A Single-Magnet Fast Field-Cycling Whole-Body MRI System with Detection at 0.2 T

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Purpose

Fast Field-Cycling (FFC) MRI systems differ from conventional MRI systems by their ability to adjust the main magnetic field strength B_0 during the pulse sequence. FFC makes possible imaging with contrast based on not just simply T_1, but its dispersion over a range of field strengths[1]. During a typical pulse sequence, the field strength is changed from a polarization field, B_{0p}, to an evolution field, B_{0e}, at which relaxation effects of interest occur, before returning to a detection field, B_{0d}. Switching the field requires novel magnets, power supplies and ancillary devices. In this abstract we describe our progress with a new whole-body sized FFC imager.

Methods

The literature contains several examples of FFC apparatus[2-6]. In general they are home-built systems with dual-magnet designs, in which a stable and homogeneous field from one magnet (superconducting or resistive) providing B_{0d} is offset by a secondary electromagnet. In contrast, this magnet follows a single-magnet design with rigorous requirements for field homogeneity and stability.

The magnet (shown in Figure 1) is constructed of three co-wound copper coils on a cylindrical former embedded in epoxy resin (Tesla Engineering Ltd, Storrington, UK). Its length is 2040 mm, and the bore has an inner diameter (net of the gradient assembly) of 500 mm, making it suitable for human subjects. Its bare inductance is 5 mH and DC resistance 85 mΩ per channel, requiring a current of 650 A (in each of three circuits) to generate its design field strength of 0.2 T. This current is provided by a specially-made bank of high-power gradient amplifiers (International Electric Co. Oy, Helsinki, Finland) with a custom control system.

Results

After commissioning and testing, the system achieved its full field strength. Implementing automatic shimming has extended the NMR FID signal (Figure 2) from a sample of distilled water doped with $CuSO_4$ from 0.5 ms to beyond 10 ms, compatible with imaging. Field stability and shot-to-shot reproducibility are within specification. A spin echo (20 ms TE) signal acquired from the same sample during gradient calibration is shown in Figure 3.

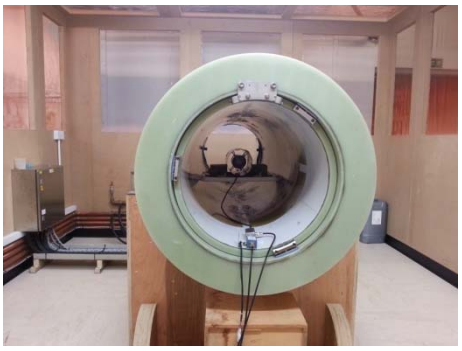

Figure 1: 0.2 T Field-cycling imager

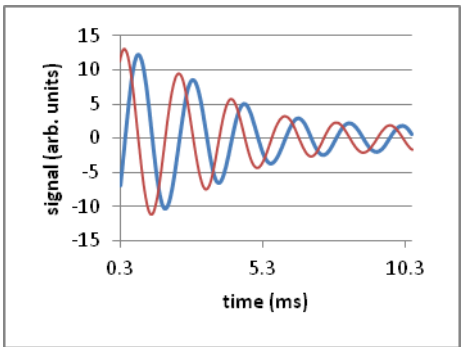

Figure 2: FID NMR signal

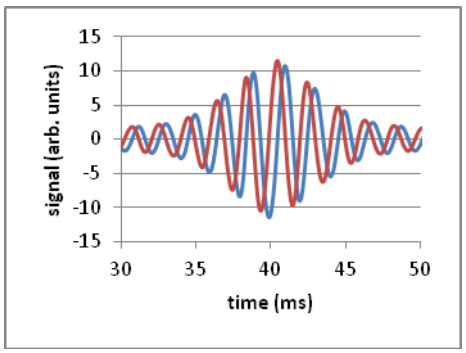

Figure 3: Spin echo NMR signal

Discussion and Conclusion

The single-magnet FFC-MRI design provides flexibility as virtually any combination of magnetic field strengths (up to 0.2 T) can be cycled between during an experiment. The system has the added advantage of zero power consumption when not in use. When compared with our previous system, we expect further benefits from the higher detection field (0.2 T versus 0.06 T) and faster field ramp time (20 ms versus 40 ms). Work is continuing to calibrate the system for imaging. Once fully in operation, it will be used to explore further the clinical benefits of field-cycling[7].

References

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