Improvement in SNR at 3T Using a LN_2 Cooled Copper RF Coil

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Introduction

Small animal imaging is increasingly important for biological and genomic research. The trend has been to use higher field magnets (4.7 T and above) to obtain increased signal-to-noise (SNR) and higher resolution. With large bore, 3T systems becoming more widely available, the potential for high-throughput imaging of animals (many animals at the same time with no loss in SNR) merits assessment for the reduced imaging cost per animal. With MRI systems going to 16 and 32 independent receiver channels, the capacity for high throughput imaging will be more readily available. While both high-temperature superconducting (HTS) coils and cryogenically cooled small copper coils have been used to improve signal to noise in analytical NMR and in MRI applications, cryo-cooled copper coils are simpler to build and need only be cooled to a temperature of around 77°K.[1,2] In cases where the coil size is small and the sample loading is reduced, significant improvements in SNR can be achieved with a cryo-cooled copper coil.

Purpose

To assess the potential improvement in SNR for at 3T with a small, cryo-cooled copper coil. The principal applications in our laboratory for this are imaging mice, rat brain, zebrafish and stickleback fish. If the image contrast-to-noise (CNR) and SNR are adequate, the routine use of 3T clinical MR systems for high throughput imaging of animals would be cost effective to assessments of phenotypes by generating anatomic and probabilitistic atlases and in preclinical drug research. The aim of this work was to assess the image SNR and resolution of a LN2-cooled 25 mm i.d. 'surfce' coil and if determined to provide a significant increase in SNR, to use the same coil design to built an 8 or 16 coil module for high throughput applications.

Methods and Results

An inductively coupled 25 mm octagonal coil and vacuum insulated dewar were built and interfaced to a Siemens Allegra 3T system. The bottom of the dewar introduced a spacing of 9.5 mm from the coil to the surface of the sample. In a test sample using a 300 ml polycarbonate tissue culture flask filled with a solution of normal saline and 5 mM $NiSO_4$, the SNR gain was 4-5 to 1 for the identical imaging sequence as compared to the room temperature version of the same coil. The imaging parameters used were: for the mouse images – multi-slice 2D (20 slices) proton density, NA=2; for the phantom 'sponge' a single slice T2W image, NA=1. The coil and dewar are shown in figure 1 (a), a single slice image of the phantom is shown in figure 1 (b) and a typical single slice image of a live mouse brain is shown in figure 1 (c)

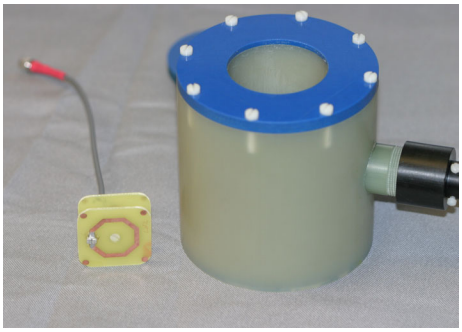
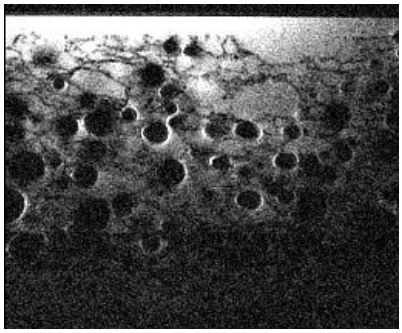
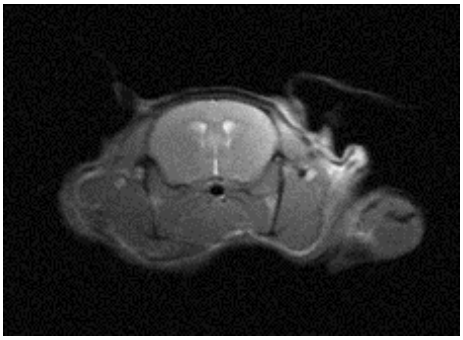


Figure 1 a) cryo-cooled coil and dewar; LN2 hold time is approx. 30 minutes. Dewar is fabricated from G10 material.



b) T2W image of sponge phantom, acq. time= 2.67min,TR=4000 msec, TE= 121 msec, in-plane resolution= 109x109 microns, slice= 400 microns.



c) PD image of a live mouse, acq. time = 11.5min, TR= 7690 msec, TE= 15 msec in-plane resolution = 140x140 microns, slice= 1mm.

Discussion

Cryo-cooled copper surface coil designs are relatively simple to implement. The next phase of this work is the implementation of an inductively-coupled volume imaging coil (phased array) to determine the feasibility for whole, live animal imaging with higher SNR compared to room temperature coils.

Conclusions

A significant improvement in SNR can be achieved using a small, cryo-cooled copper RF coil at 3T. Phantom results indicate factor of 4-5 in SNR gain by the cryo-cooled coil over the 'identical' room temperature coil; and at least a factor of 2 in SNR on live animals is typically seen for the coil geometry and size used in this work.

[1] Wright AC, Song HK and Wehrli FW. In vivo MR micro imaging with conventional radiofrequency coils cooled to 77°K. Magn. Reson. Med. 43:163-169 (2000)
[2] Miller JR et al. Performance of a high-temperature superconducting probe for in vivo microscopy at 2.0T. Magn. Reson. Med. 41:72-79 (1999)