Symmetric vs. Asymmetric Undersampling in 3D Cones Imaging

Michael Carl[1], James H Holmes[2], and Graeme McKinnon[3]
[1]*GE Healthcare, San Diego, CA, United States,* [2]*GE Healthcare, Madison, WI, United States,* [3]*GE Healthcare, Waukesha, WI, United States*

Introduction: Imaging very short T2 tissues frequently encountered in the musculoskeletal system using MRI requires specialized pulse sequences with very short echo times (TE). To address this challenge, ultrashort TE (UTE) sequences typically begin data acquisition as soon as possible after the RF excitation with k-space acquired in a center-out fashion [1]. Although radial-out sequences are less efficient than Cartesian acquisitions, undersampling the number of k-space spokes acquired is commonly used to accelerate the acquisition time. Typically, in isotropic FID sequences such as 3DUTE, this undersampling is performed symmetrically by skipping k-space lines in all directions. In 3D Cones however, the trajectories inherently lie on conical surfaces (see Fig.1) and therefore have a symmetry axis ('z-axis') allowing designs that support asymmetric FOVs [2] and undersampling. Gurney et al. suggested that selective undersampling along the x-y plane may introduce fewer artifacts than undersampling along the z-axis [3]. The purpose of our study is to demonstrate the feasibility and validate the idea of asymmetric cones sampling using numerical simulations and phantom experiments.

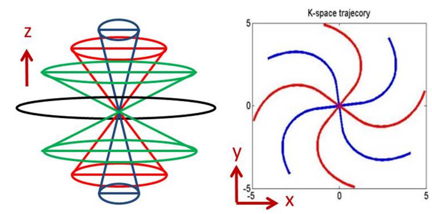

Fig.1: Left: Cones surfaces. K-space trajectories originate at the center and move outwards either straight or curved. Right: Trajectories with duration of 800µs for the equator Cones plane (black).

Numerical Simulations: For a fixed read gradient duration of 800µs, three Cones trajectories with different degrees of undersampling along the x-y or z-direction were designed and the respective point spread functions (PSFs) were generated (Fig.2A & B). The PSFs were generated at twice the FOV (48cm) of the reconstructed images (indicated by the dashed boxes), and at the same adjusted window level in order to allow visualization of aliasing structure in the region outside the supported area. All trajectories were designed to simulate a fixed data acquisition time at 55 sec with isotropic FOV = 24cm, res = 1mm. Also indicated in the figure are the undersampling factors 'under-XY' and 'under-Z'. These factors are multiplied with the desired FOV in the x-y (in-plane) and z (through-plane) directions which are used to generate the Cones k-space trajectories. The PSFs demonstrate significant undersampling for all 3 trajectories (Fig.2A & B) with a symmetric FOV in row 1 and asymmetric FOVs shown in rows 2 and 3. Generally, Fig2.B shows more coherent aliasing signal along the z-axis than the x-axis.

Phantom Experiments: Experiments were performed on a clinical 3T MRI system (Signia HDx GE Healthcare) using a standard resolution phantom inside a T/R head coil. Imaging parameters included BW = ±125kHz, isotropic FOV = 24cm and resolution = 1mm, TE/TR = 0.03/5ms, total scan-time of 55 seconds. The symmetry axis of the Cones design was along the physical z-axis of the MRI system, perpendicular to the axial images shown in Fig.2C,D. These images were also reformatted into the coronal plane as shown in Fig.2E,F. The top row shows results for symmetric undersampling (under-XY = under-Z) with some visible artifacts in both the axial and coronal planes (red ovals). Row two shows the case when the undersampling is preferentially along the z-axis with a visible increase in the artifacts in both the axial and coronal planes (red ovals). Finally, the third row generally shows less artifacts when the undersampling is predominantly along the x-y direction and less along z.

Conclusion: We have investigated the image quality tradeoffs for asymmetric undersampling using the same total same scan time as constrain. Increased undersampling along the symmetry axis of the Cones design (z-axis) was found to increase the artifact appearance, while reduced artifacts were observed when the overall undersampling was performed preferentially in the x-y plane. In future work, we will continue to make use of this asymmetry in the artifact level relative to the isotropic undersampled k-space trajectories to further minimize aliasing artifacts.

