Magnetization-Prepared Imaging Using a Concentric Rings Trajectory

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Introduction: In this work, we demonstrate the feasibility of using a concentric rings readout trajectory for magnetization-prepared imaging experiments. In a segmented *k*-space acquisition, because of the transitory signal behavior, the challenge is to capture the prepared magnetization before the intended contrast disappears. Therefore, it is highly desirable to have a readout trajectory that can capture the intended contrast in a smooth and timely manner. The concentric rings trajectory [1, 2] is inherently centric-ordered, provides smooth weighting in *k*-space, and enables shorter scan times. These properties make it well-suited as a readout trajectory for magnetization-prepared studies.

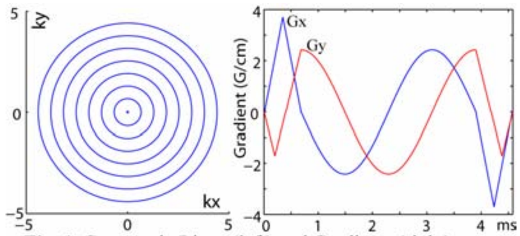

Fig. 1. Concentric Rings (left) and Gradients (right)

Concentric Rings: A set of uniformly-spaced concentric rings (Fig. 1 left) is used to sample *k*-space [1, 2]. We implement the rings in a gradient-echo sequence, acquiring one ring per TR [2]. Gradients are designed for the outermost ring (Fig. 1 right), and then scaled down accordingly for all the rings. This results in a sampling density resembling 2D projection-reconstruction (PR). Potential off-resonance blurring can be corrected by retracing the central portion of *k*-space [2].

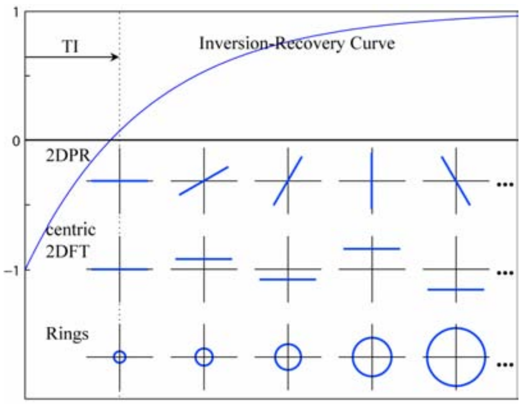

Fig. 2. Acquisition during IR signal transition

Magnetization-Prepared Imaging: To demonstrate the effectiveness of the concentric rings, we specifically considered an inversion-recovery (IR) experiment. The desired set of *k*-space encodings is acquired as *P* interleaved segments of *Q* encodings. For example, if 128 rings are to be acquired at *Q*=16 rings per segment, then the *P*=8 segments would be rings [0, 8, 16 … 120], [1, 9, 17 … 121] … up to [7, 15, 23 … 127]. This ensures a smoother *k*-space weighting than sequential segmentation. After each preparatory 180º inversion pulse and evolution over an inversion time (TI), *Q* encodings are acquired to capture the intended contrast (Fig. 2). Trajectories such as concentric rings, centric-ordered 2DFT, and 2DPR can be used for acquisition. Concentric rings have the advantage that contrast is captured the most effectively by immediately acquiring the low-frequency information. For centric-ordered 2DFT, the *k*-space weighting produces no loss of resolution in the readout *x* direction, but can lead to blurring in the phase-encoding *y* direction [3]. For the rings, *k*-space weighting is distributed isotropically in two dimensions. Depending on the segmentation parameters *P* and *Q*, blurring in the *y* direction may be reduced in certain cases for the rings.

