Dynamic Nuclear Polarization using a low field multi-channel MR system

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INTRODUCTION

Dynamic nuclear polarization is an effective way of increasing SNR in MRI (1-3). Recent experiments have shown that it is possible to generate significant proton polarization at room temperature using the free radical carbamoyl-PROXYL (1) by irradiation at the electron spin resonance frequency to produce the Overhauser effect. The aim of this study was to evaluate the capability of a multi channel low field MRI system for dynamic nuclear polarization (DNP) research.

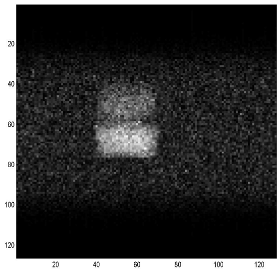
METHODS

A rapid switch time (~1s) resistive magnet (Figure 1) was interfaced to a four channel broadband digital quadrature spectrometer and experiments performed using samples of 3-Carbomyl-PROXYL (Sigma-Aldrich, UK) in distilled water at concentrations ranging from 1 to 10mM in a 28x70mm cylindrical vial. The magnet was set for MR operation at a frequency of 330 kHz and imaging was performed using a split solenoid transmit-receive coil. A second RF transmit channel operating at 226 MHz supplied 16W of power from 50W LZY-1 Power Amplifier (Mini-Circuits Europe, UK) into a 30mm loop coil at the centre of the split solenoid to provide ESR irradiation. Unlike the experiments performed in (1-3), the B_0 field was maintained constant during both irradiation and reception. The frequency of the ESR irradiation was adjusted empirically to obtain maximal polarization on the central peak of the three ESR resonances. A gradient echo sequence with TR/TE = 2000/5ms, FOV = 210mm, SLT = 10mm, NEX =1 was preceded by up to 1s continuous wave irradiation at the ESR frequency. Images were also acquired without irradiation (NEX =10).

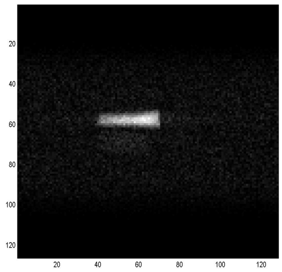
RESULTS

1. 

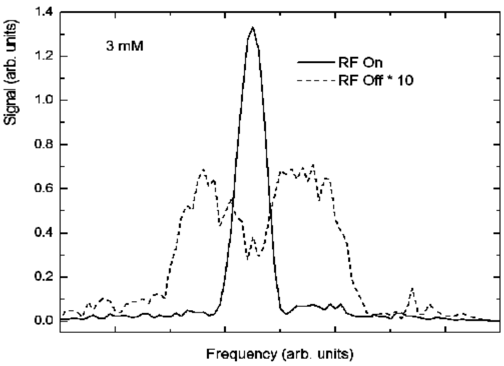
2. 



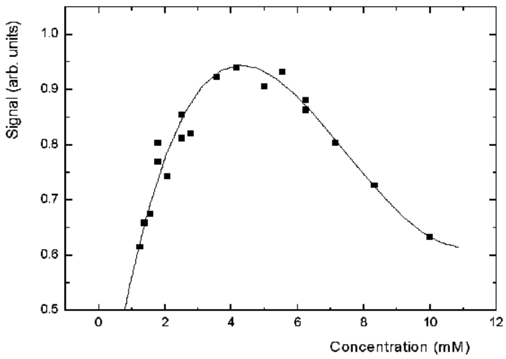
3a



3b



4.



5.

Figure 1 shows the low field 6 coil resistive magnet built in house with a gap of 150mm and pole face diameter of 600mm. Figure 2 shows the 330KHz split solenoid proton imaging coil and the 226MHz ESR loop at the centre of the split. Figures 3a and 3b show phantom images without (NEX=10) and with (NEX=1) ESR irradiation showing a 40-fold increase in SNR close to the loop coil with application of the ESR irradiation. Figure 4 shows a vertical profile through the images without and with irradiation. Figure 5 shows the effect of concentration of the free radical on the enhancement, solid line – polynomial fit.

DISCUSSION

A low field MRI system has been developed to enable DNP to be performed with a multi-channel spectrometer without the requirement for field switching, although the magnet can be switched rapidly if required. Enhancement factors up to 40 were observed for an irradiation power of 16W for 1s at 226MHz. The results confirm the study described in reference (1) with a maximum enhancement at a concentration of 4mM (1). Some problems were encountered with sample heating with the high power levels required to produce maximum polarization. Use of the multi-channel spectrometer to perform SENSE should be a good way to minimize heating effects for DNP. The system should be useful for imaging cellular systems with free radical markers which can be switched on or off as required.

REFERENCES 1. Benial A. et al., JMR 2006; 182:273-282. 2. Lurie D et al, JMR 1988;76:366-370. 3. Matsumoto S et al., MRM 2007; 57:806-811.