Multiple-channel EPI phase correction for SENSE based image reconstruction

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Introduction

Magnetic resonance imaging (MRI) studies using echo planar imaging (EPI) employ data acquisition techniques in which data is collected on both positive and negative polarity lobes of readout gradient waveforms. Phase errors are inherent in this data collection scheme and must be corrected for during image reconstruction. One technique used for EPI phase correction is to acquire a set of non-phase encoded data during an EPI reference scan, computing phase correction coefficients to be used during image reconstruction of the subsequent EPI scan (1,2,3). Parallel imaging techniques, such as SENSE (4), are often used to reduce susceptibility artifacts and reduce scan time(5,6) for EPI based applications. We propose an effective and robust SENSE based EPI reconstruction using per channel nearest-neighbor phase correction.

Methods

Experiments were performed using a 1.5 T General Electric (GE) Signa MR scanner (GE Healthcare, Waukesha, WI, USA) equipped with a high bandwidth (1MHz) data acquisition subsystem and a TwinSpeed gradient coil capable of 40 mT/m at a maximum slew rate of 150T/m/s. Conventional EPI was used with an 8-channel domed head coil (Invivo, Waukesha, WI, USA) to acquire the data. Data were collected from a number of human subjects under approved institutional review board agreements. The following diffusion weighted spin echo EPI (DWEPI) scan was performed: 2D oblique axial, number shots =1, TE = 90.8 msec, TR= 4 secs., 24 cm field of view, 5 mm slice thickness, skip 0, b=1000 s/mm^2, 3 directions, dual spin echo, 128 x128, 1 NEX, ramp sampling enabled, with ASSET (R=2), half-Fourier, and zero-filling to 256x256.

Results

During EPI reconstruction a first-order phase correction of each Fourier transformed frame of raw data is performed (1,2,3) prior to homodyne-SENSE processing (7). Empirical evidence suggests that obtaining a set of phase correction coefficients for each spatial location and each channel provides the best image quality for sum-of-the-squares (8) based multiple-channel magnitude EPI reconstruction. For SENSE based EPI reconstruction, two methods providing a first-order phase correction from each channel were compared(1,2) using identical raw data sets.
The linear and constant phase correction coefficients from each method are shown in Figure 1. Note that the nearest-neighbor phase correction coefficients are labeled as “Method 2” and provide much less channel-to-channel variation than “Method 1”. For SENSE based image reconstruction, the intrinsic channel-to-channel phase relationships determined by coil sensitivities must be maintained. Therefore, preserving channel-to-channel phase variation after EPI phase correction is desirable. Figure 2 shows that for a double oblique slice orientation, ghosting is significantly reduced when the proposed method of per channel nearest-neighbor phase correction is used.

Discussion and Conclusion

EPI phase correction techniques used with SENSE based reconstruction must preserve channel-to-channel phase relationships required for final image reconstruction from the accelerated image matrices and the complex-valued coil sensitivity matrices for each channel. The proposed method of applying nearest-neighbor EPI phase correction for each spatial location and each channel provides a robust and highly effective technique that can accommodate double oblique scan geometries and has demonstrated excellent image quality for head and body applications.

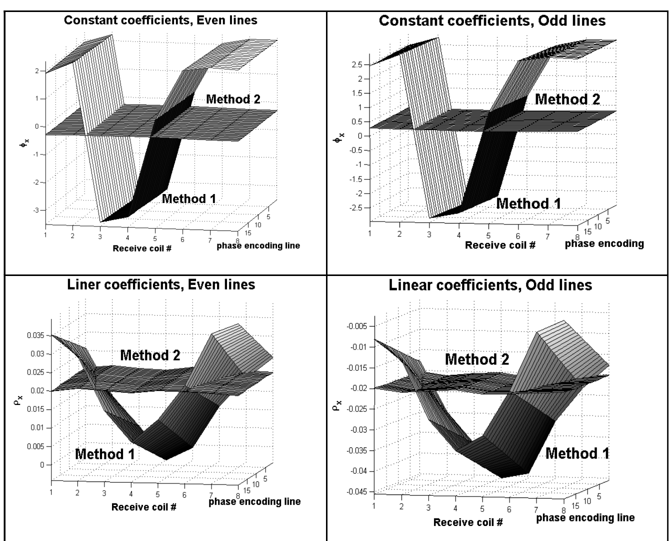

Figure 1. Constant and linear phase correction coefficients determined from non-phase-encoded EPI reference data. Method 2 exhibits less fluctuation from channel to channel than Method 1

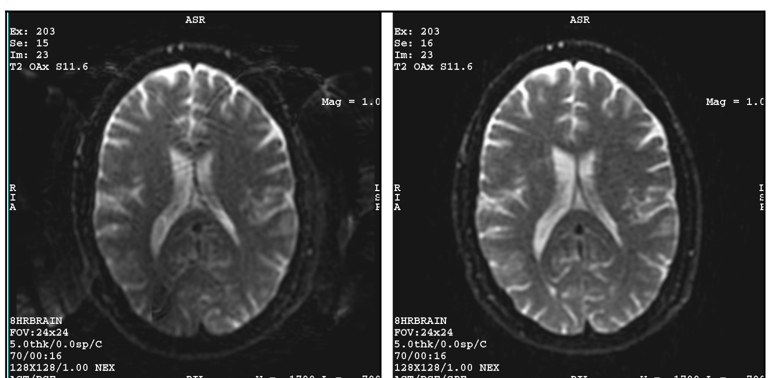

Figure 2. T2 (b=0) images from identical DW EPI scan using different phase correction techniques. Method 2 (right) provides reduced ghosting than Method 1 (Left).

References

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