Tracking Motion and Resulting Field Fluctuations Using ^{19}F NMR Field Probes

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Introduction: The degradation of image quality due to subject motion is a known problem in MRI. Several methods were presented to overcome this problem [1]. This work focuses on tracking subject motion using NMR field probes similar to the ones in [2]. The goal is to show the feasibility of tracking head motion and field fluctuations in vivo on a human scanner.

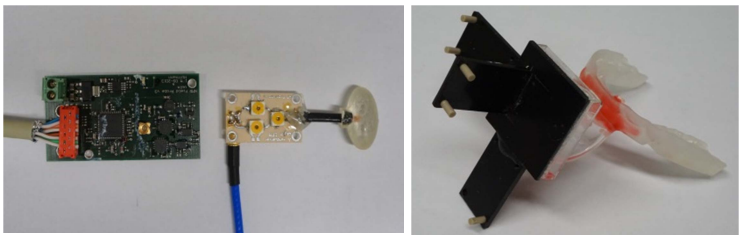

Figure 1: (left) PCB with transmit/receive electronics and field probe with attached tuning/matching board. **(right)** Custom made bite bar for attaching field probes and motion measurements.

Methods: The NMR field probes use Hexafluorobenzene (C_6F_6) as an NMR active sample. The probes are connected to a tuning matching board and are tuned to the operating frequency of 376.14 MHz and an impedance of 50 Ohm. The sample is excited via a custom build transmit/receive-chain based on microelectronic components assembled onto a PCB board [3] (Fig. 1). The signals are demodulated on the PCB board and transmitted to and from the board via a shielded ethernet cable. The demodulated signal is filtered and then digitized at a sampling rate of 200 kS/s using a commercial ADC (NI PCIe-6363, National Instruments, Austin, TX, USA) and the PCBs are operated via LabVIEW (National Instruments). Due to the external hardware, the setup doesn't block any channels of the MR Scanner. The measurements were carried out at a 9.4 T human scanner (Siemens Magnetom). The position of each probe was determined via 3 block gradients along each axis (5 mT/m, 1 ms). The phase ϕ of the signal can be used to determine the field strength using the relation $\gamma \int_0^t B(\vec{r},t)d\tau = \phi(\vec{r},t) + \omega_d$. The first part of the acquired phase information without any gradient applied was used to assess the current magnetic field strength at the probes position and its fluctuations. To measure the stability and accuracy of the position measurement as well as of the field measurements, 200 measurements were taken with a repetition time (TR) of 250 ms. For the subject measurement a TR of 500 ms was chosen since the C_6F_6 was undoped and had a T1 longer than 1 s. For the measurement of motion, three field probes were attached to a bite bar (Fig.1), which was custom made for the subject. The subject then was asked to perform arbitrary head motion and after that to hold as still as possible. The translations and rotations were then calculated using an implementation of the Kabsch algorithm [4] in MATLAB.

Results and Discussion: The accuracy measurement resulted in a standard deviation of σ_x=30, σ_y=41 and σ_z=57µm for the respective axis. The field fluctuation measurements yielded a standard deviation of σ=3.57 Hz with no subject present in the scanner. The motion measurements show the translations and rotations of the subject (Fig. 2.1&2.2). The concurrently measured field fluctuations show that subject motion can cause fluctuations above 200 Hz (Fig. 2.3). The fluctuations with the subject asked to hold still (time range from 35 s to 55s) are in the range of 10 Hz but can probably be attributed to respiratory motion.

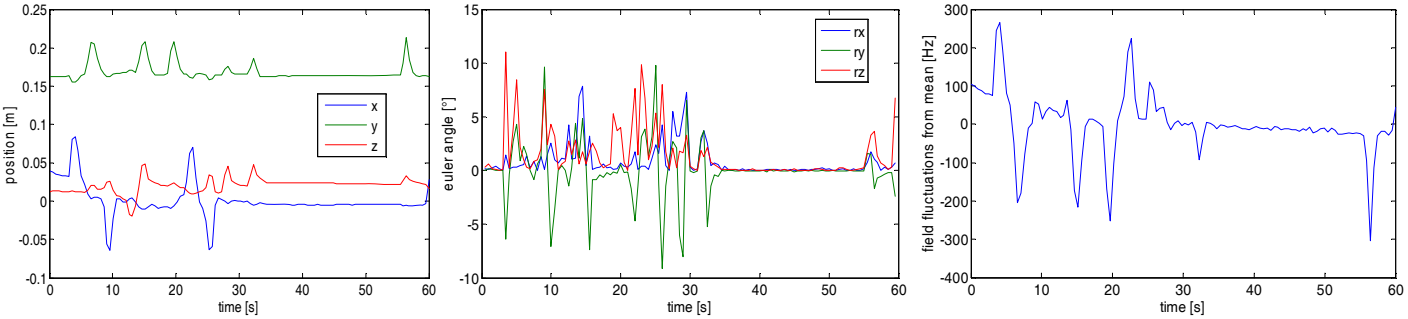

Figure 2: (2.1 left) Tracked position of one field probe. **(2.2 middle)** Euler angles of the rotations calculated from the position of 3 probes. **(2.3 right)** Measured field fluctuations at one probe's location under motion (deviation from mean frequency).

Conclusion: The proposed method shows the possibility to measure positions and motion with NMR field probes as well as monitor field fluctuations. Future work will focus on comparison to an optical tracking system as a golden standard for further assessment of the tracking accuracy. The application of the tracking data to prospectively correct for motion will be the next step.

References: [1] J. Maclaren et al., MRM 2013, 69:621-631; [2] C. Barmet et al., MRM 2008; 60:187-197; [3] J. Handwerker et al., IEEE Biomedical Circuits and Systems Conference (BiOCAS) 2013, Rotterdam, The Netherlands, ID 5027; [4] W. Kabsch (1976), Acta Crystallographica 32:922;