Correction of Artifacts in Ultrahigh Field T_2^* Imaging Using a Training Model for Field Probe Based B_0 Measurements

Anders Garpebring[1,2], Joep Wezel[1], Vincent O. Boer[3], Tijl A. van der Velden[3], Andrew G. Webb[1], Dennis W.J. Klomp[3], and Matthias J. P. van Osch[1]
[1]*C.J. Gorter center for high field MRI, Radiology, Leiden University Medical Center, Leiden, Netherlands,* [2]*Radiation Sciences, Umeå University, Umeå, Sweden,* [3]*Radiology, University Medical Center Utrecht, Utrecht, Netherlands*

Targeted audience: Researchers interested in ultrahigh field MRI, field probes (FPs), and susceptibility induced MRI-artifacts

Purpose: Strongly T_2^*-weighted gradient echo (GE) imaging is frequently used at 7 T because of its superior quality, enabling detection of e.g. cortical layering and cerebral micro bleeds [1]. The improved contrast is partially due to the increased effects of magnetic susceptibility differences at higher field strengths. However, the increased sensitivity can at the same time lead to issues, i.e. breathing can cause phase-shifts during the collection of data resulting in artifacts. To make this type of imaging more robust B_0 maps obtained from navigators [2] or FPs [3] can be used for correction of the images. In the method based on FPs, a model is required for the extrapolation of the measured FP-values to a B_0-map. Usually this model is based on the assumption that there are no sources of the magnetic field in the imaged region, i.e., one can model the B_0-field using spherical harmonics (SH). This approach fails in case of sources within the imaged region, restricts the method to low order SH-models, and the extrapolation of FP-measurements to inside the head can be a potential source of error. The purpose of this work was to investigate if a model learned from simultaneous FP measurements and fast B_0-measurements could be used for FP-based correction of T_2^*-images, and whether this approach provides improvements over the conventional method.

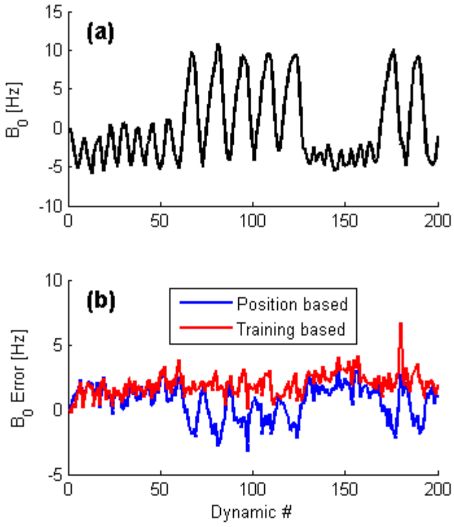

Fig 1. (a) Measured B_0 fluctuations. **(b)** Error in predicted B_0 fluctuations.

Methods: All imaging was performed on a 7 T Philips scanner using a 32-channel head coil and a FP system consisting of 15 ^{19}F transmit/receive probes (Skope Magnetic Resonance Technologies). A healthy volunteer was imaged and was instructed to do 30 s periods of normal and deep breathing during both fast EPI based B_0 imaging (the training data) and during the acquisition of the T_2^* weighted image. The EPI based B_0 imaging was repeated once to enable validation of predicted B_0. For the EPI sequence, transverse multi-slice single shot GE-EPI was used with a 64 × 64 × 10 matrix, 200 dynamics, a field of view (FOV) of 240 × 240 × 120 mm^3, TR/TE = 500/8.13 ms, flip angle (FA) = 20°, and a SENSE factor of 2.5. For the T_2^*-weighted imaging the acquisition matrix was 600 × 600 × 20, FOV 240 × 240 × 22 mm^3, TR/TE = 800/25.2 ms, FA = 35°, acquired without SENSE. FP-data were acquired during EPI and T_2^*-weighted scans with one measurement per slice and dynamic for the EPI sequence and one measurement per phase encoding line for the T_2^* sequence. A linear model was used to relate the FP values $\boldsymbol{\xi}(t)$ to $B_0(x,t)$:

