Ultrafast *in vivo* imaging by SPatiotemporal ENcoding (SPEN): Acquisition and reconstruction package for Bruker MRI systems

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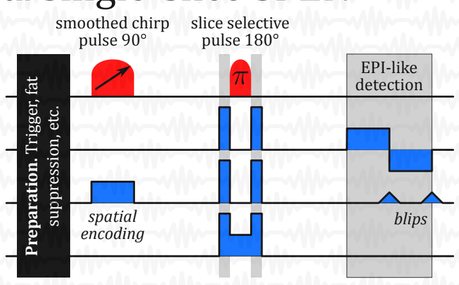
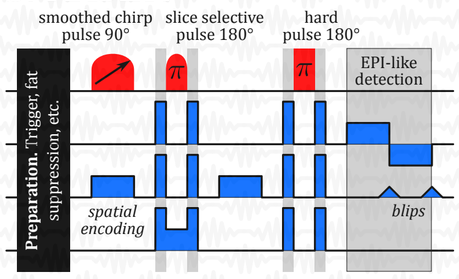
Scan me to download the installation package!

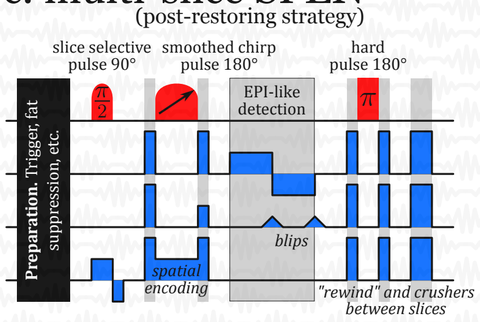
a. single-slice SPEN



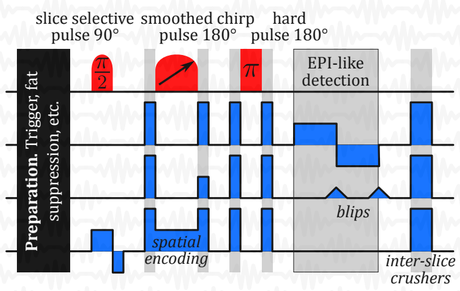
b. RASER



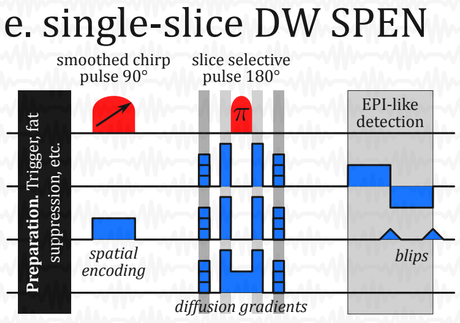
c. multi-slice SPEN
(post-restoring strategy)



d. multi-slice SPEN
(pre-restoring strategy)



e. single-slice DW SPEN



f. multi-slice DW SPEN

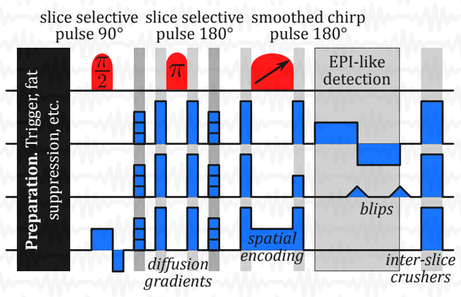


Fig. 1: Different SPEN sequence implementations available via the Bruker Paravision method.

Introduction

Reducing acquisition times is one of the most active topics in contemporary magnetic resonance research. Recently, ultrafast acquisition schemes have been proposed to collect any kind of 2D NMR data **within a single scan** [1]. Since 2010, this concept is applied for MRI giving birth to several **ultrafast single-shot SPatio-temporally ENcoded (SPEN) imaging sequences** [2]. Besides **constituting an alternative to EPI**, SPEN experiments are especially **robust regarding high-field artifacts such as B0 inhomogeneities and susceptibility effects** [3]. **Zooming abilities** are also built-in into this kind of experiments. In this paper, we present a SPEN method developed for Bruker MRI systems. **The method includes single-shot single-slice, multi-slice SPEN [4], RASER [5] and Diffusion-Weighted (DW) sequencing options; all with an online reconstruction and fully integrated in Bruker Paravision.**

