Application of FLORET to UTE Imaging

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PURPOSE – Ultra-short TE (UTE) acquisitions require very short echo-times and short sampling windows. Radial trajectories accommodate this requirement but also require a large number of excitations (πN^2, where N is the effective matrix) to sample 3D k-space at the Nyquist distance. The Twisted Projection[1] and Stack of Cones[2] trajectories were proposed as more efficient alternatives to 3D radial for UTE acquisitions. These trajectories substantially reduce the number of required excitations by sampling more of k-space during each excitation. The risk of using such trajectories is that T_2 decay over the longer sampling windows might affect the SNR and resolution of short T_2 components. Pipe et al.[3] introduced the FLORET k-space trajectory (figure 1) based on Fermat spirals. This trajectory is very SNR efficient and is relatively easy to design and implement. This work proposes FLORET as an efficient trajectory for UTE imaging.

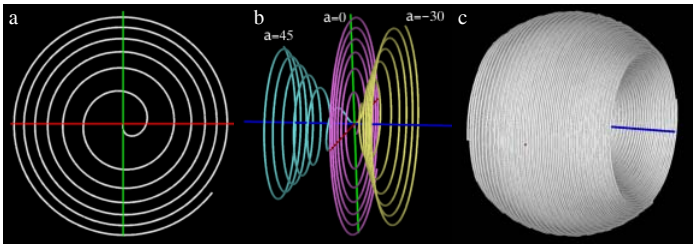

Figure 1: Illustration of the FLORET trajectory. a) A single Fermat spiral is collected per excitation. b) Each successive interleaf is acquired on a unique cone and is rotated by the golden angle. c) A set of cones fills a "hub" with a maximum angular extent defined as the angle of the outermost cone. One or more orthogonal cones are acquired to fully sample k-space.

METHODS – FLORET and 3D radial UTE data of the knee were acquired on a Philips Ingenia 3T using a 2-channel flexible coil. The following parameters were identical across scans: FOV = 16cm isotropic, voxel size = 0.8mm isotropic, TE = 160µs, TR = 7.9ms, sampling readout duration = 2ms, total scan time = 3:26. The FLORET acquisition acquired three perpendicular "hubs" each with a maximum extent of 45 degrees. Variable density sampling was started at 20 percent of the maximum k-space radius and increased linearly to a maximum undersampling factor of 3. The scan time for the radial acquisition was kept equivalent to that of FLORET by acquiring approximately 10 percent of the spokes required to meet the Nyquist sampling condition. A second set of data with TE = 1.5ms was acquired for each dataset with all other scan parameter kept identical to the UTE acquisition. This longer TE data was subtracted from the UTE data to remove signal from longer TE components (figure 2 parts c-d).

RESULTS – The FLORET and 3D radial images are compared in figure 2. Streak-like aliasing artifacts are present in the radial data that are not present in the FLORET data.

DISCUSSION – As indicated by Pipe et al.[3], the SNR efficiency of FLORET is higher than that of the stack of cones trajectory and requires a comparable number of interleaves. Figure 3 compares the effect of T_2 decay on the amplitude of the measured signal for the radial, stack of cones, and FLORET trajectories. Compared to stack of cones, the FLORET trajectory moves more quickly away from the center of k-space providing an advantage in maintaining the resolution of very short T_2 signal components.

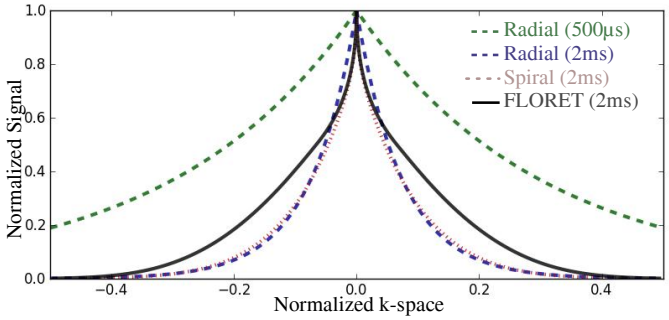

Figure 3: Plot of T_2 decay with k-space location as a 1D cross-section through k-space center. The readout duration is given in parentheses in the legend.

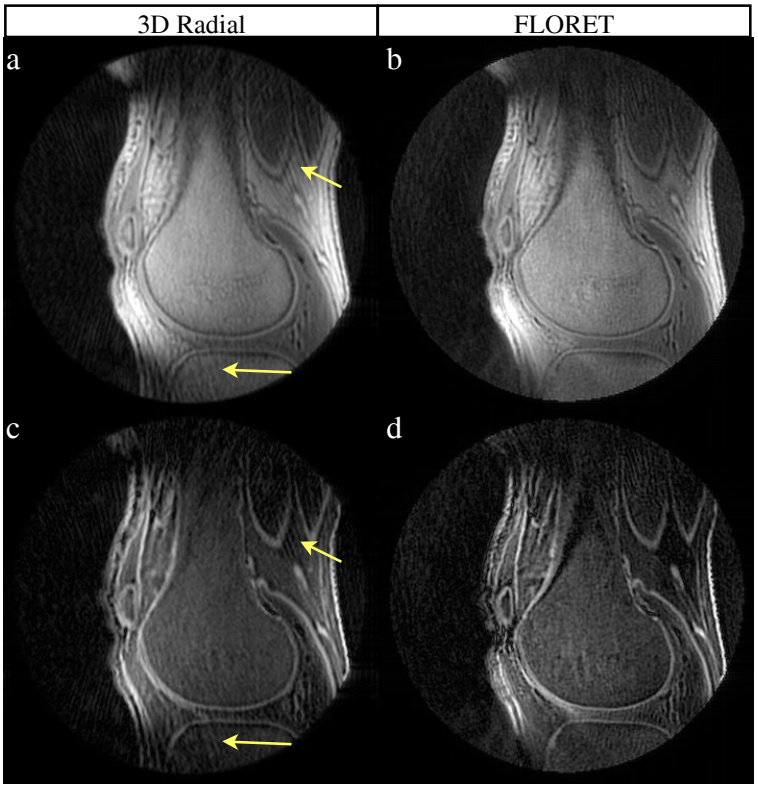

Figure 2: Example of difference in image quality between 3D radial (a, c) and FLORET (b, d) acquisitions. The top row shows UTE data (160µs). The bottom row shows difference images between the UTE data and short TE (1.5ms) data. Arrows highlight streak-like aliasing artifacts.

CONCLUSION – This work suggests that FLORET is an efficient trajectory for UTE acquisitions compared to the 3D radial trajectory and that FLORET is able to better maintain the resolution of very short T_2 signal components than the Stack of Cones trajectory.

REFERENCES – 1. Boada FE, et al. MRM 1997; 38:1022–1028. 2. Gurney PT, et al. MRM 2006; 55:575-582. 3. Pipe JG, et al. MRM 2011; 66:1303-1311.
ACKNOWLEDGEMENT – This work was funded in part by Philips Healthcare.