# Phase Sensitive SSFP imaging at 3T

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## Introduction

Recently, a phase sensitive steady state free precession (SSFP, TrueFISP) technique has been introduced[1] that provides fat suppression without additional scan time or pulse sequence complexity. In TrueFISP, the magnetization is refocused at TE=TR/2, similar to a spin-echo sequence. However there is a strong dependency on the resonance frequency as the phase of the magnetization jumps by $\pi$ at alternating resonance frequency band widths of 1/TR. So by appropriately selecting the TR, the fat and the water signal could be made to have opposing phase. Then by simply choosing the positive and negative signal, water-only and fat-only images can be generated. At 3T, the ideal TR for fat separation is 2.3ms (=1/440 Hz). However, with appropriate phase correction and resonance frequency adjustments this technique is robust even with TR >2.3ms. In this study we show, for the first time, that this technique can be successfully implemented at 3T.

## Method

Imaging was done at 3T, Siemens TRIO scanner with a maximum gradient strength of 40mT/m and slew rate of 200 T/m/s. The integrated body coil was used for RF transmission while an 8 channel phased array coil was used as the receiver. Several normal volunteers were scanned in the heart and in the abdomen. The TrueFISP method began with a sequence of 15 excitations with linearly increasing flip angles to attain steady state magnetization[5]. Imaging parameters were: TE/TR = 1.34/2.68 ms, Bandwidth = 975 Hz/Pixel, FOV = (30-36)x(30-36) cm$^2$, slice thickness = 6 mm. For cardiac imaging, ECG gating was used to acquire the images in the end diastole with suitable delay time. Matrix sizes were 128x128, and 192x144 for cardiac and abdomen studies. To find the optimal synthesizer frequency, a series of TrueFISP scans were obtained using the same imaging parameters with automatic increments of offset frequencies from -200Hz to 200Hz and the frequency offset of the image with no banding artifacts was used as the synthesizer frequency[6].

Raw data were transferred to a stand alone PC for processing. After the standard 2D FFT, the following phase correction algorithm was implemented. The complex data was divided in to cells of 2x2 pixels. For each cell, the best-fit phase, $\alpha$ was determined by the following equation,

$$\alpha = 0.5 \tan^{-1}( 2 \sum RI / ( \sum R^2 - \sum I^2 ) )$$

Where $R$ and $I$ are the real and imaginary part of each pixel in the cell. Here $\alpha$ has a $\pi$ radians ambiguity. To account for this, the direction of the average signal vector of each cell, $\boldsymbol{V_c}$ was compared with the sum of vectors of its 8 neighboring cells, $\boldsymbol{V_{cn}}$, by taking the dot product. If $\boldsymbol{V_c} \cdot \boldsymbol{V_{cn}} < 0$, $\pi$ was added to the calculated $\alpha$. This processing was done for all the cells in a region growing fashion. Finally the best–fit phase was removed by rotating each cell with its corresponding $\alpha$. The raw data from each channel of the phased array was corrected separately before combining.

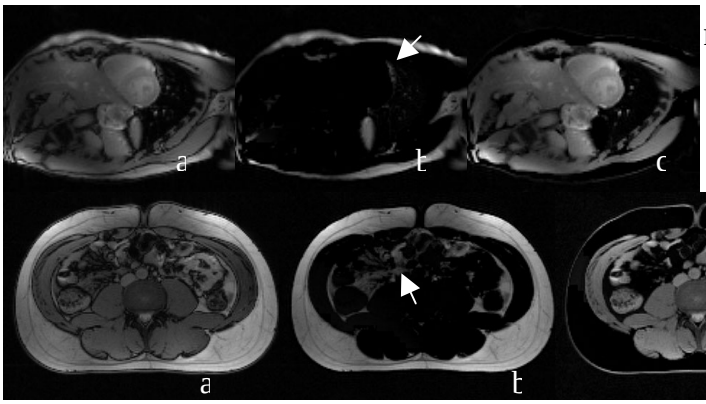


**Figure 1.**




**Figure 2.**

## Results

Figure 1, 2 show the original (a), fat-only (b) and water-only (c) images of a heart in the short axis plane and the abdomen in the axial plane. Excellent fat and water separation is depicted. Normal epicardial fat can be visualized well in Fig. [1b]. The visceral fat seen in the abdomen, Fig. [2b], is difficult to distinguish with conventional methods and even more difficult to quantify by segmenting due to it's scattered distribution. However, in this technique the fat-only image has zero values for water only pixels hence the area of fat can be easily quantified with out the need for extensive segmentation.

## Discussion

The feasibility of phase sensitive fat suppression at 3T is demonstrated. Our choice of band width is well within the theoretically expected limit of ±220Hz. This technique doesn't require any additional scans and requires negligible processing time, compared to other techniques[2-4]. Although the phased array coils introduce some phase, our results show that it is removed with a phase correction algorithm.

## References

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