SSFP fMRI with parallel interleaved multiple frequency acquisition

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Introduction

Steady-state free-precession (SSFP) fMRI is a new method for obtaining functional contrast. Since SSFP fMRI is based on balanced SSFP imaging at low flip angle, the signal is strongly dependent on the central reference frequency. In the presence of frequency variations, the area of functional activation detectable by SSFP fMRI may be reduced [1]. Previous studies employed careful shimming on the region of interest (ROI) and combined the results from multiple frequency offsets to widen the frequency profile for increased functional sensitivity. In this study, we proposed a interleaving scheme to obtain SSFP fMRI data at multiple frequency offsets within one single acquisition, such that the effects of system frequency drifts and physiologically induced fluctuations remained similar, as compared with the use of separate acquisitions. The resulting prolongation in scan time was compensated for by using parallel imaging at an acceleration factor equal to the number of frequency offsets to result in the same scan time.

Methods

The sequence was implemented with Philips Acqsim environment. Interleaving the frequency offset during the scan was achieved by adjusting phase angles of RF pulses for each SSFP scan, which was theoretically equivalent to central reference frequency adjustment through the relationship $\varphi = f \times TR \times 360°$, where φ is the phase increment and f is the frequency offset. The sequence was designed so that the user can choose the phase angle increment and setup phase alternation according to the dynamic number.

Imaging was done on a 3.0T Philips Achieva system using an 8-channel head coil. Shimming was targeted to the occipital lobe. The image parameters were 200 mm FOV, 64 by 64 matrix size, 4 mm slice thickness, 5° flip angle and TR/TE = 8/4 ms. Two sets of BOSS fMRI images were acquired: One is single-frequency experiment without SENSE and the other is triple-frequency experiment with three-fold SENSE at phase increments of -28.8°/0/28.8°, equivalent to frequency offsets of -10Hz/0Hz/10Hz. The stimulus was a 5 Hz flashing checkerboard visual stimulus in 4-on/4-off blocks (17 sec in each block, yielding 8/24 time frames for single- and triple-frequency experiments, respectively). Total experiment time was less than 2.5 min. Analysis was performed using SPM5.

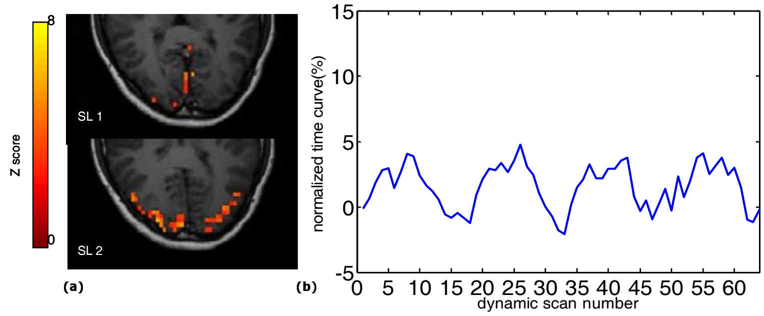

Fig. 1 SSFP functional result for single frequency experiment with 4 slices. (a) activation map (b) the percentage of signal change.

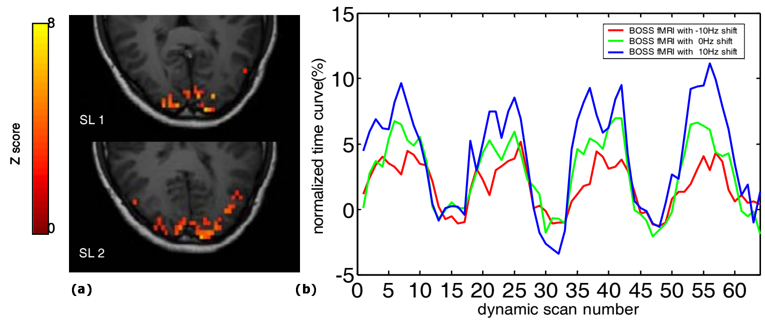

Fig. 2 SSFP functional result for triple-frequencies experiment with 4 slices. (a) activation map (b) the percentage of signal change.

Results

Fig.1a shows the activation maps for the single-frequency experiments overlaid on high resolution T1-weighted images and Fig.1b is the percentage of the SSFP fMRI signal change. Fig.2 shows the same result for triple-frequency experiment. The strategy combining three frequencies is seen to provide wider activation range to compensate the insufficiency of the single frequency experiment (arrows). The percentage signal change shown in Fig.2b shows higher functional sensitivity at one specific frequency than that shown in Fig.1b, even in the presence of SNR loss due to SENSE acceleration [2].

Discussion and Conclusion

The results from this study demonstrate that the activation range detectable by SSFP fMRI could be increased by acquiring interleaved data with multiple central reference frequencies, such that a wider ROI region could be covered during one single acquisition. This property could be important in situations such as two-ear auditory stimulations where the activation regions are expected to be much wider than the homogeneous visual cortex demonstrated in this study. The higher functional signal sensitivity in the triple-frequency experiment is likely a complicated outcome from SENSE-related signal loss, transient-state signal increase [3, 4], and difference in central reference frequency settings, which awaits further quantitative investigations.

References

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