Ultrafast in vivo imaging by SPatiotemporal ENcoding (SPEN) for Bruker MRI systems

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Target audience: MRI sequence programmers, researchers interested in fast imaging techniques.

Purpose: To develop and implement ultrafast imaging sequences based on spatiotemporal encoding as a fully integrated "method" in Bruker Paravision.

Introduction

Reducing acquisition time is one of the most challenging topics in the MRI research field. Recently, original ultrafast acquisition schemes have been proposed to collect the 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 important scan time reduction, SPEN experiments are especially robust regarding high-field artifacts such as B_0 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] and RASER [5] sequencing options; all with an online reconstruction and fully integrated in Bruker Paravision.

Method

The acquisition portion of the SPEN pulse sequences relies on a spin-echo blipped Echo Planar Imaging (EPI) scheme. The single-slice excitation scheme starts with a 90° chirp pulse applied during a magnetic field gradient in order to perform the SPEN encoding along the phase encoding direction; the slice selection is performed with a 180° *sinc* pulse (Fig. 1a). The multi-slice version (Fig. 1b) includes a double spin-echo excitation scheme where the spatiotemporal encoding is performed by a 180° chirp pulse. Full refocusing (i.e., $<T_2^*>=0$ for all acquisition times) is set as default. The sequence is fully integrated in Bruker Paravision as a "method". The method calculates the optimal parameters depending on the FOV, incorporating "zooming". The SPEN super-resolution image reconstruction algorithm [2] is also fully integrated in this Bruker Paravision software (4.0 & 5.1).

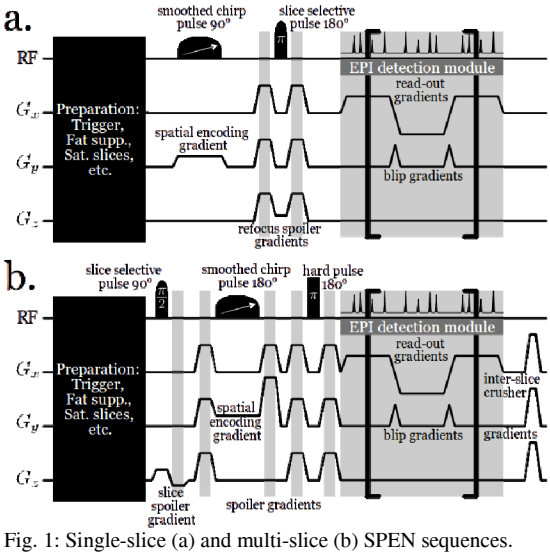

Fig. 1: Single-slice (a) and multi-slice (b) SPEN sequences.

Results

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 multi-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. 2).

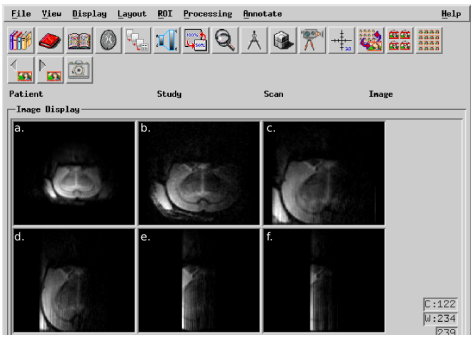

Fig. 2: Screen capture of the Image Display window after performing 6 SPEN acquisitions on an ex-vivo rat brain at 21.1T: 40ms/10kHz chirp pulse, 2 mm slice thickness, 30x30mm FOV, 100x100 points, 70ms scan time (a), 20x20mm FOV (b), 15x15mm FOV (c), 40ms/8.3kHz chirp pulse, 15x10mm FOV (d), 40ms/4.1kHz chirp pulse, 15x5mm FOV (e), 40ms/3.5kHz chirp pulse, 15x4mm FOV (f).

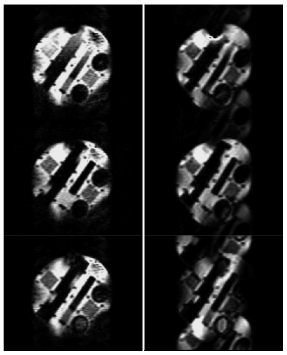

Fig. 3: Multi-slice SPEN (left) and EPI (right) images acquired on an imaging phantom at 4.7T: 20ms/10kHz chirp pulse for SPEN, 2mm slice thickness, 80x80mm FOV, 100x100 points.

Discussion & 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, 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 experiments (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. This implementation –including online reconstruction– is available for all Bruker MRI systems.

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References

1. Shrot Y, Frydman L. *Spatially encoded NMR and the acquisition of 2D magnetic resonance images within a single scan.* J Magn Reson. 2005;172:179–190

2. Ben-Eliezer N, Irani M and Frydman L. *Super-resolved spatially encoded single-scan 2D MRI.* Magn Reson Med. 2010;63:1594-1600

3. Ben-Eliezer N et al. *High-definition, single-scan 2D MRI in inhomogeneous fields using spatial encoding methods.* Magn Reson Imag. 2010;28:77-86

4 Schmidt R and Frydman, L. *New spatio-temporal approaches for fully refocused, multi-slice ultrafast 2D MRI*. Magn Reson Med. 2013

5 Chamberlain R,Park JY, Corum C, et al. *RASER: A New Ultrafast Magnetic Resonance Imaging Method.* Magn Reson Med. 2007;58: 794-799