Scan Time Reduction for Ultrashort TE Imaging at 3T

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Introduction

Sequences with ultrashort echo times (UTE) are used to image tissues with short T2 relaxation times. Such sequences may benefit from high field strength, yielding an improved signal-to-noise ratio and spatial resolution. For 2D imaging, ultrashort echo times can be achieved using half-sinc RF excitation pulses, which limit the echo time to only the hardware switching time [1,2]. Usually, two subsequent excitations with slice-selection gradients of opposite sign are applied (Fig.1), and their MR signals are added to form the signal from the desired slice profile. Thus, the scan time is inherently doubled. In this paper, a possible scan time reduction by measuring each profile only once and interleaving the excitation pulses is investigated.

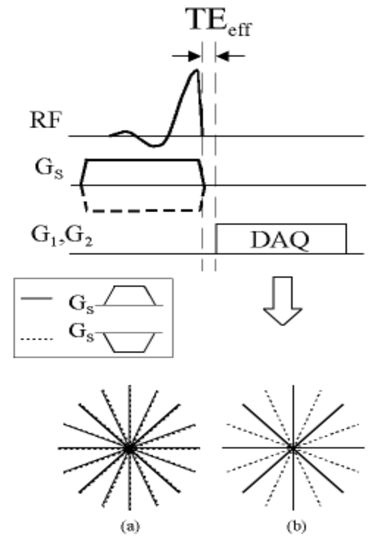

Figure 1: Ultrashort TE imaging sequence. The half-sinc excitation pulse is followed by fast FID sampling. Two excitations are required per k-space line to excite a 2D slice: (a) fully sampled radial acquisition, (b) reduced interleaved acquistion.

Theory and Methods

UTE sequences employ self-refocused half-sinc RF excitation pulses [1,2] in combination with a fast FID signal read-out (Fig.1). Primarily, spiral or radial sampling schemes are used, or a combination of both [3]. Usually, two excitations (one with a positive and the other with a negative slice-selection gradient) are required for each spiral arm or radial line to excite a 2D slice (Fig.1(a)). However, sampling schemes that over-sample the center of *k*-space are less prone to an angular *k*-space sub-sampling, allowing a scanning time reduction by measuring each profile only once and interleaving profiles with positive and negative slice-selection gradients (Fig.1(b)).

Each half-sinc excitation by itself excites magnetization throughout the entire object [3] as shown in Fig.2. Upon summation of the excited signals, the imaginary parts of the excited signal cancel and the real parts, which are equal for both excitations, form the desired slice profile. If each profile is measured only once and excitations with the positive and the negative slice-selection gradient are interleaved (Fig.1(b)), the real parts of the signal add to form a fully sampled image of the 2D slice. The imaginary parts, however, are both sub-sampled (because only every second profile is measured), and their cancellation will be incomplete. For spiral acquisitions, sub-sampling artifacts from signal outside of the slice may occur and could interfere with the image of the slice. With the radial FID acquisition, on the other hand, the center of *k*-space is inherently over-sampled, and sub-sampling artifacts are reduced. With the reduced interleaved acquisition, the scanning time is reduced by a factor of 2.

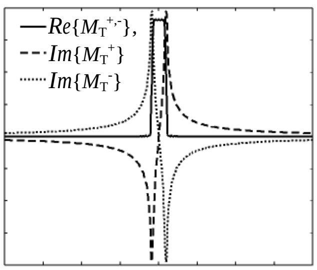

Figure 2: Excited slice profiles from the two half-sinc pulses. Upon summation, the imaginary parts of the two excitations cancel.

Results and Discussion

Experiments were performed on a Philips 3T whole body scanner using a Tx/Rx body coil with a switching time of 55 μs and a four-element surface coil array with a switching time of 120 μs [4]. Phantom images are shown in Fig.3 (TE = 100μs; 256 matrix; spiral: 256 one-turn interleaves, radial: 512 half-lines). For the spiral acquisition (Fig.3(a)), the fully sampled image shows the proper slice (left), whereas slight sub-sampling artifacts are visible with the reduced acquisition (right). For the radial acquisition (Fig.3(b)), artifacts occur neither with the full (left) nor with the reduced acquisition (right). With the reduced acquisition scheme, the scan time is reduced by a factor of 2. However, with the full acquisition the SNR of the acquired image is higher by a factor of $\sqrt{2}$, because the signal of the desired slice is measured twice and thus averaged. The loss in SNR may be compensated by using a surface-coil phased array. The localized sensitivity of the phased array yields the further advantage of dampening the signal from outside the excited slice and thus reducing image artifacts.

In-vivo measurements of the human knee are shown in Fig.4 (TE = 150μs). Radial FID sampling was applied, and the four-element surface coil array was used. By using the reduced interleaved acquisition, the scanning time was shortened. Weak sub-sampling artifacts are visible in the outer region of the FoV, which, however, do not diminish the image quality.

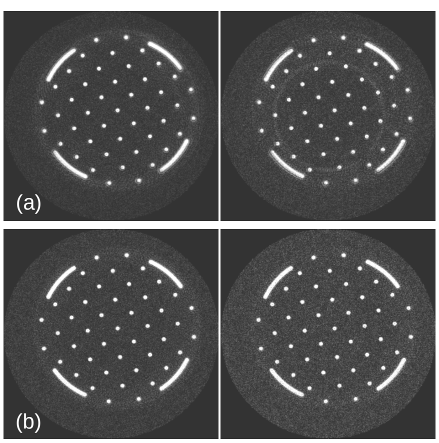

Figure 3: Phantom measurements with regular UTE acquisition (left) and reduced interleaved acquisition (right). (a) spiral acquisition, (b) radial FID acquisition.(TE = 100 μs, TR = 25 ms, α = 10°, T/R body coil)

Conclusion

For UTE imaging in combination with radial FID sampling, a scan time reduction by a factor of 2 becomes possible at the expense of a reduced SNR. A further scan time reduction is feasible by using phased arrays in combination with SENSE. Short scan times are mandatory, for example, for fast UTE scout scans or for dynamic UTE scans.

References

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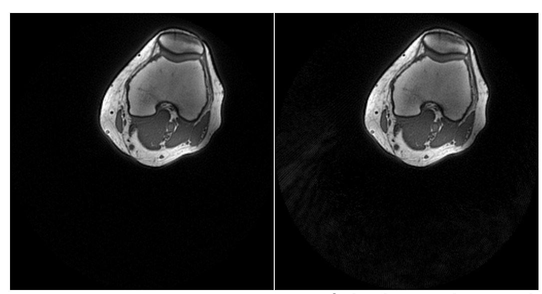

Figure 4: In vivo measurements of the human knee with regular UTE acquisition (left) and reduced interleaved acquisition (right). (TE = 150μs, TR = 50ms, a = 10°, FoV = 250mm, 256 matrix, 512 radial acqs., four-element phased-array for signal reception)