Implementation of SWIFT on a Siemens clinical scanner

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Introduction

SWIFT (sweep imaging with Fourier transformation) is a recently introduced MRI technique [1], which offers novel and beneficial properties compared to conventional pulsed Fourier transform sequences, due to its unique acquisition mode. In SWIFT, excitation is performed by a gapped frequency swept RF pulse [2], e.g. a hyperbolic secant (HS) pulse, in the presence of a B_0 gradient. Signal is sampled during each gap of the pulse, when the RF is off. The signal sampled throughout the pulse can be reconstructed, essentially by Fourier transform, into a profile along the direction of the gradient. The direction of the gradient is then changed and the sequence repeated in order to acquire profiles along other directions. Due to the small variation of the gradient strength between the successive orientations, SWIFT is an extremely quiet sequence. In addition, because excitation and acquisition are virtually simultaneous, the sequence allows imaging very short T_2 species, like water in teeth and bones, or even allowing the visualization of iron oxide nano-particles with a positive contrast [3]. Although ultra-short echo (UTE) sequences [4] also allow the observation of very short T_2 species, these sequences are based on the shortening of the excitation-refocusing pulse length (and hence on the increase of peak B_1), while SWIFT is not limited by the maximal B_1 available. For all these reasons, the SWIFT sequence may prove beneficial in a clinical context, for example to visualize the targeting of pathological markers by iron oxide nano-particles in anxious patients that would be stressed by the noise of a classical MRI sequence. However, due to its non-conventional nature, the implementation of SWIFT on a clinical scanner is challenging. The goal of this work was therefore to assess the feasibility of SWIFT implementation on Siemens clinical scanners.

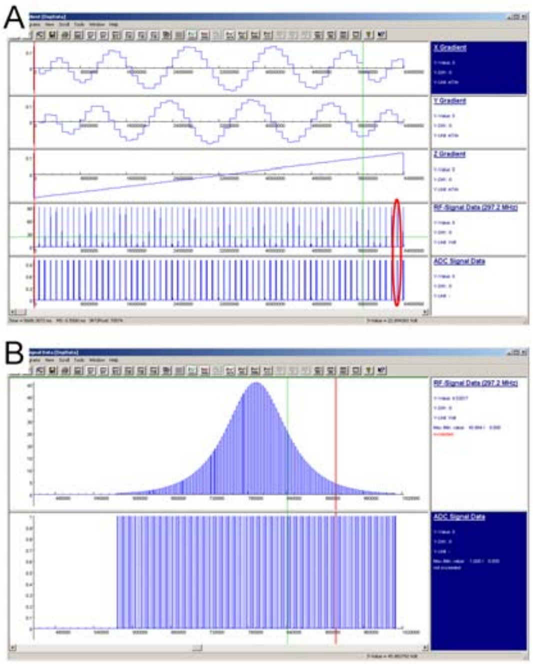

Fig. 1: A) Chronogram of the SWIFT sequence simulated with POET, for 64 directions. B) Zoom on a gapped pulse and related acquisition events included in the red ellipse of 2A.

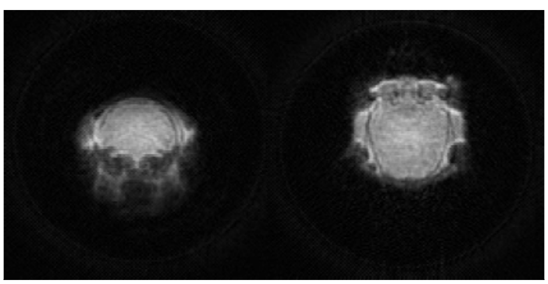

Fig. 3: Selected coronal (left) and axial (right) slices of a monkey brain SWIFT image acquired on a Siemens Tim Trio.

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Methods

Pulse sequence programming: The SWIFT sequence has been implemented under the Siemens programming environment (Idea vb15). The elementary sequence unit (kernel) consists in a segment of the RF pulse, followed by signal sampling. The shape of the RF segment is varied between each repetition of the kernel, in order to generate the different segments of a gapped HS pulse. When all the segments of the pulse have been played, the gradient orientation is changed in order to cover a regular 3D distribution, and all the pulse segments are played again. Like conventional sequences, SWIFT can be simulated with POET, the Siemens simulation environment (fig. 1).

Acquisitions: SWIFT images were acquired on a clinical 3 Tesla Siemens scanner (Tim Trio). A spherical water phantom (ø=17 cm) was imaged using a Siemens birdcage coil, with FOV=35 cm and a 2.5 kHz acquisition bandwidth (BW). A macaque monkey was also imaged using a single loop positioned around the head (FOV=18 cm, BW=3 kHz). All acquisitions were performed using HS1 pulses with time-bandwidth factor R=128, pulse duty cycle d_c=50%, pulse oversampling L_{over}=16 [2], 8192 directions, and TR=100 ms.

Image reconstruction: 3D SWIFT images were reconstructed offline using dedicated Matlab routines based on a *k*-space gridding algorithm. No filtering was performed.

Results

A slice of the reconstructed 3D image for the water sphere is presented in fig. 2, demonstrating that the SWIFT acquisition yields the correct geometry. In order to illustrate how more complex objects are captured, coronal and axial slices of the monkey head are displayed on fig. 3: the shape of the head and brain can be easily identified, although the edges of the head are distorted and blurred due to B_0 inhomogeneities. These effects are expected to disappear at significantly higher acquisition bandwidth, which is currently not achievable due to the limited T/R switching capabilities of the coils used.

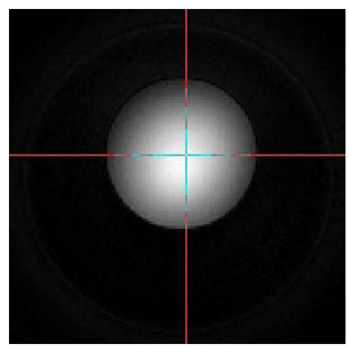

Fig. 2: Selected slice of a water sphere SWIFT image acquired on a Siemens Tim Trio.

Discussion and conclusion

Despite its non-conventional nature, the SWIFT sequence was successfully implemented on a Siemens clinical scanner. The main limitation arises from the limited T/R switching capabilities of available coils, which prevent in practice reaching high BW, and consequently make SWIFT images susceptible to geometric distortions associated to B_0 inhomogeneities. Future efforts will aim at developing fast T/R switches interfaced to Siemens scanners, in order to take full advantage of SWIFT. These developments might ultimately lead to new and exciting possibilities in the fields of clinical investigation and diagnosis.

[1] Idiyatullin et al., J Magn Reson 2006; [2] Idiyatullin et al., J Magn Reson 2008; [3] Corum et al., proc ISMRM 2008; [4] Robson et al., J Comput Assist Tomogr