A clinically useful HTS knee coil for 0.35 T MRI

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

Purpose: To design a clinically useful knee coil which will improve the image quality of a low field MRI system (Fig. 1).

Methods:_A quadrature receive-only knee coil was designed to operate at 83K in a vertical field MRI system. The high temperature superconducting (HTS) coil made from thin tape of bismuth strontium calcium copper oxide (BSCCO) is passively detuned during transmit with a pair of cross diodes. The isolation between two elements of the quadrature coil is better than -20dB. The coil is built on the surface of a cylindrical liquid nitrogen (LN2) container with 1900 ml capacity. The coil and LN2 container was mounted in a vacuum insulated cryostat containing additional thermal insulation material. An extremely low nitrogen boil-off rate (320ml per hour) was achieved by using well designed thermal insulation structure. Knee images were obtained on a Time Medical PICA 0.35T MRI system and compared to a commercial quadrature knee coil with the same inner diameter of 20cm and length of 20cm.

Figure 1.HTS Knee Coil within 0.35T system

Figure 2. T2 weighted image of knee with room temperature copper coil

Figure 3. T2 weighted image of knee with HTS coil

Results: The vacuum of the cryostat after 2 hours of evacuation reached 10^{-4} mbar before filling LN2 and 10^{-5} mbar after filling with LN2. The temperature of the coil reached a stable 83K after about half an hour. The unloaded and knee loaded Q factor of the HTS and commercial coils are listed in Table 1. The unloaded Q factors of the HTS coil was a factor of more than two higher than the commercial copper coils which operate at room temperature. The SNR of the HTS knee images within the indicated ROI was about a factor of 2-3 higher than that of the commercial coil for various pulse sequences as shown in Table 2.

Coil Element	HTS Knee Coil		Commercial Knee Coil	
	Solenoid	Saddle	Solenoid	Saddle
Unloaded Q	600	600	280	280
Loaded Q	120	300	90	150

Table 1. Q of HTS knee coil and commercial knee coil.

Sequence	Cryo Knee Coil	Commercial Knee Coil
SE	140	87
FSE	132	43

Table 2.SNR comparison of SE and FSE sequences.

Discussion: Cryo coils[1,2] have been studied since the early 90's. However the main application of cryo coils still remains in research. To achieve clinical implementation[3,4] of cryo coils is still challenging. Current dewars take up space with insulation which limits the ultimate filling factor compared to a room temperature coil. The current preliminary design at 0.35T achieves the same SNR as room temperature coils operating at field strengths between 0.6 and 1.0T which are typically beyond the range of low cost permanent magnets. While low bandwidth techniques can achieve similar SNR gains, HTS coils do this without increasing the echo sampling time and TE, and without the chemical shift artifact associated with higher fields and lower bandwidths.

Conclusion: We have demonstrated a very preliminary design of a HTS volume knee coil that boosts the SNR up to more than 3 times that of a room temperature Cu coil on a low cost 0.35T permanent magnet. Since liquid nitrogen is far more available around the world than liquid helium, this has implications for improved, more affordable MR imaging worldwide.

References:

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