Mapping and correcting respiration-induced field changes in the brain using fluorine field probes

Mads Andersen[1,2], Kristoffer Madsen[1], Lars Hanson[1,2], Vincent Boer[3], Tijl van der Velden[3], Dennis Klomp[3], Joep Wezel[4], Matthias van Osch[4], and Maarten Versluis[4]
[1]*Danish Research Centre for Magnetic Resonance, Copenhagen University Hospital Hvidovre, Copenhagen, Denmark,* [2]*Biomedical Engineering Group, DTU Elektro, Technical University of Denmark, Kgs. Lyngby, Denmark,* [3]*Department of Radiology, University Medical Center Utrecht, Utrecht, Netherlands,* [4]*C.J. Gorter center, Department of Radiology, Leiden University Medical Center, Leiden, Netherlands*

Target audience: MR physicists, high field imaging

Purpose. Breathing induced dynamic B0 field perturbations in the head can lead to artefacts in ultra-high field MR by causing line broadening in spectroscopy and signal dropout, ghosting, displacement artifacts and blurring in imaging. It has recently been proposed to continuously stabilize the magnetic field by real-time updating of the shim fields, based on synchronous field measurements with external probes[1,2]. A thorough analysis of how accurate such field measurements at few (e.g. 16) positions outside the head can reflect the spatially varying dynamic fields *inside* the head is currently lacking. In this study a comparison between scanner-acquired field maps of the head, and corresponding field probe measurements is presented both during in- and expiration. In addition, the field probe measurements have been used to perform real-time updating of the linear shim-settings.

Methods. *Setup:* The experiments were performed on a 7T MRI system (Philips Healthcare, Best, NL) using a 32-channel Nova Medical head coil. Fourteen fluorine T/R NMR field probes[3] were firmly distributed around the transmit/receive head coil. A stand-alone spectrometer[4] digitized the field probe signals, and calculated field strength values from signal phase by linear fitting. Ahead of imaging, the field probe positions were determined for each subject, by applying known gradients in all three dimensions while measuring with the field probes. *Experiments:* Measurements were performed in 4 male subjects instructed to hold the chest position in fully inhaled and exhaled positions alternating between successive measurements. In each breath hold, a field probe measurement and a volume field map of the brain was acquired. The field probe data was fitted up to second order spherical harmonics. The experiments were repeated with real-time shim-updating based on the field probe measurements, using only 0^{th} and 1^{st} order fitting. Each experiment was repeated twice. *Imaging:* Field mapping was done using 2 interleaved 3D gradient echo acquisitions with TR/TE/ΔTE = 5.9ms/3.2ms/1ms, flip angle 10°, voxels of $4x4x4mm^3$. Scan duration for a single volume was 11s, which was easily tolerated during a breath hold. The field probes were triggered to perform a measurement (3ms duration) 75 ms prior to the first excitation in each dynamic, when no scanner generated RF pulses or gradients were applied. In case of real-time shimming, the scanner software was updated with f0 and first order shim values, before the acquisition of every volume. *Evaluation:* To assess whether the dynamic field changes were captured by the field probe data, the field probe fitted fields were subtracted from the scanner B0 maps to model shimming. We then assessed whether these absolute differences were significantly smaller in the corrected B0-maps using a paired t-test over the entire volume. For real-time updating a two sample t-test was used because the samples were from two different sessions in this case.

Results. The figure shows the dynamic field changes in a sagittal slice of one of the volunteers. Field probe fits, scanner B0 maps, and corrected B0 maps are shown for the case of fitting up to first and second order. The tables show p-values from statistical tests over entire volumes.

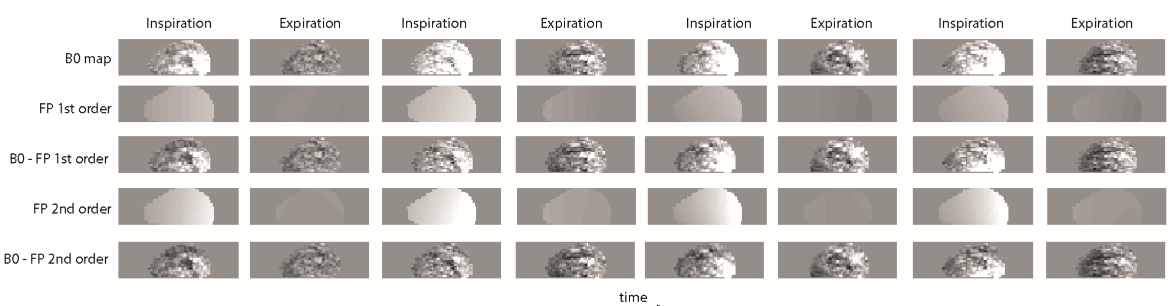
Discussion: Using a significance level of 0.05, the p-values in table 1 show that the field can be significantly stabilized in all 4 subjects using field probe measurements fitted to 0^{th} and 1^{st} order spherical harmonics. By fitting also the 2^{nd} order spherical harmonics to the field probe data, a significant stabilization is still seen in subject 1,3,4, and in these subjects, the 2^{nd} order correction is significantly better than the first order correction. This is not the case for subject 2. The figure illustrates the stabilization. It is seen that the corrected B0 maps fluctuate less in intensity over time compared to the uncorrected ones, and the field correction in the back of the head appears better with the second order correction, compared to the first order correction for this subject. Comparing the real-time updated field maps with the non-corrected ones (table 2), a significant improvement is seen in subject 3 and 4, but not in subject 1 and 2. Such a comparison has inherent limitations though, as it compares data from two different sessions where the amplitude of breathing can be different.

Conclusion It was shown that 14 external field probes reflect the field in the head sufficiently well so it can be significantly stabilized.

Subject	1^{st} vs. no correction	2^{nd} vs. no correction	2^{nd} vs 1^{st}
1	0.0090	0.0017	0.00079
2	0.049	0.066	0.51
3	0.0045	0.0020	0.0049
4	0.0040	0.0011	0.0009

Table 1: P-values from tests of whether the retrospective corrections using field probes significantly stabilize the field maps.

References **1**.Wilm et al.,MRM 2013; **2**. Duerst et al. Proc. ISMRM, 2013, p. 669; **3**. Barmet et al., MRM, 2009, 62:269-76; **4.** Dietrich et al., Proc. ISMRM 2012, p.700



Subject	P-value
1	0.58
2	0.92
3	0.025
4	0.043

Table 2:Real-time correction P-values from tests of whether field variation is reduced in real-time corrected field maps compared to uncorrected field maps (acquired in separate scan sessions).