Method

Pulse sequence. The acquisition portion of all SPEN pulse sequences relies on a spin-echo blipped Echo Planar Imaging (EPI) scheme. The excitation involves the use of a **frequency-chirped RF pulse during a magnetic field gradient in order to perform the spatiotemporal encoding**; this obviates the need for performing a FFT along the SPEN (low-bandwidth) axis. The single-slice excitation scheme starts with a 90° chirp pulse; slice selection is performed with a 180° sinc pulse (Figs. 1a,1b). Alternatively multi-slice versions (Figs. 1c, 1d) include a double spin-echo excitation scheme where the SPEN encoding is performed by a 180° chirp pulse. In the package hereby presented, **full refocusing** (i.e., <T2*>=0 for all acquisition times) is set as default. **The method calculates automatically the optimal spatial encoding parameters** depending on the targeted FOV, allowing "zooming" and increasing the spatial resolution. DW SPEN sequences (Figs. 1e, 1f) were recently implemented in the method (reconstruction is not yet available for DW imaging in the downloadable package).

Integration to Bruker Paravision. All sequences are **fully integrated in Bruker Paravision** as a "method". As for other regular imaging sequences, the slice thickness, position and the FOV can be adjusted using the Geometry Editor. The **SPEN super-resolution image reconstruction** [2] is also fully integrated in Bruker Paravision.

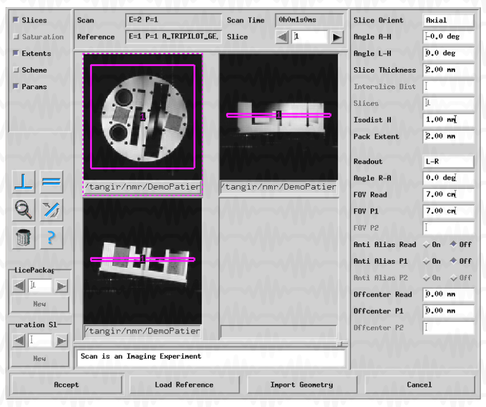


Fig. 2: Screen capture of the Geometry Editor interface when adjusting the slice parameters.

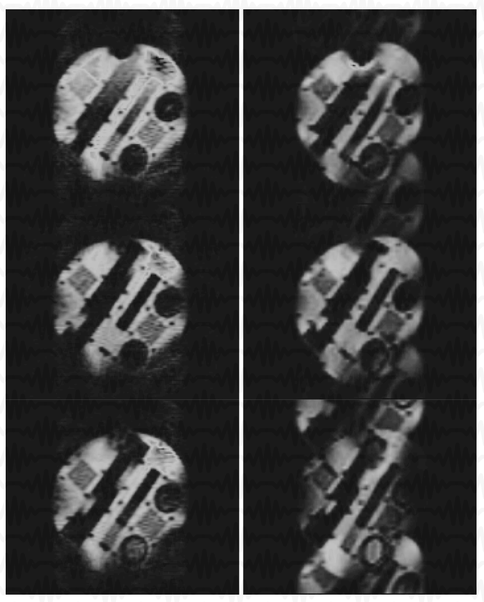


Fig. 3: Multi-slice SPEN (left) and EPI (right) images acquired on an imaging phantom at 4.7T: 20ms/10kHz chirp pulse for SPEN, 2mm slice thickness, 80x80mm FOV, 100x100 points.

Validation

The SPEN method was **installed and successfully tested** on 3 different Bruker MRI systems equipped respectively with a 4.7, a 9.4 and a 21.1T magnet. Comparative experiments between single-slice EPI and SPEN were carried out at 4.7T (Fig. 3) while *ex-vivo* experiments were performed on a rat brain at 21.1T (Fig. 4).