$$B_0(x,t) = \mathbf{p}^T(x)\boldsymbol{\xi}(t) + \epsilon(x,t), \qquad (1)$$

where $\mathbf{p}(x)$ are a set of coefficients for the pixel, found from least squares fitting to the training data, and $\epsilon(x,t)$ is noise. The resulting B_0 maps were fitted to a third order SH model to reduce noise and to extrapolate maps to regions with low SNR. The method developed by Wilm et al. [4] was used for reconstruction. For comparison, B_0 maps were also estimated using the positions of the probes and a second order SH model [3] (conventional method).

Results: Fig. 1a shows the variation in B_0 during the validation scan. In Fig. 1b the differences between the FP based predictions and the curve in Fig. 1a are shown for the proposed method and the conventional method. In Fig. 2 uncorrected and corrected T_2^*-images are shown.

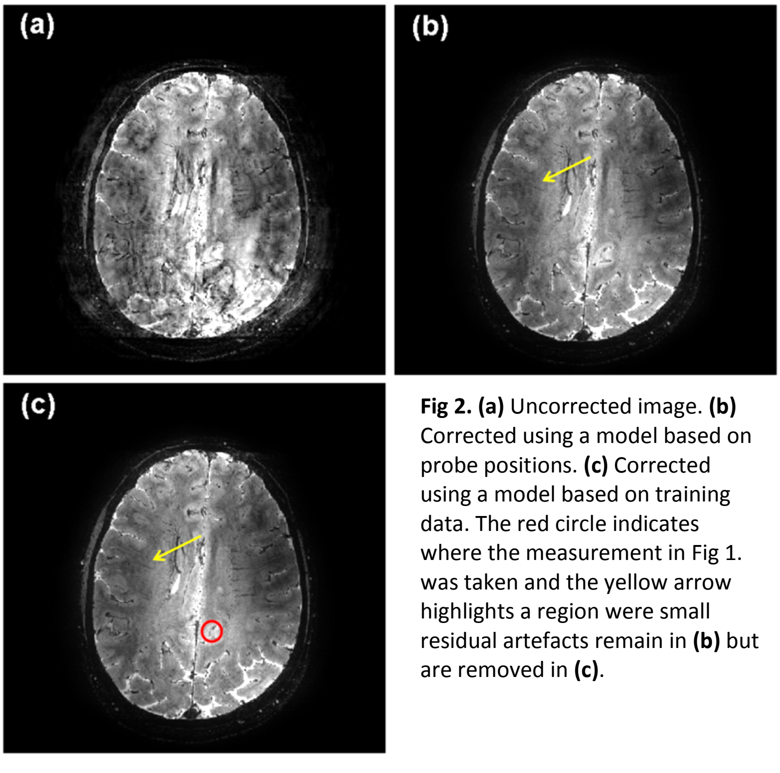

Fig 2. (a) Uncorrected image. **(b)** Corrected using a model based on probe positions. **(c)** Corrected using a model based on training data. The red circle indicates where the measurement in Fig 1. was taken and the yellow arrow highlights a region were small residual artefacts remain in **(b)** but are removed in **(c)**.

Conclusion: The proposed training based method was able to predict B_0 fluctuations in the validation dataset and correct for most artifacts in a T_2^*-image. The performance regarding the prediction of B_0 maps was better than for the conventional method, resulting in a small but detectable improvement in the corrected image. This study shows that B_0 maps based on training data and FPs could be a feasible approach for B_0 correction of T_2^* images and that it may provide some improvements over the conventional approach. Continued research will focus on evaluating the method in a larger group of subjects.

References: [1] Conijn M.M.A. et al. AJNR 2011 32(6):1043-9. [2] Versluis M.J. et al. MRM 2012 68(6):1836-45. [3] Vannesjo S.J. et al. MRM 2014 e-print (doi: 10.1002/mrm.25303). [4] Wilm B.J. et al. IEEE TMI 2012 31(6):1396-403.

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