# DYNAMIC AND INHERENT B0 CORRECTION FOR DTI USING STIMULATED ECHO SPIRAL IMAGING

**A. V. Avram[1,2], T-K. Truong[2], A. Guidon[1,2], C. Liu[2], and A. W. Song[2]**
[1]Biomedical Engineering Department, Duke University, Durham, NC, United States, [2]Brain Imaging and Analysis Center, Duke University Medical Center, Durham, NC, United States

## Introduction

Off-resonance effects (due to eddy currents, tissue susceptibility, chemical shift, $B_0$ inhomogeneities, or hardware instabilities) can significantly degrade diffusion tensor imaging (DTI) images especially at high fields. In spiral DTI these dynamic effects cause image blurring and inaccurate estimates of fractional anisotropy (FA). Previous methods to address these problems include acquiring a field map during an extra scan (does not correct for intra-scan variations), estimating the field map from the acquired data [1] (less robust), segmenting the acquisition to reduce the readout window (increases scan time, does not correct for intra-scan variations) or acquiring a dynamic field map [2], for example using a spiral-in/out navigator (significantly restricts the time available for diffusion preparation in spin-echo DTI). In this work we present a new technique for dynamic off-resonance correction in DTI using a stimulated echo (STE) implementation. For white matter signal (T2=69ms) the increase signal at short echo time (TE=22ms, b=600s/mm$^2$) achieved with STE compensates for the 1/2 signal loss compared to spin echo (TE=70ms, b=600s/mm$^2$), while the long diffusion time enables imaging at large b-values. Moreover, this implementation further allows for the simultaneous acquisition of a dynamic field map (through a secondary spin echo coherence pathway) that can be used to inherently correct for artifacts due to $B_0$ inhomogeneities. To complement this dynamic off-resonance correction, we also incorporated a self-navigated interleaved spiral (SNAILS) acquisition [3] that inherently corrects for non-linear phase errors (e.g. due to motion). Taken together, our integrated technique will be able to improve the spatial accuracy of DTI in an inherent and dynamic manner, while achieving large b factors and preserving a short TE. It is hoped that this new methodology will find increased utility in modern DTI applications where both spatial accuracy and tissue specificity (e.g. myelin water with short $T_2$) [4] are desired.

## Methods

A STE SNAILS DTI sequence was implemented on a GE 750 3-Tesla MRI scanner. In addition to the stimulated echo (which is formed after the third 90$^o$ pulse), a separate spin echo coherence pathway formed by the 1$^{st}$ and 2$^{nd}$ 90$^o$ pulses is preserved and used to successively acquire two images at different TEs. These two images can then be used to determine a field-map for every diffusion-encoding direction. The pulse sequence is illustrated in Fig. 1.

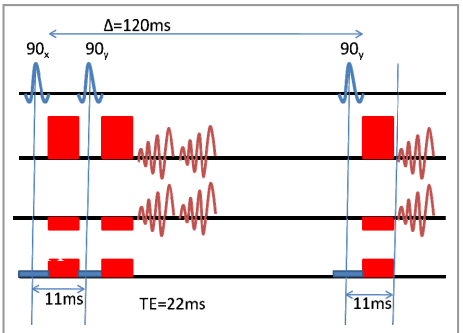


**Figure 1:** Pulse sequence schematic for STE SNAILS DTI with dynamic field map correction.

A set of DTI images were acquired with a matrix size of 192x192 on a 24x24cm$^2$ FOV with 10 interleaves, 5 slices with 5mm slice thickness, TE/TI/TR=22/125/4000ms, b=600s/mm$^2$, 11 directions. Within each diffusion direction, an additional set of symmetric and asymmetric spin echoes were acquired using the same spiral readout but with a TE difference of 25ms. To estimate the field map the phase images from these two additional echoes were unwrapped and subtracted. For each diffusion direction, the corresponding field map was then used to dynamically correct the STE DTI image using a conjugate phase reconstruction [5] with simultaneous motion correction [3]. It should be noted that the diffusion weighting in the spin echo pathway used to generate the dynamic $B_0$ map was only b=55s/mm$^2$ and any phase errors accumulated due to motion were eliminated by the subtraction of the two echoes.

## Results

All images (DTI and field maps) were acquired within one DTI series. As shown in Fig. 2B and 2D, both baseline and individual diffusion weighted images were inherently corrected, as compared to the uncorrected images in 2A and 2C. It can be seen that the various local blurring artifacts are specifically corrected, leading to greatly improved spatial accuracy.

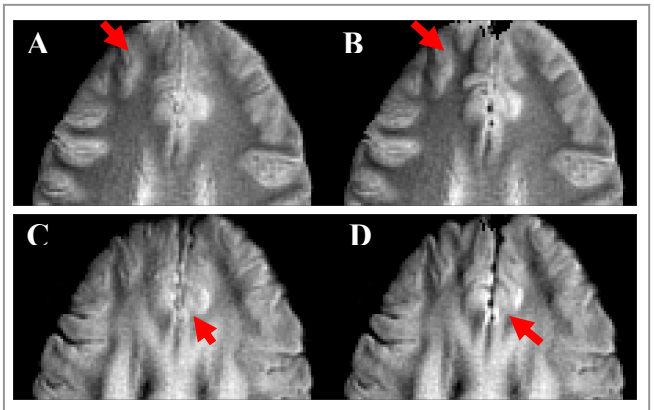


**Figure 2:** Original (A) and off-resonance corrected (B) non-DW images. Original (C) and off-resonance corrected (D) DW image

Because the use of STE acquisition also effectively preserves short TE while maintaining large b factors, it would allow sufficient sensitivity for many short $T_2$ species (such as myelin water) to facilitate tissue-specific microstructural imaging using DTI.

## Conclusions

A new and integrated DTI acquisition technique based on STE spiral imaging was proposed and implemented. It can simultaneously generate DTI images and field maps along individual diffusion directions. Our preliminary results show that this new technique can inherently and dynamically correct for off-resonance effects and motion-induced non-linear phase errors, while preserving short echo time and large b factors.

**References: 1**. Noll et al., MRM 1992;35:319, **2**. Truong et al., MRM 2010;64:1121, **3**. Liu et al. MRM 2004;52:1138, **4**. Avram et al., Neuroimage 2010;53:132, **5**.Noll et al. IEEETMI 1991;10:629.