Two New 3D Spiral-Based Trajectories

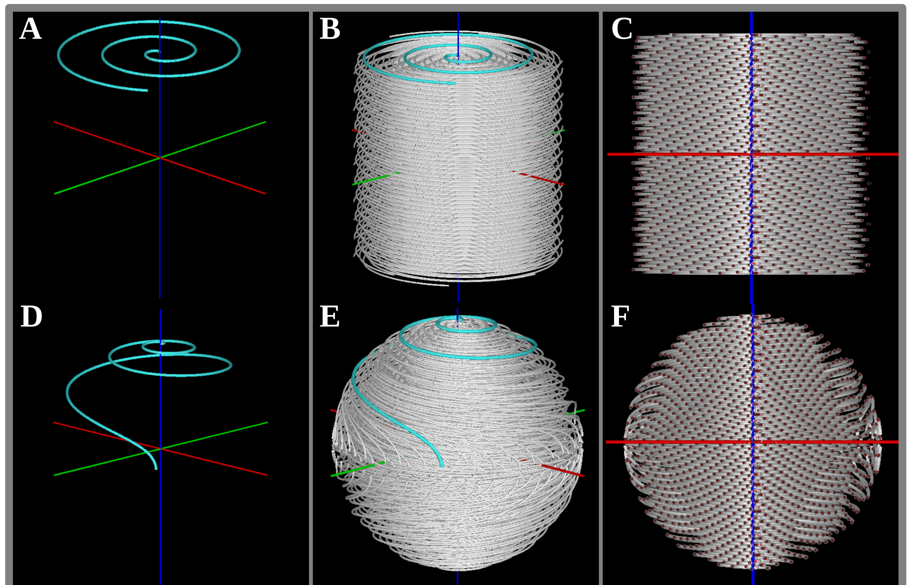
Introduction: This work presents two new 3D spiral-based trajectories comparable to conventional Stack of Spirals (SOS), namely Golden EquiDistant Interleaves (GEDI) and Spherical-GEDI (S-GEDI). Both trajectories have incoherent aliasing patterns in all three directions. S-GEDI collects a sphere in k-space and is not sensitive to 3D blurring nor does it require calculation of multiple spiral waveforms, which are problems present in both conventional Spherical SOS[1] and 3D Stack of Cones[2].

GEDI: The golden angle has been used by several groups because of its uniform sampling distribution in time[3,4] and space[5,6]. Both of our proposed trajectories use M spiral interleaves which are equally spaced along the k_z axis and are rotated in-plane by $\theta \approx m*137.5^o$ where $0<m\leq M$. In SOS, the ability to tailor the ADC time is constrained by the fact that the total number of interleaves is required to be an integer number of interleaves per slice. In the proposed trajectories, M can be any number, leading to greater flexibility in designing the scan compared to conventional SOS, especially for long ADC scans.

S-GEDI: The initial k_z spacing is similar to GEDI in that each interleaf begins at a unique k_z location but in S-GEDI, the k_z location changes with $\sqrt{1-\beta*k_r}$, $0\leq k_r<1$ and $0\leq\beta\leq1$. Radial undersampling of the spiral arm ($dk_r/d\theta$) changes with $1/\sqrt{1-\beta*k_r}$. The product of dk_z/dk_r and $dk_r/d\theta$ produces in a sphere of nearly uniform sampling distribution throughout the sampled volume, as shown in Figure 1F. This is accomplished by adding a single z-gradient waveform after phase encoding that is scaled with each TR.

Results: The PSF of S-GEDI has less ringing than GEDI or conventional stack of spirals, whose PSF are identical. Both GEDI and S-GEDI have incoherent aliasing patterns in all three directions. See Table 1 for a summary of select features.

Conclusion: This method creates two new spiral-based trajectories which are comparable to SOS in terms of scan time, blurring properties, SNR efficiency and ease of implementation while providing an incoherent aliasing pattern in all three directions. The parameter β allows one to create intermediate trajectories between GEDI and S-GEDI.



