A Method To Measure Gradient Delay Due To Gradient Coupling

A. Devaraj[1], and J. G. Pipe[1]

[1]Keller Center for Imaging Innovation, Barrow Neurological Institute, Phoenix, Arizona, United States

INTRODUCTION:

Loss of image quality due to gradient delays can be pronounced in spiral and other non-cartesian scans. The image degradation is further accentuated in 3D spiral scans like SPI[1,2]. Several methods[3-6] to measure and correct for these imperfections have been proposed. Most these are based on measuring delays while playing out waveforms on an individual gradient. However spiral scans usually require waveforms to be played out concurrently on the three gradient systems making it necessary to account for delays due to interactions between the gradient systems. This work presents a simple approach to measuring the changes (if any) in gradient delays caused by gradient coupling.

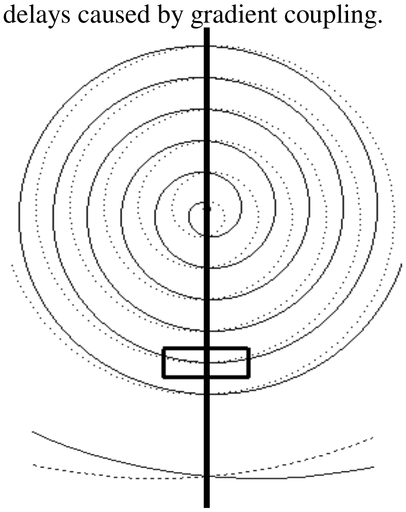

Fig 1. A typical 2D spiral interleave (solid) and the same interleave with sign reversed in k_x direction (dotted). The bottom part shows the marked portion zoomed-in.

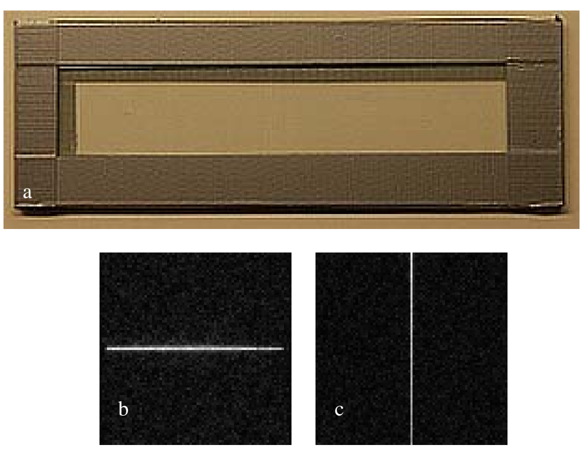

Fig 2. The constructed phantom (a). The image space (b) and k-space (c) data from imaging the line phantom with a 256x256 matrix, 24cm FOV Cartesian scan

THEORY:

A delay while playing out a waveform on a gradient results in shifting the collected k-space data. Playing out the same waveform with the sign reversed causes the k-space data to shift in the opposite direction. The position of the peak in the cross-correlation sequence of the two k-space data segments is a good measure of the shift and consequently of the delay. If an additional waveform is concurrently played out on another gradient, the measured delay will reflect the changes (if any) due to the interactions between the two gradient systems.

METHODS:

A phantom designed to be a line function in k-space was imaged by two 2D spiral trajectories: first a regular trajectory followed by the same trajectory flipped about one k-space axis. Figure 1 illustrates two such 2D spiral trajectories with the flip about the k_x axis and the line phantom positioned to be a vertical line in k-space. The zoomed in portion shows two trajectory segments crossing at the k-space line producing a delta for each segment. The gradient delay shifts the delta in opposite directions. The cross-correlation of these segments gives the delay on the flipped gradient. The whole experiment is then repeated with the non-flipped gradient turned off.

The line-phantom was constructed by sandwiching a thin layer (< 1mm thick) of water based lubricant between two plates of glass approximately 23cm long and 7cm wide. The line phantom is essential to have a significant signal near the cross-over points and minimize the difference in k-space structure due to divergent path of the two segments.

RESULTS:

All experiments were conducted on a GE Signa Excite 3T scanner with a 150/40 gradient system. The constructed line phantom (Fig. 2a) was first tested with a Cartesian gradient-echo (SPGR) sequence. The resulting image-space (Fig. 2b) and k-space data (Fig. 2c) are consistent with the design objectives. A 2-D constant density spiral trajectory designed for a 24cm FOV, 1mm isotropic resolution and 16 spiral interleaves was used to measure the gradient delays in the axial, sagittal and coronal planes. The estimated delays from playing out each gradient waveform individually and in appropriate pairs for each plane orientation are given in the table below.

	X-Gradient Delay (us)		Y-Gradient Delay (us)		Z-Gradient Delay (us)	
	From Individual Gradient	From Gradient Pair	From Individual Gradient	From Gradient Pair	From Individual Gradient	From Gradient Pair
Axial Plane	3.79	3.78	1.71	1.69	-	-
Sagittal Plane	3.76	3.77	-	-	4.51	4.46
Coronal Plane	-	-	1.67	1.7	4.62	4.58

CONCLUSION:

The measured gradient delays from gradient pairs closely follow that from individual gradients, indicating that for spiral scans on this scanner, delay on a gradient is not substantially influenced by the other two gradients.

REFERENCES: **[1]** Mag. Res. Med. 33(5), 656-62 **[2]** Proc. ISMRM 2007, Abstract 1664 **[3]** Mag. Res. Imaging 15(5), 567-78 **[4]** Mag. Res. Med. 39(4), 581-7 **[5]** Mag. Res Med 38(3), 492-6 **[6]** Mag. Res. Med. 34(3), 446-56