Fast, Variable System Delay Correction for Spiral Trajectories

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INTRODUCTION: Spiral images can exhibit artifacts due to system delays and eddy currents. Current techniques [1-4] to measure such system imperfections are either object dependent, require phantom measurements or external hardware. This work extends the previous approach in [5] to estimate variable system delays for stack-of-spirals [6] based sequences, and provides a reduction in computational time (a total run time of ~1 minute for data sets in figs. 2 & 3). The method includes gradient coupling effects, requires no phantom measurements, is robust to off-resonance effects, and estimates time-varying system delays over the sampling period [5].

METHODS: The proposed method collected three orthogonal sets of 3D stack-of-cylinders, as shown in Fig. 1. Sampled data from each set were compensated for sampling density and gridded [7] onto separate Cartesian grid volumes. Overlapping data from orthogonally sampled sets corresponds to the same time of acquisition. System delays shift the data from each set in orthogonal directions. By cross-correlating the data between overlapping planes from each set, the delay in each direction was estimated [1,5,8]. Orthogonal sets intersecting along the entire length of each k-space axis, allowed continuous delay measurements through the data-sampling period. Correlation maps of overlapping data for each gradient channel were averaged across data sets from eight coils to reduce the noise in the estimates. ***Phantom Experiment:*** Spiral data were acquired from a GE phantom using 3D stack-of-spirals with (1 mm resolution, 240 mm FOV, 48 interleaves, 1mm slice thickness and 240 slices) in a SPGR sequence. All images were acquired on a GE Signa Excite 3.0T scanner using an 8-channel head coil. ***Simulations:*** Variable delays were also applied to synthesized stack-of spirals data from a 3D GE phantom image volume to validate the method. Images for both simulated and acquired data were reconstructed with and without delay correction.

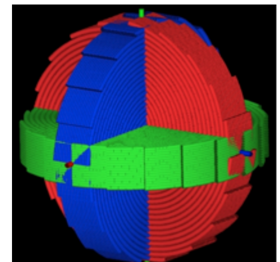

Fig. 1: 3D orthogonal stack-of-cylinders [5].

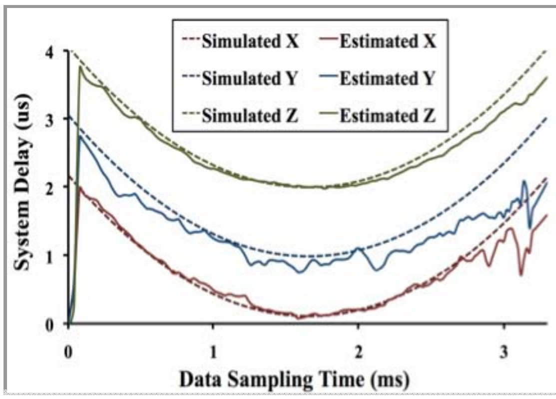

Fig. 2: Variable delays applied to synthesized stack-of-spirals data from a 3D GE phantom image volume. Figure illustrates the performance of the method in estimating the simulated delays. Estimated delays show this method works well except for the initial part of the trajectory.

RESULTS & DISCUSSION: Simulated experiments in Fig. 2 demonstrated relatively high accuracy in estimating the applied delays. Phantom images reconstructed without delay correction showed shading artifacts, which were reduced substantially by using the proposed correction, as shown in Fig. 3.

CONCLUSION: The proposed method is simple, robust and quickly estimates time-varying system delays for stack-of-spirals based trajectories. Both simulated and phantom data showed improvement in image quality by using variable delay correction.

PHANTOM EXPERIMENT

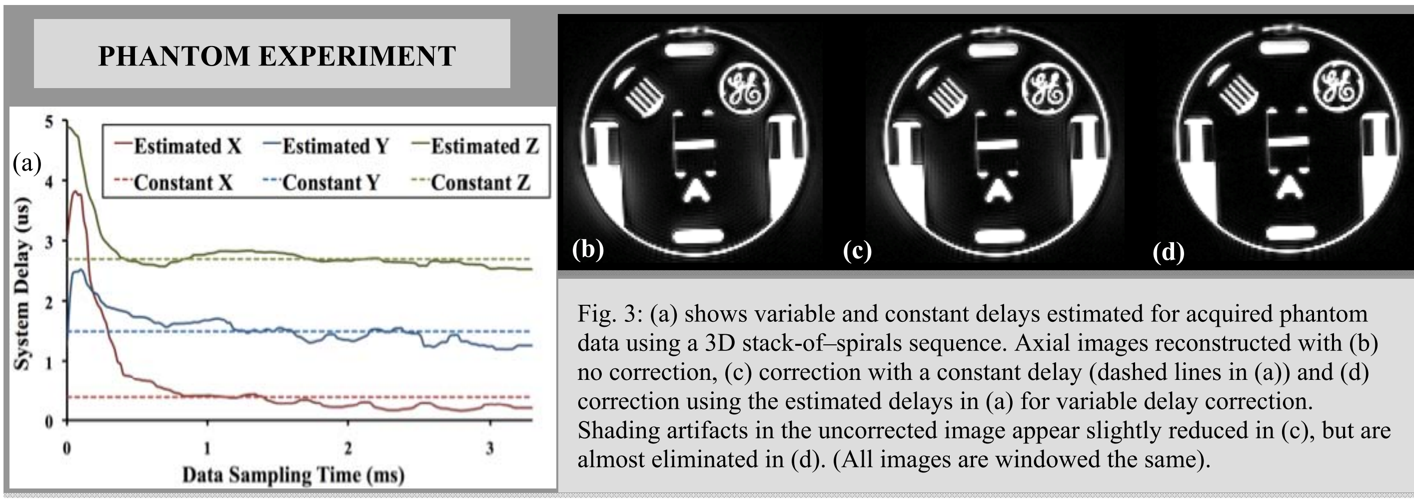

Fig. 3: (a) shows variable and constant delays estimated for acquired phantom data using a 3D stack-of–spirals sequence. Axial images reconstructed with (b) no correction, (c) correction with a constant delay (dashed lines in (a)) and (d) correction using the estimated delays in (a) for variable delay correction. Shading artifacts in the uncorrected image appear slightly reduced in (c), but are almost eliminated in (d). (All images are windowed the same).

REFERENCES: [1] Robison et. al 2010. MRM 63: 683-1690. [2] Duyn et. al 1998. JMR 132: 150-153. [3] Alley et. al 1998. MRM 39: 581-587. [4] Tan et. al 2009. MRM 61: 1396-1404 [5] Bhavsar et. al 2011. Proc. ISMRM Abstract 2804. [6] Meyer et. al 1990. Proc. SMRM. p. 403 [7] Zwart et. al 2011. Proc. ISMRM Abstract 4390. [8] Pipe et. al 1999. MRM 42: 963-969.