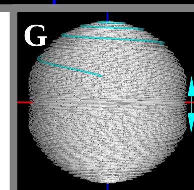


Figure 1. A-C: GEDI. **D-F:** S-GEDI. **A,D**: Single spiral arm. **B,E:** Full k-space volume to be sampled for β=0 and β=1 respectively. **C,F:** Cutting through blue-red axis shows uniform sampling density through center of the volume. **G** shows the effect of having a β value between 0 and 1, creating a sphere with a banded region of (ie) 30% (arrows).

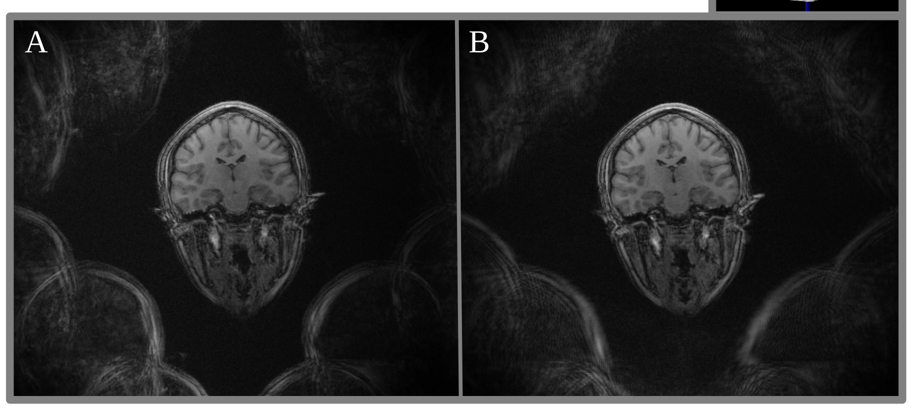
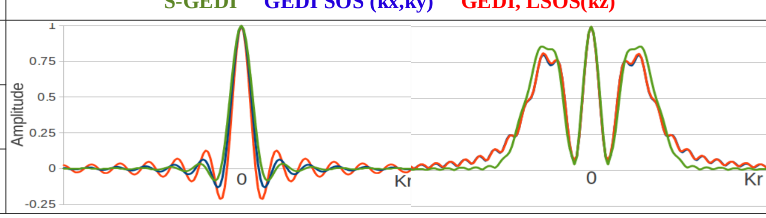


Figure 2: Coronal slices comparing GEDI (**A**) and S-GEDI (**B**). FOV/res 240/1mm, grad 40/130. ADC time 4 ms. Images were gridded to a 512^3 grid to show aliasing pattern outside the prescribed FOV.

Table 1: Features of Spiral-based Trajectories FOV/res 240/1 mm, grad 40mT/m / 150mT/m/ms, ADC:14.3 ms

Trajectory	Volume Covered Matrix (kx×ky×kz)†	PSF* (on resonance) | |PSF|* (100 Hz off resonance) S-GEDI GEDI SOS (kx,ky) GEDI, LSOS(kz)	Interleaves (∝ Total Scan Time)	SNR Efficiency
SOS	Cylinder 272x272x240		2880	.966
GEDI	Cylinder 272x272x240		2880	.964 (-0.2%)
S-GEDI	Sphere 298x298x298		2994 (+4%)	.957 (-0.9%)

*†- Sampled k-space volume for all trajectories normalized to a cube with a 240 isometric matrix. *- Normalized to 1.*

References 1. Gurney et al. MRM. 55:575-582. 2006. 2. Irarrazabal et al. MRM. 33:656-662. 1995. 3. Winkelman et al. IEEE Trans Med Imag. Vol 26. 1:68-77. 2007. 4. Chan et al. MRM. 61:354-363. 2009. 5. Pipe et al. MRM. 10.1002/mrm.22918. 2011. 6. Prieto et al. MRM. 64:514-526. 2010.