High resolution Q-space Trajectory imaging using interleaved EPI with JETS-NAVI image reconstruction at 7 Tesla: Preliminary results

Annika Hofmann[1], Zhengguo Tan[2], Martin Freudensprung[3], Patrick Liebig[3], Frederik Bernd Laun[5], Florian Knoll[1]
[1] Computational Imaging Lab, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany
[2] Michigan Institute for Imaging Technology and Translation (MIITT), Radiology, University of Michigan, Ann Arbor, MI, United States
[3] Uniklinikum Erlangen, Institute of Neuroradiology, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany
[4] Siemens Healthcare GmbH, Magnetic Resonance, Erlangen, Germany
[5] Uniklinikum Erlangen, Institute of Radiology, Friedrich-Alexander-University Erlangen-Nürnberg, Erlangen, Germany

Target Audience: Basic and medical scientists interested in advanced high resolution diffusion MRI.

Purpose: Diffusion MRI is essential for examining brain microstructures with intricate fiber arrangements, though averaging over large voxels can introduce partial volume effects[1]. One method to deal with those is QTI, which enables the estimation of microscopic diffusion anisotropy indices[2]. The purpose of this work is to push the spatial resolution limits of q-space trajectory imaging (QTI). With typical single-shot echo planar imaging, often used for QTI[3], it is challenging to achieve high image resolution due to T_2 blurring. Moreover, increasing the resolution reduces the signal-to-noise ratio (SNR). Ultra-high field MRI, may help to enhance the SNR, but the generally shorter T_2 time at 7 T increases the T_2 blurring and the increased field inhomogeneities worsen the image distortion typical for EPI. To minimize these artifacts, interleaved EPI can be used. Additionally, Navigator scans help to register the phase between individual shots[4].

Methods: Data acquisition was done with NAViEPI[5], that is characterized by the interleaved EPI and q-k-space shift, with integrating generalized gradient waveforms required for QTI, as illustrated in Figure 1. In our study, we used two types of b-tensor shapes for diffusion encoding: linear and planar. Navigator scans were used to correct shot-to-shot phase variations. Consistent echo spacing of imaging and navigator echoes was used to minimize distortion mismatch.
Image reconstruction was done using the JETS algorithm[5] with overlapping locally low-rank regularization. This was achieved by organizing spatial-angular matrices from the acquired diffusion-weighted images and applying singular value thresholding to enforce low-rank condition.

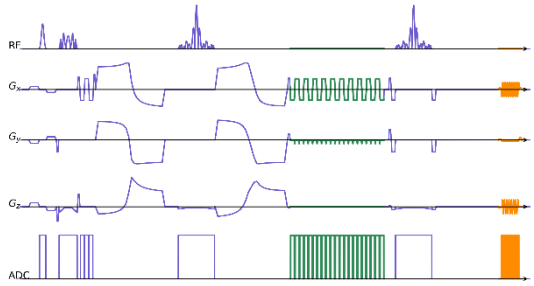

Figure 1: Sequence Diagram of one Echo Time including generalized diffusion gradient waveforms and navigator scan. The image readout is represented in green, while the navigator readout is shown in orange.

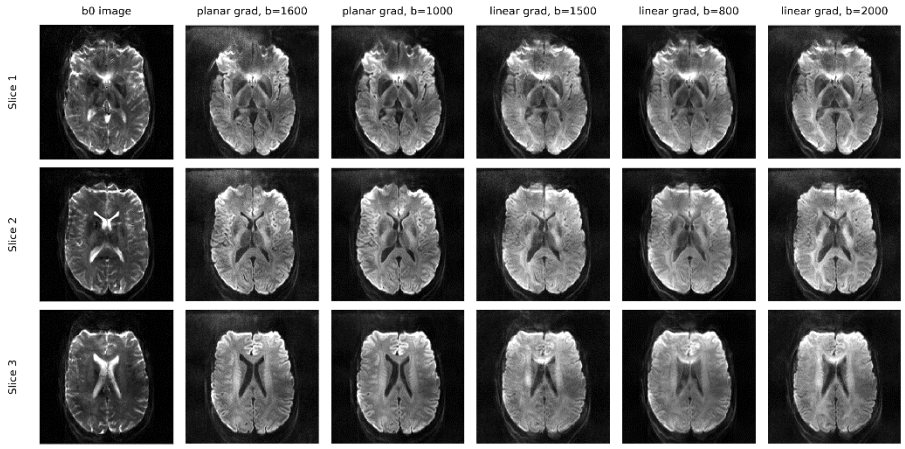

Figure 2: Images averaged over the diffusion encoding directions, acquired at different b-values. The rows represent different slices, while the columns show the b0 image and images at b = 1600, 1000, 1500, 800, and 2000 s/mm².

We performed an in-vivo experiment with a healthy volunteer on a MAGNETOM Terra 7T MRI scanner (Siemens Healthineers, Erlangen, Germany). The experiment was performed according to our local IRB protocol and written informed consent was obtained prior to the start of the scan. Imaging parameters were as follows: voxel size 1.2 x 1.2 x 3 mm³, parallel imaging acceleration factor = 2, 2-shot acquisition, TE = 80 ms, TR = 2000 ms, b = 0, 800, 1000, 1500, 1600 and 2000 s/mm² with 20 diffusion encoding directions.

Results: In Figure 2, we present images, averaged over the diffusion encoding directions for three different b-values and linear and planar-shaped b-tensor diffusion encoding waveforms, along with the b0 image.

Discussion and Conclusion: This work shows the first results of a QTI-capable interleaved EPI sequence at 7 T, including navigator scans, and an advanced reconstruction method. This approach opens the door to creating high-resolution QTI maps with minimal distortion artifacts while preserving a reasonable SNR. With further optimization of the sequence, we anticipate achieving sub-1 mm in-plane resolution. Additionally, protocol settings can be refined for QTI mapping. While our results demonstrate the feasibility of acquiring diffusion weighted data with linear and planar-shaped b-tensor producing gradient shapes with an interleaved echo planar readout, more work is needed to compute the QTI maps.

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