

Off-resonance Magnetisation Transfer Contrast MRI using Fast Field-Cycling Technique

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Introduction

The use of fast field-cycling (FFC) with MRI has increased over recent years. The ability to change the external magnetic field (B_0) during MR data acquisition affords access to new contrast mechanisms. In this work, we have applied the FFC technique to magnetisation transfer contrast (MTC) imaging experiments. A continuous-wave off-resonance irradiation pulse (or MT pulse) is widely employed in MTC imaging [1] to saturate semisolid protons, without directly affecting mobile protons. In order to achieve this conventionally, a constant RF magnetic field (B_1) is required with varying RF offset frequency. However, B_1 tends to decrease significantly with increasing offset frequency, particularly at low field, due to the limited bandwidth of the RF transmit system, in turn requiring B_1 correction [2]. Moreover, the range of offset frequencies available may be limited. Here, we demonstrate an alternative off-resonance MTC method using the FFC technique which makes it possible to counter these complications. Essentially, the MT pulse is applied at constant frequency, but B_0 is altered (using FFC) in order to achieve off-resonance irradiation. The key technical feature of this new method is to switch the external magnetic field between levels (B_0 to B_{0e}) for the duration of the MT irradiation, then – crucially – back to B_0 for signal acquisition. Therefore it provides the same off-resonance effect as the conventional MTC technique, but without the necessity for B_1 correction, and with effectively no limitation on the resonance offset (actually the field offset).

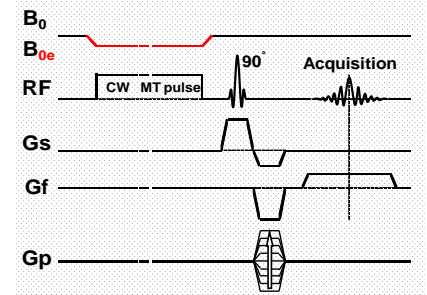


Fig. 1

Methods

Experiments were carried out using a home-built, whole-body field-cycling MRI scanner with detection at $B_0 = 58.7$ mT (2.499 MHz) [3]. An interleaved (with and without MT irradiation) FFC-MTC pulse sequence was implemented (Fig.1). In order to achieve an effective 11 kHz offset frequency irradiation, for example, the irradiation is applied at 2.499 MHz but the applied magnetic field (B_{0e}) is set to 58.44 mT (proton Larmor frequency 2.488 MHz). The magnetic field was switched between levels in 5 ms. 1%, 2%, and 4% agarose gel samples dissolved either in 0.04 mM $MnCl_2$ solution (samples A', B' and C') or in distilled water (samples A, B and C). The T_1 values of the samples doped with $MnCl_2$ were shorter than the others while the T_2 values were almost the same. (e.g. C: $T_1=770$ ms, $T_2=38$ ms; C': $T_1=667$ ms, $T_2=40$ ms.) $MnCl_2$ solution (without the agarose macromolecule) was also used as a control. Since the MT effect is strongly related to the MT pulse parameters (duration, B_1 , and offset frequency), the relationships between each MT pulse parameter and the MT effect were studied in order to determine the conditions for maximum MT with each sample: these were typically 2 sec. duration, 22 μT B_1 and 11 kHz frequency offset.

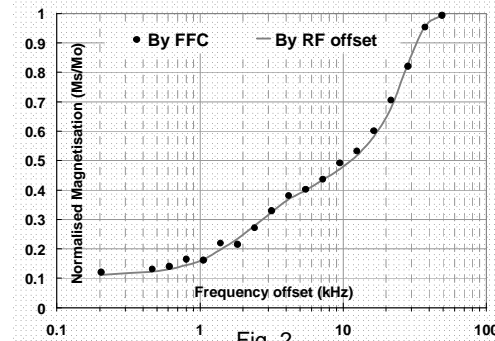


Fig. 2

Results and discussion

The Z-spectra [4] of 4% agarose gel obtained from the FFC and the RF off-resonance technique are compared in Fig. 2, where very close agreement between the methods is seen. Imaging experiments were also performed. Fig. 3 illustrates the images obtained by means of FFC-MTC (top row) and conventional RF-MTC (bottom row), with MT irradiation (right column) and without (left column). In order to evaluate the MT effect, regions of interest in the images were drawn and MT ratios (MTRs) were calculated using the equation $MTR=1-(M_s/M_0)$, where M_s and M_0 are the net magnetisation (signal) with and without irradiation, respectively. Fig. 4 describes the MTRs for each component. Due to the absence of macromolecules in the control sample, the MT effect is almost zero while MT effects increase with increasing concentration of the agarose. Furthermore, smaller MT effects are observed in the samples doped with $MnCl_2$ because of their shorter T_1 values. These results also show excellent agreement (less than 3% difference) between the measurements collected by the FFC-MTC and the RF-MTC methods.

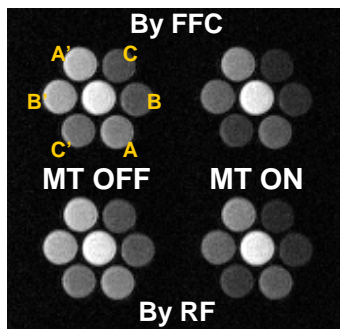


Fig. 3

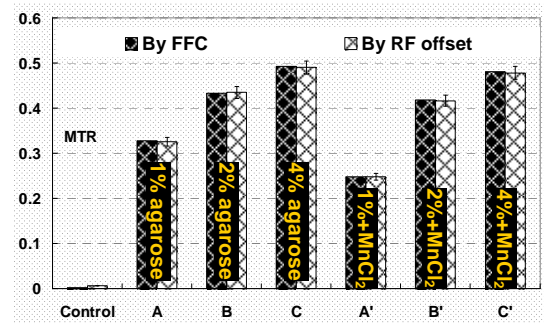


Fig. 4

Conclusions

We have demonstrated the applicability of the new FFC off-resonance MTC imaging technique. As shown above, experimental results obtained by the FFC technique agree well with those obtained by the RF off-resonance method. In the future, we intend to use the FFC technique to conduct field dependent MTC imaging, in order to measure the field-dependence of MTC using a single instrument.

References: [1] Henkelman RM, MRM 29, 759-766 (1993). [2] Samson RS *et al.*, MRI 24, 255-263 (2006). [3] Lurie DJ *et al.*, Phys. Med. Biol. 43, 1877-1886 (1998). [4] Grad J, Bryant RG, JMR 90, 1-8 (1990).