An Active Decoupled HTS Film Coil for 1.5T MRI

Lian Xue[1], Zungang Liu[1], Changwu Hu[1], Kuan Zhang[1], Erzhen Gao[1], QY Ma[1], Nikolaus M Szeverenyi[2], Rebecca Theilmann[2], and William Bradley[2]
[1]*Time Medical Systems, Inc., San Diego, CA, United States,* [2]*Radiology, Univ. of California, San Diego, San Diego, CA, United States*

Target Audience:
MRI researchers interested in coil design; vendors designing MRI equipment; clinical personnel with interest in MSK.

Purpose:
To design a clinically useful high temperature superconductor (HTS) surface coil and characterize the signal to noise ratio gains obtained with this device (Fig. 1).

Methods:
A receive only HTS resonator was constructed by etching a 10 cm diameter circular inductor and two capacitors from a yttrium barium copper oxide (YBCO) film that had been deposited on a flat sapphire substrate. An active detuning network relying on a pin diode (DH80055-40N) was utilized to detune the circuit during transmit and still provided a high Q during reception. The probe Q was measured with a network analyzer using the S11 reported parameters (Fig. 2). The probe assembly was sealed in a fiberglass cryostat which maintained a stable resonator temperature of 79 K using liquid nitrogen (330 ml capacity). Non-metallic multi-layer thermal insulation was used inside the vacuum space to achieve a very low nitrogen boil off rate. Images were obtained on various conductive phantoms as well as a wrist using a G.E. HDx 1.5 T scanner. These images were compared with images obtained on a similar sized commercial 10 cm room temperature copper surface coil. The HTS element was located 2 cm from the object, whereas the object was placed directly on the room temperature copper coil.

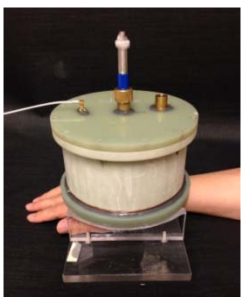

Figure 1. HTS coil positioned over hand

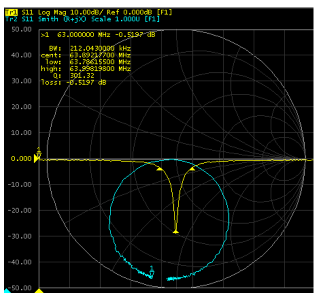

Figure 2. Smith chart plot of HTS coil

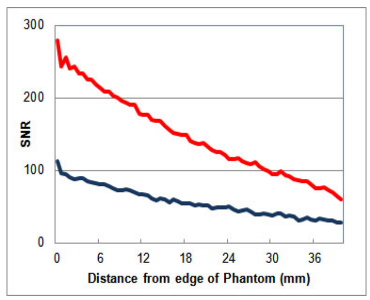

Figure 3. Sensitivity profile of HTS (red) vs RT copper (blue).

Figure 4. T1 weighted image of wrist w/ RT copper coil.

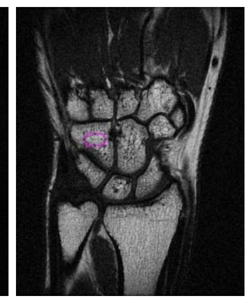

Figure 5. T1 weighted image of wrist w/ HTS coil.

Results:
The unloaded and loaded (wrist) Q of the coil were determined to be 2300 and 600. The signal intensity was measured as a function of distance from the commercial coil and surface of the cryostat for the HTS coil (Fig. 3). Sample wrist images (Fig 4 & 5) demonstrated a 2 fold increase in the SNR as measured in the indicated ROI in the center of the wrist. The sensitivity plots (Fig. 3) were consistent with the sensitivity gain observed in the wrist images. The cryostat had a liquid nitrogen refill time of 5 hrs and only needed to be re-evacuated every 4 weeks.

Discussion:
Cryo coils[1] and HTS RF receiver coils[2-4] have been studied since the early 90's as a technology to achieve higher SNR, providing improved image quality or speed in MRI. Technical challenges still remain in designing the active decoupling circuitry which isolates the HTS coil from the transmit coil. Semiconductors have undesirable behavior at low temperatures and high magnetic field strength. One has to be careful in device selection and orientation of the semiconductor in the magnetic field. Engineering a non-conductive and mechanically robust cryostat which maintains a stable cryogenic temperature for at least one day has also been challenging.

Conclusion:
In this work, a compact active decoupled HTS film coil for 1.5T MRI system has been designed and fabricated which incorporates a high efficiency cryostat able to maintain liquid nitrogen temperature for extended time. The package is small and convenient enough for clinical use. The decoupling circuitry used in this design will also find utility in receiver arrays.

References:
1. Hall AS, Barnard B, McArthur P, Gilderdale DJ, Young IR, Bydder GM. Investigation of a whole-body receiver coil operating at liquid nitrogen temperatures. Magn Reson Med 1988;7:230-235.
2. Hall AS, Afford NM, Button TW, Gilderdale DJ, Gehring KA, Young IR. Use of high temperature superconductor in a receiver coil for magnetic resonance imaging. Magn Reson Med 1991; 20: 340-343.
3. Ma QY, Chan KC, Kacher DF, Gao E et.al. Superconducting RF coils for clinical imaging at low field. Acad Radiol 2003; 10:978-987.
4. Liu J, Chong SY, Yeung SM, Ma QY. Development of Superconducting RF Probe for Low Field Orthopedic Imaging. In:Proceedings of the ISMRM 2009.