An efficient EPI pulse sequence module for active marker motion correction acquisition for EPI scans

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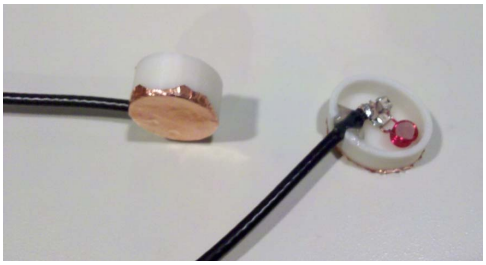
Introduction:

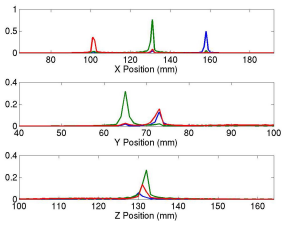
Head motion presents considerable challenges in drawing conclusions from single-shot pulse sequences such as BOLD-weighted functional imaging, diffusion-weighted imaging, and perfusion-weighted imaging studies, whether for clinical presurgical planning or research purposes. Prospective motion correction methods have been widely adopted by scanner manufacturers to deal with this problem, particularly for fMRI applications. Even though navigator-echo and active marker tracking methods present a much better solution to prospective motion correction, the currently implemented methods utilize one-volume delayed whole brain registration, followed by an update of scan parameters[2]. The problem with that strategy is that there is still a one-volume residual motion artifact in the acquired data. Active marker methods have not been more widely adopted because, in part, they require pulse sequence modifications that affect the efficiency and SNR of the acquisition. More recent methods attempt to correct for motion using optical measures [5] and microcoil-based MR active markers [6] to correct for motion on a faster timescale and remove motion before it affects some or all of the acquisition. ***We present here a novel modification of the active marker tracking method that does not impact on the time and SNR efficiency of the main pulse sequence.***

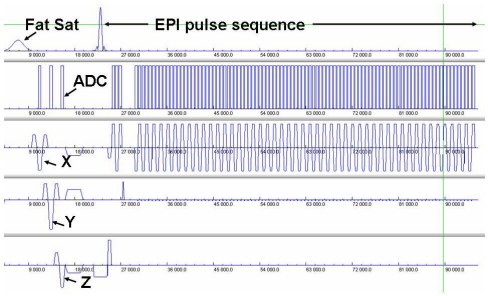
The microcoil-based method of Ooi et al [6,7] provides the fastest update time, immediately prior to every slice acquisition. **However, it requires the use of an additional RF pulse**, separate from the rest of the pulse sequence, to excite the water in each microcoil and the full module requires 25 ms per slice (with typical slice acquisition times between 70 and 130 ms, this represents roughly 30% time inefficiency). This additional weak (4° flip angle) pulse will reduce the SNR of tissue being imaged by the main pulse sequence. We have developed a modification of this method that does not affect the main pulse sequence, so long as the pulse sequence requires an RF pulse for fat saturation. We also demonstrate timing improvements that reduce the additional module time to 5 ms per slice, reducing the time inefficiency to 5%. **By using a fat-based marker and the existing fat saturation RF pulse for marker excitation, the marker acquisition is a few percent more SNR-efficient and 25% more time-efficient.** Here we report the pulse sequence module for this method and demonstrate projection-based marker localization using our method.

Methods:

We constructed three small receive-only coils, tuned, matched and interfaced after preamplification to the standard table plug on a Siemens 3T Trio MRI scanner. The MR-visible sample used in each microcoil was a small (~1 mm I.D.) sealed polyethylene cylinder, containing soybean oil (see Fig to the right). The active markers were set in fixed positions relative to each other on a plastic former intended to rest on a human forehead while in the supine position, with each microcoil resting in a printed holder with a shielded base. The product echo-planar pulse sequences for BOLD and diffusion-weighted sequences were modified such that the fat saturation module incorporated three projection readouts immediately following the fat saturation and before fat spoilers (see Fig to the right of pulse sequence diagram).







Results and Discussion:

In the figure to the far right, the magnitude of the microcoil signals during projections is shown. The SNR of each fat-based microcoil ranged from 400 to 900, sufficient for tracking, without any modification of the fat saturation RF pulse itself. **This demonstrates proof-of-principle that it is possible to use the fat saturation for tracking.**

Correcting all data for rigid-body head motion after acquisition [1] or during acquisition [2] (using image-based registration) reduces the problem if the motion is small. However, spin-history effects and residual movement-related signal changes are unaffected and incompletely removed by regression-based second-order motion correction methods [3,4], and the resulting residuals induce bias and reduce sensitivity. The active marker method is a potential solution to head motion. ***We have demonstrated that it is possible to use the marker method without substantial drawbacks on the main pulse sequence.***

References: 1) Cox, RW et al, MRM 1999; 42:1014–1018., 3) Thesen, S et al, Magn Reson Med 2000; 44:457–465., 3) Friston, KJ et al, MRM 1996; 35:346-355., 4) Bullmore, ET et al, HBM 1999; 7:38-48., 5) Zaitsev, M et al, NeuroImage 2006; 31:1038-1050., 6) Ooi, MB et al, Magn Reson Med 2009; 62(4):943–954., 7) Ooi, MB et al, Magn Reson Med 2011; 66(1):73-81.