

Local Signal Recovery in Clinical FLASH Imaging with Parallel Transmission

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Target Audience: MR physicists and radiologists. **Purpose:** At higher field strengths (3T and above), T2* weighted images acquired with gradient-echo (GRE)-based sequences, e.g. FLASH, SWI and BOLD fMRI, are often impaired by local signal loss induced by susceptibility effects. In the human brain, susceptibility-related artifacts typically appear near the orbital frontal and inferior temporal cortex and hinder the diagnosis of stroke and hemorrhage. The effect becomes worse with increasing echo time (TE) and is often dominated by the through-plane signal loss component. Recently, Deng et al. (1) proposed a method to mitigate through-plane susceptibility artifacts using parallel transmission without increasing scan time or changing the slice coverage. Their approach relied on a custom-built head coil with four local transmit-channels and suffered from severe B1 inhomogeneity. Most clinically available scanners are solely equipped less transmit channels and therefore less degrees of freedom to recover local signal losses.

In this work, we successfully transferred the proposed approach to a clinical and commercially available 3T scanner equipped with two whole-body transmit channels. Furthermore, we extended the method to also correct for B1 inhomogeneity. Finally, we evaluated the proposed method with human in-vivo experiments using a clinical multi-slice FLASH sequence.

Methods: The proposed method is based on the approach of Deng et al. (1), which basically applies two excitation pulses on separate transmit channels. By introducing a time delay between those two pulses, a linear phase is imposed on the slice profile, which can be used to compensate the phase cancellation induced by the through-plane susceptibility. We extended this approach for B1 inhomogeneity mitigation by considering the respective excitation coil profiles within the pulse calculation. For this purpose, we combined the approach with a slightly modified version of the pulse optimization framework in (2). To evaluate the potential benefits of the approach, human in-vivo experiments were performed on a 3T MAGNETOM Skyra scanner (Siemens, Erlangen, Germany) using a prototype multi-slice gradient-echo based FLASH sequence. Images were acquired with FOV 240x240 mm², matrix 256x256, slices 26, slice thickness 5 mm, TE/TR 20/870 ms and GRAPPA acceleration factor 2, using the standard RF excitation pulse or the presented time-delayed excitation. The time-delay t_{delay} was adjusted to a) offer the best compromise between local signal recovery and SNR level ($t_{\text{delay}} = 300 \mu\text{s}$) and b) focus on the signal recovery ($t_{\text{delay}} = 800 \mu\text{s}$). The setup was chosen to provoke strong B1 inhomogeneity effects towards the most cranial slices.

Results/Discussion: Exemplary slices of the experiments are shown in Fig. 1. The images acquired with the standard excitation pulse suffer from strong susceptibility artifacts in the frontal orbital and temporal cortex (slices 10 & 11). Subtle to prominent B1 shading towards the image center can also be observed in slices 17 and 20. In contrast, images based on the proposed time-delayed excitation show significantly less signal loss and less B1 shading effects. The difference images (Fig. 1 third row) reveal that the signal level could be maintained while recovering up to 50% signal in the areas suffering from through-plane susceptibility. Moreover, full signal recovery can be obtained at the cost of global SNR (Fig. 2).

Conclusion: The proposed method enables the compensation of local signal loss induced by susceptibility effects on a clinically available scanner system. At the same time, it allows for B1 inhomogeneity correction. Furthermore, the method provides the user to balance the trade-off between SNR level and signal recovery level. The approach can be easily transferred to other GRE-based sequences, such as SWI and BOLD fMRI.

References: [1] Deng et al. (2009). MRM 61:255-259. [2] Schneider et al. (2013). MRM doi: 10.1002/mrm.24780.

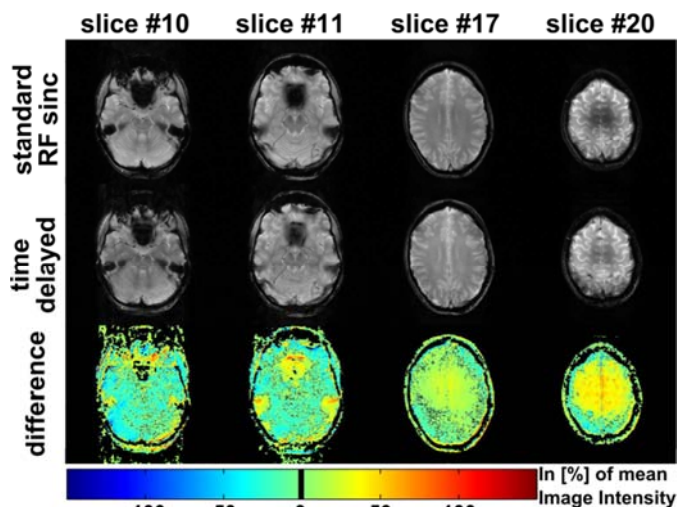


Figure 1: Selected slices using a standard RF sinc excitation (first row) or the proposed time-delayed excitation (second row). Third row shows the difference image in [%] of the mean image intensity of the image acquired with the standard RF sinc.

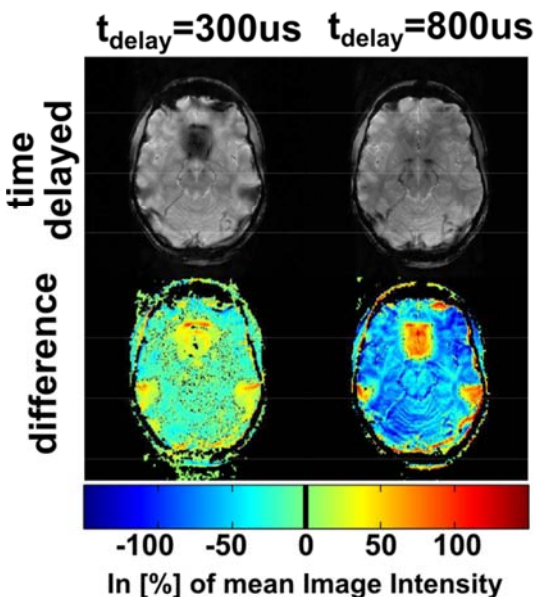


Figure 2: Similar to Fig 1. Slice #11 acquired with different time delays showing the trade-off between SNR and signal recovery level.