Design of Quadrature Microstrip Transmission Line (MTL) Volume Coil for Cat MRI/fMRI Application at 9.4T

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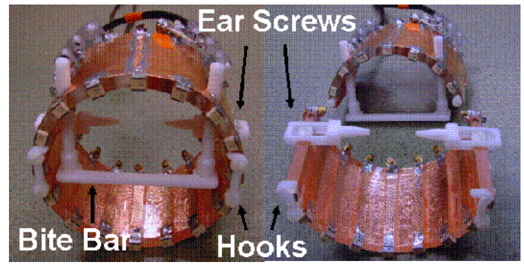
Introduction Cat brain provides a useful animal model for studying the brain function and activation. The ability to obtain high sensitivity in the deep cat brain regions such as the lateral geniculate nucleus (LGN) is of critical importance for many fMRI applications, particularly for investigating large-scale neural networks. Microstrip transmission line (MTL) volume coil has been proven to provide uniform B_1 field and deep penetration in a large region of interest for the rat brains (1, 2). In addition, with its simple coil structure, it is easy to integrate the animal head holder system into MTL volume coils, which would significantly reduce head motion artifacts and improve fMRI mapping quality. In this work, we present a new approach to designing a MTL volume coil with assembled head holder system for cat MRI/fMRI application at 9.4T. A prototype coil was built to evaluate the coil performance and both anatomic and functional mapping images were demonstrated.

Method Based on the specific requirement for performing cat fMRI application, a 16-element MTL volume coil, integrated with a head holder including two ear screws and a bite bar, was designed for obtaining better B_1 field homogeneity and high NMR sensitivity covering the entire cat brain. The system is shown in Fig. 1a. The volume coil can separate into two parts from the center line to make easy accessment to cat heads (Fig. 1b). The upper and lower coil parts are integrated with a bite bar and ear screws, respectively. Both ear screws and bite bar are adjustable for different cat sizes. The volume coil was built on an acrylic tube of 87 mm inner diameter, 101 mm out diameter and 60 mm length. The conductors were 36 µm copper tapes (6.35 mm in width) and the thickness of the substrate was 7 mm. The conductor width to substrate thickness ratio was close to 1, which not only allows each element with enough B_1 penetration for brain imaging (1, 3-5) but also makes all elements well coupled electrically. The ground plane for each part of the coil was formed by a single piece of 36 µm thick copper sheet. To tune the volume coil to 400.2 MHz for MRI experiment at 9.4T, terminating capacitors of 9.1 pF and 6.8 pF were connected to both ends of MTL elements, respectively. To increase signal-to-noise ratio and transmit efficiency, the volume coil was designed with quadrature driven. After the setup of cat head, the two coil parts were closed as in Fig. 1a.



(a) (b)

Fig. 1 Quadrature driven MTL volume coil integrated with cat head holder: (a) whole coil and (b) two separated parts - upper and lower.

Results A prototype MTL volume coil was tuned to 400.2 MHz using a network analyzer (8712ES, Agilent, CA). As shown in Fig. 2, the second resonance peak was selected at the working frequency, i.e., the coil resonated at Mode 1 with homogeneous B_1 distribution in the imaging region of interest. Images of mineral oil phantom in three orientations were acquired on a 9.4T/31 cm bore magnet (Magnex Scientific, UK) system interfaced with the Varian INOVA console (Varian Inc., Palo Alto, CA). Figure 3 presents the coronal, sagittal and transverse images with 1-D signal profiles on the top of each image. The images were acquired by gradient echo (GE) image sequence with the parameters: TE = 13.4 ms; TR = 6.45 s; slice thickness = 1 mm; FOV = 10×10 cm^2 for the coronal and sagittal images and FOV = 8×8 cm^2 for the transverse image; 128×128 image matrix. The 1-D profiles at the center line of each image show that the quadrature driven MTL volume coil can achieve highly uniform B_1 distribution, which partly benefits from the use of two-end capacitive terminations in each MTL line. The averaged signal-to-noise ratios measured in the images were > 65. Twenty one multiple-slice images of entire cat brain were acquired *in vivo* using GE image sequence with flip angle = 11°, TE = 5 ms, TR = 10 ms, FOV = 8x8 cm, 128×128 imaging matrix, 5 averages, slice thickness = 2 mm and no gap between slices. The anatomic images are shown in Fig. 4, which illustrate that the MTL volume coil provides good sensitivity in the whole cat brain, especially in the deep brain regions. To examine the feasibility of the volume coil for fMRI application, an fMRI experiment with visual task was carried out. Figure 5 illustrates the fMRI activation maps of the cat brain during visual stimulation, showing excellent activation in the LGNs bilaterally and the primary visual cortex (V1). The background anatomical image clearly shows the optic tracts and its projection to LGNs.

