Dynamic multiband calibration for improved signal fidelity

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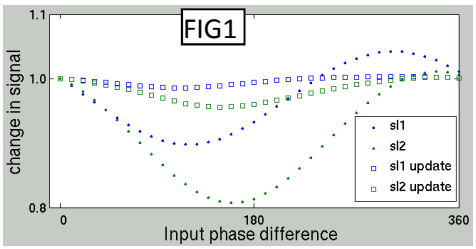
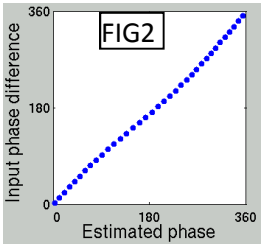
Introduction. Simultaneous multi-slice imaging is a parallel imaging technique {1, 2} which has received renewed attention, due to its recent implementation in 2D-EPI and its subsequent ability to significantly reduce the volume TR in both resting state fMRI and diffusion imaging, without significant penalties in image SNR, whereby improving the sensitivity of these methods. Slice-GRAPPA {2} is usually preferred due to the advantages of a k-space method versus an image space method that relies on explicit sensitivity profiles. Irrespective of the method, the *relative* phase difference between aliased slices is used in the reconstruction, since both magnitude and phase of individual coil sensitivities are used for unaliasing.

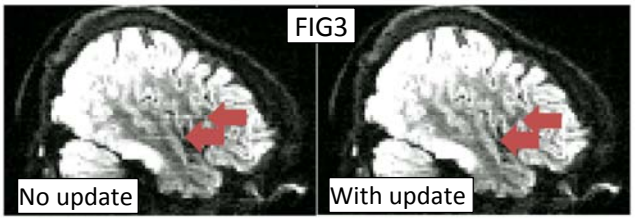
$$\begin{bmatrix} SB_1 \\ e^{i\gamma_2} SB_2 \end{bmatrix} = \textbf{MBGRAPPA}\ [SB_1 + e^{i\gamma_2} SB_2] \quad \text{(eq1)}$$

$$SENSE^{R=1} = \sum_{ch} \bar{C}_{ch} SB^{slice}_{ch,unalias} \quad \text{(eq 2)}$$





Background/Simulations The relative phase-difference can change during successive acquisitions (i.e. in an fMRI time series or in subsequent acquisitions of multiple diffusion directions), leading to temporal fluctuations in signal intensity, which increases the variability in fMRI and in the detection of neuronal fibers in diffusion imaging. A two slice experiment was simulated by adding measured k-space using acquired single band data from a 32 channel coil. A DC phase ($e^{i\gamma_2}$) was added (by multiplication) to one slice prior to a simulated multiband acquisition (eq. 1). For unaliasing, two different slice-GRAPPA kernels (**MBGRAPPA**) where compared, one with knowledge of the imposed DC phase and one without. The relative signal changes of the reconstructed images where compared to the original images (γ_2 =0). The results plotted, as a function of γ_2, in figure 1 show reduced variability with the correct phase. To demonstrate the ability to estimate this phase, a second simulation was performed. Using an (**MBGRAPPA**) kernel for γ_2 =0, a SENSE(R=1) (eq. 2) was applied to the unaliased data for different phases (γ_2). In figure 2, a correlation between the relative phase of unaliased slices (also with SENSE(R=1)) and the simulated phase difference is plotted, showing a high correlation.



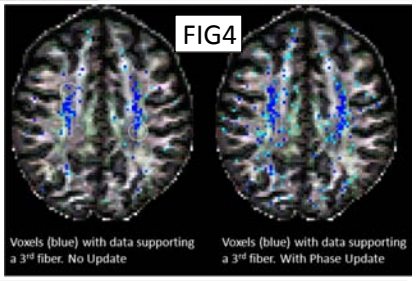


Fig 1: Signal fluctuation when relative phase between slices changes. Fig 2: Estimated relative phase difference with multi-band reconstruction. Fig 3, left: Standard slice-GRAPPA reconstruction. Fig 3, right: Updated slice-GRAPPA reconstruction. Fig 4, left: Map of existence and uncertainty for 3rd fiber with standard slice-GRAPPA reconstruction. Fig 4, right: Map of existence and uncertainty for 3rd fiber with updated slice-GRAPPA reconstruction

Experiment. Diffusion MRI data was obtained along 64 gradient directions at a b-value of 2000 s/mm^2, with 5 additional b0 volumes, on the Siemens 3T connectome Skyra (32 ch. coil) using a slice acceleration of 4 (MB=4), voxel size 1.8x1.8x1.8 mm^3, and an oblique slice orientation. The relative phase was iteratively estimated and for each set of slices and diffusion direction, a new **MBGRAPPA** kernel is calculated for the slice-GRAPPA algorithm (a representative sagittal slice is shown in figure 3). For quantification, the data was corrected for head motion, eddy current and geometric distortions, followed by fiber orientation mapping in FSL{3,4}. In Figure 4, quantitative maps for areas supporting a 3rd fiber are shown overlayed on anatomy. Voxels (blue) in the centrum semi-ovale area (along the superior longitudinal fasciculus) detect more fibers when the dynamic phase update is used. **Conclusion:** The relative phase between multiband slices is importance for accurate separation of simultaneously acquired slices. The relative phase can be estimated from a sensitivity weighted reconstruction of unaliased multi-slice data. Using the correct phase results in a reduction in uncertainties of fiber orientation estimation in diffusion imaging. The use of higher accelerations, including the combination of in-plane and slice accelerations, will increase sensitivity to motion and the subsequent variability on the relative phase difference. In this particular data set, while the improvements demonstrated reduced uncertainties in 3rd fiber detection, they did not significantly affect 1st and 2nd fiber orientation estimation.

References: [1] Moeller, MRM 63(5):1144-53, 2010, [2] Setsompop, MRM 67(5):1210-24, 2012, [3] Behrens, MRM, 50(5):1077-1088, 2003, [4] Anderson, ISMRM 2012, p2426. **Aknowledgement:** P41 EB015894, S10 RR26783 and WM KECK Foundation, P30 NS057091, P30 NS076408, Human Connectome Project (1U54MH091657-01).