Development of an in-theatre brain biopsy proton spectroscopy system

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Introduction

Proton spectroscopy is becoming increasingly used to add evidence in the diagnosis of brain tumour type and stage through use of automated database classification schemes. Although there have been many studies which correlate post procedure in-vitro proton spectroscopy with histology, it has not been practical to take spectra immediately during a procedure which might offer the future possibility of the surgeon moving immediately to tumor removal in cases of pathology. The aim of this study was to develop an economical, dedicated high field spectroscopy system which could be located directly in a neuro- operating theatre environment. This report discusses the design and initial evaluation of the system prior to installation.

Methods

A novel pulse tube cooled (PTC) 8.5T superconducting magnet with a sealed cryogenic system and no requirement for helium or nitrogen refills was designed and assembled by Magnex Scientific (Oxford, UK). The PTC was provided by Sumitomo Heavy Industries (Japan). The magnet weight was approximately 500Kg and the magnet height/diameter was 800mm, mounted on a moveable trolley to enable portability. The field homogeneity was optimised over an 8x20 mm oblate ellipsoid and the fringe field was completely contained within the magnet cryostat. The spectrometer was based on extension of a design by InnerVision MRI (London, UK) and was contained in a portable 22U rack supplied by a standard 240v/13A supply. The spectrometer was capable of broadband operation between 10-512 MHz. A prototype (non-spinning) proton spectroscopy probe with an 8mm coil capable of accepting standard 5mm NMR tubes was developed for operation at 360 MHz. Software was developed using LabWindows CV/I under the Windows XP operating system. On-line shimming could be achieved using X,Y,Z and Z^2 room temperature coils. Post processing of spectra used standard 3rd party software from Acorn NMR (CA, USA). The system could be accessed and data acquired remotely using a modem.

Results

The pulse tube cooler operated effectively and cooled the magnet to liquid Nitrogen temperatures within three days allowing the small Helium reservoir used with the PTC to be filled without use of Nitrogen for pre-cooling. The spectrometer system has recently been integrated with the magnet as shown in Fig 1 and is currently undergoing optimization at 360 MHz. Figure 2 shows a simplified schematic of the spectrometer rack based on modular RF components (Mini-Circuits, UK). Fig 3 shows a single shot water FID with an SNR of ~ 1000:1 obtained from the spectrometer at 128 MHz showing broad band operation of the system.

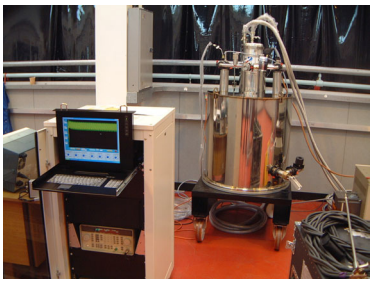
Fig 1 

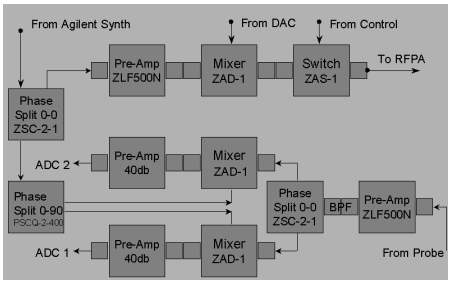
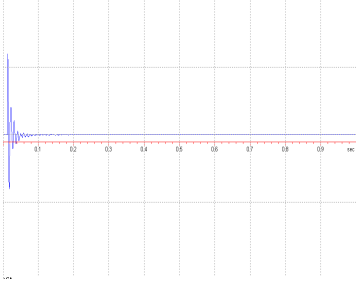
Fig 2 

Fig 3 

Discussion

Initial evaluation of the magnet has shown that a sealed cryogenic system using a pulsed tube cooler is a feasible option which removes the need for constant nitrogen and helium fills as required for conventional high field spectroscopy magnets. The fully contained fringe field and compact spectrometer makes the system suitable for installation in small sites. After further testing, the system will be installed in an ante-room of a neuro-operating theatre for clinical evaluation of proton spectroscopy versus conventional histology of tumor core biopsy samples.