Cryogenic Litz-wire receiver for low field MRI

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Introduction

We have designed and built a cryogenic Litz wire receiver coil for an open access MRI system with a B_0 of 10 mT. At low field strengths it is particularly important to use a low noise receiver since the image *SNR* is frequently dominated by receiver losses rather than losses from the sample. The receiver coil resistance produces voltage noise with spectral density $V = (4kT_C R_C)^{1/2}$, where k is Boltzmann's constant, and T_C and R_C are the temperature and AC resistance of the coil[1]. For a given coil geometry $SNR \propto N(Q/T_C)^{1/2}$, where N is the number of turns and Q is the Q-factor. High temperature superconducting (HTS) receiver coils have been developed to minimise receiver noise[2]. For some applications at liquid nitrogen temperature (77K), however, cooled Litz coils[3] have certain advantages since they can be produced with more turns and in complex shapes, while HTS coils are restricted to planar structures.

Subjects and Methods

The receiver coil is a first order gradiometer and is shown in Figure 1. This design generates a strong B_1 component parallel to the coil plane and so is suitable for use in a vertical B_0 field. The gradiometer design also helps to reject unwanted RF interference and so reduces the requirement for RF shielding. The coil is wound from Litz wire comprising 270 enamelled copper conductors of 40 µm diameter. The gradiometer is wound with 20 turns on each side and has an outside diameter of 95 mm and inductance 70 µH. The table lists Q factors measured at 425 kHz, DC resistances and maximum Q factors and corresponding frequencies for cooled and uncooled operation.

Figure 1: Gradiometer receiver coil design.

	T=300K	T=77K
Q at 425 kHz	305	380
R_{DC} [mΩ]	438	55
Q_{MAX}	570	550
$f\,(Q_{MAX})$ [MHz]	1.2	0.2

Results

The receiver coil was tuned to 425 kHz with low-loss capacitors and then coupled to a J-FET preamplifier, of in-house design, with a noise temperature of approximately 20K. The coil was placed in a fibreglass liquid nitrogen cryostat and was used to collect transaxial Spin-Echo (SE) images of a 4 x 3 array of 25 mm diameter tubes, filled with $CuSO_4$ solution (T_1 =95 ms, T_2=87 ms, measured at 0.36T). Transmit pulses were generated by a 200mm diameter, 10 turn circular coil, which was placed between the cryostat and sample. Figure 2 shows images recorded with the receiver coil at room temperature and at 77K.

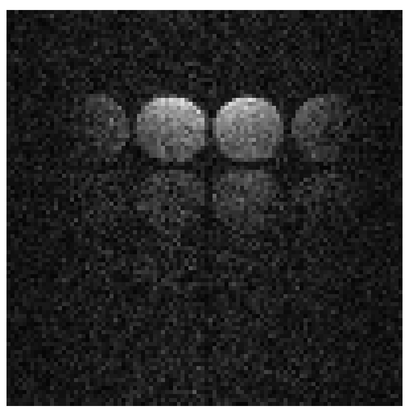

Figure 2a: Transaxial SE image with the coil at room temperature (TE=5.8ms, TR=72ms, 15 mm slice thickness 128^2 pixels-cropped, 8 averages).

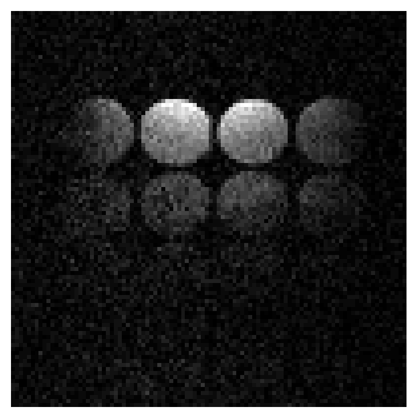

Figure 2b: Transaxial SE image with the coil at 77K (same image params).

Discussion

The *SNR* in Figure 2b is visibly better than that of Figure 2a and the phantom structure is more clearly visualised. The results shown in the table indicate that the cooled coil is operating above its optimum frequency. Simulations[4] indicate that by using Litz wire with finer stands (20 µm) it ought to be possible to reduce the coil's AC resistance at 425 kHz by a factor of at least 3 and further reduce image noise.

References

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