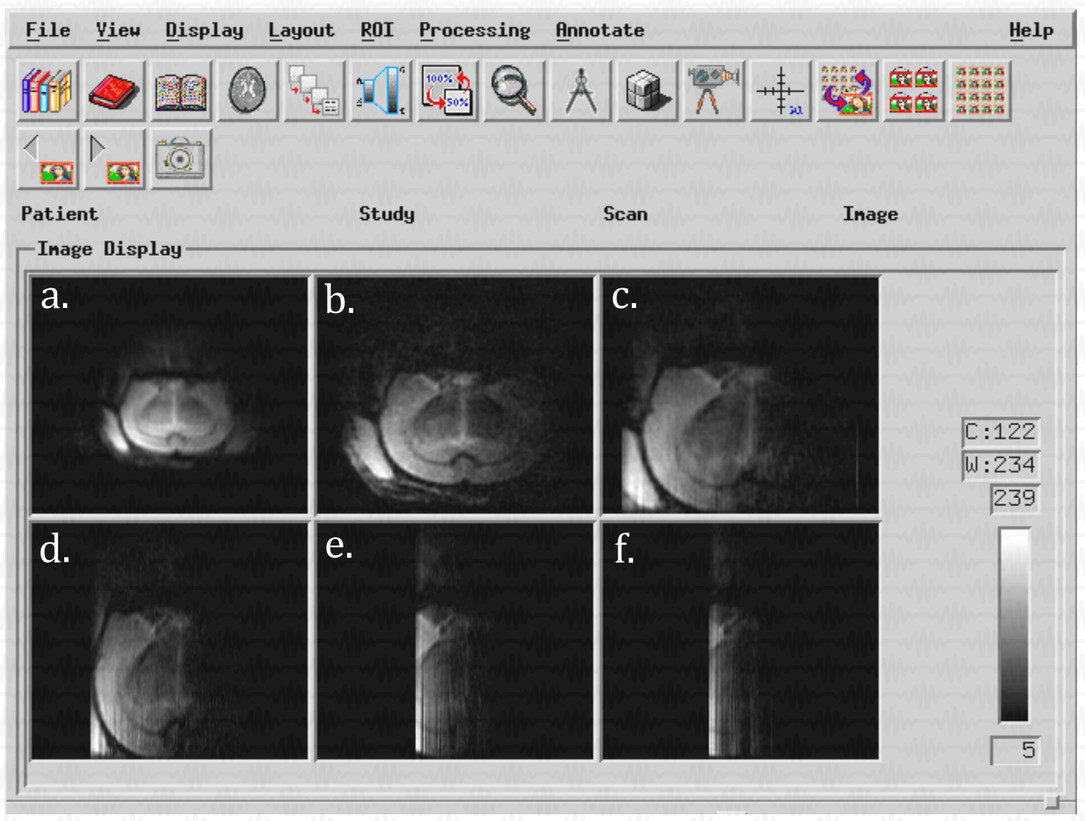


Fig. 3: Screen capture of the Image Display window after performing 6 SPEN acquisitions on an ex-vivo rat brain at 21.1T: 40ms/10kHz chirp pulse, 2 mm slice thickness, 30x30mm FOV, 100x100 points, 70ms scan time (a), 20x20mm FOV (b), 15x15mm FOV (c), 40ms/8.3kHz chirp pulse, 15x10mm FOV (d), 40ms/4.1kHz chirp pulse, 15x5mm FOV (e),

Conclusion

The SPEN images shown in Fig. 2 were acquired in a **single scan (less than 100ms)**. The "zooming" feature allows higher spatial resolution as shown in the following images. Unfortunately, a strongly reduced FOV implies a loss in signal in the SPEN direction (Left-Right here) probably due to the SPEN bandwidth reduction. Compared to EPI (Fig. 3), the images obtained with SPEN show **lower ghost artifacts and geometrical distortions**. The proposed ultrafast SPEN imaging sequence is thus **an excellent alternative to EPI when targeting heterogeneous regions**.

This implementation –including online reconstruction– is available for all Bruker MRI systems (Paravision 4.0, 5.0 and 5.1). If you want to give it a try, **please scan the QR-code with a smartphone (up-right corner of the poster) to download the installation package or contact me by email.**

References

1. Y Shrot, L Frydman J Magn Reson 2005;172:179-190
2. N Ben-Eliezer, M Irani and L Frydman Magn Reson Med 2010;63:1594-1600
3. N Ben-Eliezer et al. Magn Reson Imag 2010;28:77-86
4. R Schmidt and L Frydman Magn Reson Med 2014;71:711–722
5. R Chamberlain, JY Park, C Corum et al. Magn Reson Med 2007;58:794-799

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