Robust calibration strategy for multiband EPI at 7 Tesla

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Introduction: Multiband echo planar imaging (EPI) is an important enabler for achieving high temporal and spatial resolution for connectivity studies in the brain [1-2]. We describe a novel calibration procedure for multiband separation and reference phase correction, and demonstrate its performance in phantoms and *in vivo* at 7T. This procedure ensures spatial alignment of the calibration slices and the desired imaging slices.

Methods: The studies were conducted on a GE [Waukesha, WI USA] Discovery MR950 7 Tesla human research system with a 2 channel transmitter and 32 channel receiver array developed by Nova Medical [Wilmington, MA USA]. Multiband excitation was performed by modulating a single windowed sinc excitation pulse by $(1+2*\cos(2\pi\Delta ft))$, where Δf is the frequency shift in Hertz corresponding to the desired slice displacement. 30 kHz separation was used, corresponding to 30 mm in the example data. Two similar pulses are also constructed with constant phase shifts of $2\pi/3$ and $-2\pi/3$ for the outer two slices. Subsequent excitations with the three pulses thus allow the slices to be separated directly using a discrete Fourier transform. These pulses were incorporated into a gradient echo EPI sequence, and a single image set with each pulse was acquired to prepare calibration data for slice separation. An additional set of 3 reference scans was acquired without phase encoding gradients to determine the phase correction parameters for EPI reconstruction. Finally, a series of time points was acquired with the in-phase multiband pulse to provide images for the desired functional dataset. Volunteer scans were performed under an IRB-approved protocol with informed consent. Data were transferred offline for reconstruction and analysis.

The flow-diagram of the calibration data preparation is shown in Figure 1. The slice separation coefficients were then determined from the calibration data by concatenating the simultaneously excited slices into a large FOV[3], by using the ARC algorithm [4]. These kernel coefficients were then used to separate simultaneously excited slices in the actual data.

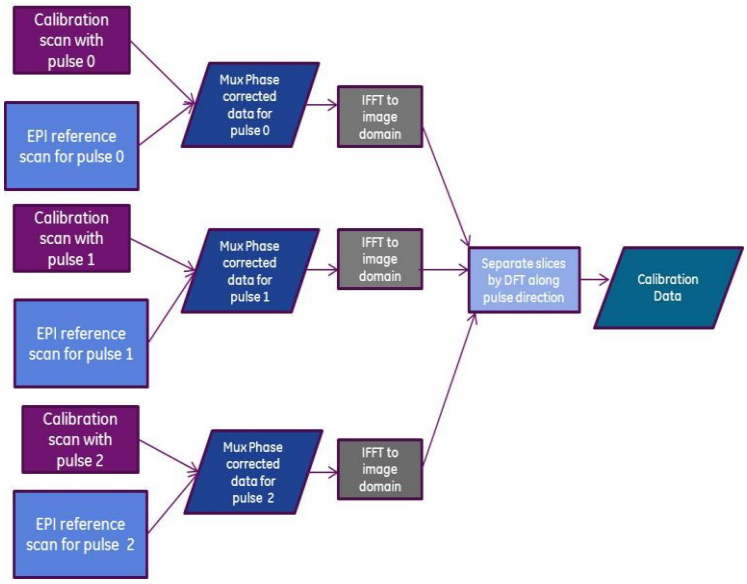

Figure 1: Flow-diagram of calibration strategy

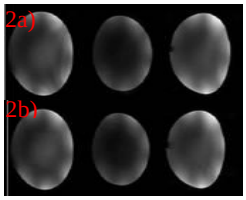

Figure 2 shows phantom results for 3 simultaneously excited slices **a)** separated by DFT **b)** by ARC

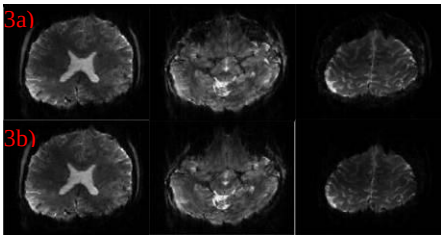

Figure 3 shows in vivo results for 3 simultaneously excited slices a) separated by DFT (calibration data) b) separated by ARC

Results and Discussion: Figures 2 and 3 show results from a spherical phantom and a normal volunteer. In both of these figures, the top row shows the calibration data and bottom row shows the same simultaneously excited slices separated by the ARC algorithm. Good separation with minimal slice crosstalk is clearly demonstrated. Image distortion can be reduced by incorporating in-plane acceleration.

Determination of the slice separation coefficients in multiband acquisitions is generally performed using single slice acquisitions. Care must be taken to avoid geometric distortion effects due to gradient nonlinearity and static field distortions, particularly at 7T. This method, by using equivalent modulation schemes for both the calibration scans and the actual acquisition guarantees that to whatever extent the effects are present in the actual acquisition, they are similarly present in the calibration and thereby compensated. This procedure adds very little time to the experiment and can be fully automated.

References

(1) Moeller S et al, MRM 63: 1144-1153, 2009 (2) Setsompop K et al, MRM 0?1-15,2011 (3) Blaimer M et al, JMRI 24, 444 (2006) (4) Beatty P.J, ISMRM 2007 #1749