

Diffusion weighted image domain Propeller EPI (DW iProp EPI)

S. Skare^{1,2}, S. J. Holdsworth¹, and R. Bammer¹

¹Radiology, Stanford University, Stanford, CA, United States, ²MR-Center, Clinical Neuroscience, Karolinska Institute, Stockholm, Sweden

Introduction

Geometric distortions in Echo Planar Imaging (EPI) are dependent on two sequence parameters: the phase encoding FOV and the echo spacing between two consecutive k_y lines, both of which affect the k -space traversal speed. Assuming that a maximum readout gradient bandwidth is used, the echo spacing can be reduced by decreasing the resolution in the k_x (not k_y !) direction. Both Short Axis Propeller (SAP)-EPI and Readout-Segmented (RS)-EPI exploit this feature. The most common way to reduce the phase encoding FOV is with parallel imaging, where an R times lower phase FOV is acquired and unfolded to the desired full FOV using SENSE or GRAPPA. This leads to a corresponding distortion reduction by a factor of R . The phase encoding FOV can also be reduced for certain applications like spine imaging, where the final desired FOV is rectangular. For this case, a tilted or orthogonal refocusing pulse or a 2D spectral spatial RF pulse can be used to only excite the area of interest and avoid aliasing from tissue outside the FOV [1-4].

In this work we present a new pulse sequence for diffusion imaging, called *image domain Propeller EPI* (iProp-EPI). Here, we acquire a blade in the image domain with a reduced FOV, with successive blades acquired in subsequent TR's. The final isotropic FOV image is reconstructed by gridding the blades together in the image domain. This is different to other propeller-driven diffusion pulse sequences, such as PROPELLER and SAP-EPI, whereby blades are defined in k -space. iProp-EPI has some useful advantages for brain diffusion applications: (1) Similar to Zonally magnified (ZOOM)-EPI [4], geometric distortions are reduced by an amount corresponding to the FOV ratio between the frequency and phase encoding directions; (2) Since the overlap of blades occurs in the image domain, N_{blades} averages are obtained in the center of the brain – the most SNR-starved region for 'many'-channel coils (and often of special interest in deep WM DTI studies); (3) Even if each blade covers only a strip of the final image FOV, there is enough overlap between adjacent blades to make motion correction straightforward; (4) Since the image phase of the blade does not need to be preserved when combining the blades in the image domain, the gridded image is immune to potential spatially-varying non-linear phase changes, such as seen in DWI.

Materials and Methods

An axial brain slice of a healthy volunteer was acquired on a GE 3T Discovery MR750 system equipped with a 50 mT/m, SR=200 T/m/s gradient system using an 8-channel head coil. The iProp-EPI sequence was used with a Stejskal-Tanner diffusion preparation with the following relevant imaging parameters: FOV = 26×4.33 cm (6:1 ratio, hence 6 times less distortion than ss-EPI), 5 mm excitation slice thickness, 32 mm for the orthogonally applied refocusing pulse with a flip angle of 180°, ETL= 42, $TE_{\text{fullFourier}}/TR = 94/4000$ ms. 16 blades of size 252×42 (freq.×phase) were rotated isotropically over 0-168.75°. The signal sensitivity profiles along both the phase and frequency encoding directions were mapped first on a homogeneous phantom. Signal variations in each direction were modeled by a cosine basis set and the result was a combined coil and RF pulse sensitivity map, unique for each blade.

Results

Fig. 1a) shows the intensity profile of the first blade on a homogenous phantom. Variations in signal are due to coil sensitivities and imperfect slice profiles of the refocusing pulse. A fitted version of this 2D profile is shown in the right panel. In Fig. 1b), the sum-of-squares of all profiles are shown, with actual data on the left and fitted data to the right. Since the phantom did not cover the entire FOV, the fitting processes were essential to provide enough information for reconstructing a proper weighting of the acquired brain blade data.

