Methods for the Spatial Localisation of Field-Cycling Relaxometric Data

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Introduction

Field-cycling MR systems have the ability to switch the main magnetic field B_0 (conventionally held rigidly stable) during the acquisition of data. In this way, they allow access to new sorts of endogenous information originating from the complex variation in nuclear magnetic relaxation with field strength. Systems have been described for whole-body FC-MRI [1], pre-polarised MRI of extremities [2] and relaxometric studies of small samples [3] but *in vivo* research has been limited both by lengthy acquisition times and the availability of the specialised field-cycling hardware.

This abstract describes a software approach for accelerating the collection of the T_1 dispersion curve (a plot of T_1 versus evolution field strength B_0) and presents the first details of a removable electromagnetic 'insert coil' intended to add field-cycling capability to existing systems by generating a field offset.

Methods

Firstly, an interleaved inversion-recovery / saturation-recovery pulse sequence with PRESS localisation [4] has been implemented on our home-built whole-body field-cycling MRI imager [1], enabling the estimation of T_1 by a two-point method in a matter of seconds after a volume of interest has been marked on a pilot image.

Secondly, in designing an insertable field-cycling coil we considered the factors: mass, cooling, duty cycle, and magnetic field efficiency. The coil (Fig. 1) comprises multiple windings (not all visible) and generates a projected homogeneous region (+/- 5% over 50 mm DSV) centred 50 mm from the coil's front face. Our static field is generated by a permanent magnet but in cryogenic systems consideration would have to be given to the coil's leakage field and the potential for eddy current interactions with the magnet.

Figure 1: The insert coil.

The coil has been constructed (Tesla Engineering Ltd, UK) and interfaced with a commercial MRI console (SMIS Ltd, UK). The finished coil is 38 cm in diameter, 6 cm high and weighs around 25 kg. Its electrical current (187 A for 56 mT) is delivered by a high-power amplifier (Copley 266, Analogic Corporation, MA, USA) and high-voltage DC power supplies (TDK Lambda, NJ, USA) in a custom configuration. As the coil is designed to dissipate up to 12 kW, water is passed through the hollow copper conductors of the coil windings for optimum cooling. Placed in the bore of a body-sized imager with 59 mT permanent field, the insert coil's ability to offset magnetic field strength was measured with a hand-held gaussmeter (probe 52 mm from coil surface).

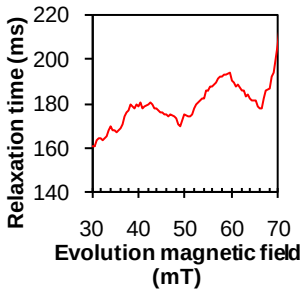

Figure 2: T_1 dispersion plot for voxel of muscle selected from volunteer's thigh (NEX 2). Protein-rich muscle shows quadrupole dips centred on 49 and 65 mT.

Results

Figure 2 shows a dispersion plot of a human thigh with measurements of T_1 at 1 mT field intervals between 30 and 70 mT. Pronounced reductions in muscle T_1 can be observed. These correspond to well-known NMR frequencies where interactions with the quadrupolar nucleus ^{14}N occur [4].

In Figure 3, we show a graph of net field strength (i.e. 59 mT from the static field minus the offset coil's field) versus electrical current for the new insert coil. The steady state temperature of the coil is also shown.

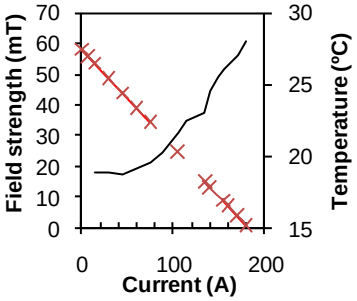

Figure 3: Net magnetic field strength (crosses) near the coil surface as current is ramped from zero to full design value. Steady-state temperature (solid line) was measured at coolant outlet.

Conclusions

Our PRESS-like volume-localised method was sufficient to measure localised T_1 dispersion in realistic scan times. The concept of an insertable offset coil allows the magnetic field of a conventional system to be shifted allowing magnetic field cycling within a small volume. While the data for Figure 2 was from our whole-body FFC-MRI scanner, our next step is to combine a similar pulse sequence with localised field cycling using the offset coil shown in Figure 1.

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