Brain fMRI with dual echo steady-state (DESS) imaging: preliminary findings on signal behavior and flip-angle dependency

Pei-Hsin Wu[1], Hsiao-Wen Chung[1,2], Ming-Long Wu[3,4], Tzu-Chao Chuang[5], and Tzu-Cheng Chao[3,4]

[1]Department of Electrical Engineering, National Taiwan University, Taipei, Taiwan, [2]Institute of Biomedical Electronics and Bioinformatics, National Taiwan University, Taipei, Taiwan, [3]Department of Computer Science and Information Engineering, National Cheng Kung University, Tainan, Taiwan, [4]Institute of Medical Informatics, National Cheng Kung University, Tainan, Taiwan, [5]Department of Electrical Engineering, National Sun Yat-Sen University, Kaohsiung, Taiwan

Introduction

Dual echo in the steady state (DESS) pulse sequence is a technique that allows simultaneous acquisitions of two echoes within one TR. The extended readout gradient for the formation of FID (S^+) and echo (S^-) signals results in two images with distinct contrast behaviors, and its incomplete compensation of the gradient moment provides images without banding artifacts as those found in bSSFP imaging. Previous study demonstrates that optimal contrast for morphological depiction could be obtained by appropriate selection of the scanning parameter values [1]. In this study, we apply DESS imaging to brain functional MRI experiments to investigate the relationship between functional contrast and the imaging parameters for S^+ and S^- images, respectively. Preliminary results from phantom and human experiments are reported.

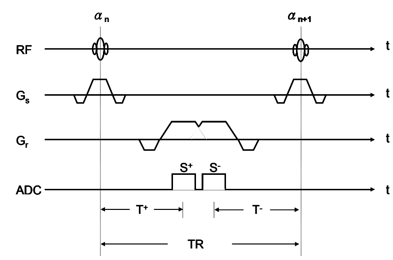

Fig. 1 DESS pulse sequence

Methods

The basic structure for the DESS sequence is shown in Figure 1, where a dual-acquisition window is applied. Phantom imaging experiments were performed on a 3.0T Siemens Trio system using a 12-channel head coil. The image parameters were 180 mm FOV, 128 by 128 matrix size, 5 mm slice thickness. To examine the signal behavior of S^+ and S^-, different TR (10, 30, and 50 ms) and flip angle (FA) values (5°, 10°, 15°, 25°, 35°, 45°, 55°, 65°, and 70°) were used, where $TE^+ = T^+ = T^-$ and $TE^- = 2TR - T^+$, and BW = 320 Hz/px. To further examine the relationship of off-resonance effects, as might be encountered in alterations of oxygenation level in the brain, on the magnitude and phase signals between S^+ and S^-, a sweep scan was performed for dataset with TR=10 ms at 45° FA by adjusting the phase angles of RF pulses for each DESS scan.

Human imaging experiments for the investigation of DESS fMRI sensitivity were performing by acquiring two sets of images with 200 mm FOV, 64 by 64 matrix size, 4 slices, 260 Hz/px BW and 10 ms TR at FA of 45° and 70°, respectively. The stimulus was a 5 Hz flashing checkerboard visual stimulus in 4-on/5-off blocks (10 frames in each block) for 4.26 min. Analysis was performed using T-test in SPM5.

Results

Figure 2 shows the results from the 27 datasets with varied TRs and FAs, where the blue and red colors represent S^+ and S^- signals, respectively, suggesting that larger flip angle leads to larger signal intensities, benefiting low-sensitivity experiments such as fMRI. For varying TR, longer TR results in larger intensity for S^+ but reduced S^- signal due partly to T2 decay effect (not shown), consistent with a previous study that the shortened TR in DESS results in increasing similarity in contrast for the FID and echo images [2]. Figure 3a and 3b are the sweep scan results for the magnitude and phase images, where the the blue and red lines represent the results from S^+ and S^-, respectively. Only the phase of S^- was affected by off-resonance frequency.

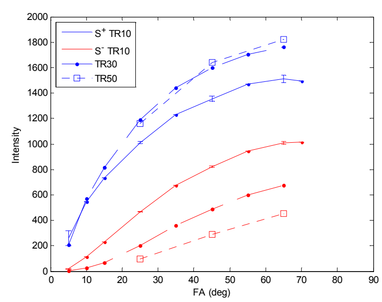

Fig.2 Magnitude of DESS signal plotted as a function of flip angle.

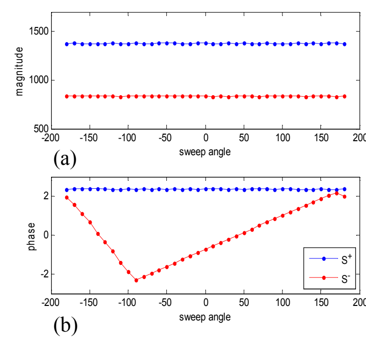

Fig.3 Sweep scan at 10-degree increments of RF phase (a) magnitude (b) phase.

Figure 4 demonstrates the visual fMRI results, where 4a-4d are the temporal time curve displayed in the percentage of the DESS fMRI signal changes at 45° and 70° FA (blue: S^+, red: S^-), and 4e-4f show the activation maps for visual fMRI near the primary visual cortex at 70° FA. The functional contrast estimated from S^- was slightly higher than that from S^+ at the same flip angle, in agreement with its better sensitivity to off-resonance effects as in Fig.3. Moreover, larger functional signal changes were observed at larger FA, which is likely a result from the better SNR as shown in Fig.2.

Discussion and Conclusion

The preliminary findings suggest that a larger flip angle seems to be beneficial for better functional contrast in DESS imaging. While the functional contrast for S^+ might arise from changes in cerebral blood flow, the phase variations in the presence of off-resonance may contribute at least partially to the functional contrast of S^- (Fig. 3b). Since the DESS technique shows wide signal profiles with no geometric distortion, it may have potential as an alternative to EPI and bSSFP for brain fMRI studies. Mechanisms responsible for the functional sensitivity of DESS observed in the experimental results as well as the comparative efficiency are currently being investigated.

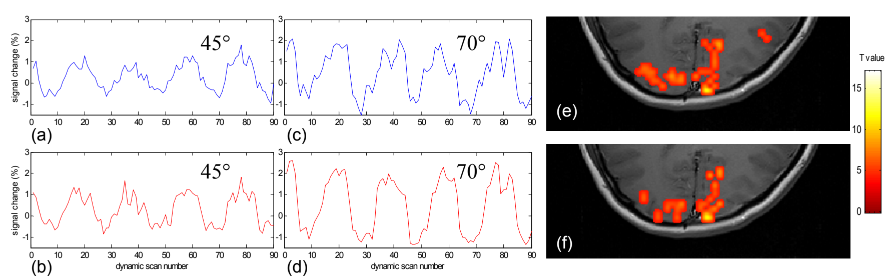

Fig. 4 DESS fMRI with different FA: (a,b) the percentage of signal change for S^+ and S^- at 45°, (c,d) the percentage of signal change for S^+ and S^- at 70°, and (e,f) the S^+ and S^- activation maps for 70°. Note particularly the increased functional sensitivity in (c,d) compared with (a,b).

References

[1] Hardy, P.A., et al., JMRI, 6:329, 1996. [2] Bruder, H., et al., MRM, 7:35, 1988.