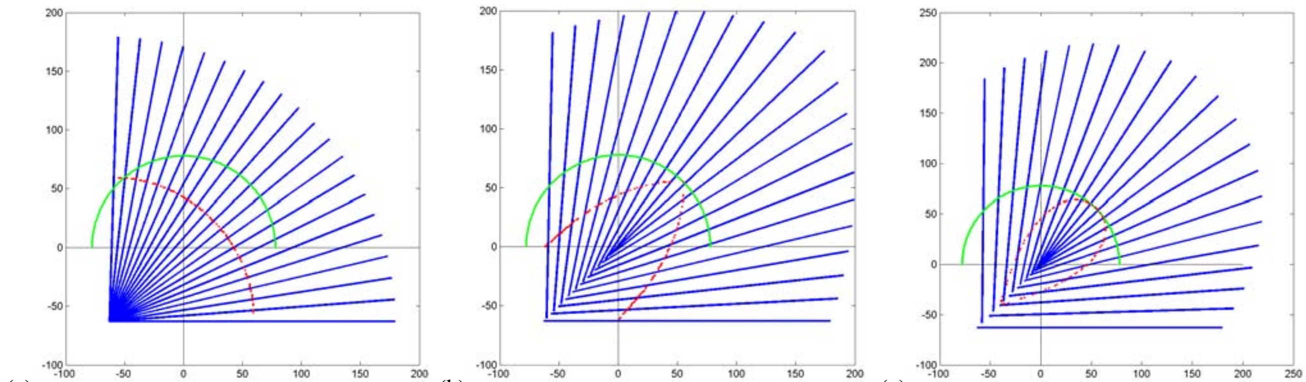
Quadrant Radial K-space (Quark) – a new trajectory in between radial and Cartesian.

K. J. Lee[1], and J. M. Wild[1]

[1]Academic Radiology, University of Sheffield, Sheffield, South Yorkshire, United Kingdom

Introduction: Recently, Xu and Haacke proposed acquiring a quadrant k-space for Cartesian partial Fourier imaging, to be reconstructed using projection onto convex sets (POCS) [1]. A quadrant allows better coverage of the central k-space information, compared with traditional Cartesian half Fourier methods sampling the same total area of k-space. In order to acquire sufficient data points, for a square k-space of width 2n points, the area covered must be equal or greater than a quadrant with coordinates (-0.41n, n), (-0.41n, -0.41n), (n, -0.41n) and (n, n) [1]. We propose to sample the quadrant with radial-based trajectories. One possibility is an offset radial trajectory (Fig 1a). This involves acquiring a region over the range $0 \le \theta \le \pi/2$, instead of the usual radial coverage over the range $0 \le \theta \le \pi$. For the same angular resolution, this trajectory requires a factor of $0.5 + 0.41/\sqrt{2}$ fewer projections e.g. 202 versus 256 for full 180 degrees radial coverage. To increase oversampling towards the k-space origin, the starting coordinates of the k-space lines along a diagonal can be brought towards the origin as a function of θ. For example, Fig 1b and c show trajectories where the function determining the offset from k-space origin is linear, f(θ), and proportional to $f(\theta^2)$ respectively. We call this new class of trajectories Quadrant Radial K-space (Quark).

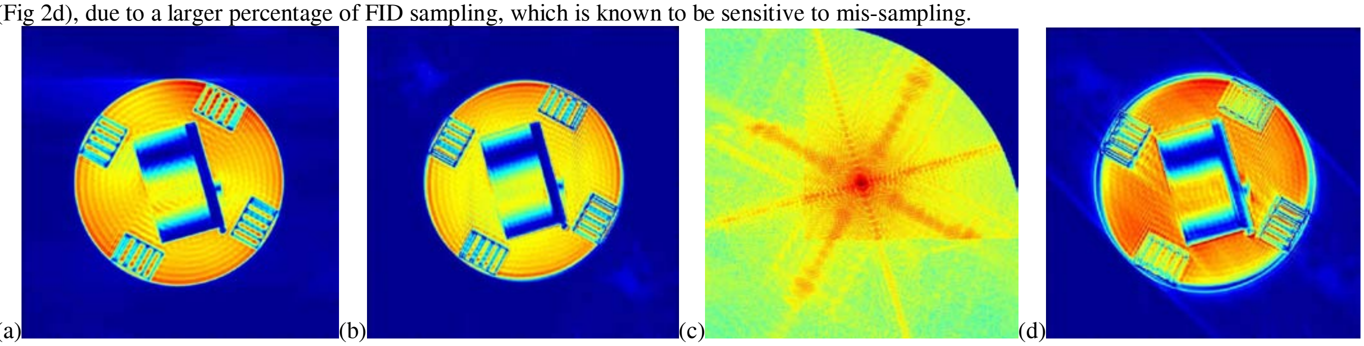


(a) (b) (c)

Figure 1. Quark k-space trajectories (blue). Nyquist radius for Quark trajectory (red) compared with radial for the same angular resolution (green) (a) constant offset (b) linear offset f(θ) (c) offset $\propto f(\theta^2)$.

Method: Phantom data were collected using (i) gradient echo radial, asymmetry = 0.27 (ii) Quark trajectory with constant offset (see Fig 1a) and (iii) Quark with linear offset (see Fig 1b), using a 1.5T system (Infinion; Philips Medical Systems). Number of encoding lines was 256 over π for radial, and 202 over π/2 for Quark. Radial data was reconstructed by regridding [2] and zero-filling. Reconstruction of Quark trajectories was by regridding and 3 iterations of POCS [1]. Sampling density functions were calculated using Voronoi cells [3]. No correction for trajectory misalignments arising from gradient imperfections or eddy currents was made.

Results: The reconstructed images are shown in Fig 2. The resolution of Quark with constant offset reconstructed with POCS is slightly better than its radial counterpart (compare parallel fins in Fig 2a and b). The radial image shows slight streak artifact typical of slight misalignment of echoes. Diagonal artifacts are seen in Quark images due to the inability of POCS to recover missing data e.g. in the top-left and bottom-right corners of the k-space in Fig 2c. There is mild distortion in the Quark image Fig 2b, due to trajectory errors. Distortion is worse with linear offset (Fig 2d), due to a larger percentage of FID sampling, which is known to be sensitive to mis-sampling.



(a) (b) (c) (d)

Figure 2 (a) radial (b) Quark with constant offset (c) log of POCS reconstructed k-space for Fig 2b (d) Quark with linear offset. Color scale chosen to accentuate artifacts.

Discussion: This paper introduces a novel class of trajectories for partial Fourier imaging which occupy a half-way house between radial and Cartesian trajectories. For example, compared with radial trajectories, Quark trajectories cover k-space more efficiently, requiring fewer projections for the same angular resolution. Therefore, we hypothesize that Quark may be used to achieve better time resolution than radial, while retaining better insensitivity to motion artifacts compared with Cartesian sampling. The main disadvantages are: (i) diagonal artifacts due to incomplete collection of k-space (ii) sensitivity to trajectory errors causing distortion (iii) varying density of coverage leading to anisotropic properties e.g. in resolution, noise etc. Future work will concentrate on characterizing these pros and cons, improving Quark images by correcting for trajectory errors and examining its use for high time-resolution imaging. We note that Quark can be extended to 3D and it should be possible to use Quark with parallel imaging methods such as SENSE [4].

References: [1] Xu Y and Haacke EM JMRI (2001) 14:628 [2] Jackson JI et al IEEE Trans Med Imag (1991) 10:473 [3] Rasche V et al IEEE Trans Med Imag (1999) 18:385 [4] Pruessmann KP et al MRM (2001) 46:638.

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