Asymmetric Two-Dimensional Spatially Selective Excitation in Echo-Planar Imaging

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Target Audience: RF engineers and MR physicists. **Purpose:** In echo-planar imaging (EPI), the effective echo time (TE) is a major limiting factor for the resulting image quality due to off-resonance effects and rapid T2* decay. One approach to tackle this problem is the application of 2-D spatially selective radio-frequency pulses (2DRF), which enable reduced-field-of-view (rFOV) imaging and thus a shortening of the echo-train length und TE (1,2). However, the 2DRF excitation requires long pulse durations and limits further TE savings. To alleviate this disadvantage, parallel transmission (pTX) was shown to shorten pulse durations without aliasing (3), but the technology is not widely accessible, yet.

In this work we propose a simple strategy to further shorten 2DRF pulse durations, which does is independent of pTX acceleration. The approach is shown to offer substantial TE savings without affecting the excitation quality. For this purpose, phantom and human in-vivo experiments were conducted to show the benefits.

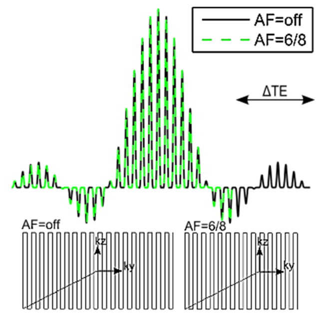


***Figure 1:** Exemplary EP 2DRF pulse with AF=6/8 and corresponding EP k-space trajectories.*

Methods: The proposed method generally applies to multi-dimensional spatially selective RF pulses, which are based on a symmetric TX trajectory, e.g. the echo-planar trajectory (EP), which is commonly used for 2DRF pulses in rFOV imaging (1,2). In this case, the symmetry of k-space can be exploited similar to the partial-Fourier method in imaging: Particularly for the TX EP trajectory, lines of the second trajectory half can be spared out to a certain degree without any severe penalties in excitation quality. The reduction of the pulse duration can be directly transferred into TE savings (**Fig. 1**). This can be applied in addition and independently of potential pTX accelerations. A phantom study was pursued to analyze the degree of asymmetry that can be applied to EP-trajectory-based 2DRF pulses without degradation in excitation quality. Asymmetry factors AF=5/8 to 7/8 were systematically applied to the EP 2DRF trajectory, i.e. only 5/8 to 7/8 of the TX k-space trajectory was encoded. 2DRF pulses were designed according to (1) using a Hamming window to suppress any truncation artifacts. Images were acquired on a 3T MAGNETOM Skyra scanner with two transmit channels (Siemens, Erlangen, Germany) using a prototype gradient echo EPI sequence with FOV 180x180 mm^2, matrix 128x128 and TR/TE 100/35 ms. The same experiments were pursued with pTX acceleration factor R=1.4 following the approach of (4). The potential benefits of the asymmetric 2DRF excitation towards TE savings and resulting SNR gains were further investigated in human in-vivo diffusion experiments of the posterior brain. Reduced-FOV diffusion images were obtained in an in-house-modified bipolar acquisition scheme with b 50, 500, 800 s/mm^2, slices 15, slice thickness 3 mm, FOV 240x90 mm^2, matrix 128x48 and TR 3400 ms. EP 2DRF pulses were designed without and with a trajectory asymmetry of AF=6/8 with and without pTX acceleration, respectively. TE was always set to the lowest possible value.

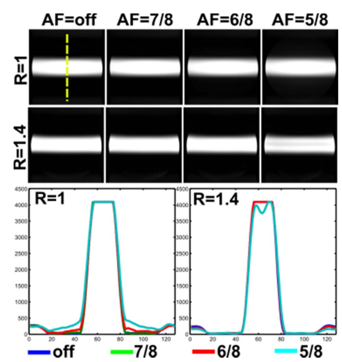


***Figure 2:** EP 2DRF excitations with different asymmetry factors. Top row: no acceleration. Middle row: 1.4 fold acceleration. Bottom row: 1D profiles of the different experiments (dashed line).*

Results/Discussion: Phantom images acquired with EP 2DRF pulses of different asymmetry factors are shown in **Fig. 2**. The excitation quality is maintained up to an asymmetry factor of 6/8 and independent of pTX acceleration. With large asymmetry (5/8), deviations from the targeted excitation profile can be observed in both the outer- (R=1) and inner-volume (R=1.4). Clearly, the savings in EP 2DRF pulse durations can be directly transferred to shorter TE and increased SNR in the human diffusion experiments (**Fig. 3a**). The level of TE savings depends on the chosen 2DRF design parameters (e.g. slice thickness) and sequence details as diffusion parameters and image resolution. In the chosen setup, TE savings up to 17 ms could be directly achieved from the introduced asymmetry. The TE savings using (AF 6/8, R 1.0) resulted in an average SNR increase of 25% compared to the experiments using the common EP 2DRF pulse (**Fig. 3b**). Same TE savings and slightly higher gains in SNR could be achieved with 2.1 fold acceleration. Moreover, when combining the asymmetric design with pTX acceleration, another SNR increase of 8% from 30% to 38% was obtained. Note that in case of TX acceleration only half of the omitted encoding lines contribute to TE shortening, as the EP trajectory is equally sub-sampled. In contrast, the savings due to the asymmetric design account completely for TE reduction.

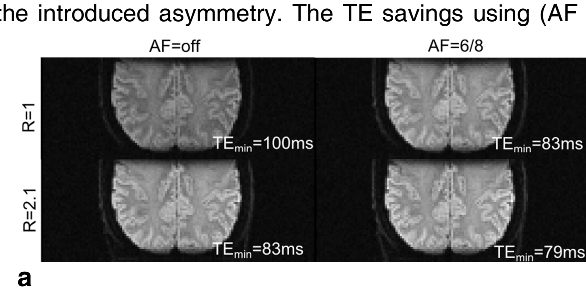
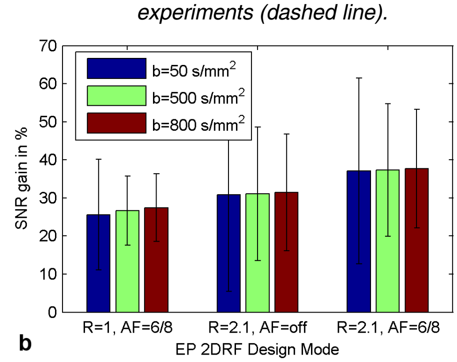


***Figure 3: a** b800 weighted rFOV diffusion images acquired with different EP 2DRF pulses. **b** Mean gain in SNR over all slices in dependence of b-values, pTX acceleration R and RF asymmetry AF. Values are stated relative to the experiments acquired with R=1 and no asymmetry (AF=off).*



Conclusion: With the introduction of asymmetry to EP-trajectory-based 2DRF pulses, the pulse duration can be remarkably reduced without affecting the excitation quality independently from pTX acceleration. The resulting savings in TE and gain in SNR can be significant in EPI-based sequences. The introduced approach can be easily transferred to other symmetric multidimensional spatially selective 2D and 3D RF pulses.

References: [1] Rieseberg et al. (2002). MRM 47:1186-1193. [2] Ellingson et al. (2011). Proc of 19th ISMRM:404. [3] Setsompop et al. (2008). MRM 60:1422-1432. [4] Schneider et al. (2013). MRM doi: 10.1002/mrm.24780.