A flexible reduced field of view imaging scheme for single-shot spatiotemporally encoded MRI

Jing Li[1], Shuhui Cai[1], Congbo Cai[2], and Zhong Chen[1]

[1]*Department of Electronic Science, Xiamen University, Xiamen, Fujian, China,* [2]*Department of Communication Engineering, Xiamen University, Xiamen, Fujian, China*

Target audience

The target audience of present paper is basic scientists and clinical scientists who are interested in ultrafast MRI and reduced field of view imaging.

Purpose

Recently, a spatiotemporally encoded (SPEN) imaging approach based on linear frequency-swept excitation has been proposed to overcome the artifacts induced by various field perturbations in single-shot echo-planar imaging.[1] To fully demonstrate the superiority of the SPEN imaging approach in reduced field of view (rFOV) imaging, a flexible rFOV imaging approach is proposed in this paper. Experiments on phantom and *in vivo* rat brain are performed. The results show that the proposed approach can improve the signal to noise ratio (SNR) and freely alter the imaging position.

Method

The pulse sequence is shown in Fig. 1. According to the rFOV imaging based on the single-shot SPEN approach developed by Chen[2] and named as fixed decoding scheme, the encoding and decoding gradients must satisfy the equation $|G_{exc}T_{exc}| = |G_{acq}T_{acq}|$. In this paper, a variable P ($P > 1$) is introduced to modify this equation to $|G_{exc}T_{exc}| = |P\cdot G_{acq}T_{acq}|$. To image the region of interest (ROI), G_{ar} and T_{ar} must fulfill the equation $|G_{ar}T_{ar}| = |Q\cdot G_{acq}T_{acq}|$, where the value of Q can vary from (1-P/2) to (P/2). In this case, the area of FOV can be adjusted by changing the P value, and ROI can be adjusted by changing the Q value. The final signal acquired can be expressed as the following integral:

$$s(t_a) \propto \int_{L_y} \rho(y)\exp\left\{ i\left[-P\frac{\gamma G_{acq}T_{acq}}{2L_y}y^2 + \gamma G_{acq}T_{acq}\left(\frac{t_a}{T_{acq}} - Q\right)y - P\frac{\gamma G_{acq}T_{acq}L_y}{8} + \frac{\pi}{2} \right]\right\} dy \qquad (1)$$

where $\rho(y)$ is the relaxation weighted spin density profile. The modulus of signal reflects the spin density profile at a single voxel:

$$|s(t_a)| \propto \Delta y_0 \cdot \rho(y) \qquad (2)$$

Here Δy_0 denotes the pixel size and is related to the second spatial derivative of the phase arising from the initial excitation. It can be expressed as:

$$\Delta y_0 = \sqrt{\frac{2\pi L_y}{\gamma G_{exc}T_{exc}}} = \frac{P\cdot L_{yd}}{\sqrt{\Delta_{Hz}T_{exc}}} \qquad (3)$$

It shows that Δy_0 is determined by the excited FOV (L_y) and the bandwidth and duration of the chirp pulse, or is determined by the imaged FOV (L_{yd}), P, and the bandwidth and duration of the chirp pulse. So the SNR can be enhanced by choosing proper value of P according to Eq. (2) and Eq. (3). This approach is called flexible decoding scheme.

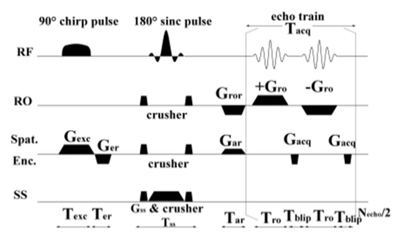

Fig. 1 SPEN sequence with flexible rFOV

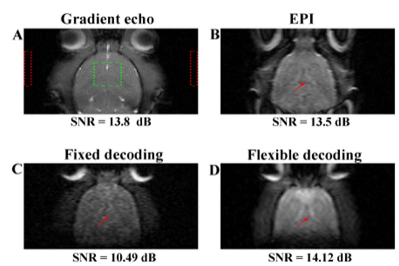

Fig. 2 Images of coronal 90° plane of rat brain. (A) Reference multi-shot gradient echo image. (B) Image from EPI sequence. (C) rFOV image from SPEN MRI with fixed decoding scheme. (D) rFOV image from SPEN MRI with flexible decoding scheme.

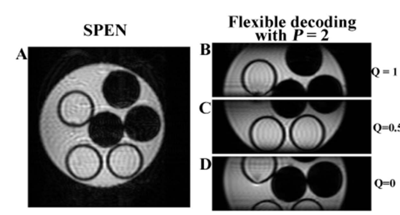

Fig. 3 Images of the phantom with freely altered region of interest. (A) Image from single-shot SPEN MRI. (B-D) SR-enhanced results from single-shot SPEN MRI with flexible decoding scheme.

Results and discussion

Experiments on a phantom and *in vivo* rat brain were conducted on 7 T Varian MRI system to verify the effectiveness of the proposed rFOV imaging scheme. The higher robustness of SPEN *vs.* EPI can clearly be seen from Fig. 2, particularly at the edges of rat brain and eyeballs where the field inhomogeneity is more serious. The image (Fig. 2C) produced by the fixed decoding scheme based on the SPEN is submerged by the noise due to the low SNR and shows no details in the region indicated by the red arrow. Compared to Fig. 2B and C, the gyrus of rat brain can clearly be seen in Fig. 2D, as indicated by the red arrow. The SNR of the image produced by the flexible decoding scheme based on the SPEN is higher than those produced by EPI and fixed decoding scheme. The representative signal and noise regions are marked with green and red squares respectively, as shown in Fig. 2A. It can be seen from Fig. 3 that as Q changes, the ROI can be locally imaged from one side to another in the excited FOV. The images are affected by the weak "stripes" due to the effect of the eddy current and mismatch of the $\pm G_{ro}$ readout gradient.

Conclusion

In summary, the flexible decoding scheme can produce images with favorable spatial resolution and SNR while maintaining the inherent immunity of SPEN to various field perturbation effects. Meanwhile, the ROI can be locally imaged and the resolution of the image can be improved.

Acknowledgement

This work was supported by the NNSF of China under Grant 81171331, and the Research Fund for the Doctoral Program of Higher Education of China under Grant 20130121110014.

References

1. Ben-Eliezer N, Irani M, Frydman L. Super-resolved spatially encoded single-scan 2D MRI. Magn. Reson. Med. 2010; 63:1594-1600.
2. Chen Y, Li J, Qu XB, et al. Partial Fourier transform reconstruction for single-shot MRI with chirp excitation. Magn. Reson. Med. 2012; 69:1326-1336.