# A comparison of the static and dynamic phase correction methods in timeseries EPI with parallel imaging

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**Target audience:** MR sequence and reconstruction engineers, mainly working on EPI

**Purpose:** Nyquist ghost (N/2) artifacts occur in single-shot echo planar imaging (EPI) due to the alternating readout (RO) direction. Positive and negative added phase offsets in the even and odd phase encoding (PE) lines generate signal amplitude modulation. Conventionally, 2 or 3 lines of readout acquisition without PE gradient is added between the slice excitation pulse and readout acquisition in a timeseries EPI scan, and the calculated linear phase error along the alternating RO direction acquisitions is corrected in each measurement. Since this phase scan information is updated for each measurement, we refer to it as *dynamic* phase correction here. When considering parallel imaging, e.g. GRAPPA [1] in timeseries EPI, the linearly fitted coefficients to estimate the missing lines in the accelerated scan are calculated from a separate auto-calibration scan (ACS) prior to the acceleration (ACC) scans. In this way, GRAPPA reconstruction can be said to be *static*. In a similar way, multiband or SMS EPI reconstruction uses a single time point of (or *static*) in-plane and slice-GRAPPA information to unfold/de-aliase the folded/overlapped images, prior to the accelerated scans [2,3].

In this study, we investigate two simple questions: "Is *dynamic* phase correction better than *static* in timeseries EPI?" and "which one is better in in-plane accelerated EPI (e.g. GRAPPA)? In this study, we conducted the following experiment to answer those questions above.

**Methods:** We acquired one full k-space and two in-plane accelerated (acceleration factor R=2/3 with ACS lines = 24/36) EPI scans from an agar phantom and a healthy subject in a 3T scanner using a 12 ch head coil. The following MR parameters are used in all scans; FOV=24×24cm$^2$, voxel size 2.5×2.5×2.5mm$^3$, 48 slices, TR/TE=3400/31 ms, and repetition = 120. All the images were reconstructed using in-house matlab code. GRAPPA kernel size of 4 × 3 in PE and RO directions was used to calculate the linear coefficient. Static and dynamic phase correction paradigms were compared for a time-series full k-space and accelerated EPI data. Fig. 1 shows the workflow of the two different phase correction methods.

For the human data, head motion was corrected using *3dAlineate* command in AFNI, and the maximum and mean displacement values are presented for the severity of head motion [4]. Temporal signal-to-noise ratio (tSNR) maps were generated without spatial filtering or detrending. Average tSNR values in gray matter (probability > 0.95 using SPM) were calculated to evaluate two different phase correction workflows.

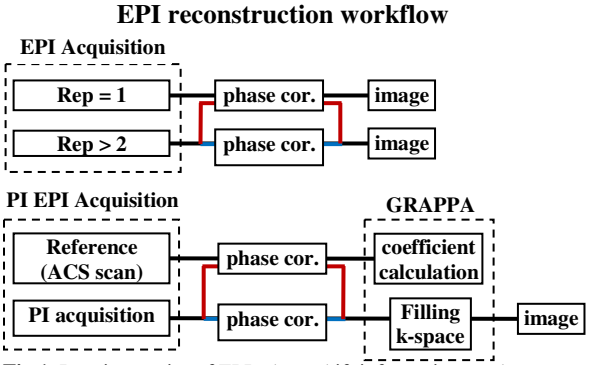


**Fig 1**. In a time-series of EPI, phase shift information can be calculated from a single scan and applied in the following measurements, referred as ***static*** and shown in red or from each measurements, referred as ***dynamic*** and shown in blue

**Results:** In the phantom study, we found that there was no visible difference of tSNR between static and dynamic phase correction methods in full k-space EPI data. However, in the accelerated EPI, the local loss of tSNR was observed in a few slices. Fig. 1 shows the local tSNR loss when using dynamic phase correction method with GRAPPA.
A similar result was observed in the human data. No visible difference between the static and dynamic phase correction methods was observed in full k-space data, and the static phase correction method generated higher tSNR and less local attenuation of tSNR than the dynamic phase correction with GRAPPA. Table 1 also shows that the tSNR values in gray matter are identical when using the static and dynamic phase correction methods in full k-space data, and higher tSNR with the static phase correction than with the dynamic phase correction method, when GRAPPA is employed.

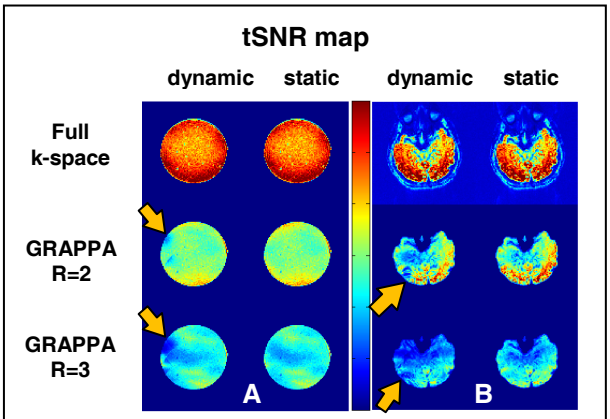


**Fig 2.** Representative tSNR maps of phantom (A) and in-invo (B). tSNR maps are scaled from 0 to 120(A) and 80(B). The local tSNR loss is observed in the accelerated scan with dynamic phase correction, as shown in the arrows.

**Discussion:** The static phase correction method is expected to be sensitive to head motion between the phase correction scan and the subsequent measurement scans. GRAPPA in EPI is also known to be sensitive to head motion between ACS and ACC. While this study with single subject does not provide conclusive evidence on the relation between the head motion and the static phase correction, the result shows that static phase correction method is robust and provides higher tSNR than the dynamic phase correction in accelerated EPI data. A possible explanation is that the measurement error in each phase correction scan might reduce the GRAPPA unfolding efficiency. Note that GRAPPA in timeseries of EPI datasets assumes no head motion between the reference and the following acceleration scans, and kernel fitting was conducted in k-space data after the linear phase addition and subtraction in alternating PE lines.

**Conclusion**: We demonstrate here that tSNR can be higher using static rather than dynamic phase correction in timeseries EPI, when parallel imaging is used. The result was robust even in the presence of head motion.

**tSNR comparison with different phase cor.**

| EPI data | Disp.(mm), (max/mean) | tSNR w/ dynamic | tSNR w/ static |
|---|---|---|---|
| Full k-space | 1.9/0.8 | 57.3 | 57.3 |
| GRAPPA (R=2) | 3.3/1.7 | 36.1 | 37.3 |
| GRAPPA (R=3) | 1.6/0.8 | 25.4 | 27.1 |

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