Progress in Fast Field-Cycling MRI

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Fast field-cycling relaxation spectroscopy (relaxometry) of small samples has been in use for several decades, and is now used routinely in many laboratories, using both custom-built and commercially-available equipment. In contrast, the use of field-cycling in imaging experiments has been limited to a few applications, carried out in a small number of laboratories, using almost-exclusively home-built equipment. This presentation will survey the techniques and applications of FFC-MRI to date, and will suggest what it might offer in the future.

Earth's Field MRI

MRI in the very weak, but potentially very homogeneous, Earth's magnetic field has been investigated since the early days of MRI. Since the Boltzmann magnetisation at 50 μT is naturally feeble, field-cycling using an inhomogeneous magnet coil is used to boost the initial magnetisation, for subsequent detection in the Earth's field, at about 2 kHz. Despite the low frequency, remarkably good quality images can be obtained [1-3].

Pre-Polarised MRI

Pre-polarised MRI is similar to Earth's field MRI, in that a strong, inhomogeneous magnetic field is pulsed for a time of the order of T_1 in order to boost the initial magnetisation, and hence improve the SNR. Here, though, detection occurs at an intermediate (though relatively weak) homogeneous magnetic field, produced by a second magnet. The stated aim of pre-polarised MRI, as pioneered by the Stanford group, is usually to build low-cost MRI systems, though low-field detection brings some advantages, including very low susceptibility artefacts [4,5]. A similar approach has been adopted by Chronik's group in Ontario, which is also developing field-cycling MRI as a way of combining MRI and PET imaging [6,7].

Relaxometric MRI

Relaxometric MRI is the imaging equivalent of "conventional" field-cycling relaxometry. The aim is to obtain spatially-resolved T_1-dispersion data, by collecting images at a variety of evolution field strengths. Often, the "quadrupole dip" effect is observed, with the potential to obtain new types of image contrast. Relaxometric imaging was first demonstrated by Carlson in 1992 [8], and since then relaxometric imaging methods have been implemented in Aberdeen [9] and Stanford [10].

Field-Cycled PEDRI free radical imaging

The final area where field-cycling MRI has found an application is in Proton-Electron Double-Resonance Imaging (PEDRI) of free radicals. This uses the Overhauser effect: irradiation of the free radical's ESR causes a transfer of polarisation from electron spins to coupled nuclear spins, resulting in a change in image intensity. Field-cycling allows the ESR irradiation to be carried out at low field (hence relatively low frequency, and low non-resonant absorption), while NMR signal detection and imaging is done at higher field, to preserve SNR [11].

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