# Improved Cardiac Shim using Field Map Estimate from Multi-echo Dixon Method

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## Introduction

Rapid field variation across the heart cause by tissue-air interface presents a challenge to cardiac imaging. An improved method for shimming is presented which estimates the fieldmap in the presence of rapid field variation and in regions containing both fat and water. The fieldmap is estimated using a multi-echo GRE acquisition and VARPRO solution for fat and water components. The multi-echo GRE sequence was implemented with parallel imaging reconstruction as a real-time, free-breathing, non-ECG gated 2D multi-slice acquisition, acquiring the volume in <7s. With the proposed shim method, the field variation in the user defined heart region was reduced significantly.

## Methods

A 2D multi-echo GRE sequence was used to acquire a volume containing the heart, with slices prescribed axially. The shim measurement was acquired free-breathing without ECG triggering. The shim sequence parameters for imaging with the Siemens Magnetom Avanto 1.5T MRI scanner were: bandwidth=900 Hz/pixel, echo-train length=6 using monopolar readout, TE = 1.18, 2.72, 4.26, 5.8, 7.34, and 8.88 ms, TR=10.25 ms, flip angle=20°, image matrix=64x48, FOV= 400x300 $mm^2$ with spatial resolution was 6.25x6.25$mm^2$ (8 mm slice thickness, with no gap). The sequence was acquired single shot using parallel imaging with 246 ms per slice using rate 2 acceleration with 24 actual PE lines per image. The 20 slice volume covering 160 mm in the head-foot direction was measured in <7 sec including the separate reference lines required for parallel imaging. Image reconstruction used the VARPRO-ICM method [1] to robustly estimate the fieldmap in the presence of field inhomogeneity, as well as produce magnitude images for water, fat, and combined signals. The fieldmap and combined magnitude image were then used by a shim adjustment algorithm which computed gradient offsets (Gx, Gy, Gz) and second order shim currents (A20, A21, B21, A22, B22) to fit the field map over a user selectable shim volume. Shim volumes were graphically prescribed to cover the heart and were typically 150x150x150 $mm^3$.

In order to test the repeatability of fieldmap estimates acquired at different cardio-respiratory phases, 50 repeated free-breathing, non-ECG triggered measurements of a single short axis slice were made using the same shim sequence. Finally, the ability to perform a cardiac shim in the presence of severe field distortions was evaluated by creating a field disturbance by placing a paper clip on the subject's abdomen. True-FISP cardiac cine images of a SAX slice were acquired before (using default shim values) and after the proposed method of shimming. Fieldmaps were also acquired for the same slice before and after shimming, using a multi-echo sequence with higher spatial resolution protocol than the shims sequence.

## Results

In the presence of severe field distortion the proposed cardiac shim method was able mitigating trueFISP banding artifacts (Fig 1) by reducing the field distortion across the heart from of 375 Hz to <65 Hz after shim (<35 Hz over 90% heart). Repeated measurements (Fig 4) showed a variation of on the order of 4 Hz (std, N=50) for this subject (Fig 5).

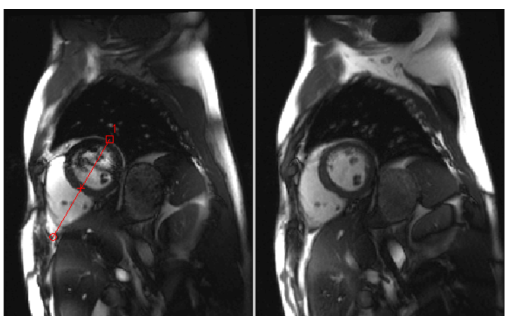

Fig. 1. Cine images for SAX slice before (left) & after (right) shimming field disturbance.

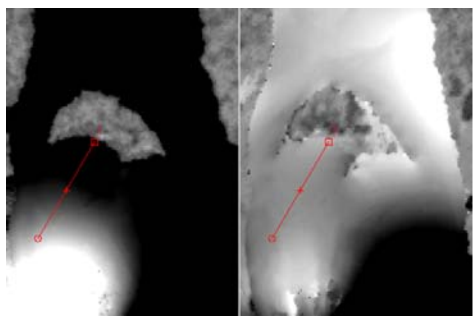

Fig. 2. Fieldmaps (±200 Hz) for SAX slice before (left) & after (right) shimming field disturbance.

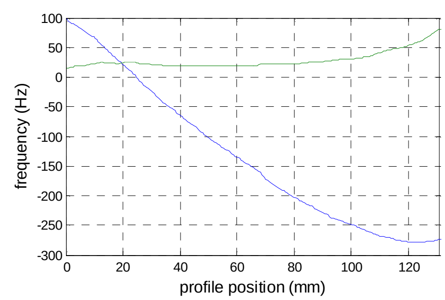


Fig. 3. Fieldmap profiles across heart before (blue) and after (green) shimming.

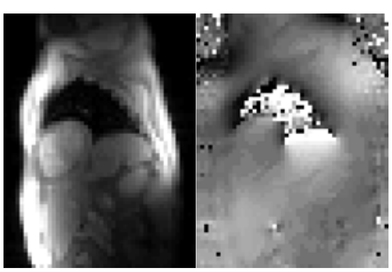

Fig. 4. Magnitude and fieldmap (±200 Hz) of SAX slice using shim sequence.

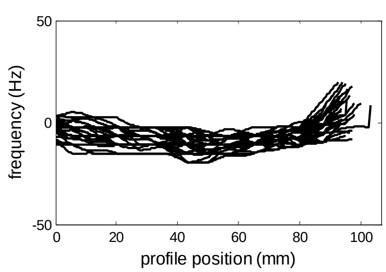


Fig. 5. Fieldmap profiles across heart for 50 repetitions using shim sequence.

## Discussion

A key component of cardiac shimming is the estimation of the fieldmap in the heart region. Initial evaluation of the proposed method for low resolution fieldmap estimation for cardiac shimming application has demonstrated it to be reliable and fast. Although the field distortion is a function of the respiratory phase due to the influence of the changing lung geometry, the variation with cardio-respiratory phase was acceptable for shim application, thus permitting a non-triggered, free-breathing acquisition. For the low spatial resolution fieldmap, there were no cardiac motion artifacts observed due to the temporal resolution using real-time with parallel imaging.

## References

[1] Hernando D, et al., Magn Reson Med. 2008 Mar;59(3):571-80.