Comparison between Single-Shot Diffusion Weighted Methodologies at 3 and 7 Tesla on Brain Volunteers

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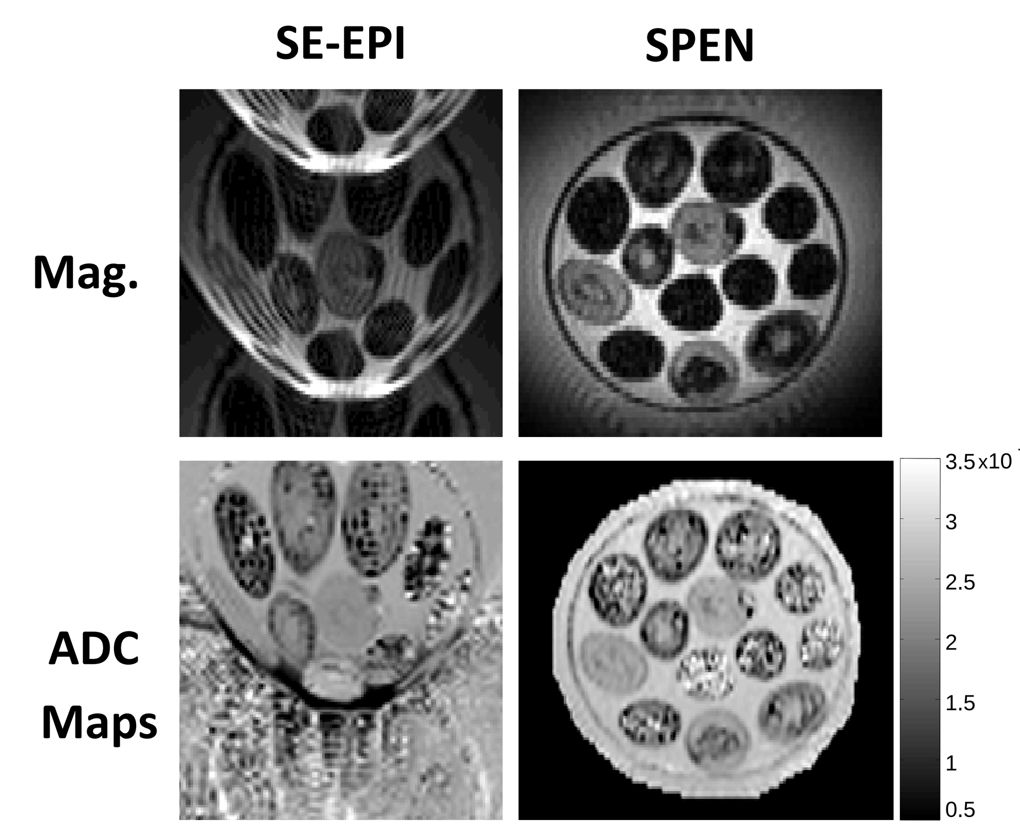
1. Introduction

Brain MRI at high magnetic fields could provide advantages over lower field counterparts, including increased contrast and better signal-to-noise ratios (SNR) enabling higher imaging resolution [1]. At the same time, considerable challenges emerge upon scanning at high fields, including RF and static B_0 field inhomogeneities that can result in poor anatomical images. These drawbacks may be particularly challenging when using single-shot experiments like spin-echo echo-planar-imaging (SE-EPI), endowed with a low-bandwidth dimension prone to artifacts. SPatio-temporal ENcoding (SPEN) is an alternative single-shot technique based on the use of frequency-swept RF pulses that showed to provide significantly higher immunity to B_0 inhomogeneities and chemical shift offsets than SE-EPI counterparts [2]. This study explores whether these improvements are maintained in a diffusion weighted experiments under a 7T whole body scanners.

