Removing Echo Planar Imaging Banding Artifact using Phase Matching

Dan Xu[1], Kenichi Kanda[1], Kevin F. King[1], Zhenghui Zhang[1], and Robert D. Peters[1]
[1]*GE Healthcare, Waukesha, WI, United States*

TARGET AUDIENCE

Scientists and clinicians who are interested in echo planar imaging (EPI) artifact reduction.

PURPOSE

Phase correction is a necessary step in EPI to reduce Nyquist ghost artifacts. Conventional phase correction methods [1-3] often applies equal amount of phase with opposing signs to odd and even echoes. While echo-to-echo phase alternations are reduced, an implicit phase is introduced. This phase is in general coil channel dependent, and can have significant variation for coils with higher channel count and asymmetric geometry. When combined with parallel imaging reconstruction, the channel dependent phase can generate banding artifact or residual Nyquist ghost. In this paper, we propose a phase matching method that equalizes the additional phase introduced by each channel before parallel imaging reconstruction, thereby removing the banding and residual aliasing artifacts.

METHODS

Assume $\boldsymbol{\theta_{ij}}$ and $-\theta_{ij}$ are phases applied to the odd and even echoes, respectively, for the *i*th coil channel and *j*th odd-even echo pair. Note that the coil dependency is in general required because the phase needed for each coil data can be different due to factors such as different local eddy currents (EC). The view dependency is also often desired to correct B0 related phase accumulation along echoes, although the phase variation along view is typically small and smooth. The choice of evenly distributing the phase difference to θ_{ij} and $-\theta_{ij}$ is rather arbitrary. In fact, for any constant α_i, one can show that $\theta_{ij} - \alpha_i$ and $-\theta_{ij} - \alpha_i$ would also remove the odd-even phase alternation and therefore remove Nyquist ghost for each channel. Without parallel imaging or when θ_{ij} does not vary much across coils, the choice of α_i is nonessential because the additional phase is either removed by the root sum-of-squares reconstruction or becomes a global phase in the final image. However, when parallel imaging such as SENSE [4] is used and θ_{ij} varies significantly across coils, α_i needs to be carefully chosen. Otherwise the phase mismatch between the phase corrected EPI data and the externally calibrated coil sensitivity map (often acquired with a GRE sequence) can create image artifacts after SENSE unaliasing. The optimal α_i theoretically should be determined by EC analysis of both the EPI and the calibration GRE sequences. However, this would be difficult because EC measurements local to each coil are required. If we assume the GRE sequence acquire data with a gradient waveform similar to the EPI odd echo gradient waveform (e.g., both are positive gradients, with maximum slew rate and ramp to maximum gradient amplitude), then the phase correction should be done with the odd echoes being the baseline. Therefore, α_i is set to $(1/J)\sum_{\boldsymbol{j=1}}^{\boldsymbol{J}} \boldsymbol{\theta_{ij}}$ in the proposed method, where *J* is the number of echoes.

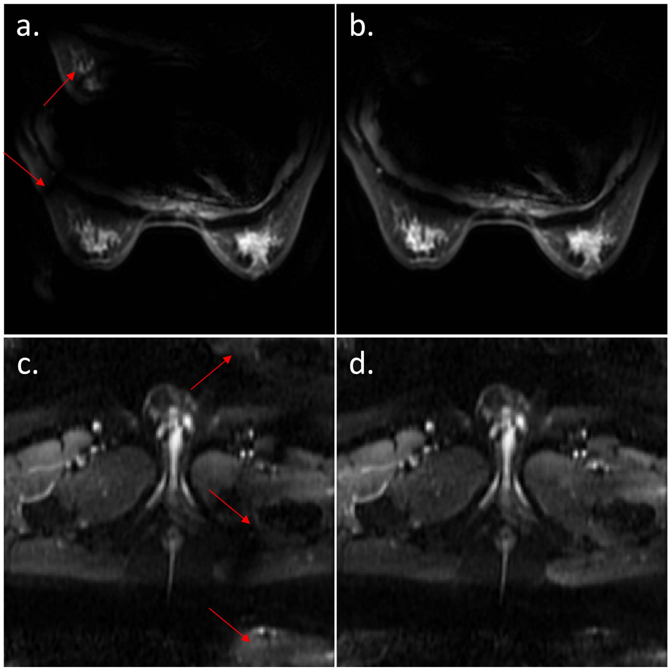

Fig. 1. a) and b):DW-EPI images acquired with a 16-channel breast coil without and with phase matching, respectively. c) and d): DW-EPI images acquired with a 16-channel torso coil without and with phase matching, respectively.

RESULTS AND DISCUSSION

Breast and pelvic diffusion weighted (DW) EPI images were acquired on a 3T GE scanner using a 16-channel breast coil and a 16-channel torso coil, respectively. Figure 1a shows the image using conventional phase correction. Large banding artifact and residual SENSE aliasing artifact (marked by arrows) appear in the image due to the phase incompatibility between sensitivity maps and phase corrected EPI data. The proposed phase matching method reduces the incompatibility while retaining capability of removing Nyquist ghost, hence the image in Fig. 1b free of banding or ghosting artifacts. Figure 1c shows a pelvis example with severe shading and residual aliasing from conventional phase correction, which is minimized with the proposed method (Fig. 1d).

CONCLUSION

Conventional EPI phase correction can introduce a channel dependent phase which could conflict with parallel imaging unaliasing especially for high channel count coils, leading to banding or residual aliasing artifacts in the final images. The proposed method removes the phase incompatibility by introducing a channel dependent phase while retaining the odd-even phase correction capability, thereby producing images free of banding and aliasing artifacts, in addition to minimizing EPI Nyquist ghost.

REFERENCES

[1] Maier et al., US Patent 5,151,656, 1992.
[2] Schmitt et al., US Patent 5,138,259, 1992.
[3] Hinks et al., US Patent 7,102,352, 2006.
[4] Pruessmann et al., *MRM*, vol. 42, pp. 952-962, 1999.