HTS tape volume coil for human wrist imaging

M. C. Cheng[1], K. H. Lee[1], D. F. Kacher[2], Q. Y. Ma[1], F. A. Jolesz[2], E. S. Yang[1]

[1]The Jockey Club MRI Engineering Center, University of Hong Kong, Hong Kong, Hong Kong, [2]Brigham & Women Hospital, Harvard Medical School, Boston, MA, United States

Introduction

High Temperature Superconductor (HTS) materials have been used to fabricate high quality RF receiver coil for over a decade [1,2]. The low electrical resistance of HTS at cryogenic temperature (~77K) effectively reduces the coil loss and hence improves the image SNR. Typical HTS coils are surface coils made of rigid and expensive thin-films. Despite the substantial SNR gain observed [1,2], it is still not widely adopted in clinical practice. The potential and benefits of using HTS tape (BiSCCO) for making high quality RF coil has been shown [3]. The advantage of HTS tape over HTS thin-film is its flexibility, enabling the construction of volume coils, non-planar surface coils and multi-turn coils [3]. Here we have successfully developed a 6"-diameter solenoid RF coil using HTS tape. Phantom and human wrist images were acquired with a 0.2T GE Signa Profile system. An SNR gain of 230% was observed over an equivalent room-temperature copper solenoid. The HTS coil was also compared with the standard GE wrist coil. Although their SNRs are similar, the GE coil has a three times better filling factor. Therefore, it is expected that HTS tape solenoid can outperform the GE wrist coil by at least 170% upon optimization of filling factor. This study showed the potential advantage of the HTS tape coil in a clinical MR system.

Materials and Methods

The HTS solenoid coil was made with the silver-alloy sheath Bi-2223 HTS tape from American Superconductor Corporation (Westborough, MA). The tape was wound into a 4-turn solenoid coil with 6" in diameter. High-Q capacitors (American Technical Ceramics, Huntington Station, NY) were used to connect the tips of the tapes to form a resonant loop. Then, the RF response of the coil was measured with a network analyzer (Agilent 8753ES). A custom-made coil holder and styrofoam based cryostat were designed to accommodate the coil and the coolant (Fig.1). The cryostat has a central opening of about 4.5" to admit a human wrist.

Imaging was performed in a 0.2T GE Signa Profile MR system (resonant frequency = 8.534MHz). During imaging, a copper tuning ring was used to fine tune the coil to the resonant frequency of the system. The MR signal received by the HTS coil was inductively coupled to the pre-amplifier. An equivalent copper tape solenoid was made for SNR comparison purposes. Both coils were used to image a Gd-doped phantom and the wrist of a healthy volunteer. Furthermore, the wrist images taken by the HTS solenoid was compared to that taken by the standard GE solenoid wrist coil with the same volunteer and pulse sequence.

Fig.1: HTS tape coil cryostat

Results

The Quality factor of the HTS tape and copper solenoid was summarized in Table 1.

Status	HTS tape	Copper
Unloaded, earth B-field	5200	130
Unloaded, magnet isocenter	1100	127
Loaded with phantom, magnet isocenter	934	124
Loaded with human wrist, magnet isocenter	850	124

Table 1: Quality factor of the HTS tape coil

Compared with an equivalent room-temperature copper solenoid, both phantom and human wrist images showed an SNR gain of about 230% (Fig. 2-3). Compared with the GE wrist coil with a three times better in filling factor, the SNR of images are almost the same. According to the relationship: SNR $\propto\sqrt{\eta}$ [4] where η is the filling factor. Reduction in filling factor will result in a reduction of 173%($\sqrt{3}$) in SNR. Therefore we expect that the HTS tape solenoid will outperform the GE wrist coil if it is optimized to the same filling factor.

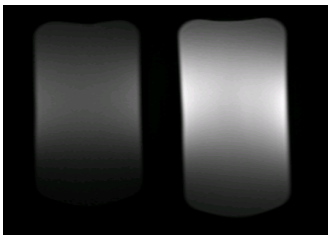

Fig.2: Phantom images of room temperature copper (left) and HTS (right) (GRE, FA: 70, TR/TE: 115/7, 5.2kHz, 20cmX20cm, 5mm/2mm, 2 NEX, 256 X 128)

Discussion and Conclusion

We have developed the first HTS volume coil for human imaging. Testing results show that the HTS tape solenoid is better than an equivalent copper solenoid at an SNR gain of 230% and has potential to outperform the existing commercial coils. From our experience, the real engineering challenges of constructing HTS tape with different configurations lie in the proper design of (i) coil holder to protect the HTS coil; (ii) cryostat to ensure safety and patient comfort. Scientifically, the challenge will be the interface (i.e. to minimize the contact resistance from interconnecting HTS tape segments and with external circuit components (e.g. capacitors)

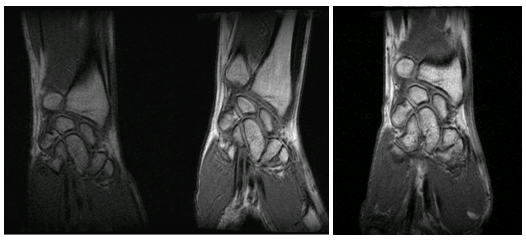

Fig.3: Wrist image by room temperature copper (left), HTS (middle) & GE wrist coil (right) (3D SPGR, FA: 60, TR/TE: 35/8, 4.5kHz, 12cm X 12cm, 2mm/0mm, 2 NEX, 224 X 192)

Reference

1. Q.Y. Ma, IEEE Trans. on Applied Supercon., vol. 9, No. 2, 3565, June 1999
2. R. D. Black et. al, Science **259**, 793-795 (1993)
3. Cheng et al., Proc. Intl. Soc. Mag. Reson. Med. **11**, 2359 (2003)
4. H. D. W. Hill et al, IEEE Trans. Appl. Supercon. **7**, 3750-3755 (1997)