References: [1] Rahmer et al. MRM 55:1075–1082 (2006), [2] Larson et al. IEEE TRANS MED IMAG, 27:1 (2008), [3] Gurney et al. MRM 55:575-582 (2006)

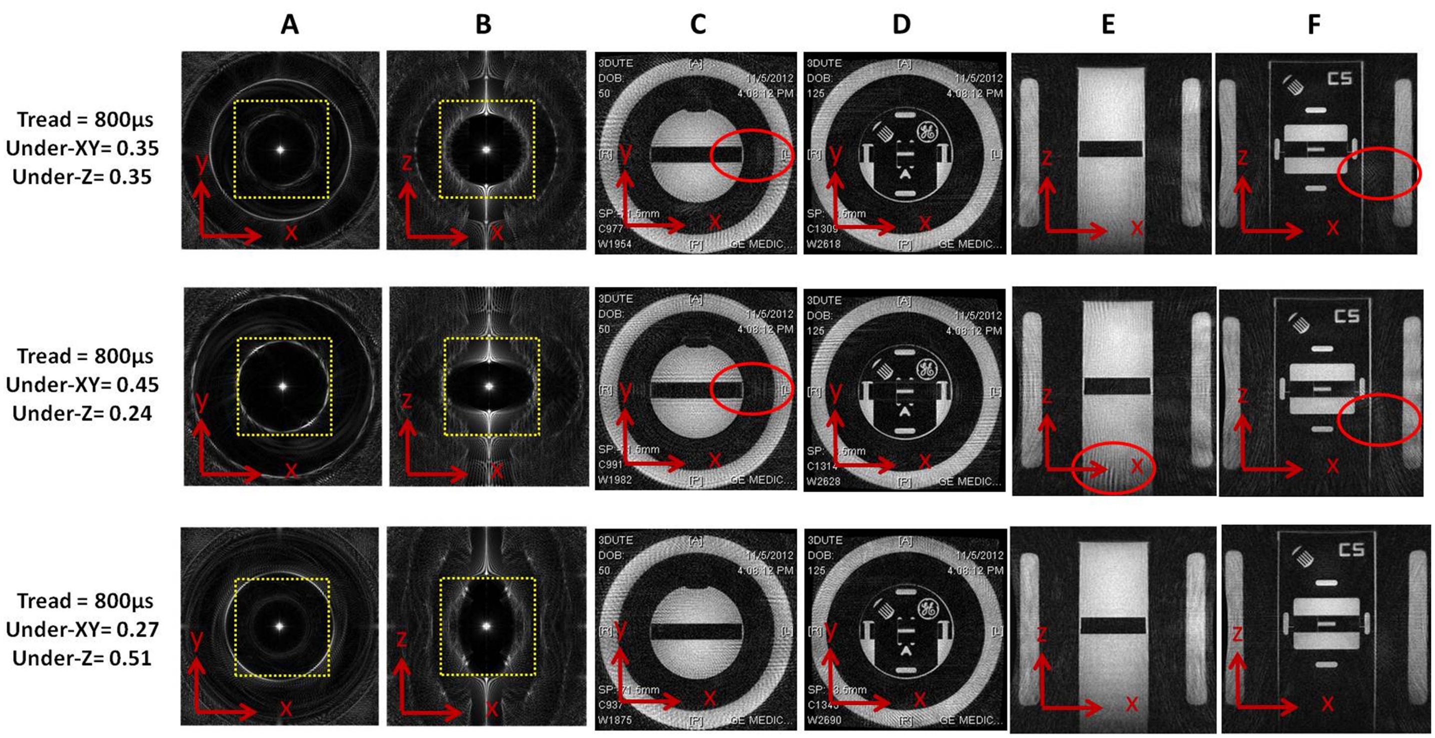

Fig.2: A) Undersampled PSFs shown in the x-y plane (A), and x-z plane (B) for the k-space trajectory in Fig.1 with a readout time of 800µs. C-D) Two axial slices. E-F) Two reformatted coronal slices. Image artifacts are highlighted by the red ovals. As can be generally seen from the second row, additional undersampling along the z-axis (together with less undersampling along x-y to preserve the same scan-time) cause more artifacts. Conversely, additional undersampling along the x-y axis (together with less undersampling along z to preserve the same scan-time) reduces the artifacts.