High Resolution Mouse Imaging using a Liquid Nitrogen Cooled Receive Only Coil on a 3T Clinical Scanner

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Introduction There is an interest in studying small animals using high field whole body scanners equipped with standard clinical protocols. High quality RF coils are required to achieve micron scale high resolution imaging of small rodents. Cooling of a copper RF coil with liquid nitrogen (LN) will greatly reduce the thermal noise and improves its SNR performance by 2 fold at 77K [1]. However designing a non-magnetic cryostat suitable for in-vivo small animal imaging is not an easy task. The requirements of providing good insulation between the cooled coil and sample, close coupling of coil to sample and providing a suitable platform for monitoring and handling small rodents are the major challenges. In this work, a novel PTFE cryostat design achieves good insulation which provides ease of use and is suitable for small rodents is proposed. A receive only cooled cooper coil is developed for a 3T MR scanner, and its low temperature performance is compared to that at room temperature.

Methods and Results *(1) Cryostat Design:* Many cryostats are designed to image small animals below the cryostat. Such an arrangement makes the handling and monitoring of small rodents on the whole body scanner very difficult. Our design has a large surface area for easy access, positioning and imaging of small rodents. The cooling unit is crafted from a 10 *10 cm PTFE block. Two pipes for circulating LN are drilled inside the block. The outputs of these two pipes are connected with the LN reservoir and flues for circulating LN back to the LN dewar. No LN pump is used. A 5*5 cm alumina plate is mounted above the PTFE block as a cooling plate for the RF coil. Continuous vacuum pumping is applied to the cryostat to improve the insulation between the sample and cooled coil. The top surface of the cryostat is made from 5 mm G10 material for its better material strength under high pressure condition. Since the whole cryostat is made entirely from one PTFE block, the possibilities for leaking of the cryostat is greatly reduced. After cooling the unit by LN after one hour, the coil reaches a stable temperature around 120 K and a high vacuum condition around 0.8 mbar is achieved. 1 litre of LN maintains the low temperature for 1 hour.

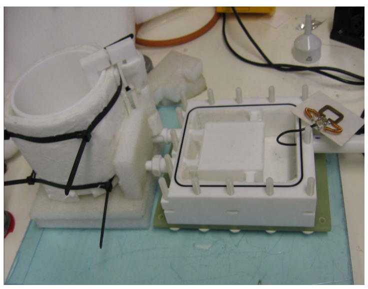


Fig. 1: PTFE cryostat design.

Fig. 2: 2cm receive only copper coil element.

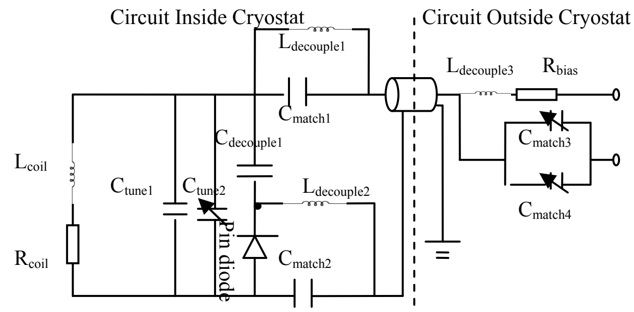
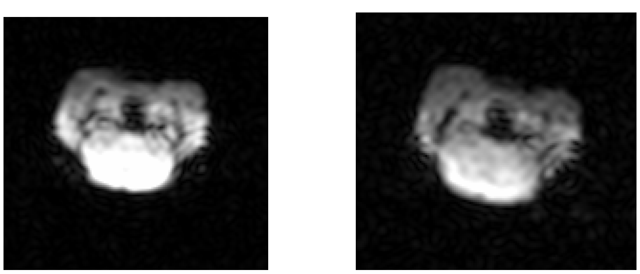


Fig. 3: Matching and decoupling circuit.

(2) Coil Element Design: From our previous study, a copper coil 2 cm in diameter achieves best SNR performance for an image depth around 1cm inside a mouse model at 120 K [1]. The 2 cm square loop coil is made from 3mm thick copper wire as shown in Fig. 2. In order to improve the homogeneity of the MR imaging and also for the RF safety reason, the volume body coil on the 3T scanner is used as a transmit coil, and the small surface coil is used as receive coil. An active decoupling circuit is added to the original tuned and matched coil as shown in Fig. 3.

(3) *Q Factor of the LN Cooled Coil:* The Q factor of the matched cooper coil at room temperature is 115, and the Q factor of this coil after being cooled to 120 K is around 170, therefore the Q factor of the cryogenic coil has been enhanced by 60%. Theoretically, such Q factor enhancement will improve the SNR performance of the coil loaded with small animal by 2 fold.

(4) *Image Experiments:* All imaging experiments were performed on a standard clinical whole-body Philips 3T MR scanner. The RF coil is connected to the MR scanner through an interface box (Pulseteq) to decouple the RF coil during transmission. A nude mouse of about 30 g is imaged. MR images were acquired with room temperature coil first, and after 1 hour cooling time, the image was acquired by using the cryogenic coil with identical settings and the same imaging protocols. A standard gradient echo with TR/TE = 20/ 7 is applied. Matrix size = 1024 * 1024 with a 40 mm FOV, flip angle = 15°, and axial slice thickness = 1 mm. The following two figures are mouse brain images obtained with room temp coil and cryogenic coil respectively. The SNR enhancement is about 1.8 folds for such small loadings as seen in Table 1. Fig. 5 shows a high resolution mouse image with 100 μm voxel size can be taken with the cooled coil by using a T2 weighted protocol on a 3T scanner.



(a) (b)

Fig. 4: Comparison SNR images: Mouse brain images acquired with (a) Cooled coil, (b) room temperature coil

	Cold Coil SNR	Room Temp Coil SNR
Slice8	1703.234	910.156
Slice7	1625.578	872.046
Sice6	1470.231	777.4943
Slice5	1317.096	691.6782
Slice4	1183.234	620.046
Slice3	1068.68	560.1609
Slice2	971.5182	509.4023
Slice1	888.6799	466.7586

Table 1: Average SNR comparison for Room temperature coil Vs Cooled coil at different slices.

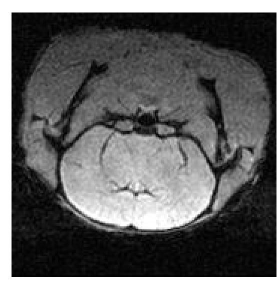


Fig. 5: T2 weighted image of mouse brain with 100 μm voxel size.

Conclusion A PTFE cryostat with good insulation has been developed, and it provides a platform for easy operation of small animal and capable of accommodate small animal monitor system. A 2 cm copper coil has been used which is optimised for a typical small animal load and which includes an active decoupling circuit. The Q factor of the coil has been enhanced by 60% after cooling down by 1 hour to 120 K, and the SNR performance has increased by 2 fold compared with its room temperature version of the same coil.

Reference

[1] B Hu et.al ISMRM, 2009, Hawaii.