2. Phantom Tests

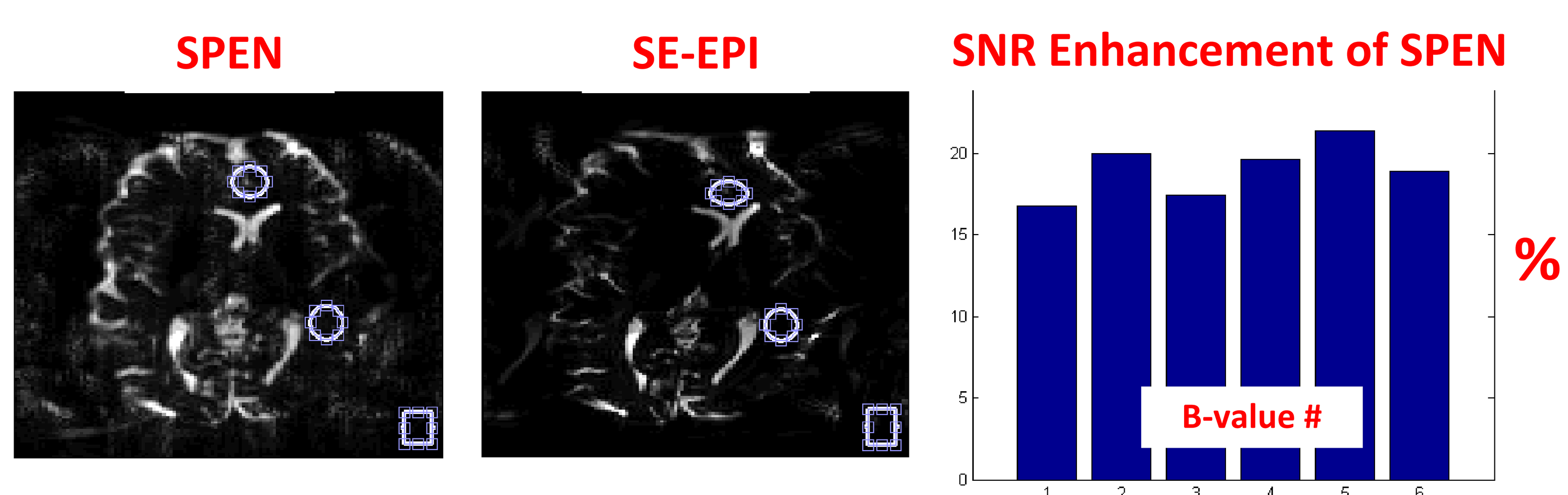
To evaluate the imaging performance of both SE-EPI and SPEN in high field (7T), we placed an asparagus bundle inside the human 7T scanner. As shown on the right, the magnitude images and ADC maps taken by SPEN showed better immunity to B_0-inhomogeneities effects restoring better the phantom shape and size when compared to SE-EPI.



Scanning parameters: Voxel size: 1.0×1.0×2.0 mm, FOV: 80 x 80 mm. Bandwidth 1078Hz/Px. Phase enc. dir. A >> P and nominal b-Values of 0,100,200,400,700 sec/mm²

3. SNR Comparison

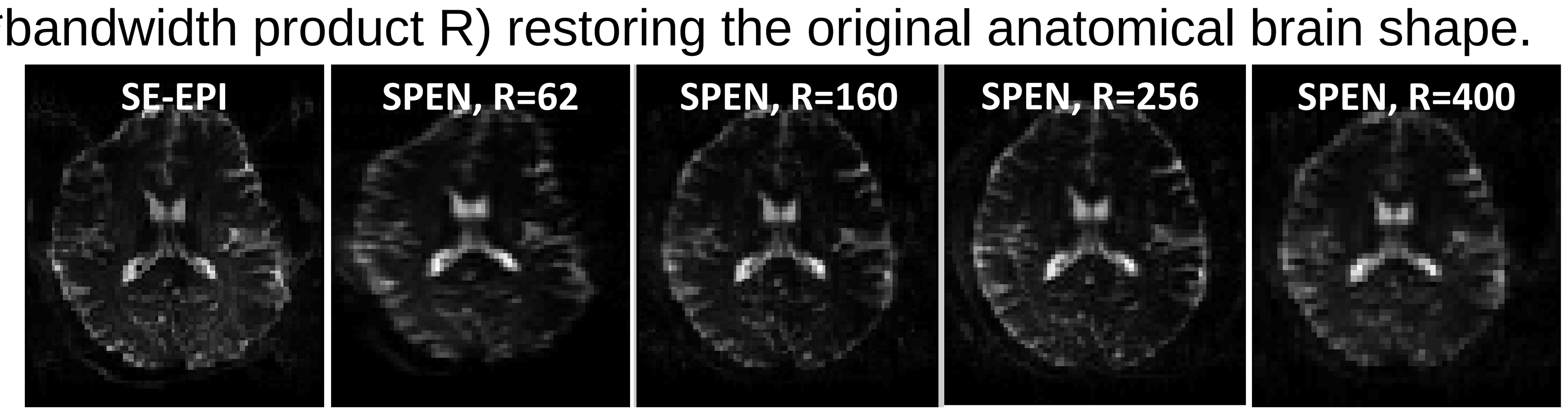
One motivation for scanning in higher field imaging systems is to increase the signal to noise ratio (SNR). Testing the SNR (on a human 7T machine) given by SPEN and SE-EPI methods over a healthy volunteer (using identical scanning parameters) – showed a signal enhancement of SPEN of up to 15-20% over SE-EPI along the different b-values.



