Steady State Free Precessing Imaging with high flip angles at 3T

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Introduction

Steady state free precessing sequences (SSFP; such as TrueFISP, balanced FFE, …) are finding widespread applications in particular in cardiac and body MRI. One major problem is the high RF power deposition due to short repetition times TR and relative high flip angles (60°), especially at high field strenghts (B0>= 3T). SAR can be somewhat reduced by sacrificing temporal or spatial resolution and by using of variable flip angles [2]. It has been shown that variable flip angle schemes [2] may be beneficial for improving image quality, contrast and the sensitivity to off-resonance signal fluctuations. The present work compares and analyzes the quality and SNR of images obtained from TrueFISP sequences on 3T with constant and with variable flip angles. Implementations were done such, that the total RF-power over the experiment was kept constant.

Methods

A SSFP sequence with variable flip angles (repTIDE = repetitive transition into driven equilibrium) is used to reduce RF energy [1,2]. Low flip angles are used in the outer k-space, whereas higher flip angles are used in the k-space center in order to keep the contrast similar [1,2]. The flip angles are varied between α_{min} and α_{max} over m steps using the trigometric function and $\Delta\alpha=\alpha_{max} - \alpha_{min}$:

$$\alpha(k) = \begin{cases} \frac{\Delta\alpha}{2}(1-\cos(\frac{\pi}{m}(k+k_{y\,max}))), & for \quad -k_{y\,max} < k < -k_{y\,max}+m \\ a_{max}, & for \quad -k_{y\,max}+m < k < k_{y\,max}-m \\ \frac{\Delta\alpha}{2}(1-\cos(\frac{\pi}{m}(k-k_{y\,max}))), & for \quad k_{y\,max}-m < k < k_{y\,max} \end{cases}$$

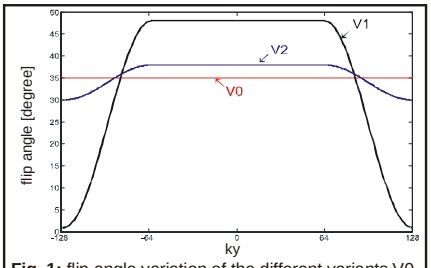

Fig. 1: flip angle variation of the different variants V0, V1 and V2.

Before the first data acquisition an additional α/2-pulse with *TR*/2 is applied. The highest possible flip angle α_{max} is determined by SAR limitations and depends on m, α_{min}, k_{ymax}, and many other parameters, including patient specific ones. Flip angles were calculated such, that the total RF-power was kept constant. In the following it is distinguished between variant V1 with a low α_{min} (α_{min}=1°) and variant V2 with a higher α_{min} (α_{min}=30°). Variant V0 uses a constant flip angle $\alpha(k)=\alpha_{max}$. Figure 1 shows the flip angle curve for different α_{min}, α_{max}, and m. Parameters are listed in table 1.

Phantom measurements without phase-encoding were performed to obtain the signal shape for different parameter variations. The corresponding point-spread functions (PSF) were calculated by applying a Fourier transformation [2]. MRI images of the abdomen and the head were acquired in healthy volunteers. All measurements were performed on a 3T system (Siemens Trio, Siemens Medical Solutions, Erlangen, Germany). An 8 channel body array coil was used for abdomen MRI.

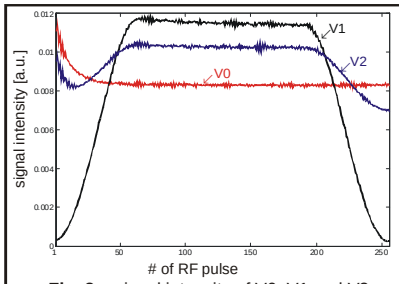

Fig. 2a: signal intensity of V0, V1 and V2

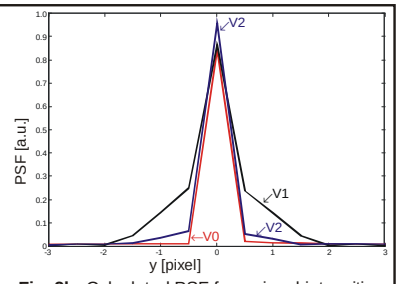

Fig. 2b: Calculated PSF from signal intensities.

