Robust diffusion-weighted imaging using split-blade PROPELLER and LRX phase modulation

Z. Li[1], X. Zhao[1], D. Huo[2], J. Pipe[2], and P. Le Roux[3]

[1]GE Healthcare, Waukesha, WI, United States, [2]Barrow Neurological Institute, Phoenix, AZ, United States, [3]GE Healthcare, Paleiseau, France

Diffusion weighted (DW) brain image plays an important role in the diagnosis of many neural diseases. FSE-based diffusion imaging techniques are insensitive to susceptibility artifacts. However, they violate the CPMG condition that leads to degraded signal. To address this issue, DW-PROPELLER [1] was proposed by using an XY2 phase modulation. However, this still requires the refocusing RF pulse be close to 180^o, causing SAR issue as well as sensitivity to dielectric effect at 3T. Its echo train length is also limited since the signal decays very fast. Le Roux proposed a phase modulation scheme (LRX) [2] allowing the use of low flip angle as well as long echo train with SSFSE. But this strategy requires double encoding due to the difference between odd and even echoes. In this work, we adapt LRX phase modulation in DW PROPELLER. To avoid double encoding (and thus doubled scan time), odd and even echoes are placed in two perpendicular blades separately [3]. This proposed technique allows longer echo train (i.e., wider blade) and thus less artifact. Its relative robustness to flip angle leads to insensitivity to dielectric effect at 3T. The low flip angle also partially mitigates the SAR issue. The feasibility of this technique was demonstrated with in vivo imaging.

METHOD A standard DW-PROPELLER sequence with split blade method was implemented with LRX phase modulation. With LRX phase modulation, the first few echoes are discarded. The phase of the refocusing RF pulses and the receiver is given in [4]. In [2], it was proposed to acquire two consecutive echoes with same phase encoding, and add/subtract them to obtain the in- and out-of-phase components. In this work, we placed the odd and even echoes from each TR into two perpendicular blades by the split blade method. Mutual calibration [5] is used to further increase the blade width and reduce scan time. Regular PROPELLER reconstruction was performed to generate the image.

EXPERIMENT DW-PROPELLER with LRX phase modulation was implemented on a GE SIGNA 3T scanner. Volunteer data were acquired with an 8-channel brain coil using TR = 6 s, ETL = 32, BW = +-50 kHz, flip angle = 140^o, NEX = 1.5, matrix size = 128 x 128, b value = 1000 s/mm^2, first 4 echoes discarded in reconstruction. For comparison, volunteer data were also collected with XY2 phase modulation using similar imaging parameters except that ETL = 16 and flip angle = 180^o and 140^o, no echoes discarded. Non phase-encoded data were also acquired to demonstrate the signal evolution.

RESULTS AND DISCSUSSION Figure 1 shows the maximal magnitude of k-space lines without phase encoding for both phase modulation schemes at 140^o. This demonstrates that the proposed technique gives more stable signal with less decay. Shown in Figure 2 are in vivo b = 0 (2a, 2c, 2e) and b = 1000 (2b, 2d, 2f) images. Although XY2 phase modulation at 180^o produces good images (2a, 2b), the results at 140^o are significantly degraded (2c, 2d). However, results with LRX phase modulation at 140^o (2e, 2f) are comparable to XY2 phase modulation at 180^o (2a, 2b). This reduction of flip angle effectively loosens the SAR limitation. Other benefits of the new technique include less background artifact, insensitivity to dielectric effect, etc. In conclusion, split blade DW-PROPELLER with LRX phase modulation is more robust to address the non-CMPG condition.

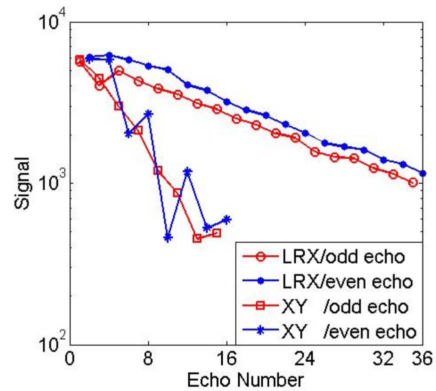

Fig.1 Signal vs echo number for LRX and XY2 phase modulation at 140^o.

REFERENCES:

[1] Pipe, J. MRM. V47, p42-52, 2002.
[2] Le Roux, P. JMR. v155, p278-292, 2002.
[3] Pipe, J. 11th ISMRM. p2126, 2003.
[4] Le Roux, P. 14th ISMRM. p3368, 2006.
[5] Huo, D. 16th ISMRM. P756, 2008.

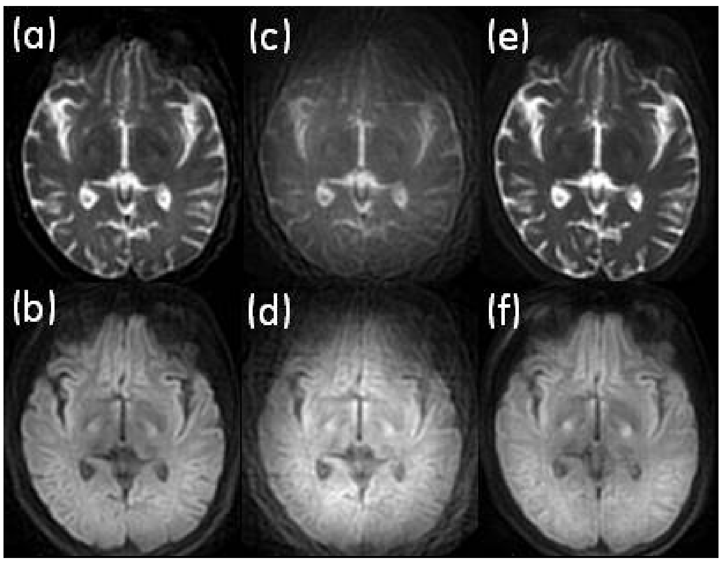

Fig. 2
a,b) are b=0 and b=1000 images with XY2 phase modulation at 180^o.
c,d) are b=0 and b=1000 images with XY2 phase modulation at 140^o.
e,f) are b=0 and b=1000 images with LRX phase modulation at 140^o.