Scanning parameters: Voxel size: 1.6×1.6×3.0 mm, FOV: 220 x 198 mm and Bandwidth 1394 Hz/Px

4. Immunity to B_0 inhomogeneities

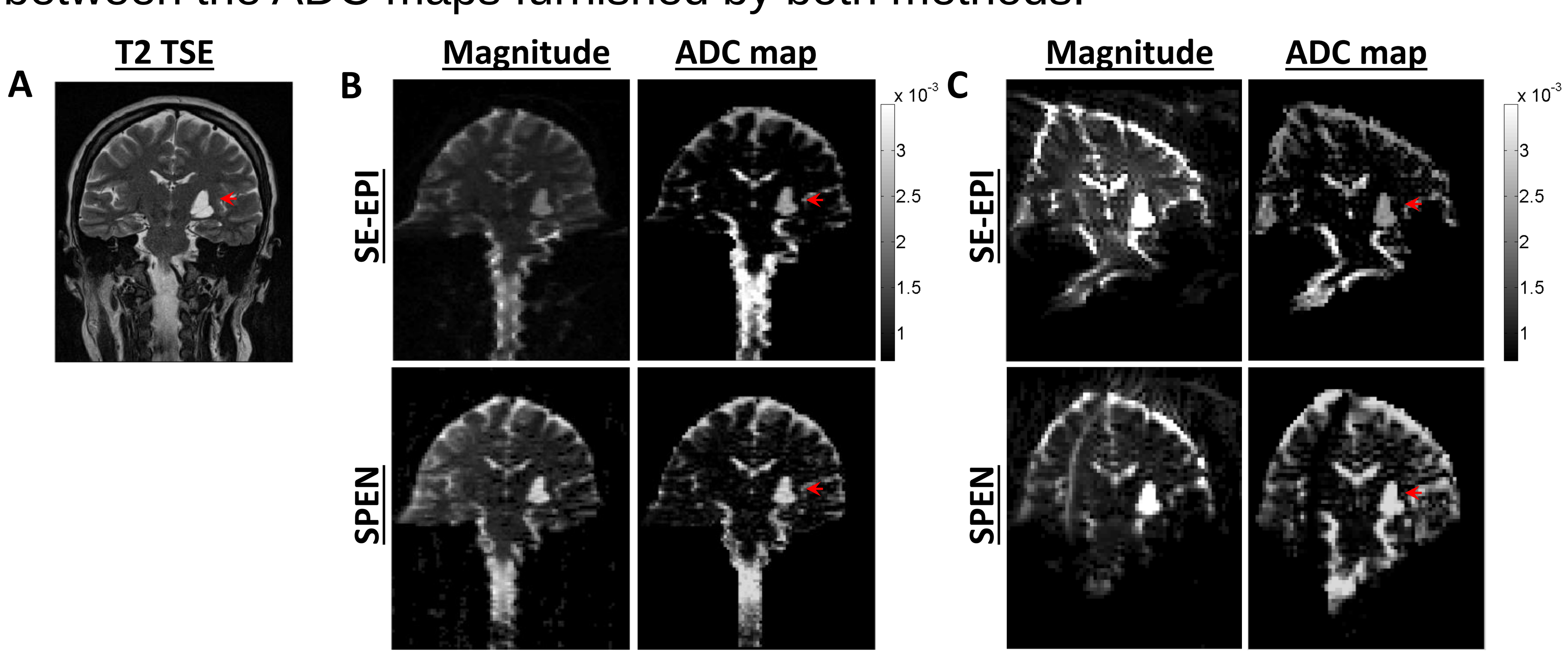
An interesting feature of SPEN is its ability to provide a T2*-refocusing throughout the acquisition time, by matching the excitation with the acquisition times ($T_{exc} = T_a$). Full T2*-refocusing is then achieved for all positions through the sample. Additionally, the use of excitation (G_e) and acquisition (G_a) gradients that are stronger than those normally dictated by FT principles in EPI, reduce distortions incurred by field inhomogeneities. Below we show a series of SPEN images with increased G_e (noted by the time*bandwidth product R) restoring the original anatomical brain shape.



