A 7T transmit and receive array combination for simultaneous investigation of electrophysiology and fMRI in non-human primates

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Target audience: RF engineers, researchers interested in simultaneous electrophysiology and fMRI.

Purpose: Simultaneous investigation of electrophysiology and fMRI in non-human primates presents several challenges on RF coil design. In addition to homogeneous excitation, the transmit coil structure should allow access for the electrodes from different orientations to allow recordings from different brain regions [1, 2]. Receive array designs aimed at maximizing the signal to noise ratio (SNR) for the fMRI experiment must be designed around head posts fixed on the animal head, leading to non-optimum coil orientations in the helmet. In cases with more than one head posts, the receive array structure must be splittable so that the two separable halves of the receive helmet can be fixed tightly on the monkey's head. We developed an RF coil arrangement that optimizes the SNR and also allow access for recordings from different regions of the brain.

Methods: Transmit array: The transmit array consisted of 4 large loops built on a 135 mm diameter polycarbonate tube. The coil elements were 105 mm long and 10 mm gap was provided between the adjacent loops. Adjacent and non-adjacent elements were inductively decoupled (Fig. 1a). The coil was tuned to 300 MHz using eight 5.6pF fixed capacitor and one variable capacitor arranged symmetrically. To actively detune, a PIN diode (MA4P7446F-1091) was inserted in series. The coil layout was realized on a polyimide sheet with 35 um thick copper layer. For easy of positioning, a splittable version of the transmit array is planned (Fig. 1b). The transmit array was driven in circularly polarized mode using a combination of three quadrature hybrids and a 90 degree delay line, which generated four outputs with equal amplitude and 90° phase offset.

Receive array: For optimum receive sensitivity, 8-channel receive arrays were built on form-shaped helmets that fitted the specific monkey head. The receive coil layout was planned in a way that the design could be adapted to animals with more than one head posts and hence require receive elements on separable halves (Fig. 2a). The coils were tuned to 300 MHz using 6 capacitors in series. The equivalent circuit of a single receive element is as per the schematic shown in [3]. A shielded cable trap was incorporated near the feed point and each receive element was connected to a preamplifier with low input impedance and the length of the cable between the coil and preamp input was adjusted for preamplifier decoupling.

Results: The decoupling between the adjacent elements of the transmit array was better than -20 dB and less than -15 dB between the non-adjacent coils. The unloaded Q of a single receive element, measured with the decoupling inductors in place, was 260. The loaded Q was 63, when the coil was loaded with a silicone phantom with tissue equivalent solution. Active detuning was better than -30 dB in the transmit and receive arrays. MR experiments were performed on a vertical 7T/60 cm Bruker Biospec equipped with 85mT/m imaging gradients. In-vivo gradient echo images shown in Fig. 3 acquired using this coil configuration has an in-plane resolution of 150x156 μm^2.

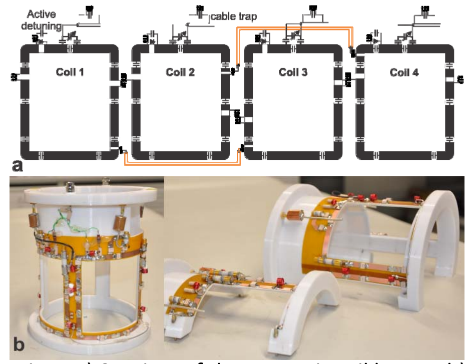

Fig.1: a) 2D view of the transmit coil layout. b) A picture of the transmit coil with large access windows from the side and from the top for recording electrodes. The picture on the right is a splittable version of the transmit array.

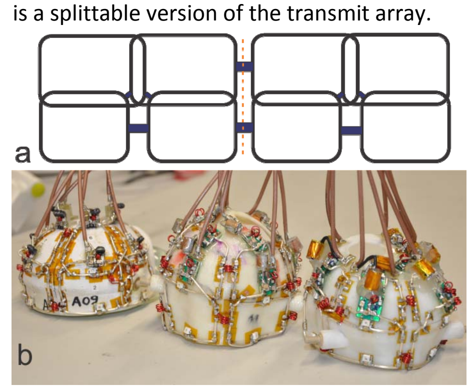

Fig.2: a) 2D view of the receive coil layout. The thick bands represent inductive decoupling. The helmet could be split along the dotted line in two halves because there is no geometric overlap between the two halves of the coil. b) 8-channel receive arrays adapted to specific animal head shapes.

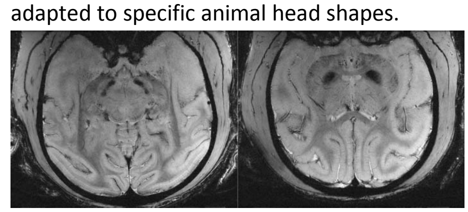

Fig.3: High resolution GE images acquired with this setup. TE = 20ms, TR = 2S, resolution: 150x156x1000μm^3

Conclusion: A 7T transmit and receive array combination was developed taking into account the requirements of simultaneous investigation of electrophysiology and fMRI. The transmit array provided flexibility to perform the required tasks during the experiment (e.g. electrode positioning by direct access to the head post) and the receive array provided high-SNR and the possibility to use parallel imaging techniques. The described hardware development in combination with method development (Balla DZ, ISMRM 2015) improved the signal sampling efficiency of fMRI by a factor of 11.2 relative to the state of the art in our lab.

References: 1. Logothetis N et. al. Nature 491:547-553, Goense J et. al. Proc. ISMRM 2014 p1348, Shajan. G et. al. MRM 71: 870 – 879 (2014)