Fast Spin-Echo Imaging of Inner Field-of-Views Using 2D-Selective RF Excitations

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Introduction

Image blurring due to the signal decay along the echo train as well as the RF energy deposited by the refocusing RF pulses limit the applicability of high turbo factors, i.e. a large number of echoes per shot, in fast spin-echo imaging [1], in particular at higher static magnetic fields.

In this work, 2D-selective RF (2DRF) excitations [2,3]are used to focus the field-of-view (FOV) to a small inner volume without aliasing in the phase-encoding direction. This reduces the image blurring as the k-space velocity in the phase-encoding direction can be increased but also reduces the number of echoes required and thus the acquisition time and the RF deposited. This is demonstrated in phantoms and the human brain at 3T where even in single-shot acquisitions high in-plane resolutions could be realized.

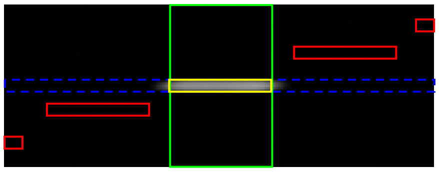

Figure 1: Magnetization profile of a spin echo (gray scaled) and basic geometry used in the present study: the rectangular excitation profile defines the inner-FOV (yellow), the side excitations (red) appear outside of the refocused section (blue) and the neighboured sections (green) because the excitation trajectory is tilted by 20° in the figure plane. Thus, the side excitations neither contribute to the spin-echo signal nor saturate neighboured sections.

Methods

Measurements were performed on a 3T whole-body MR system (Trio, Siemens Healthcare) using a twelve-channel receive-only head coil. Healthy volunteers were investigated after informed consent was obtained according to the institution's guidelines. Fast spin-echo imaging was applied with a nominal in-plane resolution of 1×1mm^2 at a slice thickness of 5mm. A bandwidth of 230Hz per pixel was used resulting in an echo spacing of 10.0ms. 2DRF excitations were based on a fly-back blipped-planar trajectory with a resolution of 5×10mm^2 in line and blip direction, respectively. The desired excitation profile was 45mm in line and 5mm in blip direction yielding a usable FOV (plateau) of 40mm and a transition region of about 12mm that was accounted for by 16mm oversampling in the phase-encoding direction. Compared to a previous approach of inner-FOV echo-planar imaging where the line direction coincided with the slice direction and the blip direction with the phase-encoding direction of the imaging plane [4], the excitation trajectory was tilted by 20° (Fig. 1). Thus, the unwanted side excitation appeared in the dead corner between the image section and the slice stack (Fig. 1) and the field-of-excitation could be reduced to 50mm yielding an 2DRF pulse length of about 4.7ms that was compatible with the applied echo spacing. The magnetization profile of the spin echo, i.e. the combined effect of the 2DRF excitation and the refocusing RF pulse is also shown in Fig. 1.

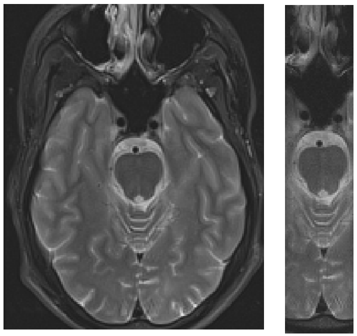

Figure 2: MR images of full (left) and inner FOV (right) fast spin-echo imaging. A fixed turbo factor of 17 was used yielding acquisition times of 27s and 12s (TR 3s), respectively. The inner FOV required only 44% of the RF energy of the full FOV.

Results and Discussion

Figure 2 shows examples of full and reduced FOV images acquired with an identical number of echoes per shot. In this case, only four shots were required for the inner FOV compared to the nine shots for the full FOV which reduced the acquisition time and the RF energy considerably. Figures 3 and 4 present comparisons where identical acquisition times were chosen (four shots in Fig. 3b and c, single shot acquisitions in Fig. 3d, 3e, and Fig. 4) and the number of echoes, and thus the echo train length, for the inner-FOV acquisitions could be reduced accordingly. Thus, the blurring caused by the signal decay along the echo train is considerably reduced for the inner-FOV acquisitions. For instance, in the single-shot acquisitions with the full FOV (acquisition time 1.6s) the phantom's inner structures cannot be resolved (Fig. 3d) while the corresponding inner-FOV acquisition (610ms) show much more details (Fig. 3e). This can also be seen in the in vivo data (Fig. 4).

In conclusion, fast spin-echo imaging benefits from focussing the field-of-view to small inner volume in terms of acquisition times, reduced RF deposition, and, in particular in single-shot acquisitions, an improved image resolution.

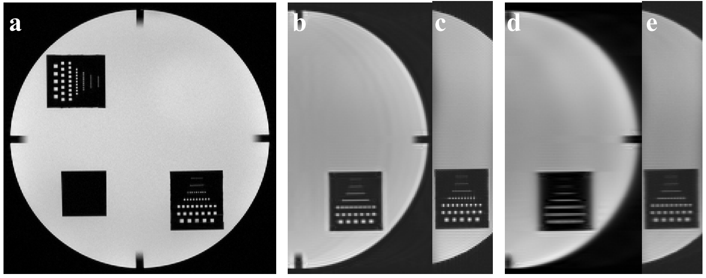

Figure 3: Phantom images obtained with (a) FLASH at 0.5×0.5mm^2, (b,c) multi-shot (4 shots) and (d,e) single-shot spin-echo imaging with (b,d) full and (c,e) inner field-of-views using 2DRF excitations.

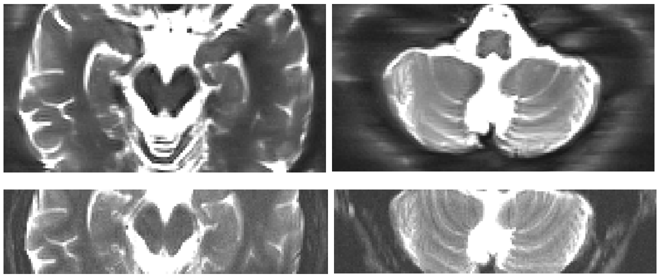

Figure 4: Single-shot spin-echo images of full (upper) and inner FOVs (lower). The full FOV required 163 echoes (acquisition time 1.6s) , the inner FOV 60 echoes (610ms).

References

[1] Hennig J *et al.*, Magn. Reson. Med. **3**, 823–833 (1986)
[2] Bottomley PA *et al.*, J. Appl. Phys. 62, 4284 (1987)
[3] Pauly J *et al.*, J. Magn. Reson. **81**, 43–56 (1989)
[4] Finsterbusch J, J. Magn. Reson. Imaging **29**, 987–993 (2009)