Tab. 1	**V0**	**V1**	**V2**
α_{min}	----	1°	30°
α_{max}	35°	48°	38°
m	-----	64	64
max(PSF) [a.u.]	0.87	0.89	1
FWHM(PSF) [a.u.]	1,01	1,40	1.07
SNR muscle [a.u.]	2,77	3,91	3,00
SNR liver [a.u.]	3,98	5,24	4,27
SNR kidney [a.u.]	5,23	7,35	5,54
SNR WM [a.u.]	11,40	13,25	11,70

Results

Figure 2a shows the signal curve and 2b the corresponding PSF of the different variants. The signal intensity in k-space center is affected by α_{max} and is highest for V1 and lowest for V0. In contrast, the signal intensity in outer k-space is affected by α_{min} and very low for V1. But this part of k-space determines the in-plane resolution. According to this the PSF of variant V2 is wider (as can be seen in 2b). Generally the PSF of variant V2 is narrower and higher than the PSF of V1, nearly independent of m and $\alpha_{max.}$ Additionally the PSF becomes brider and higher with increasing m. For low m (m=8) the PSF of V0, V1 and V2 are almost identical.

Figure 3 displays NMR images of abdomen and head obtained on a healthy volunteer using the mentioned flip angle schemes V0, V1, and V2. Corresponding SNR values of different types of tissue are listed in table 1. All SNR values from V1 and V2 are higher than the SNR from V0.

Discussion

It was demonstrated, that MR TIDE imaging with high flip angles on 3T is possible by using variable flip angles. Compared to a conventional TrueFISP sequence with constant flip angles (V0) the SNR was increased while SAR remains constant. The PSF of V1 gets broader because of the low flip angle in outer parts of k-space. Consequently the in-plane resolution will be somewhat reduced. But this effect is rather small and could not be observed in the volunteer measurements. For further experiments a systematic analysis of the parameters α_{min}, α_{max} and m is necessary in order to find an optimal compromise between SNR and resolution.

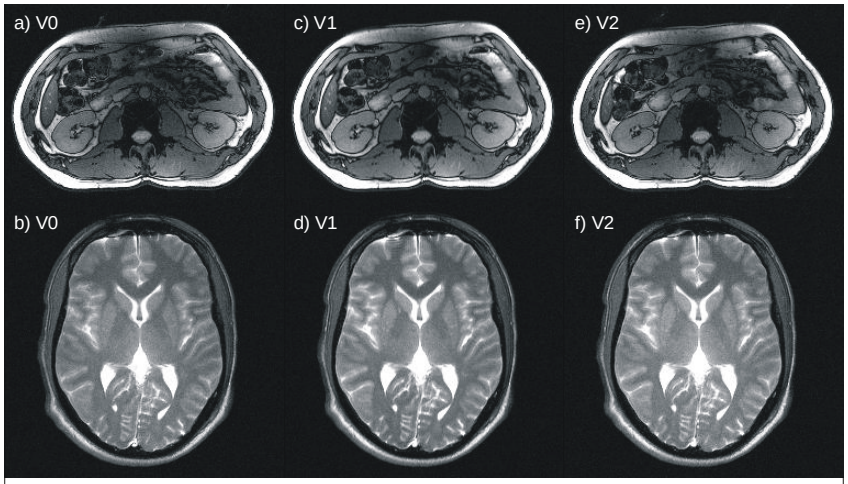

Fig. 3: MR images of abdomen and head of a healthy volunteer. Left row was acquired with V0, middle row with V1 and right row with V2.

References

[1] Hennig et. al. MRM 48:801-809 (2002)
[2] Schaeffter et. al. In: Proc. ISMRM 10