**Ghost correction for EPI at gradient insert system**

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## Purpose

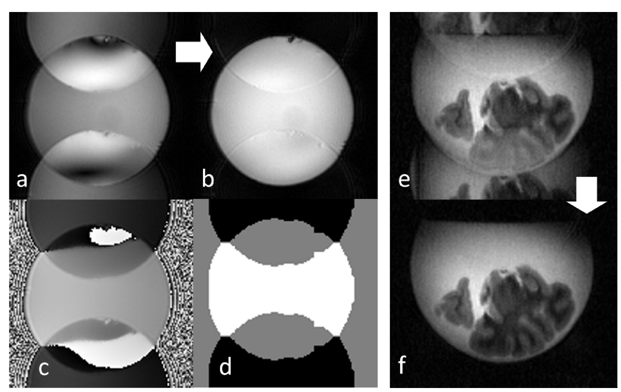
In recent years, there is an increasing number of echo-planar-imaging (EPI) based diffusion-weighted imaging (DWI) and diffusion-tensor imaging (DTI) studies in the animal brain. In these studies, the combination of a high power gradient insert system and an ultra-high field human whole-body MRI scanner will be of special interest to researchers because of its capability of acquiring high resolution DWI/DTI images. However, the nonlinearity of high power gradient outputs, especially in the EPI acquisition, often causes severe ghost artifacts, which degrade overall image quality. Because of the nature that, half the lines in k-space are acquired with positive readout polarity and half with negative, imperfection of gradient outputs results in phase error and thus signal intensity displacement halfway across the image in the phase encoding direction. Although some pre-scan methods have been reported [1-2] for the EPI ghost reduction, these techniques always prolong the acquisition time. Buonocore, et al. [3] proposed another technique to derive phase error between odd and even readout lines in k-space from the reconstructed image. This technique is attractive because it provides an image only region and ghost only region without any additional scan. However, this technique requires a user-defined region-of-interest placed on the parent image, and this is not practical. In this study, we propose a novel ghost reduction method that can derive the parent/ghost region automatically without the need for any additional scans.

## Methods

In order to reduce the ghost caused by odd/even phase error without any additional scans, it is necessary to estimate the phase error from the resultant k-space. Our proposed method finds the maximum likelihood estimate of phase error to provide maximum parent and minimum ghost regions from a bunch of reconstructed images with varying phase error "adjusting" from $-\pi$ to $\pi$. Assuming that N images are reconstructed with different phase shifts ($-\pi, -\pi(2N-1)/2N, -\pi(2N-2)/2N, ......, \pi$) of even lines, each pixel has N candidates for the estimator. A plot of these N candidates for each pixel forms a single sine wave; and the sine waves from pixels in the parent only region have similar phase, referred to as the phase pattern. This phase pattern can be used to segment parent only regions from ghost only regions and overly regions. Fourier transformation of these N candidates is used to simply find out this phase pattern. The flow of the proposed method is as follows: 1. Obtain positive and negative images by using zero-filled negative and positive readout lines in k-space respectively, 2. Prepare N adjusting images by combining positive image and negative images with different phase shifts (from $-\pi$ to $\pi$). 3. Fourier transform these N images (along "adjusting" direction) to obtain phase pattern map. 4. In the phase pattern map for each phase encoding line from the center pixel, search for parent only pixels by comparing the standard deviation of the center pixels and the target pixels. 5. Obtain ghost only region from 4. 6. For each phase encode line in final image, choose the line in adjusting images that provide maximum of (parents – ghosts).

## Results

We tested our approach with a phantom on a 7T whole-body scanner (Siemens) equipped with a gradient insert system. A standard EPI sequence was used to obtain *k*-space data. Acquisition parameters were as follows: TR = 2 sec, TE = 30 ms, FOV = 88 mm, matrix = 128×128, thickness = 1 mm, pixel bandwidth = 3000 Hz. Images a-d in the figure demonstrate the effect of ghost reduction: a, uncorrected; b, corrected; c, phase pattern map; d, parent only region (white) and ghost only region (black). Images e and f in the figure show the ghost reduction effect for a spin-echo EPI.




## Discussion and Conclusions

Our approach can be implemented as a post processing step without extra scan. The key of our method is the idea to derive the parent only region from phase adjusted images automatically. The limitation of this method is the requirements for enough background regions (i.e. air-only regions) in the phase encoding direction to estimate parent only region.

## References

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