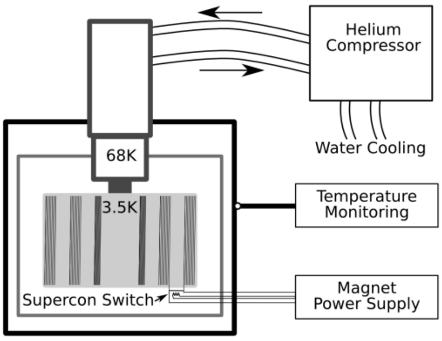
Construction of a 1.5 T Cryogen Free MRI System

Sergei Obruchkov[1] and Robin Dykstra[1]
[1]*Victoria University, Wellington, New Zealand*

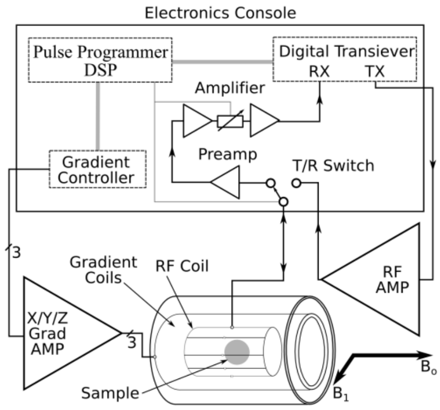
Introduction: Current advances in cryogen-free magnet design and miniaturization of the console electronics are providing easier access to MRI capabilities for a wide range of users. Thus making sophisticated MR and MRI facilities no longer the preserve of pharmaceutical companies, leading research hospitals, and major academic or industrial labs, but makes it accessible to most biomedical researchers, smaller companies, colleges and developing countries that lack cryogen handling facilities. We have constructed a 1.5T cryogen-free MRI system for small animal imaging applications such as biomedical cancer research (Figure 1).

Materials and Methods: A 1.5T cryogen-free magnet with 260mm wide bore (Cryogenic Limited ,London, UK) relies on a two stage pulse tube cold head. The NbTi wire assembly embedded in epoxy is cooled directly down to 4.2 K without the use of any cryogens (Figure 2a). A water-cooled helium compressor F50H (Sumitomo Heavy Industries Ltd, Tokyo, Japan) is used to power and operate the cold head. During a power failure or a quench the energy in the coils is partially extracted using high power diodes in the magnet power supply, the rest is thermally and safely dissipated internally in the magnet.
A compact digital electronics console based on Kea 2 (Magritek Ltd, Wellington NZ) was used to drive peripheral system electronics (Figure 2b). The console is based around a digital transceiver board capable of operation from 0-400MHz.

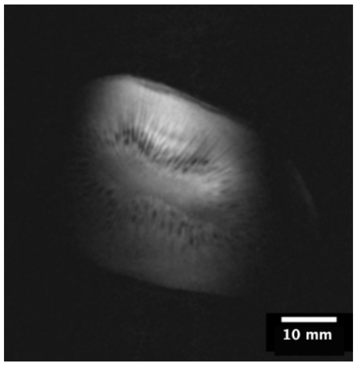
Figure 1: 1.5 T Cryogen Free MRI. The magnet bore has a 260 mm ID and the outer dimensions are 550 mm OD, 1030 mm tall and 535 mm long.



(a)



(b)



(c)

Figure 2: (a) A schematic representation of the superconducting magnet and cooling apparatus. The magnet power supply controls the superconducting switch enabling system to run in a persistent mode. **(b)** A system block diagram of the electronics and the peripheral hardware. **(c)** 1st image of kiwi fruit acquired using a spin echo sequence.

A custom built imaging module controls the gradients amplifiers with 20-bit precision. Pulse sequence timing and execution is performed using a 24-bit DSP. Pulse sequence programming, data acquisition and processing are controlled using PROSPA (Magritek Ltd, Wellington NZ) software. Of the shelf BAFPA 40 (Bruker Biospin, Billerica, MA, USA) gradient amplifier and an AMT 3205(Broadband Power Technology, Wilcox AZ, USA) 300W RF amplifier are used to drive custom built gradient and RF coils.

Results: The magnet cools down in 31 hours to the required temperature of 4.2K, and then ramped up to full field in 1.5 hrs. The magnetic field is generated by 83A of current in a persistent mode with a 20 ppm homogeneous region over 10 cm diameter of a spherical volume, with measured field stability of 0.01 ppm/hr. The complete system produces an NMR signal of 417 µV/ml of water, which is enough to perform imaging with sub millimeter resolution within minutes. The first images shown in Figure 2c are based on a spin echo pulse sequence were performed with a field of view of 60 mm with a resolution of 512x512, an echo time TE=50ms and repetition time TR=2000ms.

Discussion: Cryogen free MRI systems are slowly becoming viable technology for dedicated MRI systems [1]. Their main advantages are that they can easily be power cycled and stored for extended periods of time without needing cryogens to cool them down again.

References: 1. Lvovsky, Y. and Jarvis, P. Superconducting systems for MRI-present solutions and new trends. IEEE Transactions on Applied Superconductivity (15) 1317--1325 2005