T1FLAIR PROPELLER with parallel imaging using simultaneous crossed blade calibration APPEAR

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Introduction: The PROPELLER method has been widely shown for improving image quality in the presence of voluntary and involuntary subject motion [1]. PROPELLER with externally calibrated data driven parallel imaging has been demonstrated to improve fast spin echo (FSE) T1 FLAIR contrast by reducing the echo train length (ETL) [2]. Simultaneous calibration has been demonstrated to allow improved parallel imaging performance by training the reconstruction to a single optimal solution over multiple data sets [3]. In this work we present a method that uses simultaneous calibration on crossed external calibration blades to enable further reductions of the effective ETL for improved image contrast and reduced SAR as well as improved robustness of the external calibration method.

Methods: Normal volunteers were imaged on a standard clinical 3 T MRI system (MR750, GE Healthcare Waukesha, WI) using an 8 channel brain coil (MRI Devices, Waukesha, WI). Acquisition parameters included TR = 3 s, FOV ~24 cm × 24 cm, 384 readout, 28 x 5 mm interleaved slices in 2 acquisitions and BW = ±50 kHz. Acquisitions were performed using either ETLs of 7 (TE = 28.6) or 11 (TE = 44.1 ms) with linear view ordering to limit T2 blurring. Total scan time was fixed at 5 min for both acquisitions and 45 blades were acquired to maintain sufficient angular sampling following possible rejection of some blades due to extreme head motion. Two calibration blades per slice were acquired during the preparatory excitations designed to bring the magnetization to steady state with an oversampling factor of 2x in the frequency encode direction. The kernel width of the 3x undersampling pattern is 4, thus for the 7 ETL acquisitions no oversampling of the calibration blade was performed in the phase encode direction during data acquisition to allow at least 4 fit locations while for 11 ETL acquisitions an oversampling of 1.5x was performed while maintaining 4 fit locations along the phase encoding direction. The APPEAR non-Cartesian parallel imaging algorithm was used to determine the calibration coefficients using synthesized data interpolated from the calibration blades onto the kernel patterns determined by the undersampled imaging blade geometry [4]. Numerical simulations were performed to compare calibrating on only a single calibration blade to simultaneously calibrating on the data from the 2 orthogonally oriented calibration blades. The effective reconstructed imaging blade widths were 27 for the 11 ETL scan and 19 for the 7 ETL scan to allow effective motion correction [4]. The conventional motion correction algorithm described by Pipe et al. [1] was used. A total of 12 paired ROIs were used to measure signal in the grey and white matter and noise across image slices and in multiple regions of the brain.

Results: Numerical simulations of the 7 ETL acquisition demonstrate incomplete unaliasing when the calibration blade and undersampled imaging blades are parallel due to the limited number of fit locations in the direction of the undersampling (Fig. 1, white arrows) and zero-filled blades acquired at 0 and 90 deg. are shown for reference (top row). However when calibration is simultaneously performed on data from the 2 orthogonal calibration blades, a significant reduction in aliasing is observed for the imaging blades in both directions. Axial images from a normal volunteer demonstrate improved grey-white matter contrast with the reduced 7 ETL acquisition and crossed blade calibration with no scan-time penalty (fig. 2, arrows). An average increase in contrast of 39% was measured in the 7 ETL data compared to the 11 ETL. Despite the increased number of sampled points in the 11 ETL datasets by fixing the acquisition time and number of acquired blades, Grey-white matter CNR in volunteers from the 7 and 11 ETL scans were 18.6 and 17.9 demonstrating an increase in the signal difference between grey and white matter due to the reduced effective TE time.

Conclusions: Coil-by-coil data driven parallel imaging is known to have limitations in unaliasing the imaging data along a given direction if the k-space coverage of the calibration data is limited in this same direction. We present a method to calibrate using data acquired during the preparatory excitations used to bring the FSE acquisition to steady state, resulting in no scan-time penalty. PROPELLER and APPEAR combined with a simultaneous external calibration on two orthogonal blades was demonstrated to provide greater unaliasing performance in directions with limited k-space coverage for a single calibration blade method. This parallel imaging improvement allowed both a reduction in the acquired ETL length for improved T1FLAIR contrast and reduced SAR as well as a greater effective acceleration in blade width to maintain motion correction capability.

References: [1] Pipe et al. MRM 1999;42:963-969. [2] Holmes et al. ISMRM 2011 A4584. [3] Brau et al. ISMRM 2008 A1300. [4] Beatty et al..ISMRM 2007 A335.

Figure 1. Data acquisition scheme showing calibration blades acquired first followed (purple), by accelerated imaging blades (tan).

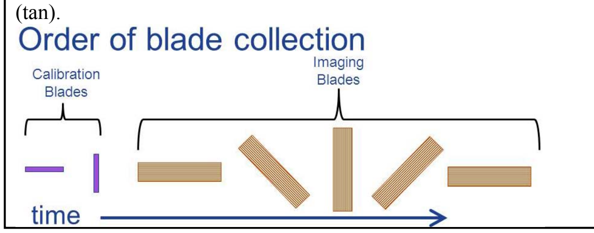

Figure 2. Numerical simulations of an ETL of 7, showing parallel imaging performance using a single calibration blade and two perpendicular calibration blades with respect to the orientation of calibration blade to the undersampled imaging blade. For reference, zero-filled blades with no parallel imaging are shown. Two reconstructed imaging blades (center columns) and the difference images between fully sampled and the reconstructed blades (right columns) are shown. Calibration performed on single calibration blades resulted in incomplete unaliasing (arrows). Significant reduction in aliasing is visible when using the simultaneous crossed calibration on both blades.

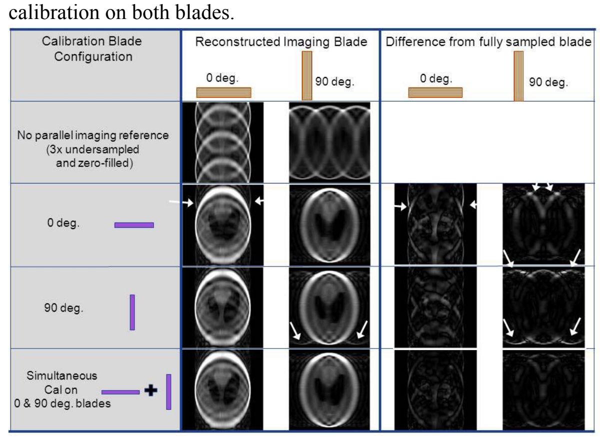

Figure 2. Axial images in a volunteer showing improved grey-white matter contrast with reduced TE and ETL (arrows).