# FIELD-CYCLING MAGNETIC RESONANCE IMAGING – A CURIOSITY OR THE NEXT BIG THING?

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The use of Fast Field-Cycling Magnetic Resonance Imaging (FFC-MRI) is a relatively new variant of MRI, aimed at increasing its medical diagnostic potential [1].

FFC-MRI was first demonstrated in conjunction with Proton-Electron Double-Resonance Imaging (PEDRI) to image the distribution of free radicals in biological samples using the Overhauser Effect (combined NMR and Electron Spin Resonance (ESR). Field-cycling allows the ESR irradiation to be applied at low field (hence relatively low frequency, and low non-resonant absorption), while NMR signal detection and imaging is carried out at higher field, to preserve SNR [2].

NMR relaxometry is usually accomplished using FFC, by switching the magnetic field rapidly between levels during the pulse sequence. In this way, a single instrument can be used to measure $T_1$ over a wide range of magnetic field strengths. FFC-MRI aims to obtain spatially-resolved $T_1$-dispersion data, by collecting images at a range of evolution field strengths [1,3,4]. We have demonstrated methods for implementing relaxometry on localised regions defined on a pilot image [5]. We have also shown that FFC relaxometry can detect the formation of cross-linked fibrin protein from fibrinogen *in vitro*, in a model of the blood clotting process, via the measurement of $^{14}$N-$^{1}$H cross-relaxation phenomena [6], and we have shown that FFC-MRI can detect changes in human cartilage induced by osteoarthritis [7]. Recent work has focussed on speeding up the collection of FFC-MRI images by incorporating rapid MRI scanning methods and improved pulse sequences and algorithms [8,9].

In our lab we have built a range of FFC-MRI equipment, including two whole-body human sized scanners, operating at detection fields of 0.06 T [10] and 0.2 T. 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; this has the benefit of inherently high field stability during the detection period. We have also demonstrated technology for localised field switching within a clinical MRI system [11].

This presentation will cover the main techniques used in FFC-MRI and will summarise current and potential bio-medical applications of the methods.

[1] Lurie D.J., Aime S., *et al.*, Comptes Rendus Physique **11**, 136-148 (2010).*
[2] Lurie D.J., Hutchison J.M.S., *et al.*, J. Magn. Reson. **84**, 431-437 (1989).*
[3] Carlson J.W., Goldhaber D.M., *et al.*, Radiology **184**, 635-639 (1992).
[4] Lurie D.J., 1st Symposium on Field-Cycling NMR Relaxometry, Berlin, p5, (1998).*
[5] Pine K.J., Davies G.R. and Lurie D.J., Magn.Reson.Med. **63**, 1698–1702 (2010).*
[6] Broche L.M., Ismail S.R., *et al.*, Magn.Reson.Med. **67**, 1453-1457 (2012).*
[7] Broche L.M., Ashcroft G.P and Lurie D.J., Magn.Reson.Med. **68**, 358-362 (2012).*
[8] Ross, P.J., Broche, L.M., and Lurie, D.J., Magn. Reson. Med. **73**, 1120-1124 (2015).*
[9] Broche, L.M., Ross, P.J., Pine, K.J. and Lurie, D.J., J. Magn. Reson., **238**, 44-51 (2014).*
[10] Lurie D.J., Foster M.A., *et al.*, Phys.Med.Biol. **43**, 1877-1886 (1998).*
[11] Pine K.J., Goldie F. and Lurie D.J., Magn. Reson. Med. **72**, 1492-1497 (2014).*

*These references are available at *http://www.ffc-mri.org/publications*