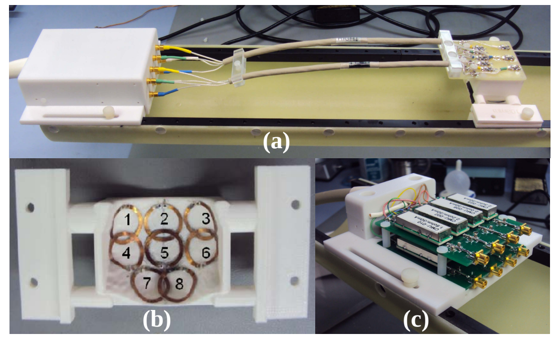

Figure 1: (a) 8-channel embedded array connected to low Z preamplifiers. (b) Bottom view of the arrangement of the individual array elements. (c) View of preamplifier set.

Results:
Figure 2 shows the noise correlation matrix obtained when the coils were loaded with a marmoset. By definition, the diagonal elements are 1.0 while the highest off-diagonal correlation coefficient was 0.24. Figure 3 shows a transversal spin-echo image reconstructed by sum-of-squares obtained from a conscious awake marmoset, acquired with the following parameters: FOV = 3.84 x 3.84 cm^2, TR=12000 ms, TE_{eff} = 72 ms, Rare Factor = 16, Slice thickness = 1mm, matrix=128 x 128, 1 average. We obtained whole brain coverage with high sensitivity throughout the entire cortical surface, except at the very frontal cortex (top of Fig. 3), which is not covered by the restraint helmet. Good coil-to-coil isolation and high sensitivity right below each element are demonstrated by the individual shuffled images, shown in Fig. 4.

Discussion:
The use of flat and flexible conductors and the placement of the coil elements on the inner surface of the restraint helmet minimized the distance between the coils and the animal's head, consequently increasing the SNR in the cortex surface. Excellent brain coverage with high sensitivity over the entire cortex was observed in the sum-of-squares image reconstructed. The noise correlation matrix measured suggests that the strongest coupling occurs between Ch-5 and Ch-7, but at a level that is not critical to image quality, as it can be verified from the individual coil images.

Conclusion:
We have demonstrated here the development of a whole-brain 8 element receive-only array for MRI/fMRI of conscious, awake marmosets. Improved sensitivity is obtained by embedding the coil elements on the inner surface of individualized restraint helmets. The array resulted in excellent brain coverage and coil-to-coil isolation. This array represents an alternative to perform MRI/fMRI experiments using awake marmosets in a completely non-invasive approach.

References:
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3. Silva, A.C., et al., *Longitudinal Functional Magnetic Resonance Imaging in Animal Models.* Methods Mol Biol, 2011. **711**: p. 281-302.
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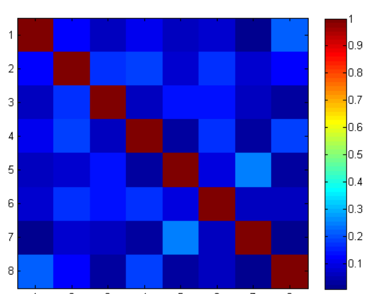

Figure 2: Noise correlation matrix. The highest correlation coefficient is 0.24.

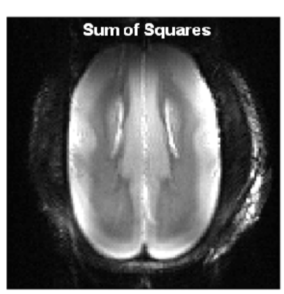

Figure 3: RARE horizontal image from a conscious awake marmoset **r**econstructed by sum-of-squares.

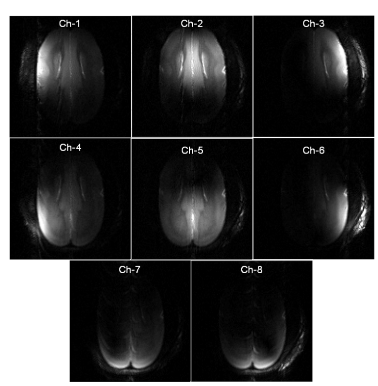

Figure 4: Shuffled images showing the spatial coverage of the 8-channel embedded array.