Turbo RF-SPRITE: Methods to Reduce Acquisition Time and SAR for In Vivo Applications

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Abstract

Single point imaging sequences such as SPRITE in their conventional form are ill suited for *in vivo* applications since the acquisition time is long and the SAR is high. Nevertheless single point imaging techniques are desirable for imaging of fast relaxing nuclei such as sodium or bound water. We developed a new sequence design with variable repetition time and variable flip angle to advance the SPRITE technique for *in vivo* applications.

Introduction

The SPRITE (Single Point Ramped Imaging with T_1 Enhancement) sequence [1] is a purely phase encoding MRI technique. Low flip angle, broadband RF pulses are applied in presence of phase encode gradients and after an encoding time t_p a single datum or multiple-points with a dwell time Δt_p are acquired with each of those points rebinned to different k-spaces. In comparison with echo acquiring techniques such as FLASH, SPRITE is time consuming and the SAR is higher. Major improvements are attained through use of the Spiral-SPRITE and Conical-SPRITE sequences [2]. To reduce the acquisition time further, the repetition time, T_R, may be varied (Figure 1). The self-spoiling gradients are higher in the outer parts of k-space and therefore the repetition time can be shortened with minor influence on the point spread function (PSF). Since the image signal intensity is determined by the centre of k-space the flip angle can be reduced in the outer parts to reduce the overall SAR (Figure 3). We modulated the pulse power and kept the pulse length, and therefore the bandwidth, constant.

Methods

PSF simulations in one dimension were performed with Mathematica 5.0 running under MAC OS X. Both, the longitudinal as well as the transverse relaxation with additional spoiling by the phase encoding gradients were taken into account. For demonstration, the simulations were performed assuming an artificial resolution phantom. SPRITE MRI measurements were performed with a proton resolution phantom on a VARIAN UnityINOVA 4 Tesla whole-body scanner equipped with a Siemens SONATA 40mT/m gradient coil using a TEM head RF coil. The repetition time, T_R, as well as the pulse power were modulated by a Gaussian function depending on the radius in a k-space plane. Additionally, a constant part around the centre and an overall offset were defined.

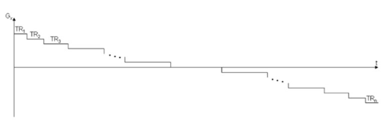

Figure 1: Variable repetition time.

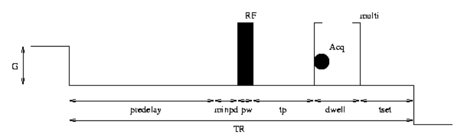

Figure 2: SPRITE sequence timing diagram.

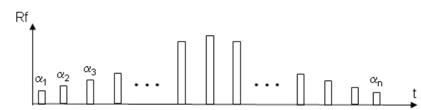

Figure 3: Variable flip angle.

Results

Results from the non-modified sequence are shown in Figure 4. To compare the influence of the repetition time reduction in (Figure 5) and the flip angle reduction in (Figure 6) on the PSF, identical Gaussian functions were chosen with the exception that the flip angle reduction had an offset of 35% of the maximum and the minimal gradient step length was ~700µs. The repetition time was T_R=2ms and a pre-delay of 1.3ms. The variance of the Gaussian function was set to 1/8 of the matrix size. Simulation and measurement results for no reduction are presented in Figure 4 and for optimized Gaussian functions for both techniques in Figure 7. The sequence parameters were: T_R=2ms, t_p=200µs, Δt_p=6.25µs, tset=200µs , pulse width: 6.25µs, α=1°, matrix size: 64×64×64, FOV: 256mm isotropic, filter bandwidth: 80kHz.

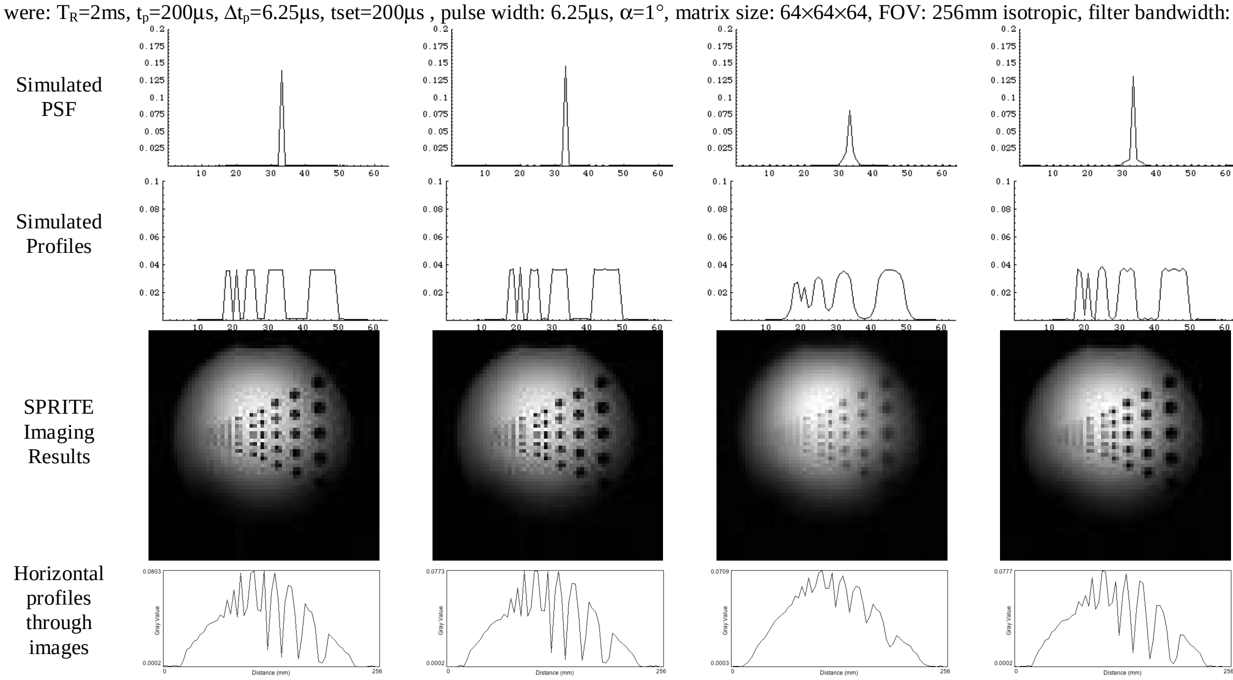

Figure 4: No reduction
Acqusition time: 729sec

Figure 5: T_R reduction
Acqusition time: 442sec

Figure 6: SAR red.: 59%
Acqusition time: 729sec

Figure 7: SAR red.: 24%
Acqusition time: 442sec

Conclusions

Despite the fact that the PSF is more sensitive to flip angle reduction than repetition time reduction, we have shown that with the Turbo RF-SPRITE technique the acquisition time can be reduced by about 50% and the SAR by about 25% compared with standard SPRITE; the influence on the PSF is still tolerable.

References

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