High-Temperature Superconducting RF surface coil Platform for In-vivo brain structural differences

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Abstract

MRI provides useful method for revealing brain structure. Neuroanatomical differences between strains have been studied at the histologic level. However, the scanning time in 3 T MRI needs more than one hour to obtain the enough resolution to reveal neuroanatomical differences between strains. High-temperature superconducting (HTS) radio-frequency (RF) coil has been proposed as a promising tool in the investigation of the tissue microscopy with high resolution due to its low-resistance characteristic for the MR probe design. Our method to reduce the scanning time is using a 40 mm in diameter $Bi_2Sr_2Ca_2Cu_3O_x$ (Bi-2223) HTS RF surface coil. In the present study, we succeed to apply HTS RF surface coil to evaluate the brain structural differences between C57BL/6J and 129S1/SvImJ mouse.

Introduction

This previous research implements HTS Bi-2223 tape coils of 40 mm in diameter under 3 Tesla [1]. Besides of the HTS coil, the cryogenic system must be designed carefully. The neuroanatomical difference between strains is an important issue on brain research. However, the scanning time in 3 T MRI needs more than one hour to obtain the enough resolution to reveal neuroanatomical differences between strains. Here, we presented a new application that applying HTS RF surface coil to evaluate the brain structural differences between C57BL/6J and 129S1/SvImJ mouse.

Materials and Methods

To reduce the coil resistance, a HTS tape material, Bi2223 tinned tape (Innova Superconductor Technology Co., Ltd., Beijing, China), were used to fabricate the RF coils in this study. Single-loop HTS surface coil of diameter 40 mm was used as the receive coil and a copper surface coil with identical size was used for comparison. To reduce the coil resistance, a HTS tape material, Bi2223 tinned tape (Innova Superconductor Technology Co., Ltd., Beijing, China), were used to fabricate the RF coils in this study. For RF signal transmission and reception, as illustrated in Figure 1, inductive coupling method was applied by using a pick-up coil (copper) [2]. All the coils were tuned to 125.3 MHz and the frequency response was measured on a vector network analyzer (HP8751A, USA). For maintaining the temperature at 77 K, LN_2 must be filled in a thermal insulated dewar to cool the HTS coil. The longitudinal cryogenic system is difficult to design because it needs good thermal insulation. The LN_2 container with a vacuum layer was designed at the middle layer to provide the better thermal insulation. The pressure of vacuum must be lower than 10^{-3} torr that can keep the thermal insulation well.

Results

MR experiments were performed on the Bruker Biospec 3T system (Bruker, Germany). The images were acquired by using the fast spin echo sequence with TR/TE = 3506/62 ms. The in-plane resolution was 234 um and the slice thickness was 1.5 mm. The scan time is one minute and thirty-six seconds. The comparison of mouse brain images from HTS tape and copper coils were shown in Figure 2, where Figure 2(a) represents the image of B5 mouse's brain acquired from HTS tape coil in 300 K and where Figure 2(b) represents the image of BALA/c mouse's brain acquired from the HTS coil in 300 K. Figure 2(c) represents the image of B5 mouse's brain acquired from HTS tape coil in 300 K and where Figure 2(d) represents the image of BALA/c mouse's brain acquired from the HTS coil in 300 K. The SNR of using the HTS tape coil in 77 Kwas 51 and 47.6, 1.7 folds higher than that of using the HTS coil in 300 K, which is 30 and 28. By high SNR, we could see the LV (lateral ventricle) and striatum are different. The comparisons of SNR were presented in Figure 3.

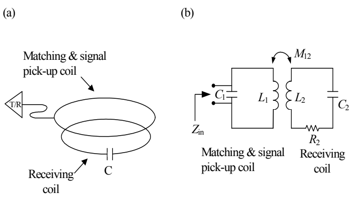

Figure 1. The equivalent circuit of the inductive coupled design shows that RF signal is picked up by using the mutual inductance coupling.

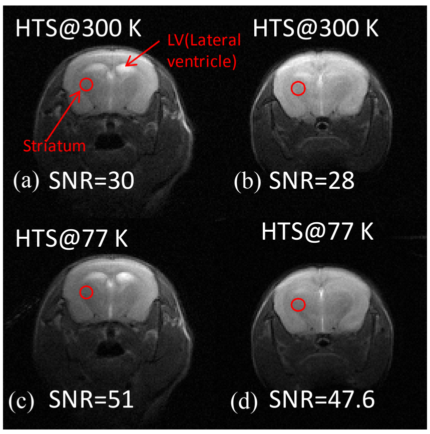

Figure 2. Images of the brain of two mices (a) B5 brain with the HTS coil in 300K and (b) B5 brain with the HTS coil in 77K. (c) BALB/c brain with the HTS coil in 300K and (d) BALB/c brain with the HTS coil in 77K. The SNR gain of 1.7 by using the HTS surface coil in 77 Kwith the same acquisition time of using the HTS coil in 300 K.

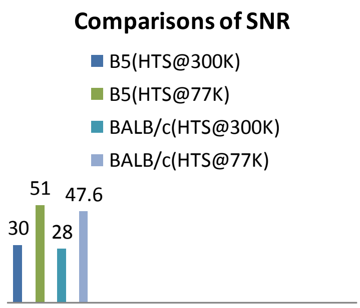

Figure 3. The comparison of SNR with different mice and temperature.

Conclusions

This present study demonstrated the different brain structure between C57BL/6J and 129S1/SvImJ strains and higher image quality can be achieved. With the high-quality HTS coil, the signal-to-noise ratio can be improved, suggesting that HTS RF coil is a potentially helpful diagnostic tool for MRI imaging in various applications. Further applications of a functional MRI system and dynamic contrast enhanced (DCE) MRI are under investigation to test the applicability of this high-temperature superconducting coil system in a 3 T system

References

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