RO extended FOV SENSE/GRAPPA for multiband imaging with FOV shift

Steen Moeller[1], An T Vu[1], Edward Auerbach[1], Kamil Ugurbil[1], and Essa Yacoub[1]
[1]*Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, Minnesota, United States*

Target Audience: Investigators using slice-accelerated acquisitions (where multiple slices are acquired simultaneously) and developers of reconstruction algorithms.

Purpose: The objective is to demonstrate that the recently reported performance challenges for multi-sliced accelerated acquisitions are more algorithmically dependent than previously reported{1,2}, and that the originally proposed SENSE/GRAPPA algorithm developed for multi-slice imaging indeed is compatible with FOV shifting (controlled aliasing) contrary to reported results, and that the SENSE/GRAPPA approach exhibits desirable properties. **Introduction**: Methods for simultaneous multi-slice imaging {3}with parallel imaging reconstruction have been quite extensively developed {4,5}lately due to the need for such acquisitions in the Human Connectome project. The SENSE/GRAPPA approach has been previously used in applications of slice CAIPIRINHA {6}. However, in the Blipped-CAIPIRINHA {5} approach, where slice accelerations are combined with a relative FOV shift between simultaneously excited slices, the approximate “slice-GRAPPA” unaliasing algorithm {5} has been the method of choice. The efficacy of the slice-GRAPPA algorithm has been analyzed in {1}, where the concept of residual slice-leakage was introduced through a monte-carlo analysis. A similar metric was used in {2} to improve the slice-GRAPPA algorithm by constraining the slice-leakage. Recently, it was described that for SENSE/GRAPPA with CAIPIRINHA an additional extended synthetic FOV could be introduced into the SENSE/GRAPPA algorithm to alleviate artifacts present in applications of slice-GRAPPA {8}. The advantage of this is that techniques originally developed for GRAPPA can be utilized, including sliding and overlapping kernels {7}. **Methods**: The SENSE/GRAPPA algorithm is applied with an extended concatenated FOV along the RO direction (Fig 1C), contrary to {5}, where it was implemented along the PE direction, as shown in Fig. 1A. It was shown in {5} that the discontinuity between slices with shifted signals introduced significant artifacts in the unaliased signals when using a SENSE/GRAPPA approach. The synthetic extended FOV algorithm from {8}, illustrated in Fig. 1B, was originally proposed with a 1/NBAND extension of the FOV, is evaluated here for even larger FOVs. A single-band multi-slice monopolar dual echo GE/FLASH acquisition with FOV =21x16*13.5cm and resolution 0.9x2.5mm, was used for the evaluation presented in figure 1. The first echo was used for calibration, and the second was used to synthesize a multiband acquisition with a relative FOV shift between aliased slices. To investigate the impact on high-quality multiband data, 3T data from the WashU human connectome project was obtained and analyzed for slice leakage with the different algorithms. Both a 1.25mm (MB3 SE-EPI) diffusion dataset (Fig. 3) and a 2mm MB8 GRE-EPI resting state fMRI dataset (data not shown) were tested. To evaluate total leakage, the unaliasing of the sum of all slices, except one, is considered, and shown in Fig.2. (top row). The same concept was used in {2} and provides an easy measure (compared with the L-factor) for the inability to separate signals from different slices. The difference between the reference single band data and unaliased synthetically generated multiband data is shown in Fig. 2 (second row). **Results and Discussion**: For the 1.25mm diffusion data, the total leakage for a representative slice is shown in Fig. 3C, with the anatomical location represented in Fig. 3b. An elevated level of total leakage is observed in Fig. 3C, although far less as compared with the FLASH in Fig. 2. The differences between the different reconstructions is shown in Fig. 3A for both the b=0, and the 4 sequentially acquired but unique diffusion weighted images. The variation in difference between the reconstruction algorithms exhibits a spatial correlation with the elevated residual aliasing in Fig. 3C.

Conclusion: The original SENSE/GRAPPA algorithm is compatible with shifted FOV encoding as introduced in CAIPIRINHA and Blipped- CAIPIRINHA. Considering slice-leakage, the RO concatenated SENSE/GRAPPA reconstruction has lower artifact levels compared with slice-GRAPPA and the synthetically extended and concatenated PE FOV with SENSE/GRAPPA. For high-resolution data, such as those from the Human Connectome Project, the differences in the reconstructions between the algorithms are less smaller. Further, with the extensive analysis techniques and the quality control of both diffusion and resting-state data from the Human Connectome Project, the effect of the higher signal leakage has not been observed to be problematic{9}, albeit for higher accelerations reduction in leakage can be expected to be more critical . **References**: 1.[Xu, Neuroimage 2013], 2.[Setsompop, MRM 2013], 3.[Larkman, JMRI, 2001], 4.[Moeller, MRM 2010], 5.[Setsompop, MRM 2012], 6.[Breuer, MRM 2005], 7.[Wang, MRM, 2005], 8.[Blaimer, MRM 2013]. 9.[Neuroimage, 2013, special issue] **Acknowledgement**:P41 EB015894, P41 RR008079, P30 NS5076408, P30 NS057091, U54 MH091657.

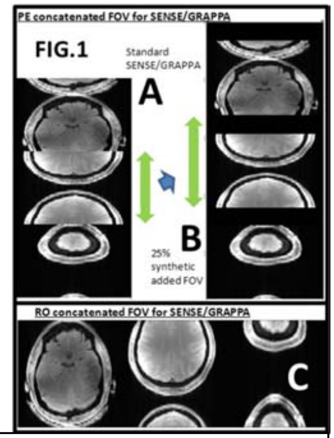

Fig1. A/ the concatenated slices along PE for SENSE/GRAPPA. B/ with synthetic gaps. C/ concatenated along the RO direction

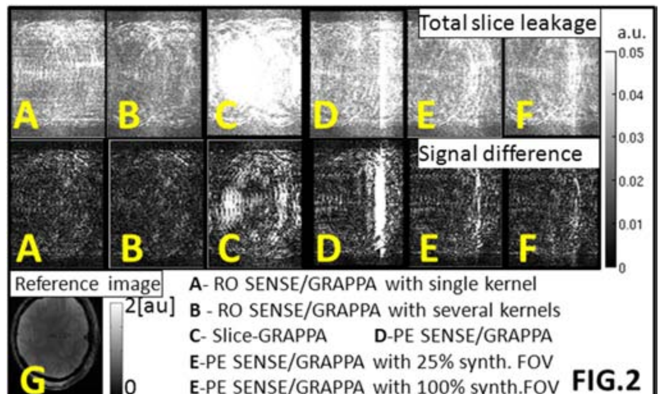

Fig2. Top row/ signal leakage for 6 different reconstructions. Middle row/ Difference to ground truth in 2G. Gray scales are in [a.u.]

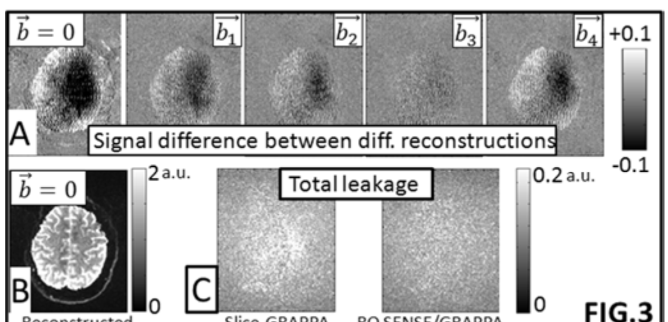

Fig3. A/The difference between 2 recon. for different diffusion directions. B/ the b=0 image C/ the leakage maps relative to 3B.