Reducing Gradient Imperfections for Spiral CSI

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Introduction

Spiral readout based CSI (Chemical Shift Imaging) [1] offers several potential advantages over conventional phase encoded CSI. The minimum total scan time to collect the data is dramatically reduced due to the k-space coverage method of the spirals. This characteristic enables spiral CSI to be used for applications such as full volumetric coverage CSI or spatially resolved two-dimensional spectroscopy [2,3]. However, using time varying gradients during the readout period are susceptible to system imperfections such as eddy current effects or maxwell fields, which can lead to a discrepancy between the desired and actual k-space trajectory. This can ultimately limit the performance and thereby restrict the usefulness of the spiral CSI sequence. Although the nature of these imperfections are pretty well understood, the effect on the spiral CSI seqeunce both spatially and spectrally is nonintuitive. This abstract illustrates the effects on spiral CSI resulting from the presence of the nonideal time varying readout gradient.

Methods

All data acquisition and simulations were performed with the following spiral CSI sequence at 1.5 T: 32x32 cm FOV inplane, single slice acquisition, 4 spatial interleaves to cover the required k-space, 256 spiral lobes per readout which resulted in 0.54 sec readout time, each spiral 2.096 ms long. Data reconstruction consisted of gridding in kx and ky and inverse FFT. The spectral bandwidth after reconstruction was 477 Hz with 1.85 Hz resolution. K-space trajectories were measured for each interleave and for the whole duration of the readout using the technique by Duyn [4] (16 nex, 1:48 minute scan). Data were reconstructed assuming desired k-space trajectory as well as actual measured trajectories. Also, simulations were performed assuming ideal k-space data collection with reconstruction based on actual measured k-space trajectory to illustrate the effect when there is a discrepancy.

Results and Discussion

Figure 1 shows an illustration of a spiral readout trajectory drifting off from the actual trajectory during the readout interval. The amount of drift depends on the gradient system and can be significant. Figure 2 shows the desired versus the measured k-space trajectory. To illustrate the discrepancy more pronouncely, the plot shows the 64 th spiral lobe of the total 256 lobes. The accumulation of the drift can be seen in Fig. 3. Desired k-space trajectory for each spatial interleave is shown along with the difference between the measured and desired trajectory. In all cases, we see a drift of the trajectory along k_x to be the most significant feature.

Figure 4 shows simulated results obtained assuming data collection from ideal k-space versus reconstruction with the measured trajectory. The plot shows a spatially dependant frequency shift of the peak which correlates to the k_x drift of the measured trajectory. The amount of frequency shift from left to right is approximately 4 Hz. Figure 5 shows phantom data reconstructed with the measured k-space trajectory. The inherent B_0 inhomogeneity can be observed from the spatially dependant frequency shift of the peak. If the data were reconstructed assuming the desired k-space trajectory, this can lead to additional frequency shifts as seen in Fig. 4. This is illusrated in Fig. 6 where data were reconstructed assuming desired k-space trajectory (top) and measured k-space trajectory (bottom). As can be seen, using the measured k-space trajectory for the reconstruction reduces the amount of frequency shifts compared to desired k-space trajectory. The amount of frequency shift difference was approximately 2 Hz within the illustrated region.

Conclusion

Gradient imperfections resulting in k-space trajectory discrepancy can lead to spatially varying frequency shifts for spiral based CSI. In addition, we have observed minor spatially varying amplitude modulations. Measurement error can lead to decreased SNR or other types of effects. If the trajectory was designed to critically sample the k-space region, aliasing artifacts can be present when measured k-space trajectory does not critically. A simple method to overcome this is to apply a 2x gridding algorithm to move the aliasing artifact to outside the field of view. Misadjusted gradient timing can also cause frequency dependant phase shifts in the presence of B_0 inhomogeneity.

Acknowledgements

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References

[1] E. Adalsteinsson, et al., MRM,1998;39:889-898 [2] E. Adalsteinsson, et al., MRM 1999;41:8-12 [3] B Hiba, et al., MRM 2004;52:658-662 [4] J. Duyn, et al., MRM 1998;132:150-153.

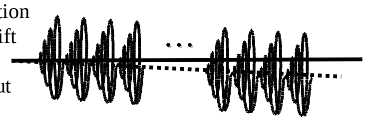

Fig.1 Illustration of k-space drift (dotted line) during readout

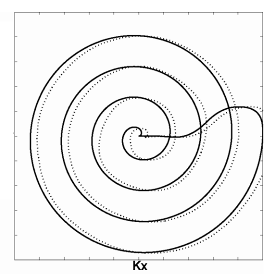

Fig. 2 Desired k-space (solid) vs. measured (dotted) of the 64 th spiral

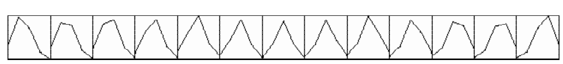

Fig. 4 Simulation across a 16 cm phantom assuming discrepancy in desired and measured k-space trajectory. The data is shown between a +- 3 Hz region.

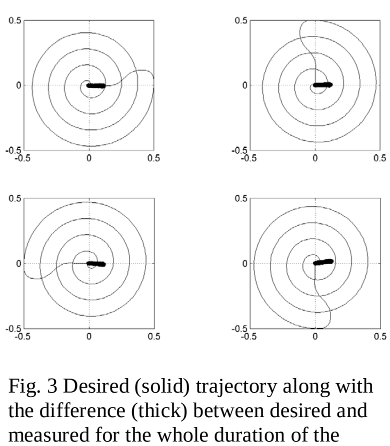

Fig. 3 Desired (solid) trajectory along with the difference (thick) between desired and measured for the whole duration of the readout for each spatial interleave.

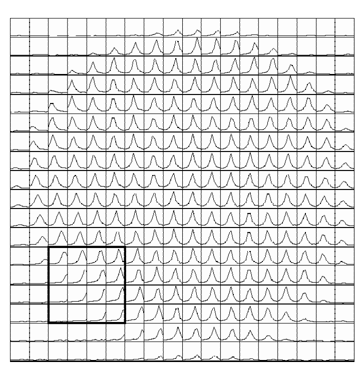

Fig. 5 Spectra from phantom data reconstructed with the measured trajectory. Each voxel has spectra of +- 7 Hz from the water peak. The peak shifts are mostly due to B_0

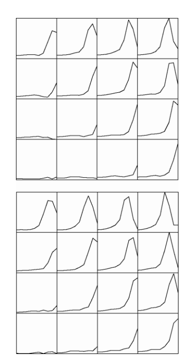

Fig. 6 Highlighted region from Fig. 5 using reconstruction based on desired k-space data (top) and measured k-space (bottom). Measured k-space shows reduced frequency shift.