Reduced SAR with BASE Sequence at 7 Tesla

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Introduction:

To reduce measurement time, sequences are required which either significantly reduce the repetition time or acquire several echoes within each excitation. Among those the Turbo Spin Echo (TSE) is widely used today on clinical scanners at typical field strength of 1.5T to 3T. The step towards 7T provides a significantly higher MR signal potentially allowing for decreased scan time and significantly higher resolution. Increased field strength however is associated with a quadratic increase of the deposited RF energy [1], which especially applies to TSE due to its large number of refocusing pulses. Therefore, at higher fields, such as 7T TSE cannot be used without restrictions such as e.g. longer repetition times and lower refocusing angles. In this work, we examine the applicability of the BASE sequence [2] at 7T in order to reduce SAR. BASE is a combination of BURST [3] and spin echo and was originally developed to speed up acquisitions. In this work we show the first images obtained on a 7T whole body scanner using the BASE sequence.

Materials and Methods:

The BASE sequence was implemented as shown in figure 1. After six subsequent excitation pulses the signals are refocused by one or multiple refocusing RF pulses. For every second excitation pulse the polarity of the slice selection gradient is inverted to refocus the signals from earlier excitations. The phase of the RF excitation pulses are varied according to [4] and the flip angles are chosen to be 30° close to the theoretical maximum of $\pi / (2*\mathrm{sqrt}(6))$ in order to provide optimal signal utilization. Different phase encoding of the individual echoes is achieved by applying blipped gradients between subsequent excitation pulses. The phase encoding scheme is shown in fig. 1 b) and was chosen to provide a smooth transition of signal intensity in k-space. The moment of the spoiler gradients was changed between segments in order to prevent unwanted stimulated echoes. The sequence was implemented on a clinical 1.5T scanner (Siemens, Avanto) as well as on a 7T scanner for fundamental and clinical research (Siemens).

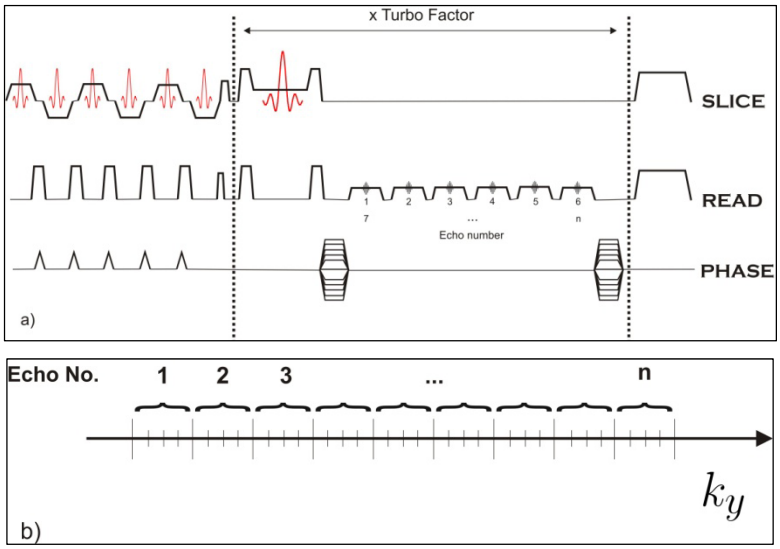

Fig 1: a) BASE sequence b) reordering

Results:

Fig. 2 a) and b) show images of a phantom obtained with the 7T whole body scanner (24 channel head coil, Nova Medical, Wilmington, VA) with TSE(a) and BASE (b). Sequence parameters for the images are TR=3s, BW=210Hz/Px, Matrix=320x320, Turbo-Factor=18, Δs=5mm for TSE and TR=3s, BW=210Hz/Px, Matrix=320x320, Turbo-Factor=3, Δs=5mm for BASE. Under visual inspection the two images look nearly identical.

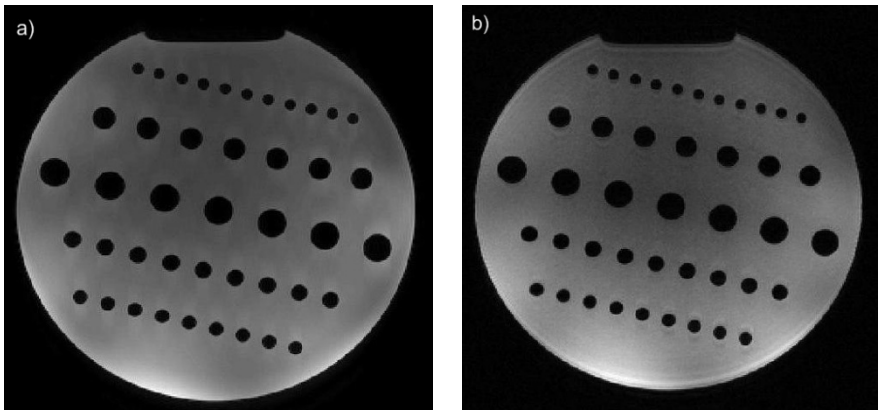

Fig 2: a) phantom image with TSE at 7T b) phantom image with BASE at 7T

Discussion

In this work we have demonstrated the applicability of the BASE sequence at 7T. We have shown in the phantom experiment that high resolution images on a 7T whole body scanner can be achieved using the BASE sequence. Compared to TSE SAR was reduced approximately by a factor of four. Thus, BASE has the potential to improve SAR related problems associated with high magnetic fields. The in vivo images at 7T (data not shown) still show residual motion artefacts in phase encoding direction and the expected lower SNR compared to conventional TSE-technique and thus leave room for further improvements.

Reference:

[1] Bottomley, et al., MRM 2: 336–349 (1985)
[2] van Gelderen et al., MRM 33:439–442 (1995)
[3] Hennig et al.,MAGMA 1:39–48 (1993)
[4] van Gelderen et al., JMRB 107:78–82 (1995)