Mapping inversion efficiencies of adiabatic pulses at 7T

M. Narsude[1,2], J. Marques[1,2], F. Eggenschwiler[1], and R. Gruetter[1,3]
[1]Laboratory for Functional and Metabolic Imaging, Ecole Polytechnique Fédéral de Lausanne, Lausanne, Vaud, Switzerland, [2]Department of Radiology, University of Lausanne, Lausanne, Vaud, Switzerland, [3]Department of Radiology, University of Geneva, Geneva, Switzerland

Introduction: At high magnetic fields (7T and above) as the RF wavelength becomes comparable to the sample size, transmit B_1 field suffers from inhomogeneous distribution. This, together with increased SAR, makes the task of homogeneous inversion throughout the whole brain difficult to achieve which is typically required by applications such as perfusion imaging and T_1 mapping [1]. In this work the performance of different adiabatic pulses was analyzed in phantom, and in-vivo at 7T. The inversion efficiency in three orthogonal planes in vivo was compared to the predicted outcome using in vivo B_1 mapping and in-vitro measurements of the inversion efficiency.

Methods: Experiments were performed on a 7T system (Siemens, Germany) using an eight channel coil (Rapid Biomedical, Germany). 3 subjects were scanned in accordance with the procedures approved by the local research ethics committee.

A B_1 mapping sequence [2] was modified in order to map inversion efficiency. The sequence consisted of an inversion pulse, followed by a turbo flash readout using centric reordering in order to minimize T_1 relaxation between inversion and acquisition of the center of k-space. Main sequence parameters were: TR=25s, TR_{flash}/TE=3.5/1.7ms, 64x33 matrix size, $\alpha=4^o$ allowing one slice to be acquired per TR. For the phantom calibration studies, the peak amplitude (γB_1) of the adiabatic pulse was varied from 0 to 670 Hz (due to hardware limitations) in 16 steps.

HS1, HS2, Sin2, Gauss and GS7 [3] pulses with durations of 8, 12, 16, 20ms were evaluated. Inversion efficiency maps were calculated for each receiving channel by taking the ratio of the turboflash images preceded and not preceded (reference image) by an inversion pulse. The inversion efficiency maps of different channels were subsequently combined by sum of squares weighting based on the reference image.

B_1 maps for the whole human brain were measured using the Sa2RAGE sequence [4] with the following parameters: Sa2RAGE TR=2.4s, TR_{Flash}=2.9ms, α_1 /α_2 =6/12 deg, TD_1/TD_2 = 106/1800ms, 32 slices (total scan time =59s). Human brain images in three orthogonal planes were acquired with this peak B_1 and were compared with predicted inversion efficiency images. Using the Sa2RAGE B_1 maps of subjects' brains and inversion efficiency curves as a function of γB_1, it was possible to predict inversion efficiency of a certain RF pulse and the minimum peak amplitude to obtain inversion over the whole head.

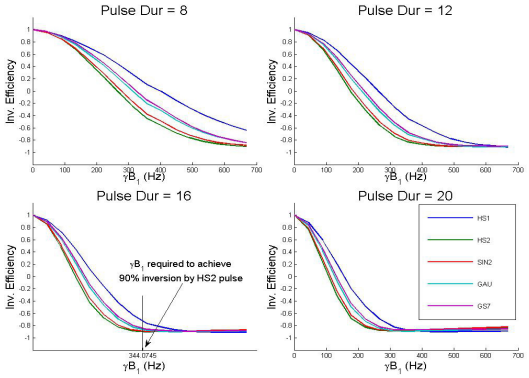

Fig 1: γB_1 vs. Inversion efficiency of on resonance adiabatic pulses for 8ms, 12ms, 16ms and 20ms durations

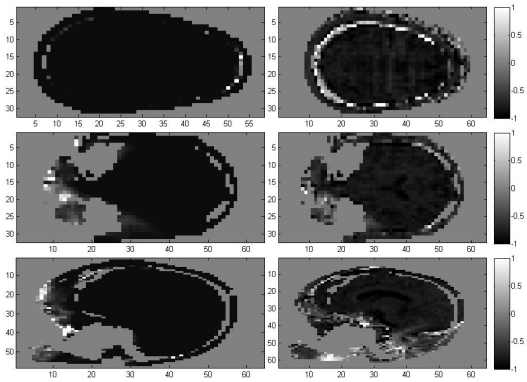

Fig. 2: Predicted inversion map (left) and actual inversion obtained in human brain (right)

Results & Discussions: Fig. 1 shows the inversion efficiencies of these pulses with respect to the peak γB_1 (Hz) delivered. As can be seen from this figure, SIN2 and HS2 pulses achieved maximum inversion at a lower peak γB_1 compared to the remaining pulses (although at a cost of higher SAR for the same peak γB_1). Fig. 2 shows human head images for three orthogonal planes using HS2 pulse with 16ms duration. Left column shows the predicted inversion maps whereas right column shows brain inversion obtained when peak γB_1 required for 90% inversion efficiency was applied.

It is demonstrated that it is possible to perform whole head inversion at 7T. Inversion achieved in the CSF regions (deviation ~2%) was as predicted from the phantom studies, while in the tissue regions reduced inversion efficiency was observed with biggest deviations (~14%) being found in white matter. The cause of these deviations should not be related to T_2^* effects as both inverted and reference images have the same T_2^* weighting. The T_1 recovery between inversion and acquisition of center of the k-space also cannot be the cause since this time period is very short compared to T_1s observed at 7T. The point spread function of turbo flash during acquisition is less likely to decrease the observed inversion efficiency since 33 phase encode lines take only ~115ms for their acquisition. This decrease in inversion efficiency, which is under investigation and is likely due to $T_{1\rho}$ during the inversion [5], might not pose a significant problem for arterial spin labeling (ASL) as arterial blood has long T_2.

References: [1] Gardener et al., MRM 61 (2009), 874-882, [2] H-P. Fautz et al., ISMRM 16 (2008), p.1247, [3] Tannus et al., NMR in Biomedicine 10 (1997) 423-434, [4] Eggenschwiler et al., ISMRM Annual meeting 2010, [5] Michaeli et al., JMR 181 (2006) 135-147

Acknowledgement: Supported by the CIBM of the UNIL, UNIGE, HUG, CHUV, EPFL and the Leenaards and Jeantet Foundations.