A field offset coil for spatially localised *in vivo* field-cycling relaxometry

K. J. Pine[1], F. Goldie[2], and D. J. Lurie[1]
[1]Aberdeen Biomedical Imaging Centre, University of Aberdeen, Aberdeen, Scotland, United Kingdom, [2]Tesla Engineering Ltd, Storrington, West Sussex, United Kingdom

Introduction

Field-cycling MR systems differ from conventional MR systems in their ability to rapidly switch the main magnetic field strength B_0 during a pulse sequence. Because it is possible to change the magnetic field experienced by the subject, one can study the complex variation of relaxation times with field strength (T_1 dispersion). For example, reductions in T_1 ('quadrupole dips') at well-known frequencies are observed in samples containing protein due to interactions with the quadrupolar nucleus ^{14}N, an effect we have previously demonstrated *in vivo* [1].

Hardware for *in vivo* field-cycling has to date been limited to a handful of home-built systems [2,3]. One recent development that could facilitate more widespread research is the concept of an 'insert coil' [4]: a removable electromagnetic field offset coil intended to provide a field-cycling capability to existing systems. In this abstract we describe the design & integration of such a coil, and its use to aid spatially resolved relaxometry measurements with a human subject.

Methods

An insertable field-cycling coil was designed to suit an existing whole-body permanent magnet-based imager with 59 mT vertical field [2]. Parameters considered included: cooling, magnetic field efficiency, mass, physical dimensions and rise time. The coil (Figure 1) was constructed (Tesla Engineering Ltd., UK) and is comprised of multiple windings (not all visible) to generate a projected homogeneous region (+/- 5% over a 50 mm DSV) centered 50 mm from the coil's front face. Due to the imager's construction from ferrite and fiberglass, no active shielding is required as would be the case with a cryogenic system. It is portable and easily installed in the imager by one person in around 15 minutes. The main properties are summarised in Table 1.

Cooling:	Direct water cooling through coil conductors
Dimensions:	Ø 38 cm, 6 cm thick
Duty cycle:	Up to 100% (DC)
Field strength:	56 mT @ 187 A typical
Inductance:	10 mH
Mass:	~30 kg
Resistance:	335 mΩ

Table 1:Properties of the insert coil

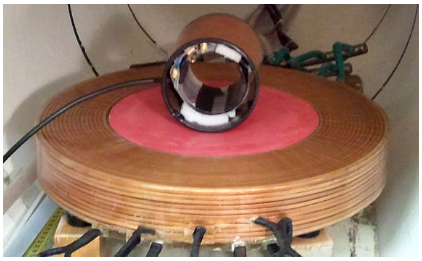

Figure 1: The insert coil (lower) with RF coil in place

Electrical current for the coil 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 allowing for ramp times of 10 ms. Field control is automatic and performed within the pulse programming environment (SMIS Ltd., UK). A hand-held gaussmeter was used first to calibrate field strength and then to measure the insert coil's ability to offset the magnetic field of the imager (probe 52 mm from coil surface).

An interleaved saturation-recovery / inversion-recovery pulse sequence with PRESS for localisation [1] was used to measure T_1 of a volume marked on a pilot image. The RF coil used was a solenoid with 15 turns and a diameter of 7 cm.

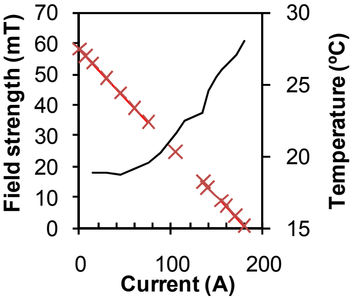

Figure 2: Net magnetic field strength (crosses) near the coil surface as current is ramped from zero to full design value. Steady-state temperature (solid line) measured at coolant outlet.

Results

Figure 2 shows a graph of net field strength (i.e. the static field of 59 mT minus the offset coil's field) versus electrical current for the insert coil. The steady state temperature of the coil is also shown.

Figure 3 is a dispersion curve of a voxel centered over the PIP joints of the fingers of a human volunteer, with measurements of T_1 at 1 mT intervals between 20 - 80 mT. Quadrupole dips are observed at points corresponding to well-known NMR frequencies, due to the presence of immobilised protein.

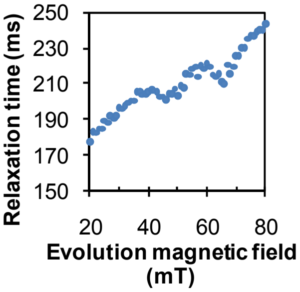

Figure 3: T_1 dispersion curve for voxel selected from volunteer's fingers (NEX 2).

Conclusions

A compact and portable insert coil was used to offset the magnetic field of a body-sized imager, allowing the *in vivo* study of relaxation dispersion. The target area of the scan is currently restricted by the geometry of the solenoidal RF coil. A surface RF coil would enable more flexibility.

Acknowledgements

The authors wish to acknowledge financial support for the FFC-MRI project from Research Councils UK and the Engineering and Physical Sciences Research Council (EPSRC), under the Basic Technology scheme (grant number EP/E036775/1).

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