Superconducting MR Surface Coils for Human Imaging

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INTRODUCTION

It was previously believed that a substantial gain in signal-to-noise ratio (SNR) of MRI images could be obtained by high temperature superconducting (HTS) RF receiver coils only at low frequency and low field (<20 MHz and <0.3 T) or for small samples (less than 1 cm in size) [1-4]. However, recent advances in HTS RF device technology and cryostat design provide gains at higher frequencies, fields and larger sample sizes. We demonstrate substantial gains in SNR for human studies at low field (0.2 T) and intermediate fields (0.5 T, 1.5 T). The HTS surface coils of 1 - 2 inch in diameter were made of TBCCO and YBCO 2-inch films, with a quality factor 2 orders of magnitude higher than that of a conventional Cu coil. Human finger and wrist images with an 8 cm field-of-view (FOV) were obtained with a SNR gain of 3.5 at 0.2 T and 0.5 T, and of 2 at 1.5 T.

DESIGN AND FABRICATION

Custom designed cryostats were built for housing the HTS coils. Liquid helium or nitrogen was used as a cryogen to maintain the temperature of the coil assembly at 30 K or 77 K, respectively.

The HTS coils were made from TBCCO or YBCO thin films on two-inch $LaAlO_3$ substrates. Two coil structures were designed: interdigital and spiral. The interdigital coil design consists of a single turn inductor with interdigital capacitors between the inner and outer portions of the turn. The spiral coil contains multi turns. The designs are also aimed at reducing the dielectric loss and providing single layer device processing. The coils were fabricated using chemical etching or ion implantation patterning technique.

To compare with HTS coils, copper surface coils were made from copper wires with a similar dimension of 1- or 2-inch in diameter and high Q-value capacitors. The typical unloaded Q-value of an HTS coil is 20,000 at 77 K, while that of a copper coil is about 200.

HUMAN IMAGING

We have performed human images on clinical 0.2 T (GE-Profile), 0.5 T (GE-Signa SP) and 1.5 T (GE-Signa) MRI systems. The initial data showed an improvement of SNR by a factor of 3.5 on human finger and wrist imaging using HTS coils at 0.2 T and 0.5 T (Table 1). The comparison images of wrist at 0.2T with a copper surface coil (a) and an HTS coil (b) are shown in Fig. 1. Figs. 2 and 3 show the comparison images of finger and wrist at 0.5 T with a copper surface coil (a) and an HTS coil (b). It is obvious that the images obtained with HTS coils have much higher contrast than those with copper coils. In addition, we have performed imaging of wrist at 1.5 T (Fig. 4). A factor of 2 in SNR gain was obtained. These results demonstrated, for the first time, that the superconducting coils can be used in intermediate and high-field clinical MRI scanners. This SNR gain clearly shows one could obtain a similar image quality using HTS coils at low field as that using copper coils at intermediate field.

Table 1. SNR gains Vs field strength & coil temperature

SRN gain	3.5	3.5	2.0
Field strength	0.2 T	0.5 T	1.5 T
Coil temperature	77 K	30 K	30 K

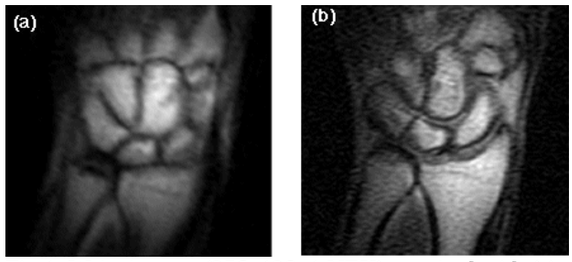

Fig.1. Wrist images (256x128, 1 NEX) acquired with (a) copper and (b) HTS coil at 0.2 T.

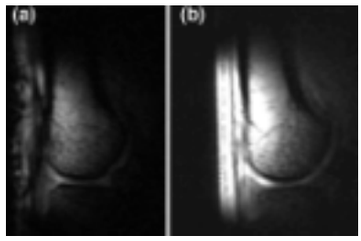

Fig.2. Thumb images (256x128, 2 NEX) acquired with (a) copper and (b) HTS coil at 0.5 T.

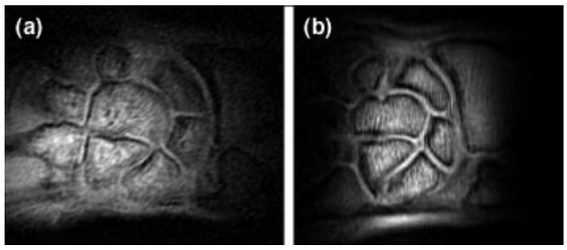

Fig.3. Wrist images (256x128, 2 NEX) acquired with (a) copper and (b) HTS coil at 0.5 T.

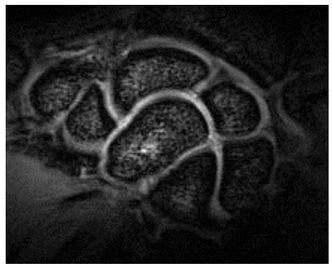

Fig.4. Wrist image (256x192, 2 NEX) acquired with an HTS coil at 1.5 T.

In summary, we have designed, fabricated and tested HTS coils and cryostats for human MRI applications at 0.2 T, 0.5 T, and 1.5 T. The images of human tissue have shown a substantial improvement in SNR.

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