Discussion

(Yet) a new pulse sequence has been proposed for diffusion imaging, iProp-EPI, where blades are acquired in the image domain instead of in k -space. Similarly to the ZOOM-EPI technique, aliasing in the phase encoding direction was avoided by playing out the refocusing slice non-parallel to the excitation slice. Here we have shown data using an orthogonal 180° pulse, but a smaller angle between the excitation pulse and refocusing pulse can also be used – or even the reduced FOV 2D excitation pulse. This choice depends on what is most scan time efficient for the slice coverage prescribed. This sequence may be well suited for ~32+ channel coils: since the small coils provide excellent SNR in the cortex, the averaging property of iProp-EPI in the center of the FOV enhances the SNR where the coil SNR is the lowest. To note is the trade-off of the blade width. That is, wider blades imply shorter scan times to cover the entire FOV, and provide a wider 'high-SNR' area in the center of the brain. However, this comes at the expense of increased geometric distortions. On the other hand, increased geometric distortion may be tolerated by modifying our previous distortion correction algorithm for SAP-EPI and applying it to iProp-EPI data.

References

[1] Mansfield P. Phys. E: Sci. Instrum. 1988 21:275. [2] Kiefer C. ESMRMB 1999;302. [3] Saritas E. MRM 2008;60:468. [4] Symms M. ISMRM 2000;160.

Acknowledgements

This work was supported in part by the NIH (5R01EB002711, 1R21EB006860, 1R01EB008706, 1R01EB006526, the Swedish Research Council (K2007-53P-20322-01-4), the Center of Advanced MR Technology at Stanford (P41RR09784), the Oak Foundation and the Lucas foundation.

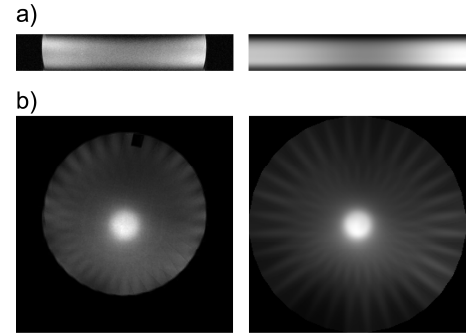


Figure 1. a) One blade acquired on a homogenous phantom showing intensity differences due to both RF pulse profiles and coil sensitivities. Left: original data. Right: fitted (and extrapolated) data. b) Same as in a), but with the sum-of-squares taken over all blades, outlining the averaging effect in the center of the FOV. Note that outside the most central region, the number of averages is gradually reduced towards the edge of the FOV due to less and less overlap between the blades.

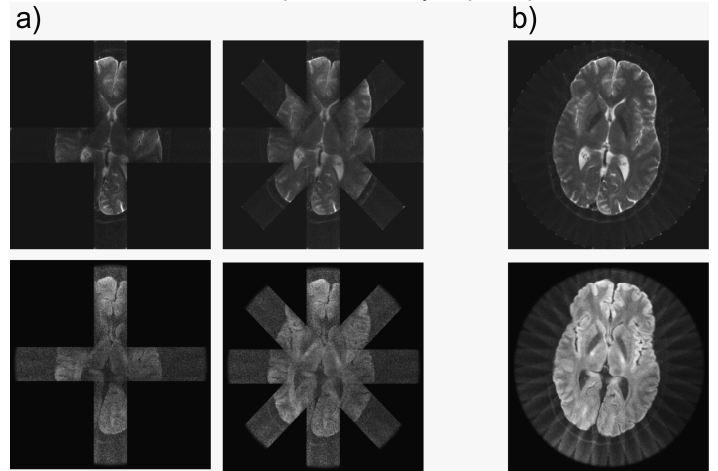


Figure 2. a) Two and four out of a total of 16 image domain blades merged together to illustrate the concept. The top row shows the $b=0$ s/mm² data and the bottom row one diffusion direction using $b=1000$ s/mm². b) The final $b=0$ image (top) and the isotropically averaged $b=1000$ s/mm².