Adiabatic Magnetization Preparation Pulse for T_2-contrast at 7 Tesla

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Introduction: High-resolution MRI at 7T has the potential to provide tremendous improvement in the diagnosis and treatment of a wide range of neurological diseases. High-resolution T_2-weighted sequences are sensitive for assessing subtle structural abnormalities associated with many of these diseases [1]. Unfortunately, conventional T_2-weighted sequences, such as Fast Spin Echo (FSE), utilize a train of high flip-angle Shinnar Le-Roux (SLR) [2] refocusing pulses that are very susceptible to the severe B_1 inhomogeneity and SAR limitations observed at 7T. We propose an alternative adiabatic magnetization preparation (AMP) technique to obtain B_1-insensitive T_2-contrast at 7T. A BIR-4 pulse [3,4] with a flip angle of 0° with delays inserted between segments is used to introduce T_2 decay. Such a pulse was previously described for use in zero or double quantum filters [5] and T_2 magnetization preparation at 3T [6]. We use the adiabatic SLR technique described in [7] to generate the BIR-4 segments so that the peak RF amplitude at adiabatic threshold is minimized and a greater range of adiabaticity is achieved. An AMP pulse was designed for use at 7T and validated with phantom and *in vivo* experiments.

Method: The adiabatic SLR algorithm [7] was used to create an adiabatic full passage pulse with the following pulse parameters: 5 kHz bandwidth, 14ms duration and peak B_1 value of 11.46μT. The pulse was divided into adiabatic half passage segments and used to compose a BIR-4 pulse with a 0° rotation. Symmetric time delays were introduced between half passage segments 1 & 2 and 3 & 4 to create the final AMP pulse with a total duration of 53ms. Amplitude and phase waveforms for the AMP pulse are shown in Figs. 1 A and B. Simulations were performed to test the B_1-insensitivity of the AMP pulse. The profile of the AMP pulse followed by a 90° linear-phase excitation pulse was simulated for a range of AMP pulse amplitudes above the adiabatic threshold. Figure 1 C shows the simulated spectral profile for a range of B_1 overdrive factors (i.e. percentage by which B_1 was increased above the adiabatic threshold for the AMP pulse).

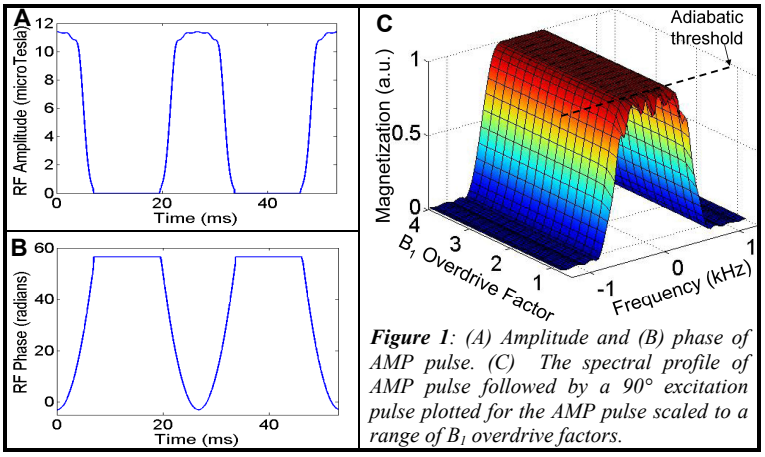

***Figure 1**: (A) Amplitude and (B) phase of AMP pulse. (C) The spectral profile of AMP pulse followed by a 90° excitation pulse plotted for the AMP pulse scaled to a range of B_1 overdrive factors.*

Phantom Experiments: Phantom experiments were conducted using a 7T scanner (Echospeed whole-body magnet; GE Healthcare, Waukesha, WI, USA) to validate the pulse performance. The AMP pulse was added to a standard GRE sequence prior to the 90° excitation pulse in order to test if B_1-insensitive T_2-contrast was achieved. Images were obtained of a spherical agar phantom with the AMP sequence and a conventional spin echo (SE) sequence. TE was set to 63 ms for both sequences. The receive B_1 profile was measured using a double angle method [8,9] and images were compensated by the measured profile to remove receive shading.