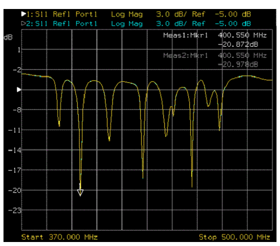


Fig. 2 S11 plot of volume coil.

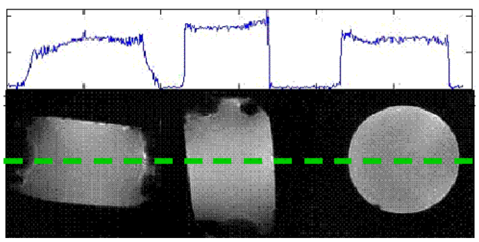


Fig. 3 Mineral oil images acquired by GE MRI sequence using the MTL volume coil.

Conclusion The preliminary images suggest that the MTL volume coil contains good homogeneity and sensitivity in the whole cat brain. The cat head holder system provides easy access and comfortable fixation for the animal. Moreover, it is feasible to use the MTL volume coil for investigating brain functions in deep brain regions.

References 1) Zhang X, *et al.* 12th annual meeting of ISMRM, 2004, p1547; 2) Bogdanov G, *et al.* 13th annual meeting of ISMRM, 2005, p945; 3) Zhang X, *et al. IEEE Trans on Biomedical Engineering*, 52: 495-504 (2005); 4) Zhang X, *et al. MRM*, 46: 443-450 (2001); 5) Adriany G, *et al. MRM*, 53: 434-445 (2005).

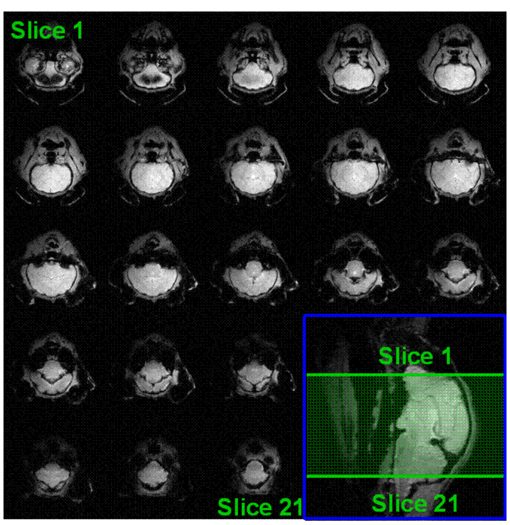


Fig. 4 Whole cat brain multislice images with transverse orientation. The location of each slice is indicated in the green region of the sagittal image.

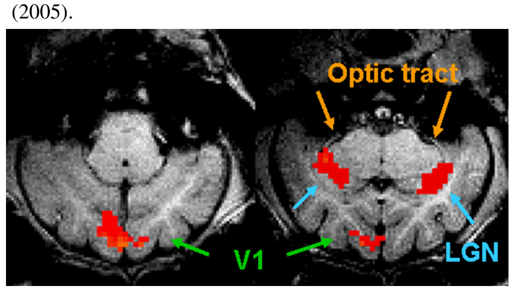


Fig. 5 Functional MRI mapping of visual activation in the cat brain.

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