# Localized *In Vivo* Fast Field-Cycling Relaxometry

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## Introduction:

Fast field-cycling (FFC) promises access to new sorts of endogenous information through study of the complex variation with magnetic field strength of a sample's NMR relaxation times. In the well-known FFC relaxometry method, the applied magnetic field is rapidly switched between levels, allowing the nuclei to "evolve" at different field strengths (but, crucially, with signal detection always at the same field strength). In proteins and other biopolymers, pronounced reductions in $T_1$ occur at certain well-known NMR frequencies, due to interactions with the quadrupolar nucleus $^{14}$N. On a $T_1$ dispersion plot ($T_1$ versus evolution field $B_0^E$), these so-called "quadrupole dips" have previously been observed in human tissues *in vivo* [1,2], but usually from a entire samples (e.g. the whole forearm). In this work we have explored the use of image-selected volume-localised FFC relaxometry. This offers potential advantages, including less partial-voluming than whole-sample relaxometry, and better SNR and faster acquisition times than image-based techniques [3]. In order to achieve this, localisation methods borrowed from point resolved spectroscopy (PRESS) [4] are combined with a field-cycled inversion-recovery pulse sequence to produce $T_1$ dispersion plots of volumes of interest selected on pilot MR images.

## Methods:

The imager used for these experiments was a home-built whole-body field-cycling MRI system [5]. The detection field is provided by a whole-body permanent magnet with a 59 mT vertical field and clear bore of 65 cm (Field Effects Inc., USA). A co-axial resistive saddle-shaped magnet (Magnex, UK) allows field-cycling through field compensation. All functions of the system are controlled by a commercial MRI console (SMIS, UK).

A field-cycled, interleaved inversion-recovery / saturation-recovery pulse sequence (Figure 1) was used to measure $T_1$ values by a two-point method, with PRESS selecting the targeted volume. A 10 ms adiabatic fast passage (AFP) inversion is applied, followed by an evolution period of the order of $T_1$. A 5-lobe sinc 90° RF pulse with bandwidth 4500 Hz is then applied in the presence of a field gradient, followed by two 180° RF pulses with orthogonal gradients, resulting in a spin echo from a selected volume. The saturation recovery part of the sequence is almost identical, except that the AFP inversion is not applied. The sequence is repeated at each evolution field step to collect $T_1$ data over the desired range (e.g. 30 mT to 70 mT) at 1 mT intervals. Magnetic field gradient magnitudes and RF frequency offsets are calculated automatically by the system software after marking the volume of interest on one or more pilot images.

An analysis of the magnetisation behaviour using the Bloch equations (including the effect of field-cycling) allows determination of $T_1$ at each evolution field using two points (assuming monoexponential relaxation).

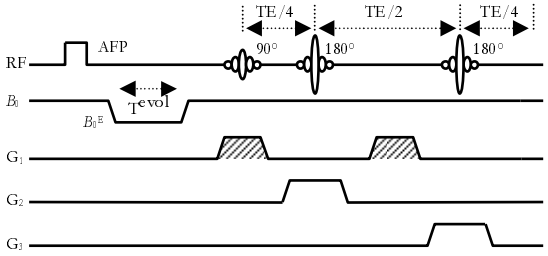


*Figure 1: Pulse sequence diagram. AFP inversion occurs on every alternate execution. The signal acquired is an echo with centre located TE after the 90° excitation.*

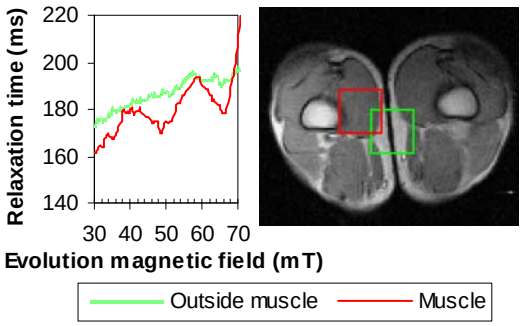


*Figure 2: $T_1$ dispersion plot (left) for selected voxels of a human volunteer's thigh (right) (2 averages). Protein-rich muscle shows quadrupole dips.*

## Results:

Figure 2 shows a $T_1$ dispersion plot of a human volunteer's thigh, with voxels placed over areas of muscle and more superficial tissue identified on pilot images. Due to the relatively high concentration of rotationally immobilised protein in muscle, two quadrupole dips at 49 mT and 65 mT can clearly be seen. The positions of the dips are in agreement with previous work.

Figure 3 shows a $T_1$ dispersion plot obtained from our FFC-PRESS sequence (0.2 mM $MnCl_2$ solution selected from a phantom with nine solutions of differing $T_1$) alongside those of the same sample but from non-localised inversion-recovery sequences executed on our home-built system and a commercial relaxometer (Stelar, Italy). Relaxation times and dispersion behaviour are in excellent agreement.

## Discussion and conclusions:

Image-selected volume-localised FFC relaxometry has been successfully implemented, using a PRESS-like selective-excitation scheme. The method is sufficiently sensitive to observe quadrupole dips on $T_1$ dispersion curves *in vivo*. Our technique offers the possibility of rapidly obtaining localised NMR relaxometry data in human subjects. The non-invasive measurement of protein via quadrupole dips could be of use in many diseases, including muscle-wasting and plaque-mediated conditions.

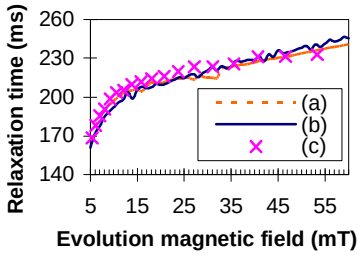


*Figure 3: $T_1$ dispersion plot for the same sample (0.2 mM $MnCl_2$) (a) using non-localised IR, (b) using our sequence, selected from a multi-compartmental phantom, and (c) measured by a commercial relaxometer.*

## References:

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