The sensitivity of TrueFISP to mesoscopic field inhomogeneities

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Synopsis
The purpose of the present study is to investigate the sensitivity of TrueFISP to mesoscopic field inhomogeneities and to analyse the effect of intravoxel dephasing in TrueFISP sequences compared to conventional gradient echo experiments. Numerical simulations on different off-resonance distributions were performed and compared to MR imaging experiments at 11.75T. In conclusion, TrueFISP shows a similar sensitivity to intravoxel dephasing than gradient echo experiments. In certain circumstances, TrueFISP is even more sensitive to intravoxel dephasing than gradient echo experiments.

Introduction
Steady-state free precession (SSFP, TrueFISP [1]) methods allow the acquisition of T2/T1-weighted images with high SNR in short acquisition times. A major drawback of these sequences is their sensitivity to off-resonance frequencies caused by macroscopic field inhomogeneities. The steady-state signal is modulated with a periodicity of 1/TR, whereby the signal phase is alternating between consecutive periods (Fig. 1) [2]. This leads to the well-known dark stripe artifacts in TrueFISP images with long TR or in inhomogeneous fields. These banding artifacts can be avoided if the range of resonant frequencies across the image plane is within the plateau of this intensity profile. In the present study, the sensitivity of TrueFISP to mesoscopic field inhomogeneities and the effect of intravoxel dephasing is investigated.

Methods
Numerical simulations of TrueFISP and RF-spoiled FLASH signal amplitudes for different distributions of off-resonance frequencies were performed. First, a one-dimensional inhomogeneity created by a constant gradient field was analysed. In a second case, the field inhomogeneity created by a cylinder of radius r and constant susceptibility $\chi$ placed perpendicular to the direction of the magnetic field $B_0$ was investigated.

The results of the simulations were compared to MR experiments performed on a Bruker AMX-500 microscopy system at 11.75 T. With a matrix of 256 x 256 a TR/TE = 4.0/2.0 ms was achieved for the TrueFISP sequence and TR/TE = 4.5/2.0 ms for the FLASH sequence. Using a FOV of 20 x 20 mm an in-plane resolution of 78 µm was obtained with a slice thickness of 500 µm.

Results
Figure 2 shows the simulated signal behavior for a TrueFISP and a RF-spoiled FLASH sequence for a off-resonance distribution in a given voxel created by a constant gradient field. The two types of imaging sequences show a similar signal behavior on the off-resonance distribution. The signal intensity behaves like a sinc function and shows a signal minimum when the off-resonance distribution in a voxel is a multiple of $2\pi$. In Figure 3 the results obtained by a field inhomogeneity created by a cylinder are illustrated. Figure 3a shows the voxel signal intensity in dependence from the distance from cylinder axis. Near the cylinder intravoxel dephasing is observed, whereas at a certain distance signal attenuation is caused by the banding pattern of TrueFISP. The corresponding TrueFISP image is shown in Figure 3b and the FLASH image in Figure 3c.

Discussion & Conclusion
Our results indicate, that TrueFISP is very sensitive to intravoxel dephasing. If the range of resonant frequencies in a given voxel is not within the plateau of the intensity profile, then signal attenuation occurs due to the fact that the signal phase alters between consecutive periods. Thus, in the presence of large mesoscopic field inhomogeneities signal loss in TrueFISP imaging is not only caused by the banding pattern, but also from intravoxel dephasing due to the alteration of signal phase. In the case of intravoxel dephasing, TrueFISP shows a similar sensitivity to off-resonance frequencies caused by susceptibility differences than conventional gradient echo techniques. In certain circumstances, TrueFISP has even a higher sensitivity to intravoxel dephasing than RF-spoiled FLASH. This sensitivity depends mainly on the bandwidth of off-resonance frequencies and on the position of the bandwidth in relation to the on-resonance for every voxel and can lead to a first signal minimum in Fig. 2 for a off-resonance bandwidth of $\pi$.

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References