Scanning parameters: Voxel size: 2.5×2.5×3.0 mm, FOV: 200 x 175 and Bandwidth: 2500 Hz/Px

5. Coronal Slices at 3 and 7 Tesla

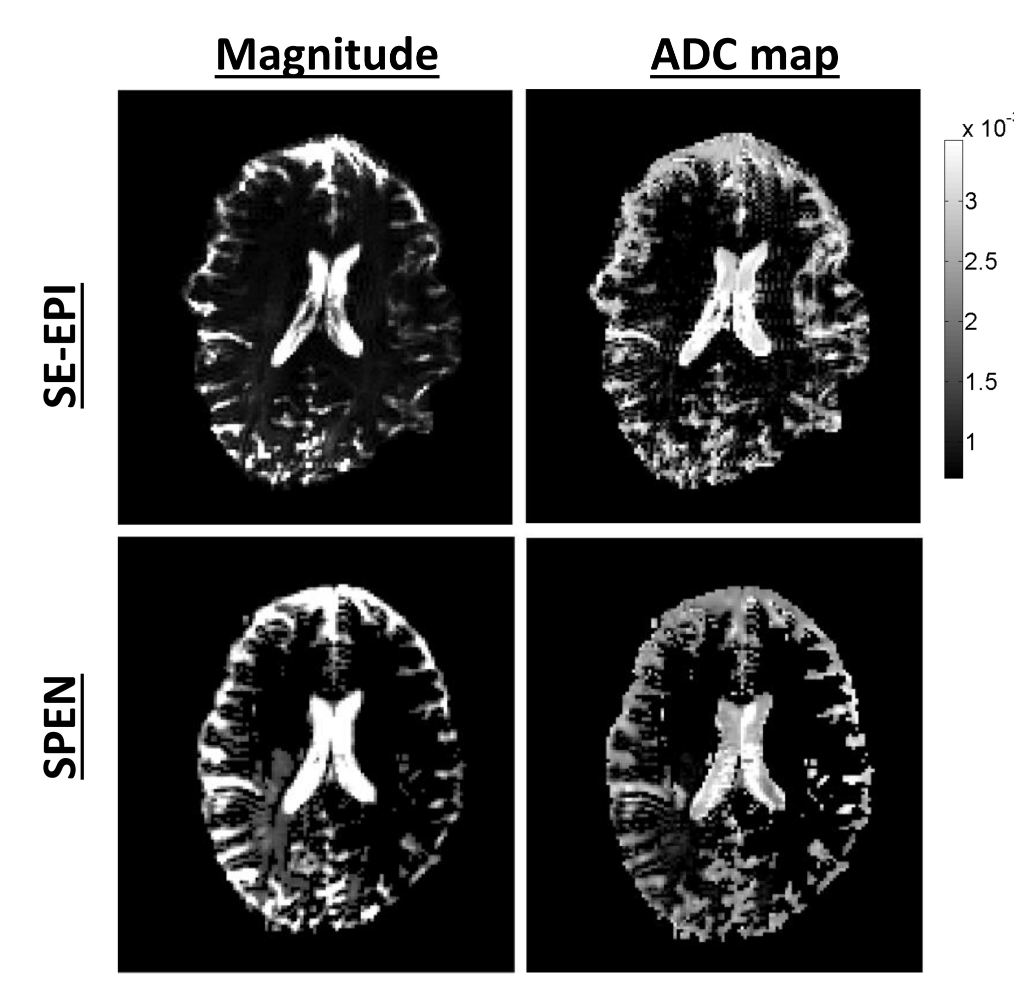
A representative set of coronal slices collected on a healthy volunteer exhibiting a benign brain cyst (red arrow) taken by SE-EPI and SPEN at both 3 and 7 Tesla, revealed (1) clear susceptibility-driven distortions that arise upon going to higher fields; (2) SPEN's capability to deliver less distorted images –not only at 7 T, but also for certain interphase regions also at the lower field; (3) an overall good agreement between the ADC maps furnished by both methods.



Scanning parameters: Voxel size: 0.7×0.7×3.0 mm (T2 TSE) and 2.3×2.3×3.0 mm (SE-EPI and SPEN. Phase enc. dir. R>>L. b-Values of 0,100,200,400,700 sec/mm² with δ=20 ms and Δ=30-35 ms.

6. Axial slices at 7 Tesla

Once again, the overall brain shape is substantially less distorted in SPEN than in SE-EPI. Also the susceptibility distortions arising from air/fat/tissue interfaces in the brain periphery are less marked in the SPEN images. Overall, however, the ADC maps arising from both methods are once again in good agreement.



Scanning parameters: Voxel size: 1.6×1.6×3.0 mm (SE-EPI and SPEN. Phase enc. dir. R>>L. Diffusion parameters are identical as in section 5.

7. Conclusions

Our results show SPEN's capability to obtain reliable brain anatomical images and ADC maps in high magnetic field while showing significant advantages in terms of robust reduction of artifacts.

[1] Bandettini PA et al., Magn Reson Med. 2012 Feb;67(2):317-2.
[2] Ben-Eliezer N, Shrot Y and Frydman L, 2010, Magn Reson Imag, 28, 77-86.