High-Temperature Superconducting RF Coils for 3T MRI

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Abstract

One way to reduce receiving coil noise in MRI scans is using non-resistive high-temperature superconducting (HTS) coils[1]. In this work we built a Bi-2223 tape HTS RF coil and tested its performance. Test results were in agreement with predictions, and a SNR gain of about 2.5 was obtained from the HTS tape coil over a conventional copper surface coil.

Introduction

Using superconducting coil in MRI scan can minimize signal loss caused by receiving coil resistance, and significantly raise image SNR. Most HTS RF coils developed so far are film coils[2]. However in the past few years, Bi-based HTS tapes focused on ac power transportation applications have been increasingly developed. When we are interested in larger scale images Bi-based tape coil can be a good alternative of film coils for their easier fabrication, frequency adjustment, flexibility in coil configuration, and much lower cost[3]. In this study, we implemented tape HTS coils and conventional copper coils on Bruker Biospec 3T system and compared the SNR advantage with predictions.

Materials and Methods

Bi-2223 ($Bi_2Sr_2Ca_2C_3Ox$) tape coils of 7 cm in diameter were fabricated with high-Q capacitors (Q~1000 at 125 MHz, American Technical Ceramics, Huntington Station, NY, USA). The tuning and matching method we chose was mutually inductive coupling. Experiment setup is shown in figure 1; Small copper loops were used as fine-tuning, matching and signal pick-up coils [5]. Coils were cooled down to 77 K by liquid nitrogen in a polystyrene container.

MR experiments were performed on the Bruker Biospec 3T system (Bruker, Germany). All images were acquired with gradient echo sequence and TR/TE = 300/6 ms. The in-plane resolution was 270 um and the slice thickness was 3 mm. Cylindrical saline-filled of different concentrations coupled to the coils to find the loaded Q-values and image SNR. Predicted SNR gains were calculated from loaded Q-values[6] and compared with measured results. Kiwi fruit was also scanned to compare the performance of each coil.

Results

Images of phantoms with different conductivities are shown in figure 2. Predicted and measured SNR advantage of the 7 cm HTS coil over equivalent copper coil with respect to sample conductivity are shown in figure 3. From the prediction we see that the SNR gain we can get from implementing HTS coils descends with the increase of phantom conductivity. This is because higher sample conductivity leads to higher sample loss, and the coil resistance becomes less dominant. Our measured results showed the same descending trend of SNR gain, and the predicted data were within the error range of the measured data. Figure 4 showed the images of the kiwi fruit. SNR of different conditions were 71, 51 and 28 for HTS in 77k, copper coil in 77k and copper coil in room temperature, respectively. SNR gain of HTS coil was 2.5 folds higher than that of using the copper coil.

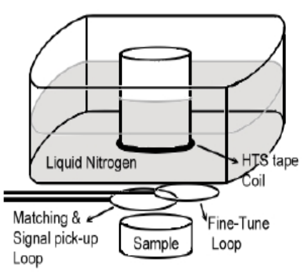
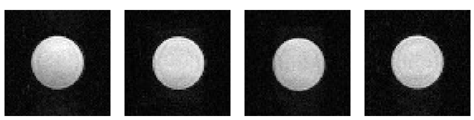
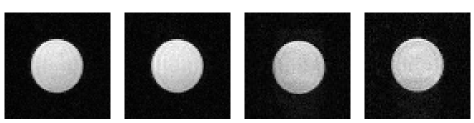


Figure 1. Experimental setup



a **b** **c** **d**

HTS coil in 77k, the conductivities of phantom a,b,c,d were 0, 0.5, 0.96 and 1.41 S/m. SNR were 69, 60, 55 and 45 for a, b, c and d, respectively.



e **f** **g** **h**

Copper coil in 77k, the conductivities of phantom e,f,g,h were 0, 0.5, 0.96 and 1.41 S/m. SNR were 43, 40, 36 and 39 for a, b, c and d, respectively.

Figure 2. phantom images with different conductivities

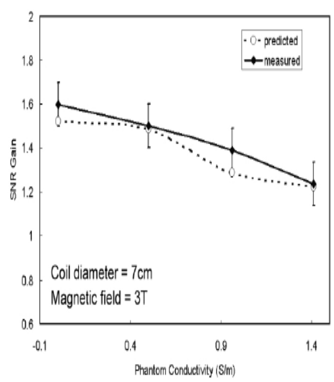
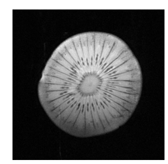
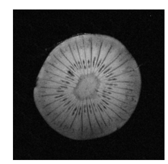


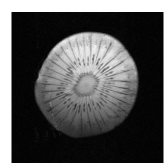
Figure 3. Predicted and measured SNR advantage of 7 cm HTS coil over equivalent copper coil v.s. phantom conductivity



a) HTS coil (77k): SNR ~71.1



b) Copper coil (77k): SNR~51.3



c) Conventional copper coil (room temperature): SNR~27.8

Figure 4. Images of kiwi of HTS and copper coils

Conclusions

A HTS tape coil was implemented on 3T MRI system successfully. Test results were in agreement with theoretical predictions and showed a SNR advantage of 2.5 folds over copper coil was obtained in the kiwi image. The HTS coil can be expected to generate higher SNR gain after optimization. In the future, in-vivo experiments will be conducted to farther test the capability of the HTS tape coil.

References

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