A High Temperature Superconducting (HTS) Coil for Imaging of Human Extremities

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Introduction

Recent advances in fabrication techniques allow MRI surface coils to be made of high temperature superconducting (HTS) materials. The low intrinsic resistivity of HTS coils can offer an improvement in image quality for clinical imaging of human extremities in a low-field environment where the coil noise dominates. Here we propose a HTS coil system to allow clinical imaging of human hands.

Background

The majority of noise in low-field MR images comes from the thermal noise due to the MR coil resistivity and the conductive loss coupled from the sample. This means using HTS coils with low intrinsic resistivity can improve the image SNR when compared to conventional copper MR coils of the same size and configuration. The improvement can be significant when surface coils are used in a low-field environment (<0.2T) where the thermal noise due to the coil resistivity is at least five times larger than the conductive loss coupled from the sample [1] .

Method

The HTS coil used in this experiment was a 10-turn spiral surface coil with an outer diameter of 70mm, fabricated using YBCO onto a sapphire substrate (Figure 1). The HTS coil was placed inside a cryogenic Dewar (Figures 2 and 3) in which liquid nitrogen was added to cool the coil to 81K to achieve a superconducting state. A copper mimic coil (Figure 4) was also fabricated to acquire reference data for SNR comparisons. The phantom used to load both the coils in the imaging tests was saline doped with 1.25mg/L copper sulphate solution in a cylindrical shape. The phantom imaging tests were performed using the HTS and copper coils respectively at 81K in a Niche 0.17T scanner (Figure 5) with spin echo (SE) sequences. The imaging test was repeated at room temperature using the copper coil. A MATLAB program was written to compare the SNR of the images acquired to justify the advantages of using HTS coils over conventional copper coils. Images of human hands were also acquired using the HTS coil to study the feasibility of using such a system for clinical imaging of human extremities.

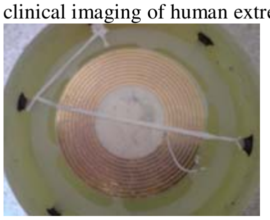

Figure 1 YBCO coil

Figure 2 Cryogenic Dewar

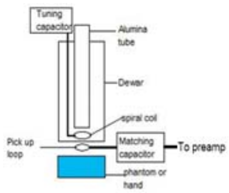

Figure 3 Coil and Dewar

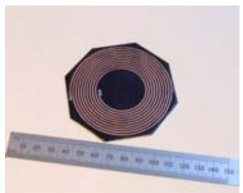

Figure 4 Copper mimic coil

Figure 5 Imaging setup

Results and Discussion

It was found that the phantom images acquired using the HTS coil (Figure 6) had SNR improvements of 80% and 270% when compared to those acquired using the copper coil at 81K (Figure 7) and room temperature (Figure 8) respectively. This confirms the superiority of geometrically matched HTS coils over equivalent copper coils in a low-field environment. The axial sensitivity profile of the HTS coil (Figure 9) shows that the image SNR is inversely proportional to the perpendicular distance between the coil and image samples. Owing to the deficiency of thermal insulation in our cryogenic Dewar, the coil-to-sample distance was currently limited to 10mm. With a better cryogenic Dewar design, this distance could be reduced to a minimum (~5mm), resulting in further improvements in image SNR. The in-vivo hand images (Figure 10-12) acquired using the HTS coil show good details of the bones and tissue structures. This means the current setup was capable of producing useful anatomical images of human extremities even in a low-field environment.

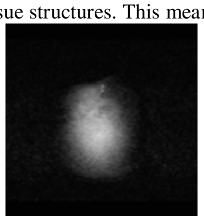

Figure 6 HTS phantom image at 81K

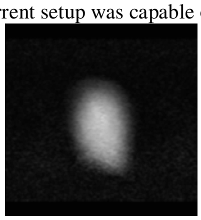

Figure 7 Copper coil phantom image at 81K

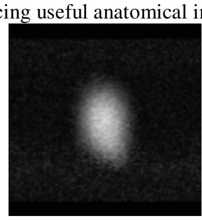

Figure 8 Copper coil phantom image at room temperature

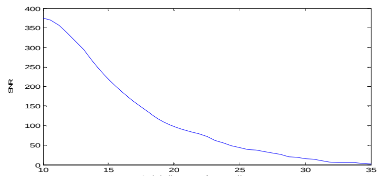

Figure 9 Axial sensitivity of HTS coil

	Coil type and temperature	SNR	Improvement w.r.t	
			(i)	(ii)
(i)	Copper coil at 292K	40.3	-	-
(ii)	Copper coil at 81K	83.2	106%	-
(iii)	HTS coil at 81K	150.3	272%	80%

Table 1 SNR comparisons

Figure 10 Coronal HTS in-vivo hand image

Figure 11 Transverse HTS in-vivo hand image

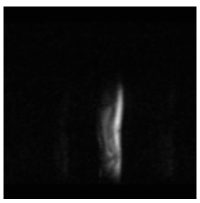

Figure 12 Saggital HTS in-vivo hand image

Conclusions

The imaging results confirm the advantages of using a HTS coil for imaging of human extremities in the low-field environment. The next phase of the study is to optimize the performance of the HTS coil by improving the electronic circuitry, cooling the electronics and an improved Dewar design.

References

1. Ma, Q.Y., et al., *Superconducting RF coils for clinical MR imaging at low field.* Acad Radiol, 2003. **10**(9): p. 978-87.