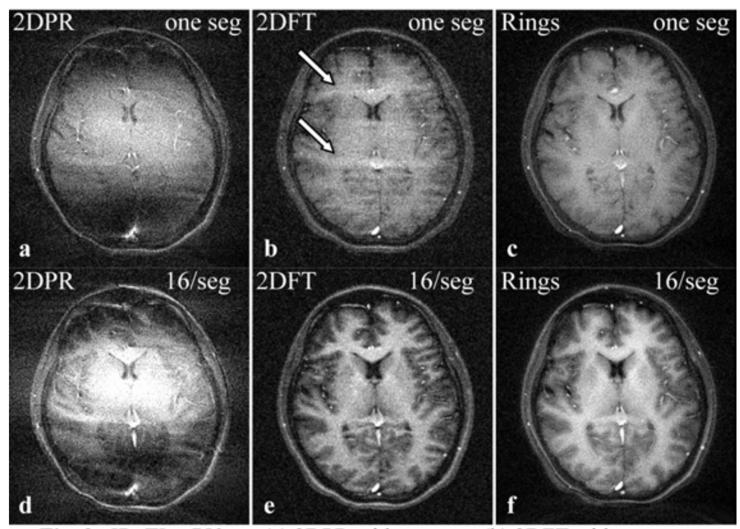

Fig. 3. IR, TI = 750ms: (a) 2DPR with one seg, (b) 2DFT with one seg, (c) Rings with one seg, (d) 2DPR with 16/seg, (e) 2DFT with 16/seg, and (f) Rings with 16/seg. All images have the same window/level.

Results: Experiments were performed on a GE Signa 1.5T Excite system. Fixed scan parameters were: TI = 750 ms, 24 cm FOV, 5 mm slice, 30º flip, 0.93 mm by 0.93 mm in-plane resolution, and +/-125 kHz readout bandwidth. The readout sequences were: 128 rings at 804 samples/ring with TE/TR = 2.1 ms/8.2 ms, 256-by-256 centric-ordered 2DFT with TE/TR = 3.5 ms/7.6 ms, and 256-by-256 full-diameter 2DPR with TE/TR = 3.5 ms/7.6 ms. TE for the rings is defined as the time from the peak of the excitation RF to the first readout sample.

One Segment (P=1) A single 180º pulse was applied, followed by acquisition of all the encodings (Figs. 3a, 3b, 3c). Scan time per image was 1.8 seconds using the rings (*Q*=128), and 2.7 seconds for 2DPR (*Q*=256) and 2DFT (*Q*=256). 2DPR did not capture the IR contrast effectively, since each spoke contributed equally to the reconstruction. Both 2DFT and the rings track the IR-prepared contrast, but the 2DFT image shows horizontal blurring (phase-encoding direction) due to *k*-space weighting and flow effects (arrows in Fig. 3b).

Multiple Segments The same slice was imaged using *Q*=16 encodings per segment for each trajectory and recovery time was 5 seconds before the next IR pulse (Figs. 3d, 3e, 3f). Scan time per image was 42 seconds for the rings (*P*=8), and 89 seconds for 2DPR (*P*=16) and 2DFT (*P*=16). Both 2DFT and the rings capture the contrast, which is now enhanced as compared to Figs. 3b and 3c. The *k*-space weighting is less dramatic than the previous *P*=1 case, as can be seen for 2DFT. 2DFT has slightly better vertical resolution (readout direction) than the rings, but the rings exhibit better white and gray matter contrast-to-noise ratio than 2DFT. 2DPR with interleaved segments still could not capture the contrast as effectively [4].

Conclusion: The concentric rings are inherently centric-ordered and offer smooth weighting in *k*-space. These advantages allow the rings to capture prepared contrast effectively. As seen from the specific IR results, good white and gray matter contrast can be achieved with the rings within an efficient total scan time that is almost half of that for 2DFT. There is a slight SNR penalty for the rings due to non-uniform sampling, but the rings require fewer encodings (readout excitations) to cover *k*-space, enabling shorter total scan times. Direct applications of this particular IR sequence include structural brain imaging and T_1-mapping. The same advantages considered here also make the rings well suited for RARE sequences [1].

References:
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