Polarisation manipulation in MRI by magnetic field-cycling and DNP

David J. Lurie, Lionel Broche, Chang Hoon Choi, Gareth R. Davies, Saadiya R. Ismail, Dara Ó hÓgáin and Kerrin J. Pine

Aberdeen Biomedical Imaging Centre, University of Aberdeen, AB25 2ZD, Scotland, UK
www.ffc-mri.org

Dynamic Nuclear Polarisation (DNP) has been investigated as a method of detecting and imaging free radicals for more than 20 years. In the basic method of Proton-Electron Double-Resonance Imaging (PEDRI) the sample's EPR is irradiated during the acquisition of a proton NMR image. Parts of the sample containing unpaired electrons exhibit altered image intensity due to the Overhauser transfer of polarisation from electron to proton spins, revealing the location of the free radical under study [1]. In biological applications it is necessary to perform the experiment at very low field (~10 mT) so that the EPR irradiation is at sufficiently low frequency (<300 MHz) to penetrate into the sample without depositing excessive heat.

The disadvantage of PEDRI at low field is the inherently low SNR. To counter this, magnetic field-cycling can be employed. In Field-Cycled PEDRI (FC-PEDRI) the field is switched between a low value (B_0^E, the evolution field) and a high value (B_0^D, the detection field) during the pulse sequence. EPR irradiation takes place at B_0^E, typically 4 mT, at a correspondingly low frequency (~100 MHz). The field is then switched to B_0^D and the NMR detection pulse(s) and imaging magnetic field gradients are applied [1].

As well as using field-cycling for free radical imaging, we have explored its use in "pure" fast field-cycling MRI (FFC-MRI). The aim is to obtain spatially-resolved T_1-dispersion data, by collecting images at a variety of evolution field strengths. This has the potential to obtain new types of image contrast. Relaxometric imaging using field-cycling was first demonstrated by Carlson in 1992 [2], and since then relaxometric imaging methods have been implemented in Aberdeen [3], Stanford [4] and Western Ontario [5].

To date we have constructed two FFC-MRI systems. Both use the "field-compensation" method of field-cycling employing dual, coaxial magnets – one for signal detection at B_0^D and the other for partial field-cancellation. The first system employs a whole-body sized (60 cm bore) 59 mT permanent magnet [6] while the second employs a 450 mT superconducting primary magnet, with a coaxial resistive field-offset coil (15 cm bore) [7]. In this case an active shield coil is used, placed between the superconducting magnet and the field-offset coil, in order to prevent eddy currents in the superconducting magnet's cryostat.

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