Exponential excitation pulses for improved water content mapping in the presence of background gradients

C. Preibisch[1], and R. Deichmann[1]
[1]Brain Imaging Center, University Frankfurt, Frankfurt, Germany

Introduction: Spin density mapping techniques are often based on the acquisition of multiple gradient echoes (GE) with different echo times (TE) which are fitted to a mono-exponential function in order to obtain the signal amplitude S_0 at TE=0 [1,2]. However, in the presence of a linear magnetic field gradient G_{susc} the signal decay is no longer exponential but in the case of a rectangular slice profile weighted by a sinc function [2, 3], giving rise to erroneous S_0 values. To overcome this effect polynomial fitting has been suggested [2]. However, this technique is relatively demanding, requiring a large number of echoes. Generally, it can be shown that the signal decay is given by $S(TE)=S_0 \cdot A(TE \cdot G_{susc}/G_s) \cdot \exp(-TE/T_2^*)$ where $A(t)$ is the time profile of the excitation pulse and G_s is the slice selection gradient. Thus, for an excitation pulse with an exponential time profile, i.e. a Lorentzian slice profile, the signal decay remains exponential and an exponential fit yields the correct amplitude S_0. We propose the use of such pulses in order to obtain accurate estimates for S_0 from exponential fitting of a small number of data points.

Methods: Multi-echo GE images (8 echoes, TE = [5, 8, 14, 20, 26, 32, 40, 48] ms) of a gel phantom (with a tiny iron piece attached for creating field inhomogeneities) and a human volunteer were acquired on a 3 T MR head scanner. Imaging parameters: voxel size 1x1x2 mm^3, matrix 256x256, no interslice gaps, interleaved slice acquisition, flip angle 50°, TR 1800 ms, excitation using both a sinc-shaped and an exponential pulse. Exponential fitting of the magnitude data yielded S_0. Phase data were used to calculate magnetic field gradient maps. Additionally, simulations were performed to investigate the influence of saturation effects on the fitted amplitude S_0 for sinc and exponential pulse shapes.

Results: Fig 1 shows gradient maps (left) and fitted S_0 maps obtained with the sinc pulse (middle) and the exponential pulse (right) in a phantom (top) and a volunteer (bottom). The maximum magnetic field gradient (a, d) was about 300 µT/m. S_0 maps based on the sinc-shaped excitation pulse (b, e) showed a clear S_0 enhancement with increasing field gradient which does not occur in images based on the exponential excitation pulse (c, f). Fig 2 shows the dependence of S_0 on G_{susc} in a simulation (a) and the gel phantom (b). There is a considerable overestimation of S_0 with a sinc-shaped excitation pulse. With an exponential excitation pulse this effect is greatly reduced. Residual enhancement is mainly due to saturation effects distorting the excitation profile and can be further reduced by using smaller flip angles and/or longer TR.

Conclusion: Simulations and measurements show that an exponential excitation pulse shape widely reduces S_0 overestimations as long as major distortions of the pulse shape by saturation effects are avoided, i.e. for flip angles < 50° and TR > T1.

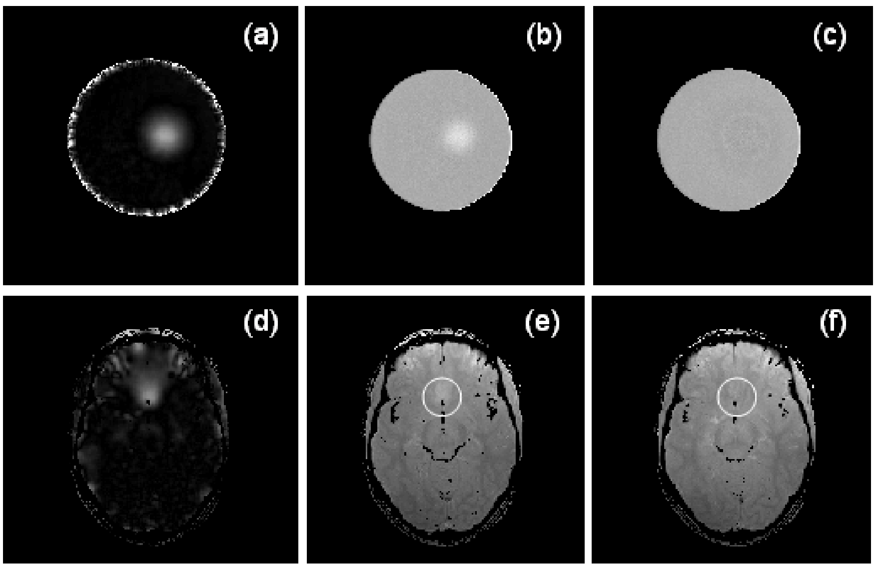

Fig 1: Single slice of the gel phantom (a-c) and a healthy volunteer (d-f). Susceptibility gradient G_{susc} (a) maximum: 322 µT/m, (b) maximum 280 µT/m and normalised fitted amplitude S_0 for excitation pulses with (b, e) sinc and (c, f) exponential pulse profile.

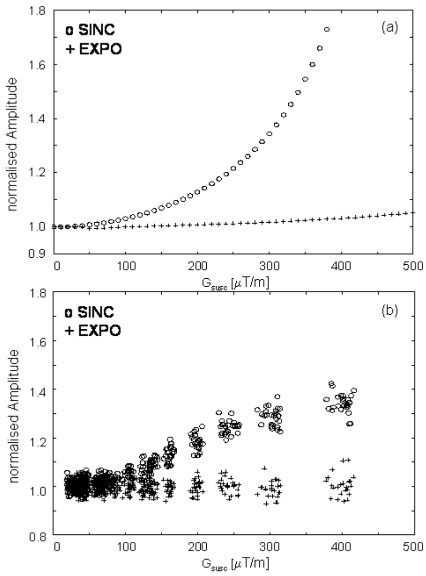

Fig 2: Normalised fitted amplitude $S_0(G_{susc})$: (a) simulation (T1 = 1200 ms, TR = 1800 ms, FA 50°). (b) gel phantom

References: (1) Warntjes et al., MRM 57: 528 (2007). (2) Neeb et al., Neuroimage 31: 1156 (2006). (3) Fernandez-Seara & Wehrli, MRM 44: 358 (2000).