Phase Contrast MRI with Reduced Eddy Current Distortion

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Introduction

Phase contrast (PC) MRI can capture fluid flow in real-time without the use of a contrast agent. A bipolar gradient is used to impart a velocity dependent phase on the flowing spins. Ideally the bipolar gradient has no effect on the phase of stationary spins, however eddy currents associated with the switched gradients cause non-zero phase errors in the measured velocity [1]. This effect is particularly pronounced while encoding very slow flows, which require high gradient strengths and/or duration to increase the velocity sensitivity. Retrospective eddy current correction can estimate the phase error after the scan by fitting a first or second order polynomial in a static region of interest (ROI), which is then subtracted from the entire velocity map [1]. However this method has several drawbacks: 1) requires a static ROI be present in the image which can be difficult to locate while encoding very slow flows *in-vivo* (perfusion effect), 2) needs to be performed on each slice individually in a static ROI, and 3) is subjective and may dependent on the ROI chosen. In this study, we introduce a prospective method to reduce eddy current distortions by changing the shape of the flow encoding bipolar gradient from the usual trapezoid to shifted cosine. The new gradient shape is smoother than the trapezoid, which greatly reduced the eddy current artifacts in the scan itself. The new technique expands the application of PC-MRI for the measurement of very slow flows, which could provide a valuable tool to study biology *in-vivo*.

Experimental

MR experiments were performed on an Agilent 4.7 T magnet in the AMRIS Facility of the NHMFL. The 3D velocity field in a rat brain *in vivo* was obtained using a Hadamard scheme [2] at a velocity encode value of 12.23 mm/s with trapezoidal ($G_{bipolar}$ = 60 mT/m and $t_{bipolar}$ = 4 ms) and shifted cosine gradients ($G_{bipolar}$ = 120 mT/m and $t_{bipolar}$ = 4 ms). The shifted cosine gradient strength was doubled to equate its first moment to that of a trapezoid.

Results and Discussion

The *in vivo* rat brain z-velocity maps, obtained with trapezoidal and shifted cosine gradients are given in Figure 1. The flow map from trapezoidal gradient clearly shows the *B0* eddy current error as constant non-zero velocity (orange-red color) throughout the entire image. The shifted cosine waveform almost eliminates this error, as shown by the zero velocity (green) as expected.

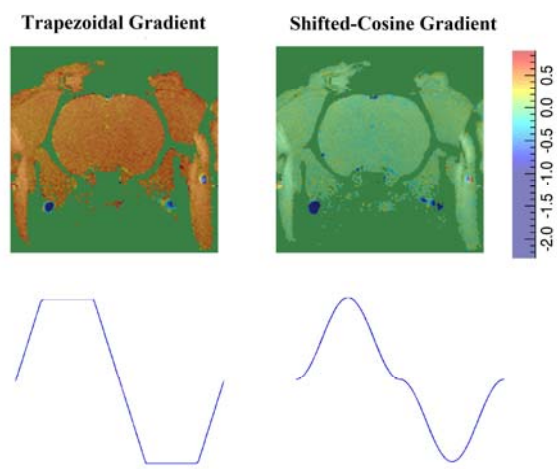

Figure 1: *In-vivo* flow in rat brain with V_{enc}= 12.23 mm/s using trapezoidal and shifted cosine flow gradients, after zero filling the raw data and phase unwrapping,: (Top row) Normalized z-component of velocity. (Bottom row) Flow encoding gradient shapes

Conclusions

The shifted cosine waveform greatly reduced the eddy current artifacts in the flow map, which allows the measurement for very slow flow. In the future, the study would be further extended to encode even slower flows using eddy current complesation modifications to the gradient waveform shapes.

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References

[1] Bernstein, et al. *Handbook of MRI pulse sequences*. Elsevier, 2004. [2] Haacke, et.al. *MRI: physical principles and sequence design*. pp 731-732. New York: Wiley-Liss, 1999.