Design and Implementation of a Standalone Magnet Field Drift Correction Unit

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Introduction – Magnetic field drifts are encountered in almost all MR experiments and on almost all MR systems. The inherent magnet drift, as specified by the manufacturers, is on most modern MR systems relatively small. However, magnets that are installed with passive iron shims inside the shim and gradient former can exhibit strong field drifts due to gradient-induced heating of the passive shims. Other gradient-induced magnetic field drifts can occur in damaged superconducting shims. Besides hardware related drifts, the subject (animal or human) can create its own magnetic field variations due to motion or respiration. Independent of the underlying cause, the manifestations of magnetic field drifts are typically line-broadening in MR spectroscopy, additional (phase) noise in MRI and potentially false activations in BOLD fMRI. Henry et al (1) have previously developed a software solution to this problem, specific to Bruker MR systems. Here we present the design and implementation of a hardware-based Field Drift Correction Unit (FDCU) that can in principle work on any MR system, for any kind of MR sequence and for all nuclei.

Methods – The FDCU consists of 4 stages (Fig. 1). Firstly the analog front end is interfaced between the spectrometer's receiver and digitizer. A low flip angle FID is gated into the system under real time control from the pulse program. The gain of the input signal is automatically adjusted to maximize the dynamic range. The real and imaginary signals are then filtered and sent to analog-to-digital converters. The digitized data is then sent to a C based Microcontroller (Rabbit Semiconductor, Davis CA) where it is compared to a reference scan. The frequency drift, relative to the reference scan, is calculated by comparing the phase difference of each complex point (either 255 (standard) or 63 (for short TR acquisitions)) of the two scans. The linear frequency drift and the corresponding Z0 correction is then calculated. The Z0 correction value is sent from the microcontroller to a digital-to-analog converter who's output is summed with the Z0 shim drive and sent to the Z0 amplifier. Timing for the system is performed within a dedicated on-board timing controller. The only inputs required from the pulse program are a single start pulse and a flag to differentiate a reference scan. All measurements were made on a Magnex 4 T 94 cm magnet interfaced to a Bruker Avance spectrometer. To demonstrate the principle, signal was acquired from a water-filled spherical phantom following 100 ms 29 mT/m gradient pulses on all 3 axis and non-selective excitation (TR = 2000 ms). The experiment was repeated for 900 scans for a total experiment time of 30 minutes.

Results - The data displayed in Fig. 2 was acquired using 255 complex points with a time of 215 ms between the start of acquisition and updating of the Z0 current. Fig. 2 shows the uncorrected and corrected frequency drifts as a function of time. It can be seen that the uncorrected gradient-induced frequency drift (coming from a combination of passive shim heating and a damaged superconducting shim) changes the magnetic field by more than 25 Hz, many times the typical linewidth in an *in vivo* MRS experiment of human brain. The FDCU was able to keep the corrected frequency of the magnet to within +/-0.2 Hz over the entire experiment.

Discussion - It has been demonstrated that a stand-alone Field Drift Correction Unit (FDCU) can correct any magnetic field drifts to within +/- 0.2 Hz. While the results were obtained *in vitro*, the principle can be extended to MRS applications without any modifications. For MRS, the FDCU guarantees the best possible linewidths for a given shim setting and it ensures that water suppression and spectral editing pulse selectivity will be constant throughout the experiment. For MRI applications, improvements can be expected for (BOLD) functional MRI, and any gradient-recalled MRI sequence, including echo-planar imaging (EPI). The unit can update the Z0 currents in < 100 ms, so the technique can also be implemented for real-time respiratory-induced frequency drift correction.

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[1] Henry et al. Magn. Reson. Med. 42, 636 (1999)

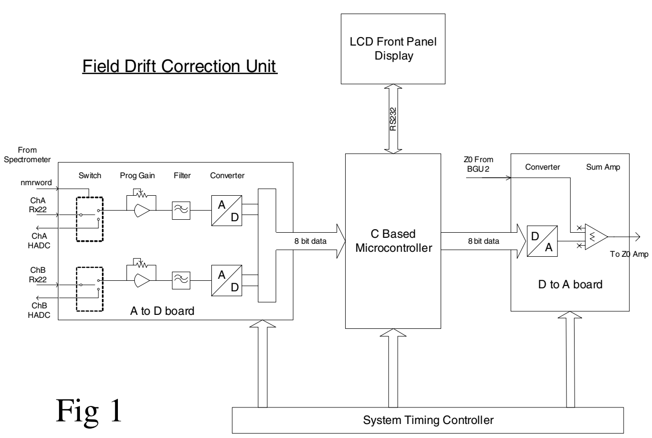

Fig 1

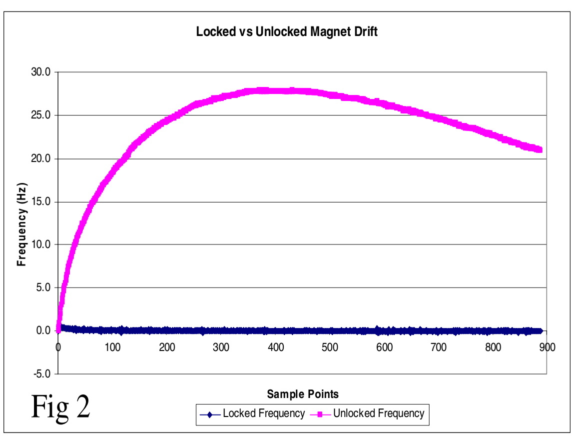

Fig 2