Body DWI Using nCPMG FSE

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Introduction: Body MRI has progressed as a detection method for many pathologic processes (e.g., oncologic diagnosis/staging/restaging/monitoring, inflammatory bowel disease, gynecological disorders). Extending DWI to body MRI poses additional technical challenges to a conventional DW-EPI sequence such as organ movement, and off-resonance due to proximity to gases in bowels and lungs, as well as chemical shift from lipids.[1] Despite these challenges, DWI is increasingly used in many body MR protocols.[2] While single-shot FSE acquisitions could be used to improve robustness to off-resonance, this is problematic as diffusion weighting leads to the loss of the CPMG condition. Various methods have been proposed to work around the loss of CPMG condition, but suffer loss of SNR, increased readout time, or high flip angles. We propose modifications to the nCPMG ss-FSE sequence[3] including SENSE reconstruction[4] and shorter echo mixing gradients[5] for body DWI applications.

Methods: A ss-FSE sequence was modified to include the phase cycling in [3] to facilitate robust DWI (Fig. 1). This phase cycling leads to an additional (1,-1,1,-1…) phase on the quadrature component of the signal and thus aliasing (Fig. 2). The in-phase and quadrature components can be separated by doubling the FOV_y or by reacquiring phase-encodes at a cost of doubling the echo train [3,6]. We propose instead to use the b_0 image using a standard ss-FSE acquisition and extracting coil sensitivity maps through ESPIRiT.[4] With these maps, the *k*-space from the odd and even echoes from the nCPMG sequence are separated (Fig. 3) and used to separately reconstruct images with SENSE and the images averaged. Mixing gradients were also added (Fig.1), though they were added to the *z*-gradient as opposed to *x*-gradient [5] in order to achieve the minimum possible echo spacing. Scans were performed on a GE 750 3T scanner. Agar phantom images were acquired using FOV=24cm, 192x128 matrix, TE/TR=50ms/1500ms, and a 32-channel head coil. *In vivo* scans were performed on a male child with FOV=36cm, 192x128, TE/TR=50ms/1500ms, and a 32-channel cardiac array. In all DWI cases b=500 s/mm^2. All images were acquired with 56% partial k-space. A separate EPI DWI (b=500s/mm^2, NEX 8) was obtained as a clinical standard for comparison purposes.

Results: The phantom images in Fig. 4 suggest that the proposed method does cleanly resolve the image where the CPMG condition is violated. This is most clearly seen in the DWI where a normal ss-FSE acquisition leads to ghosting and signal dropout. The acquisition with the RF phase cycling and mixing crushers (nCPMG ss-FSE) shows that these artifacts largely disappear. The *in vivo* images (Fig. 5) show a similar trend. Comparing with standard EPI images, we also notice the nCPMG ssFSE images do not show the image distortion and signal dropouts that are usually seen in abdominal EPI images. A large fat signal is still present as standard fat suppression techniques have not yet been used.

Discussion: We have implemented a nCPMG ss-FSE sequence and have applied it to abdominal DWI to generate distortion-free images. The novel additions include SENSE reconstruction, optimal mixing gradients, and the application to body DWI. Future work will feature generation of ADC maps to evaluate against EPI-DWI in the clinic. **Acknowledgements:** GE Healthcare, NSF DGE-1147470, NIH P41 EB015891, NIH R01 EB009756 **References:** [1] Attariwala, JMRI, 2013 [2] Kohl, Amer. Jour. Of Roent., 2012 [3] LeRoux, JMRI, 2002 [4] Uecker, MRM, 2014 [5] Pipe, ISMRM, 2009 [6] Bastin, MRM, 2002

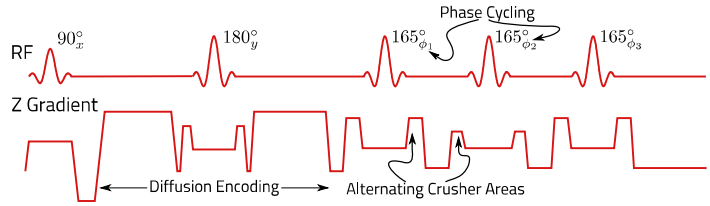

Figure 1: nCPMG ssFSE sequence with alternating crusher areas

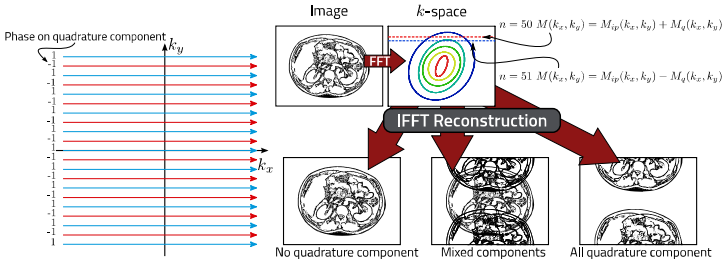

Figure 2: (*left:*) Illustration of alternating quadrature component of M_{xy} for nCPMG ssFSE (*right:*) Effects of signal modulation

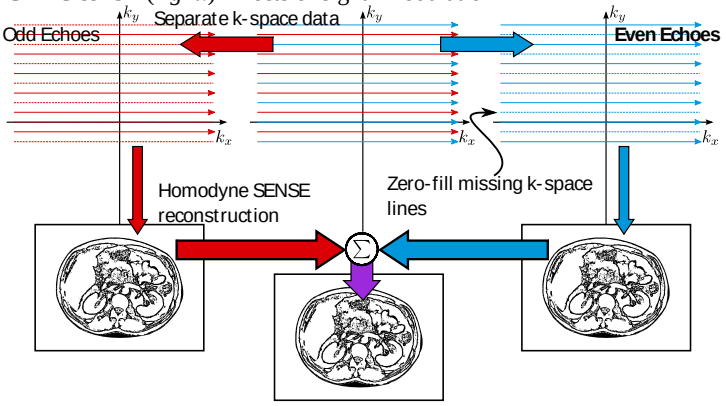

Figure 3: Reconstruction flow for nCPMG ssFSE

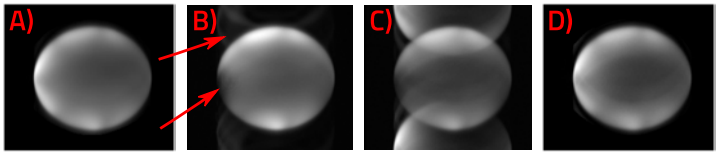

Figure 4: Agar phantom A) normal FSE acquisition B) DWI with FSE acquisition, b=500s/mm^2 C) DWI with nCPMG FSE without SENSE reconstruction, b=500s/mm^2 D) DWI with nCPMG FSE with SENSE reconstruction, b=500s/mm^2. Note the signal dropout and ghosting for the DWI-FSE acquisition (B).

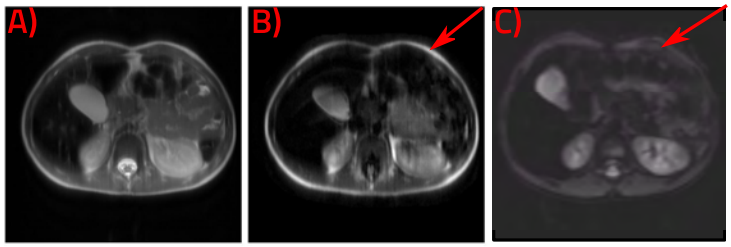

Figure 5: abdominal images A) standard ss-FSE acquisition B) nCPMG ss-FSE b=500 s/mm^2 C) Standard clinical DWI EPI acquisition with 8 NEX overscans, b=500 s/mm^2