Design of a Highly Sensitive Solenoid-based RF-coil for Small Animal Brain Imaging

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Introduction

Using MRI to study brain functions and viability of small animals presents unique challenges [1]. The quadrature (QD) Birdcage coil or the multi-channel phased array coils has been used as an RF coil for small animal brain imaging in the high field MRI system. However, when there is sufficient space for RF coil placement in a relatively large scanner gantry, higher sensitivity can be achieved by using a solenoid coil and the subject being placed perpendicular to the direction of the static magnetic field. The solenoid coil has several inherent advantages including limited loss of conduction owing to a smaller number of capacitors required. In this study, we have designed a multi-channel RF coil that is based on a solenoid coil for highly sensitive animal brain imaging using commonly available human 3T scanners.

Method

Simulations: The characteristics of coils were simulated numerically by using computer codes based on Richmond's Moment Method [2]. The simulation model took the effect of the body with an arbitrary geometry and material properties into account by incorporating the impedance method into the moment method [3]. We calculated the input-impedance and sensitivity of coils with loads. The designed coils were optimized for 3.0 T (127.8 MHz). The load was 24 mm in diameter and 40 mm in length. The conductivity and relative permittivity of the load used were 0.9 S/m and 70, respectively. The sensitivity of the coil was defined by the circularly polarized B1 field strength generated by the coil when a signal of 1 W was applied to the coil.

Coil Design: In order to improve sensitivity further, the Counter-Rotating-Current (CRC) coil and the surface coil were combined with the solenoid coil. Figure 1 shows the coil design. The surface coil improves the sensitivity of the region of interest (brain). The CRC coil improves the sensitivity distribution along the direction of the body axis of the animal. The CRC coil and the surface coil are compatible with a solenoid coil respectively. However, CRC coil and a surface coil usually interfere mutually. Thus, we prepared the loop at the top of the CRC coil so that the coupling between CRC and Surface coils could be canceled out by adjusting the area of the top loop of the CRC coil.

Results and Discussion

We first compared the sensitivity of the solenoid coil to the QD birdcage and the multi-channel phased-array coils. Figure 2 shows the configurations of the coils ((a):Solenoid coil; (b):8-rungs QD birdcage coil; (c):8-channel phased array coil). These coils had same sizes of 40 mm in diameter and 28 mm in length. Figure 3 shows the sensitivity profiles on the coil axis of these coils. At the center of the coil, the sensitivity of the solenoid coil was 12% and 19% higher than those of QD birdcage and phased-array coils, respectively. In addition, the homogeneity of the sensitivity along the direction of the coil axis was 30% or more greater than those of other coils. Figure 4 shows the sensitivity distribution of the solenoid, surface, and CRC coils and combined sensitivity. The combined sensitivity at the center of coil and the average combined sensitivity of the region of interest (brain) improved 16% and 30%, respectively, as compared to that of the simple solenoid coil. The homogeneity of the sensitivity along the direction of the coil axis improved 20%. This coil sensitivity distribution is suited for the brain imaging of small animals that have a long brain axis in the direction of its body axis such as rodents.

Conclusion

We have demonstrated that the proposed coil structure and sensitivity distribution suitable for small animal brain imaging. The sensitivity of the coil is superior to those of QD birdcage and multi-channel phased-array coils of the same size. The biological experiments using this coil are under way.

References

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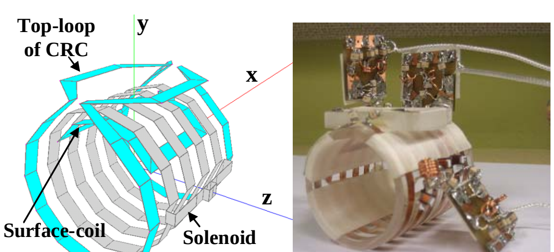

Fig. 1 Proposed coil structure.

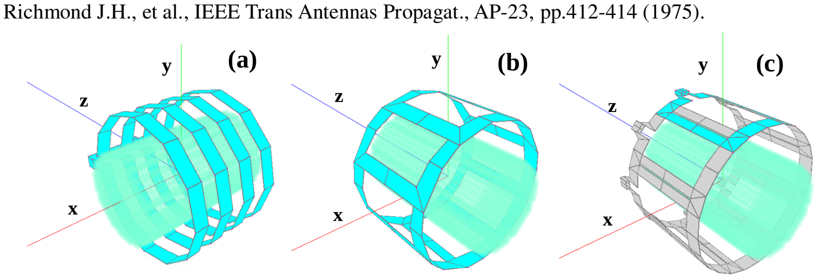

Fig. 2 Configuration of coils, Solenoid (a), 8rungs-Birdcage (b) and 8channel-phased-array coil(c).

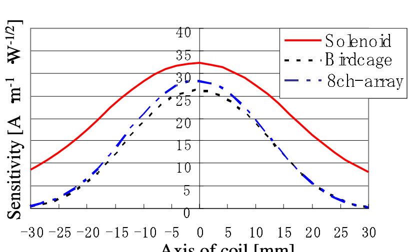

Fig. 3 Sensitivity profiles on the coil axis of coils shown in Fig.2.

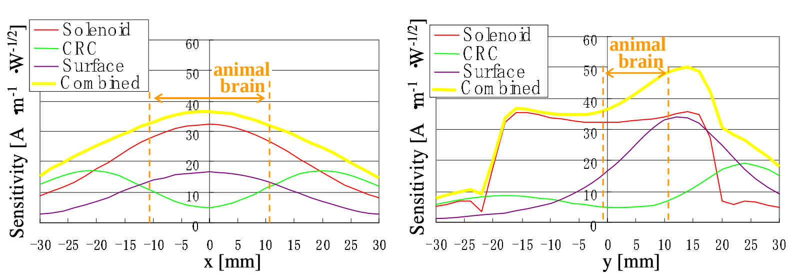

Fig. 4 Sensitivity distribution of the proposed coil.