***In Vivo* Experiments**: Images of the brain of a normal volunteer were obtained at 7T using the AMP sequence and compared to a SE sequence as described for the phantom experiments. Acquisition parameters for both phantom and *in vivo* scans were: TE/TR= 63/1500 ms, matrix size=256x128, 5mm slice and FOV of 22x22cm.

Results: See Fig. 2 for phantom images obtained using the (A) AMP pulse sequence, and (B) SE sequence. Central vertical cross sections through the images are shown in (C). The transmit B_1 profile is significantly more uniform for the AMP pulse than the SE sequence, resulting in more uniform signal intensity. The 180° SLR pulse used in the SE sequence is overdriven at the center of the phantom, resulting in greater signal loss when compared to the AMP pulse. Figure 3 shows *in vivo* images obtained using the (A) AMP pulse sequence and (B) SE sequence. The AMP pulse achieves more uniform T_2-contrast and SNR over the entire slice. Some B_1-sensitivity still exists due to the linear phase excitation pulse.

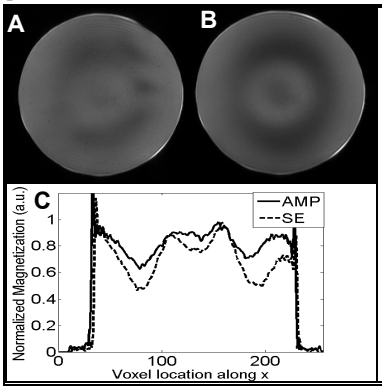

***Figure 2**: Images obtained from a spherical agar phantom at 7T using (A) the AMP pulse in a GRE sequence for T_2 preparation and (B) a conventional SE sequence for T_2-contrast. Images have been unshaded by the measured receive B_1 profile. TE/TR = 63/1500 ms, 5mm slice, FOV 22x22 cm, 256x128 grid. (C) Central vertical cross sections through phantom images. Greater signal variation is present in the SE image.*

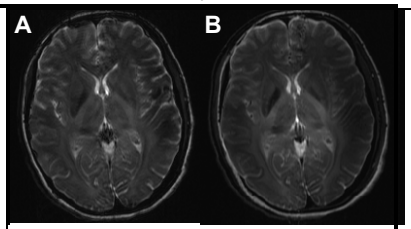

***Figure 3**: In vivo data from a healthy volunteer at 7T: Images obtained using the AMP pulse in a GRE sequence & (B) an SE sequence. Signal and contrast loss near the edges of the brain is greater for the SE sequence than the AMP sequence.*

Discussion: In this work, we present a method to achieve B_1-insensitive T_2-contrast at 7T utilizing an adiabatic magnetization preparation pulse. The contrast achieved is a combination of T_2 and $T_{2\rho}$ contrast as the magnetization is spin-locked for the duration of the adiabatic pulse segments. In addition to greater immunity to the inhomogeneous RF field, the pulse is suitable for use as a T_2 magnetization preparation pulse in a Fast Spoiled Gradient Recalled (FSPGR) sequence. Such a volumetric T_2-weighted sequence is potentially advantageous at 7T because the AMP pulse need not be applied every TR, reducing the SAR and enabling greater spatial coverage at high resolution before exceeding SAR constraints. Our next step is to integrate the AMP pulse into an FSPGR sequence.

References: [1] Atlas S, MRI of the Brain and Spine, Lippincott Williams & Wilkins, 1996. [2] Pauly J, et al. *IEEE TMI* 1991; 10(1):53–65. [3] Staewen RS, et al. *Invest Radiol* 1990; 25:559–567. [4] Garwood M, Ke Y. *J Magn Reson* 1991; 94:511–525. [5] De Graaf R, et al. *JMR, Series B* 1995;109(2):184–193. [6] Nezafat R, et al. *MRM* 2009; 61(6):1326 – 1335. [7] Balchandani P, et al. In Proceedings of ISMRM 17. Honolulu, 2009; 178. [8] Stollberger R, Wach P. *MRM* 1996;35(2):246–251. [9] Insko EK, Bolinger L. *JMR, Series A* 1993;103:82–85.

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