

# Centric reordered 2D bSSFP imaging using variable flip angles for fourier decomposed MRI in the lung

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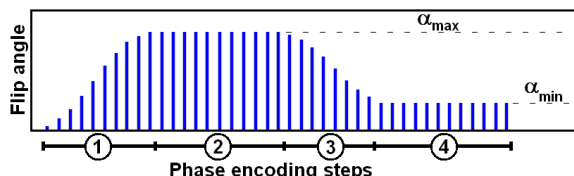
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## Introduction:

Balanced steady-state free precession (bSSFP) imaging sequences [1] have found a wide variety of applications in MRI. One example is the recently proposed fourier decomposition (FD) technique for proton pulmonary imaging [2,3]. This technique requires both a rapid acquisition rate and a high flip angle to obtain feasible signal from the lung parenchyma [4]. The maximum specific absorption rate (SAR) greatly limits the achievable signal to noise ratio (SNR) and the usability of the technique at higher field strengths. One possible approach to address this problem is the variation of flip angles in the pulse sequence. This method was already applied to other modalities such as brain or abdominal imaging and showed great potential [5]. The purpose of this study was to evaluate the variable flip angle approach for both the perfusion and the ventilation modality of proton FD pulmonary imaging.

## Subjects and Methods:

The implemented flip angle variation scheme, which was used in combination with a centric k-space sampling trajectory, is outlined in Fig. 1.



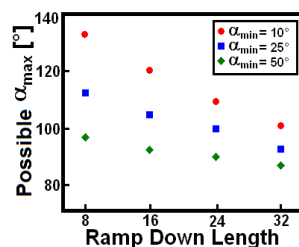
**Fig. 1.** The used flip angle scheme can be split into four sections. To ensure good signal propagation a preparation ramp is applied (1). Then the center of k-space is sampled with maximum flip angle (2). Finally while measuring the periphery of k-space the flip angle is ramped down (3) and kept at a minimum (4). Both ramps are modelled after the Kaiser Bessel function which was shown to yield optimal results [6].

The measurement sequence including the 10 preparation steps consisted of 69 radio frequency pulses. The number of pulses used to acquire the center of k-space was kept constant at 27. The reason behind this was to avoid problems arising from signal changes during the acquisition of the calibration lines for the GRAPPA acceleration technique. For a systematic investigation 12 different combinations of ramp down lengths and minimum flip angles were investigated and compared to a regular 2D-bSSFP sequence with a constant flip angle of 75°. Both the regular sequence and all analyzed modifications had the same SAR limit. The properties of the examined variations as well as the possible maximum flip angles (as determined by SAR limits) are illustrated in Fig. 2. All excitation pulses in both the regular and the modified sequence had a Gaussian shape, a duration of 500µs and thus only differed in their amplitude.

Measurements were performed on two healthy male volunteers using a 1.5T MR scanner (Magnetom Avanto, Siemens Healthcare, Germany). A combination of a 6 channel body and a 24-channel spine matrix coil were used.

The remaining imaging parameters of the utilized 2D-bSSFP sequence were as follows:

TR/TE/TA = 1.90/0.95/112ms, centric reordering, slice thickness = 10mm, FOV = 400mm<sup>2</sup>, matrix = 128x128, bandwidth = 1302Hz/px, total acquisition time = 1minute, GRAPPA=3 and Ref. Lines = 24.

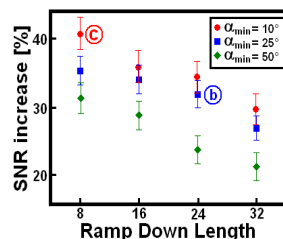


**Fig. 2.** Dependency of the possible maximum flip angle on the different parameter settings.

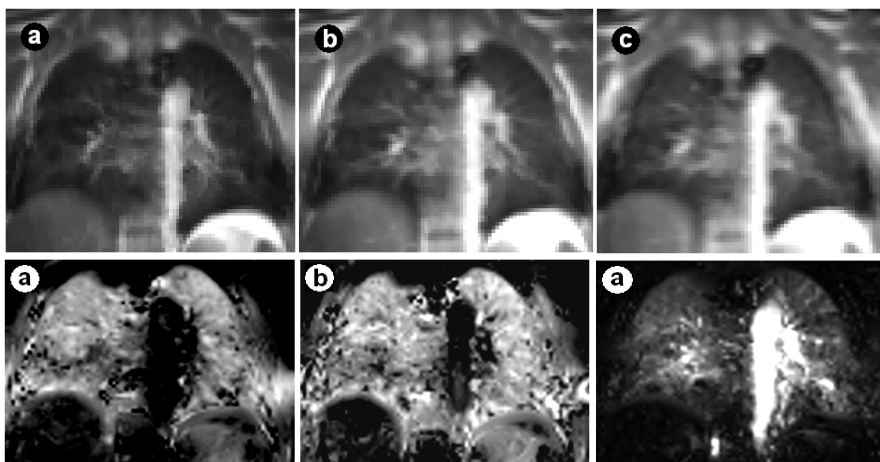
## Results:

The variable flip angle approach resulted in a gain of SNR between 41% and 22% in the lung parenchyma compared to a regular bSSFP sequence with constant flip angles and equal SAR. Detailed results of the SNR gain of the 12 investigated combinations are shown in Fig. 3. Some representative results of the obtained images are given in Fig. 4. However it has to be noted that a qualitatively noticeable loss of resolution occurs when the flip angle in the periphery is chosen to be very small. This can be observed in Fig. 4c.

The increase in SNR is directly passed on in the same magnitude to both the ventilation and perfusion maps acquired using the FD method. Two example images are displayed in Fig. 5.



**Fig. 3.** Resulting SNR gains depending on the utilized parameter setting. The settings marked with (b) and (c) are used as exemplary cases.



**Fig. 4.** Example images obtained with different sequence parameters. Image (a) was obtained using a bSSFP sequence with constant flip angles. Both (b) and (c) were obtained using the modified sequence (parameters as indicated in Fig. 3). Slight blurring artefacts are visible in image (c) while image (b) shows no such degenerations.

**Fig. 5.** Ventilation (left) and perfusion (right) obtained with a regular bSSFP (a) and the modified sequence (b). The parameters of the modified sequence are indicated in Fig. 3.

**Discussion/Conclusion:** The modified sequence was able to improve the SNR in both the direct images and the ventilation/perfusion maps obtained with FD. The expected drawback of a loss in resolution is observable as a slight blurring if the minimum flip angle is chosen to be very small. Apart from that no significant artefacts were observable between the modified and the regular sequence. In the future a more detailed examination of the ideal trade-off between SNR and blurring is planned.

**References:** [1]Carr H.Y. Phys. Rev. 1958;112:1693-701. [2]Deimling M. et al. Proc. of ISMRM 2008, p.2202. [3]Bauman G. et al. Magn. Reson. Med. 2009,62(3):656-664. [4]Zapke M. et al. Resp. Research 2006,7:106. [5]Paul D. et al. Magn. Reson. Imaging 2009,27:933-941. [6]Le Roux P. JMR 2003;163(1):23-37.