# Comparison of extended Point Spread Function and Reverse Gradient Polarity distortion corrections in quantification of DW EPI at UHF

Oleg Posnansky[1], Myung-Ho In[1], and Oliver Speck[1]

[1]*Department of Biomedical Magnetic Resonance, Institute of Experimental Physics, Otto-von-Guericke University, Magdeburg, Germany*

**Purpose/Introduction.** Diffusion weighted (DW) imaging at ultra-high magnetic field (UHMF) typically relies on single shot spin echo echo-planar imaging (EPI) [1] due to its fast acquisition time. However, the low bandwidth in the phase-encoding (PE) direction leads to local spatial distortions. Moreover, these distortions interact with eddy-currents (EC) induced by the diffusion gradients, which results in additional varying distortions in DW-EPIs. Based on the assumption that EPI scans with opposite PE polarity yield two identical images, but having opposite geometric distortions along the PE axis, *reversed gradient polarity* (*RGP*) approaches had been proposed previously to perform EPI distortion correction [2]. Recently, an *extended point spread function* (*PSF*) method was suggested to correct distortions in the both EPIs more accurately [3]. In this work, we perform the comparison study to demonstrate their reliability and capacity for diffusion tensor (DTI) applications.

**Subjects and Methods.**

*Data acquisition.*

Two healthy volunteers were studied on a 7T whole-body MR scanner (Siemens AG, Healthcare Sector, Erlangen, Germany) equipped with gradients of up to 70mT/m per axis and a 32-channel phased-array RF head coil (Nova Medical, Wilmington, USA). Forward phase-encoded PSF data were acquired with an acceleration factor of 3 in the PSF dimension corresponding to 60 scans. Forward and reverse phase-encoded DW-EPIs were obtained with a Stejskal-Tanner DW-EPI sequence (TR/TE=5910/56 ms, echo-spacing=0.71 ms, pixel bandwidth 1532 Hz, voxel size 1.2 $mm^3$, matrix $180^2$, 80 transverse slices without gap to cover the entire brain, GRAPPA 3 with 48 ref. lines, partial Fourier 6/8), which resulted in pairs of DW-images with opposite distortions in the PE direction. EPI dataset included non-DW images with *b*-value=0 s/$mm^2$ and 30 DW images with *b*-value=1000 s/$mm^2$ and non-collinear DW gradients.

*Image processing.*

1. An *extended PSF method* with the *RGP* approach. The *extended* method for distortion correction in both EPIs with opposite PE polarity and a fast PSF-based calibration method for eddy correction were used as suggested in Ref. [3].

2. *RGP method.* From the forward and reverse EPIs with b-value=0, a distortion map was estimated by iterations to minimize the cost function that reflects the inconsistency of the distortion-corrected EPI pair and the optimization was carried out based on Least-squares restoration (*LSR*) and Jacobian modulation (*JacM*) methods [4,6]. After eddy current correction and registration, final distortion-free DW-EPIs were obtained by the weighted combination of the pairs of DW-EPIs with opposite PE polarity .

From three sets of final DW-EPIs (the *extended PSF* and *RGP methods* with *LSR* and *JacM*), fractional anisotropy (FA) maps [5] were calculated using DTI toolboxes of FSL [6] and the DTI fiber tracking [7] was followed.

**Results.** Orthogonal views of a 3D image as an anatomical reference (Fig. 1) and corresponding gray-scale and color-coded FA maps are shown for selected regions of interest (ROIs) (Fig. 2). Compared to the anatomical reference, a high conformity of diffusive peculiarities in tissue was obtained in FA maps by the *extended PSF method* (Fig.2a). Although FA maps obtained using the *RGP methods* with *JacM* (Fig. 2b) and *LSM* (Fig. 2c) are overall consistent with the anatomy, the local connectivities were not fully recovered in the areas with strong geometric distortions (see arrows in Fig. 2). Since strongly compressed distortions were not fully recovered by *RGP methods*, erroneous FA values appeared along the boundary line of the compressed EPI (see red arrows in Figs 2a and 2b). However, such disruptions were not observed in FA maps obtained by the *extended PSF method*. The effects are more clearly seen in the corresponding diffusion tensor fiber tracks in the frontal part of the brain (Fig. 3, see arrows). Compared to the result by the *extended PSF method* (Fig. 3a), the spatial coherence of fiber bundles was violated in the results by *RGP methods* (Figs.3b and 3c).

**Discussion/Conclusion.** This comparison study shows that the *extended PSF method* is very efficient for distortion correction in both DW EPIs with opposite PE polarities and thus to unveil properly positioned and fully recovered fine anatomical structures in the brain FA maps and fiber tracks. Due to its high accuracy, the *extended PSF method* provides overwhelming correspondence between anatomy and connectivity of the tissue. While the information for distortion correction is calculated quickly compared to the *RGP methods*, an additional time is required for the *PSF* reference scan in the *extended PSF method.*

**References: 1.** Mansfield P (1977) J. Phys. C 10: 5-58. **2.** Holland D, et. al. (2010) NeuroImage, 50: 175–183. **3.** In MH, *et. al.*, *submitted to ISMRM2014*. **4.** Andersson JLR, Skare S, Ashburner J (2003) NeuroImage, 20(2):870-888. **5.** Basser P *et al.* (1994) JMR, B103(3): 247-254. **6.** www.fmrib.ox.ac.uk/fsl. **7.** www.med.inria.fr.

**Acknowledgements:** Authors are thankful for funding support by DFG (DFG-grant No. SP632-4).

**Fig.1.** Distortion-free images as an anatomical reference were obtained from the measured PSF data. **a.** Full scale images with overlaid ROIs. **b.** Reference ROIs with arrows pointing on problematic areas in local FA calculations. **Fig.2.** Gray scale and color-coded FA maps created from distortion corrected DWIs using the *extended PSF* (**a**), *and RGP methods with JacM* (**b**), and *LSR* (**c**) algorithms. **Fig.3.** DTI fiber tracks built on the base of *extended PSF* (**a**), *and RGP methods* with *JacM* (**b**), and *LSR* (**c**) algorithms. The differences are pointed out by arrows.