Design of a detachable rat head coil for MRI-guided stereotaxic interventions

Jijun Han[1], Fulang Qi[1], and Bensheng Qiu[1]

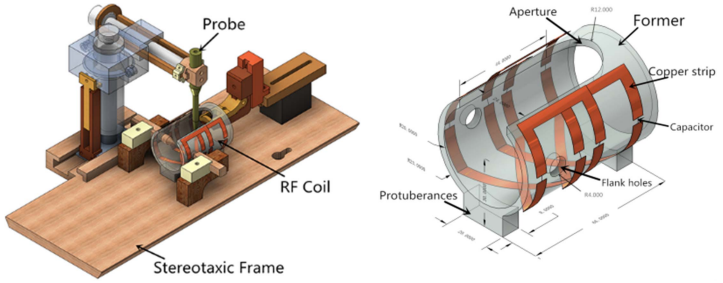
[1]*Department of Electronic Science and Technology, University of Science and Technology of China, Hefei, Anhui, China*

Introduction:

MRI has many advantages for not only brain imaging but also MRI-guided neural interventions, such as deep brain stimulation (DBS), ablation and biopsy,[1, 2] with an assistance of a MRI-compatible stereotaxic head frame, in which the head coil is critically important. Previous studies focus on the adjustment of the size of the RF coil by adapting the structure to such frame, [3, 4] regardless of the operational space for surgical instruments, such as catheters or needles. Therefore, it is necessary to develop a RF coil with free physical path for surgical instruments to pass. In this study, a detachable head coil with an aperture for MRI-guided stereotaxic rat brain surgery was proposed.

Materials and methods:

The RF coil includes two parts: a cylindrical coil former and a butterfly-shaped layout of the coil, which is conjunct with the MRI-guided stereotaxic surgical frame (Fig.1a). The outer diameter and the inner diameter of the cylindrical RF coil were 4.6cm and 4cm, respectively. At the top of former, a 2.4cm×6.6cm aperture was left to enable a needle attached on the stereotaxic frame can directly insert into rat skull. In addition, two flank holes were designed for placement of ear plugs, and two small protuberances on the bottom were used to fix the former coil on the base plate of the stereotaxic frame.



(a) (b)

Fig.1 Framework of a) MRI-guided stereotaxic surgical system, b) detached RF head coil of rat

The butterfly-shaped saddle configuration was designed to arrange each individual channel of the coil (Fig.1b). The devised coil consisted of two channels overlapping mutually to receive the B1 field. The cross-section of the saddle coil was located at the bottom so that no copper strip was applied in the aperture area on the top of the former.

To evaluate the performance of the coil, computer simulation was accomplished with Method of Moments (MoM). The numerical model of the coil loaded with the spherical uniform phantom was shown in Fig.2. During the simulation, the sinusoidal source was set at the frequency of 128MHz for an 3T MRI system. The loaded phantom with 2cm radius was placed at the center of the coil. Dielectric parameters of this phantom were σ=0.34214S/m and ε_r=52.534, the values for normal white matter of brain. S-parameters were measured to ensure the excellent implement of tuning and decoupling between two channels. Then, the feature of B1 field was obtained with numerical calculations with FEKO solver, EM software and systems.

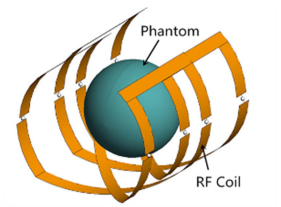


Fig.2 Configuration of the RF coil with loaded phantom

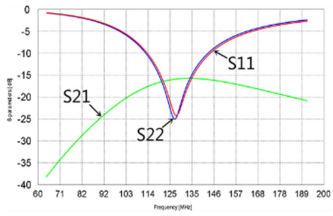
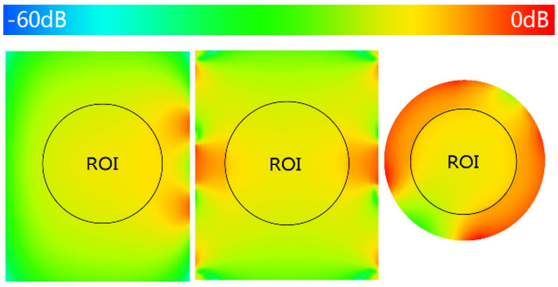


Fig.3. S-parameter curves of the coil

Results and Discussion:

The proposed coil with loaded phantom was tuned with eight equivalent capacitors of 29.5pF. The S11 and S22 representing the return loss showed that the peak values of each channel at the resonance frequency were -24.4dB and -25.3dB, which indicated both channels were well tuned (Fig. 3). The values caused by signal loss also illustrated by the S21 curves between the two channels, which exhibited the degree of the coupling between the channels. The distance of overlap between the channels was properly adjusted to 2cm to obtain the lowest coupling value of -15.78dB at 128MHz in this design. After tuning and decoupling, the distribution of the B1 field of the three planes (i.e. sagittal, coronal and transverse planes) was obtained (Fig.4). The results showed that the B1 field was extremely homogenous within the ROI that indicated the identical sensitivity of the coil.



(a) (b) (c)

Fig.4 Distribution of B1 field of a) sagittal plane, b) coronal plane, c) transverse plane

Conclusions:

The design of the detachable RF head coil is capable of not only producing the homogenous B1 field, but also providing a free operation path for interventional instruments, which will enable MRI-guided stereotaxic neurosurgery of rat *in vivo*.

References:

[1] John WR, et al. *Magn Reson Imaging*. 1986;4(2):138.
[2] Silverman SG, et al. *Radiology*. 1995;197(1): 175-181.
[3] Kamiryo T, et al. *Acta Neurochir*. 1995;133(1-2):87-92.
[4] Colin AR, et al. *Concept Magn Reson B*. 2013;41B(1):22-27.