Fast Field-Cycling Magnetic Resonance Imaging

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Much of the contrast in conventional MRI arises from differences in the NMR relaxation times, especially the spin-lattice relaxation time, T_1. It is also well known that the variation of T_1 with the strength of the magnetic field (known as T_1-dispersion) is tissue-dependent, and that a tissue's T_1-dispersion curve is altered in disease. However, T_1-dispersion is invisible to conventional MRI scanners, because each scanner can only operate at its own magnetic field (e.g. 1.5 T or 3.0 T). Our work exploits T_1-dispersion as a novel MRI contrast mechanism, by building new types of scanner which make use of Fast Field-Cycling (FFC)[1].

In FFC, the applied magnetic field B_0 is switched rapidly, while the sample (or patient) is inside the scanner. This field switching, or cycling, allows the measurement of T_1-dispersion. After polarisation (usually at the device's highest field) the field is switched to an intermediate "evolution" field at which relaxation occurs. The magnetic field is finally switched back to a high value for signal detection, always at the same field so that the instrument's radiofrequency system does not require retuning during the procedure.

We have built a range of FFC-MRI equipment, including two whole-body human sized scanners, operating at detection fields of 0.06 T and 0.2 T. [2,3] The 0.06 T scanner uses a double magnet, with field-cycling being accomplished by switching on and off a resistive magnet inside the bore of a permanent magnet. Our newest scanner (0.2 T) uses a single resistive magnet, giving increased flexibility at the expense of greater complexity and increased susceptibility to magnetic field fluctuations. Three orthogonal pairs of coils in rectangular Helmholtz configuration provide compensation of the Earth's magnetic field, allowing measurements as low as 1 μT evolution field. A photograph of the scanner is shown in Figure 1, while Figure 2 shows typical FFC-MRI images from the scanner.

We are exploring bio-medical applications of FFC-MRI, and early results have shown promise in the areas of thrombosis[4] and osteoarthritis[5]. Recent work on FFC-MRI methodology has focussed on speeding up the collection of FFC-MRI images by incorporating rapid MRI scanning methods[6] as well as improved pulse sequences and data analysis algorithms[7].

FFC-MRI is showing significant potential as a new variant of MRI. Our web site (*www.ffc-mri.org*) contains further information, including copies of publications.

Fig. 1 *Photograph of the 0.2 T human-scale FFC-MRI scanner. The magnet and Earth's field correction coils can be seen.*

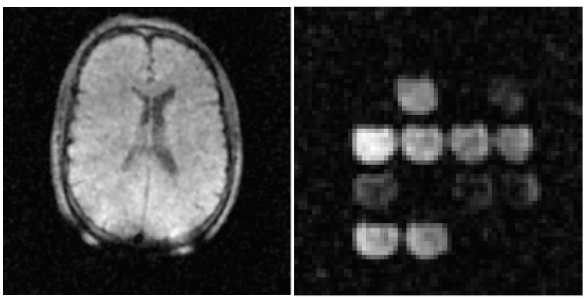

Fig. 2 *Left: head of normal volunteer at 0.1 T evolution field (FOV 280 mm; SL 8 mm; 128x128; NEX 1). Right: Array phantom ($MnCl_2$ solns) at 1 μT evolution field (FOV 300 mm; SL 10 mm; 64x64; NEX 1).*

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