

PROPELLER DUO: Applied to Diffusion-Weighted Imaging

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Introduction: Fast Spin Echo (FSE) could suffer from the non-CPMG condition that results in destructive echo interference, unstable echo train and signal cancellation. Diffusion-weighted (DW) PROPELLER [1], an FSE-based sequence, mitigates the non-CPMG issue by XY phase cycling [1] combined with split-blade acquisition [2]. However, XY phase cycling requires refocus flip angle be close to 180° to stabilize echo train, resulting in long scanning time on 3T due to SAR limitation. DW SPLICE PROPELLER [3] is another approach without the high flip angle constraint. SPLICE [4] uses imbalanced readout gradient and extended acquisition window to split all the echoes in pathways into two self-coherent echo groups, E1 and E2. Destructive interference between E1 and E2 is naturally avoided because they are acquired and reconstructed separately. The tradeoff of SPLICE PROPELLER is the increased echo space and scanning time. In this work, a novel PROPELLER sequence is presented. Instead of using imbalanced readout gradient, “phaser” gradients are used to separate E1 and E2 into two perpendicular blades in a single k-space. Echo interference is avoided by the phase correction during PROPELLER reconstruction. The sequence is named as PROPELLER DUO, based on the facts that the “two” echo groups (E1 and E2) are separated and form “two” blades in a single shot.

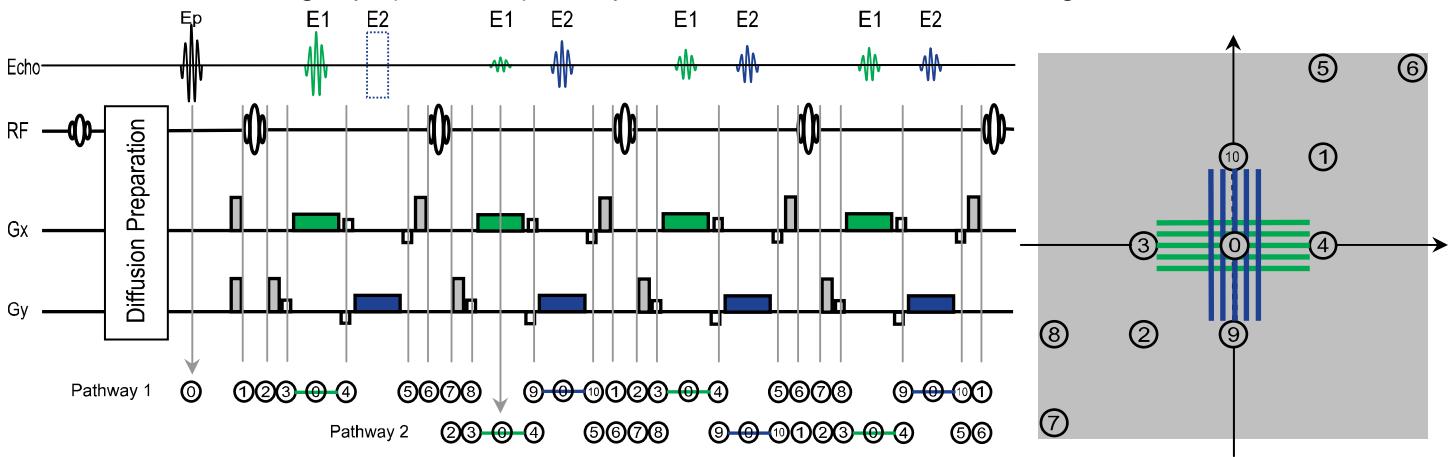


Figure 1. The pulse sequence of PROPELLER DUO (a) and its k-space illustration (b).

Methods: As shown in figure 1a, all the E1 echoes are acquired during X readout gradients (green), while all the E2 echoes are acquired during Y readout gradients (blue). E1 and E2 are separated into two perpendicular blades (Figure 1b) by the synchronized play-out of the readout gradients, the refocus RF pulses, and the phaser gradients (grey). This is illustrated by two echo pathways. Pathway 1 is the pure spin echo pathway starting from the primary spin echo (Ep in Figure 1a). Pathway 2 shows the first stimulate echo (starting at the 2nd E1) and following spin echoes. A pathway's k-space dynamics is indicated by a series of circled numbers whose k-space positions are shown in figure 1b. The echoes in a pathway are alternatively placed in E1 blade and E2 blade. In real implementation, each readout gradient has a pair of side crushers (not shown here) to eliminate the possible interference of signal from high k-space region. The constraint of the pulse sequence is, along each gradient axis, the area of a phaser gradient shall be half of the readout gradient.

Experiments and Results: DW PROPELLER DUO was implemented for GE 3T scanners. In vivo data were acquired using 8-channel receiver coil with refocus flip angle 111°, ETL 26, BW +/-50 kHz, NEX 2.5, matrix size 128 x 128, b-value 1000 s/mm². Echoes from the first 2 echo spaces were discarded. ARC and center-out view ordering [5] were used. Within 1 minute 30 seconds, whole brain coverage (>= 20 slices) was achieved. Figure 2 shows the in vivo results.

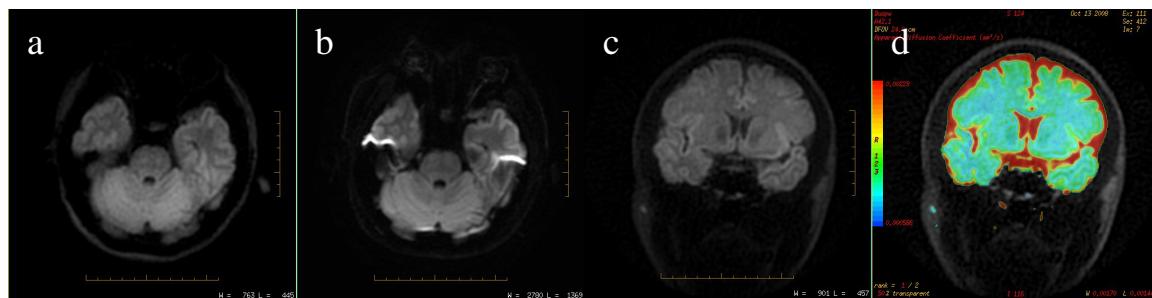


Figure 2. An axial DW PROPELLER DUO image (a) and a DW EPI image (b) for distortion comparison. A coronal DW PROPELLER DUO image (c) and its ADC map (d).

Reference: [1] Pipe, J. MRM 47:42-52 (2002). [2] Pipe, J. 11th ISMRM. p2126 (2003). [3] Deng J. etc. MRM 59:947-953 (2008). [4] Schick F. MRM 38:538-644 (1997). [5] Zhao, X. etc. 16th ISMRM, p3033 (2008).