IMPLEMENTATION OF MAGNETISATION TRANSFER MRI AT LOW FIELD

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Magnetisation transfer contrast (MTC) has been widely used for over a decade as one of the most important MRI contrast-generating mechanisms. Most MTC research to date has been performed at medium or high magnetic field strengths, typically at 0.5 T or above. Nevertheless, there is value in implementing MTC at low field, although this presents technical challenges not encountered at higher magnetic fields. In this work, we have implemented MTC at very low magnetic field, 0.059 T, corresponding to 2.5 MHz proton resonant frequency.

The key technical aspect of MTC is the ability to apply off-resonance irradiation, in order to saturate protons in the bound pool, without directly affecting protons in the free pool; the basic method employs continuous-wave (CW) off-resonance irradiation [1]. In order to study MT effects a range of offset frequencies is needed, from 0.01 kHz to around 50 kHz resonance offset. This presents the main technical difficulty of MTC at low field, because the larger offset frequencies are likely to be outside the bandwidth of the RF transmit system (amplifier and RF coil), causing the applied B_1 RF magnetic field to vary with the frequency offset. With increasing frequency offset, a higher CW amplitude is required to maintain a desired constant B_1 field strength. To counter this effect, B_1 calibration curves were measured (Fig. 1) and the results incorporated into the pulse program via a look-up table. In this study, seven B_1 values (5, 7.5, 10, 15, 20, 30, and 40 μT) were used and 32 frequency offsets were chosen from 0.01 kHz to 49 kHz. The frequency offsets were distributed on a logarithmic scale in order to cover a wide range of offsets, with high frequency-resolution close to resonance (zero to 1 kHz offset range). A home-built MRI scanner operating at 59 mT was used in this work [2].

Experiments were carried out using samples composed of Agarose gels (1 %, 2 % or 4 %) doped with $MnCl_2$ (0 mM, 0.03 mM or 0.3 mM). T_1 and T_2 can be controlled by altering the concentration of the gel and of $MnCl_2$, respectively [3]. Two phantoms, each containing 7 samples, were also prepared for imaging experiments, combining Agarose gels with either $MnCl_2$ solutions or distilled water. In addition, samples containing aqueous solutions of $MnCl_2$ (without agarose) were used as a control. In order to estimate the extent of the direct effect, T_1 and T_2 values were measured using Inversion Recovery and Spin Echo pulse sequences.

The MT effect was studied as a function of CW duration, with the optimum being around 2 seconds. The MT effect was also measured as a function of frequency offset at a range of B_1 values. From these data, conditions for the maximum MT effect with each sample were determined: these were typically B_1 = 20 μT and approximately 10 kHz offset frequency. Finally, the phantoms were imaged using an interleaved (CW-off and CW-on) MTC Gradient Echo imaging pulse sequence, and the magnetisation transfer ratio (MTR) was determined [4].

Fig. 2 shows the MT effect observed in a control sample and in 1, 2, and 4 % Agarose gels under the conditions of 10 kHz frequency offset, 20μT B_1, and 2s CW duration. Due to the absence of macromolecules in the control sample, the MT effect was zero while MT effects increased with increasing concentration of macromolecules, as expected.

In conclusion, MTC has been implemented on a 59 mT home-built MRI scanner. Initial results from Agarose gel test objects compare well with those in the literature, obtained at higher fields. We intend to use the scanner to measure MT effects as a function of magnetic field, using magnetic field-cycling.

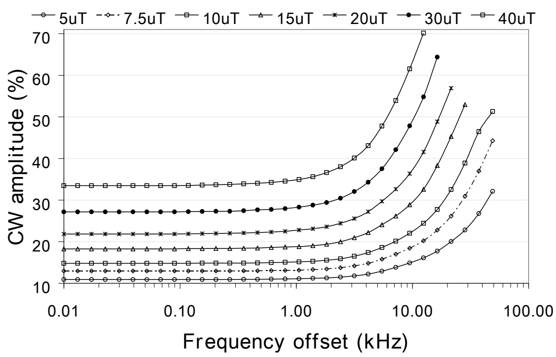

Fig.1. B_1 calibration curves

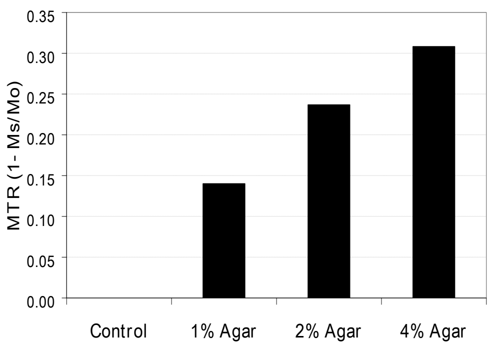

Fig.2. Magnetisation Transfer Ratio of Agarose gels

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