Prospective real time rigid body motion correction at 7 Tesla using inductively coupled wireless NMR markers.

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INTRODUCTION

Active nuclear magnetic resonance (NMR) probes have recently been employed successfully in head motion correction (MC) in MRI [1]. However, active NMR probes need cable connections and matching capacitors, which increase the size of the probes, they require spare receiver channels and are less comfortable. We have therefore developed inductively coupled wireless markers [2,3] and have used these for prospective rigid body motion detection and correction at 7 Tesla.

THEORY AND METHODS

Inductive coupling between wireless markers and the transmit B_1 field results in flip angle amplification in the makers by a factor equal to the *Q* of the markers. As a result, sufficient SNR is generated for even very low flip angle excitations (~1°), enabling robust localization of the markers. Three ^{1}H probes were built for use on a human 7 Tesla MR scanner (Philips Healthcare, USA) with a single channel transmit, 32 channel receive head coil (NOVA Medical, USA). Each probe was a 298 MHz tuned LC circuit with the solenoid containing a 2 mm cell of gadolinium-doped tap water (Figure 1a). The probes were mounted in a non-collinear setup on a head-shaped phantom.

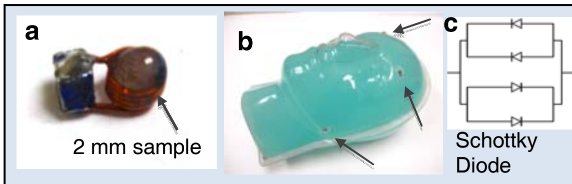


Figure 1 (a): Wireless probe (b) Probes on a life-sized head phantom (c) Back-to-back Schottky diode.

Probe localization and slice tracking: A 12 ms 3D linear navigator with a non-selective 1° flip angle was interleaved every TR for position encoding of the probes. Figure 2 displays magnitude profiles in the 3 directions showing distinct marker peaks. The 6 rigid body motion parameters were calculated in real time using a three-step algorithm: ***Step1***. A recursive peak finding algorithm in which a peak was identified as the maximum value, followed by zeroing of that and the nearest neighbor points was executed until three distinct peaks were found in each projection. The three probe positions from the three projections were backprojected to yield a grid of $3^3 = 27$ points in 3D space. ***Step2*.** From the backprojected set of 27 points, triangles in 3D space were listed using C (27,3) = 2925 combinations. A condition that none of the projections was omitted in each triangle further reduced the set of possible triangles. ***Step3.*** From the list of all the possible triangles, the triangle with the least difference in side lengths and area compared to the initial known dimensions of the triangle was accepted as the current position of the probes. The extracted probe positions were then used to calculate the rotation and translation parameters assuming rigid body motion, as in [1]. The geometry of the imaging module was updated prospectively to compensate for the estimated motion.

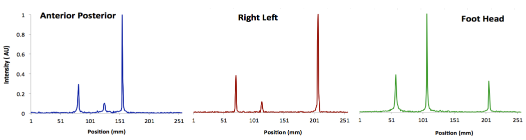
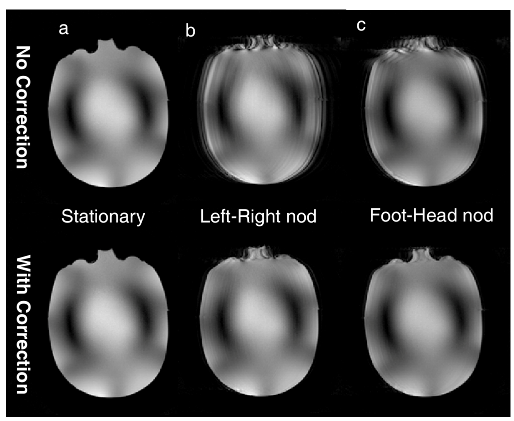


Figure 2: Navigator data showing marker peaks.

MC Scans: High-resolution gradient echo scans with three manually induced motion patterns: ***a***. No motion. ***b***. Left-Right motion nodding motion and ***c.*** Foot-Head nodding motion, were performed on the head phantom to test the MC system (1 mm^3 voxel, TR/TE = 100/4 ms, Taq = 24 secs, single axial slice). All scans were performed with and without MC.

RESULTS

Figure 3 shows images without and with prospective MC demonstrating effective real time correction of complex motion patterns in each type of motion induced.



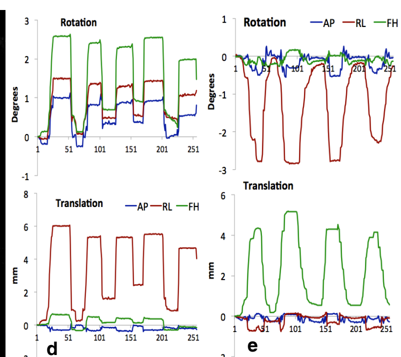


Figure 3: MC results (a) No motion (b) Left-Right motion (c) Foot-Head motion (d, e) Motion parameters for corrected scans in b and c.

DISCUSSION

Inductively coupled markers add significant benefits in flexibility, comfort and size to marker-based MC while maintaining performance. They eliminate the need for spare receiver channels. Further work is needed to improve probe localization algorithms and detuning mechanisms. In the absence of active detuning, RF level actuated antiparallel Schottky diodes (Figure 1c) may be used to detune the markers. In-vivo application to head MC will follow appropriate safety testing of the markers.

REFERENCES

1. Ooi, M.; et al. *MRM* 62. 943 (2009). 2. Burl, M.; et al. *MRM* 36. 491 (1996). 3. Flask, C.; et al. *JMRI* 14. 617 (2001)