A Long Duration High-Temperature Superconducting RF Platform

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Abstract

High-temperature superconducting (HTS) radio-frequency (RF) coil has been proposed as a promising tool for MR microscopy due to its zero-resistance characteristic for the MR probe design. However, the cryogenic system is very difficult to design due to its thermal insulation demands. In this study, we have succeeded to design a longitudinal dewar that can keep animal body temperature for more than three hours. A 40 mm in diameter $Bi_2Sr_2Ca_2Cu_3O_x$ (Bi-2223) tape HTS RF coil with this dewar was demonstrated. The signal to noise gain is 3.79 compared to the copper coil with the same geometry at room temperature

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. A 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. For RF signal transmission and reception, as illustrated in Figure 1, inductive coupling method was applied by using a pick-up coil (copper)[1]. 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 77K, LN_2 must be filled in a thermal insulated dewar to cool the HTSC. The longitudinal cryogenic system is difficult to design due to its thermal insulation demands. The LN_2 container with a vacuum layer was designed at the middle layer to provide better thermal insulation. The pressure of vacuum was kept lower than 10^{-3} torr to achieve the thermal insulation. MR experiments were performed on the Bruker Biospec 3T system (Bruker, Germany) using the fast spin echo sequence with TR/TE = 3506/62 ms. The total scan time is 131 minutes, In-plane resolution was 234 μm and the slice thickness was 1.24 mm

Results and Discussions

During the measurement, the temperature at the bottom of the dewar was decreased from 22^0C to 9.8^0C.The time-to-temperature curve was shown in Figure 2. With a heater turned on during the experiment, the animal can be kept at its body temperature for more than three hours. This performance is much better than the previous cryoprobe we have published in 2007, in which animal can be kept from cooling for only30 min or so. The SNR of the HTS tape coil was 46 (Figure 3, 4) which is 3.79 folds higher than SNR using the copper coil.

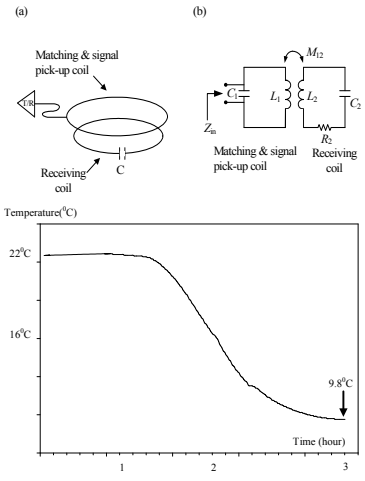
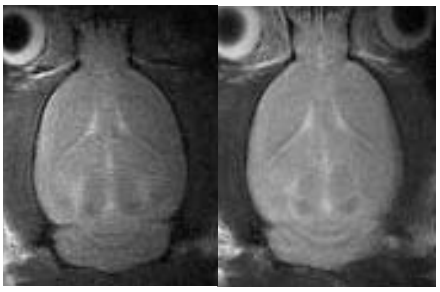


Figure 1. The equivalent circuit of the inductive coupled design shows that RF signal is picked up by using the mutual inductance coupling.

Figure 2. The time-to-temperature curve shows that the dewar can keep temperature at 9.8^0C after 3 hours.



(a) (b)

Figure 3. Images of the brain of a rat with (a) the copper coil in the room temperature and (b) the HTS coil in 77K. The SNR gain is 3.79 by using the HTS surface coil

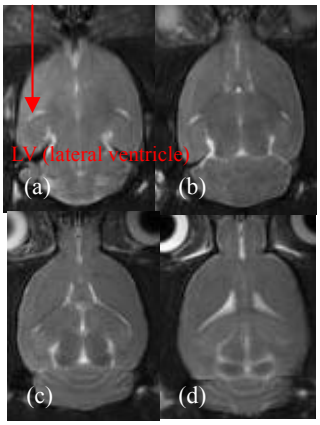


Figure 4. The longitudinal in-vivo rat brain images acquired from HTS tape coil.

Conclusions

The capability of a long duration HTSC coil for *in-vivo* rat brain applications was demonstrated. With the high-quality HTS coil, the signal-to-noise ratio can be improved significantly, 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 3T system.

References

[1] D. Hoult and B. Tomanek, "Use of mutually inductive coupling in probe design," *Concepts in Magnetic Resonance,* vol. 15, pp. 262-285, 2002.