# Ghost-Free Spin-Echo Echo Planar Imaging Method for Diffusion Weighted Images using Adaptive RF Pulses

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## Introduction

Diffusion tensor imaging (DTI) can provide valuable information regarding brain connectivity and neurological diseases. However, acquiring DTI is not an easy process because it has to be acquired in a short period of time with high enough spatial resolution to calculate the minute fiber tracts. Many techniques have been developed and applied to DTI and as for now, single-shot SE-DW-EPI seems to be the optimal method for its short acquisition time and robustness to motion [1]. To acquire even better image with EPI, Wang et al. suggested a reduced-FOV approach with saturation pulses [2]. However, this method requires extra saturation pulses which result in increased imaging time. Thus, we suggest an adaptive RF selection method which can generate ghost-free DT images without extra RF pulses.

## Methods

In the spin-echo EPI, two RF pulses (90° pulse for excitation pulse and 180° pulse for refocusing) are applied so that the echo is generated from the selected slice. These RF pulses are applied to the same slice so that the spins in the selected slice are consecutively excited and refocused. However, we applied the excitation pulse to half of the FOV in the phase encoding direction with the refocusing pulse in the slice selection direction so that the echo is generated from half of the selected FOV only. To remove the N/2-ghost, the image from each half of the FOV was acquired separately, and then concatenated in the image domain. Since the excitation 90° pulse is applied repetitively to the same volume in the half of the FOV, the spins tend to be saturated after acquiring several consecutive slices. Thus, we applied the 90° pulses to alternately excite 'half-FOV's as shown in fig.1. In this way, we acquire the first set of images consisting of half of the FOVs as marked in black and then the other half of the FOVs, consecutively. After acquisition of two separate sets of half-FOV images, they are simply concatenated in the image domain. Since no phase terms are introduced in the image concatenation, the N/2 ghosts do not appear in the final images.

## Results

By applying the proposed imaging sequence, we acquired a set of diffusion weighted images having the matrix size of 128x128, with TE=219ms and TR=7500ms using 3 Tesla MRI scanner (ISOL Technology, Korea). Total acquisition time for one volume consisting of two 'half-FOV's is 15s. High b value (b=1000s/mm$^2$) and 4 NEX DT images are then acquired with δ=28ms, Δ=54.8ms, and gradient strength of 1.4G/cm in the directions of (0,1,-1), (1,1,0), (0,1,1), (1,0,1), (1,-1,0), (-1,0,1), and (0,0,0) as a reference. Images were also acquired with the conventional SE-DW-EPI sequence as a comparison and the diffusion values were calculated using a home-made software. When acquiring conventional SE-DW-EPI, and 8 NEX images were acquired to match the total acquisition time with the proposed method.

## Discussions

Figure 2 shows the DWIs acquired using the conventional SE-DW-EPI (left) and the proposed method (right). The intensity of the images is amplified for displaying purposes. As shown in the images, It is clear that the proposed method produces ghost-free images with no loss in signal strength. This is because the N/2 ghosts are generated because of the phase difference in odd and even lines of the k-space data. Since a perfect phase error correction is very difficult, we rather suggested that the images to be acquired separately with even N/2 ghost and odd N/2 ghost. Each image contains N/2 ghost on the other side of the main image but the other side of the image containing the N/2 ghost is cut off during the concatenation, producing a ghost-free full image. Note that the signal strength from the conventional method does not look much better even though it is averaged twice the number of averages used for the proposed method. Calculated diffusion matrix images are shown in fig.3. The matrix calculated from the images acquired by the proposed method (top) seems clearer than that from the conventional one (bottom). In case of tensor calculation, it is more important to reduce N/2-ghost because the artifact can significantly alter the final tracking results. A further analysis of the diffusion images and calculated valued need still to be done.

## Conclusions

We acquired ghost-free diffusion weighted images using alternating RF selection pulses applied in the phase encoding direction. When used in combination with other methods which can reduce ghost-related artifacts, acquisition time can be further reduced and we can acquire images with better SNR which are free of N/2 ghosts.

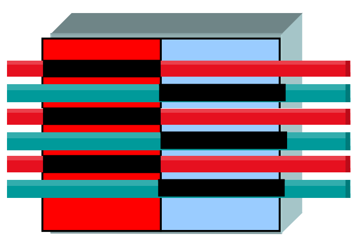



**Fig. 1.** Alternating RF selections

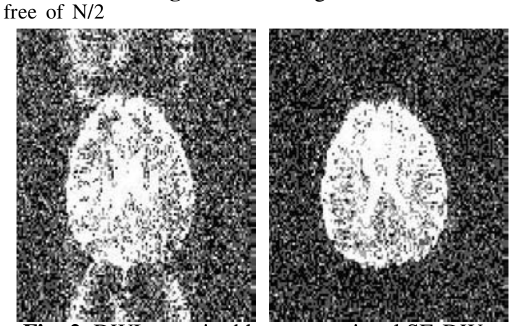
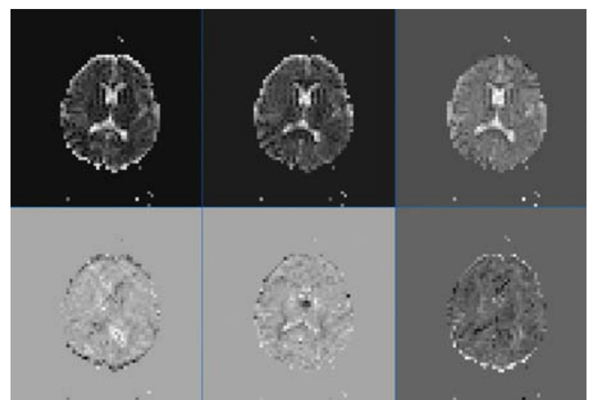
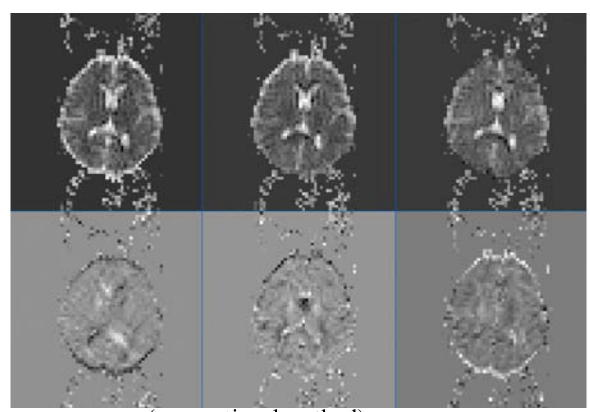


**Fig. 2.** DWIs acquired by conventional SE-DW-EPI (left) and the proposed method (rignt). The intensity of the images was amplified to emphasize N/2 ghosts.



(proposed method)



(conventional method)

**Fig. 3** Calculated diffusion matrix (Dxx, Dyy, Dzz, Dxy, Dyz, Dzx from top left to bottom right.)

## References

1. David G. Norris, "Implications of Bulk Motion for Diffusion-Weighted Imaging Experimetns: Effects, Mechanisms, and Solutions", Journal of Magnetic Resonance Imaging 13:486-495, 2001.

2. Jiun-Jie Wang, Ralf Deichmann, Robert Turner, and Roger Ordidge, "3D DT-MRI Using a Reduced-FOV Approach and Saturation Pulses", Magnetic Resonance in Medicine 51:853-857, 2004.