Slice-selective adiabatic T2 preparation using a modified STABLE pulse

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Target audience: Physicists and radiologists interested in the development of new and robust sequences for ultrahigh field MRI.

Introduction: At ultrahigh field strengths, such as 7T, T_2-prepared FLASH is an attractive alternative to the widely used turbo spin echo (TSE) sequence for generating T_2 contrast, because it allows for reduced RF power deposition. Previous studies have proposed using a modified B_1-insensitive rotation (BIR-4) pulse to achieve homogeneous T_2 preparation at high field [1,2]. However BIR-4 pulses are not slice-selective, which results in acquisitions with low SNR-efficiency because of long repetition times. Here we present a new adiabatic T_2 preparation technique that achieves B1-insensitive slice-selective T_2 contrast by employing a modified slice-selective tunable-flip adiabatic low peak-power excitation (STABLE) RF pulse [3].

Methods: A STABLE pulse (figure 1A) was designed using the adiabatic Shinnar-Le Roux algorithm [4]. Pulse characteristics were: 4 ms-long full passage segment, 2 ms-long half passage segments and peak B_1 of 12 □T at adiabatic threshold. Spacing was added between the segments and zero rotation flip angle was used to generate a modified STABLE preparation (mSTABLE). The 60 ms-long mSTABLE T_2-prep module was then inserted before a centric-ordered FLASH readout (flip angle 8°, bandwidth 130 Hz/pixel, acquisition matrix 192 x 144, parallel imaging R=2, TE/TR 4.2/10.3 ms). In order to compare mSTABLE to the previously used BIR-4 T_2-prep, we designed an adiabatic 4 ms duration pulse and used it to create a modified BIR-4 (mBIR-4). Both T_2-prep modules were tested on a 7T scanner (Magnetom, Siemens Healthcare, Erlangen, Germany) in a healthy volunteer, after informed consent was obtained.

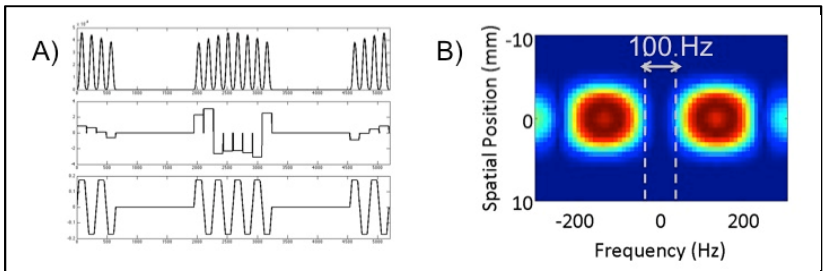

***Figure 1**: A) Pulse amplitude, phase modulation, and gradient waveforms for the STABLE excitation with 0° flip angle used as a T_2 preparation. B) Magnetization amplitude as a function of frequency and position.*

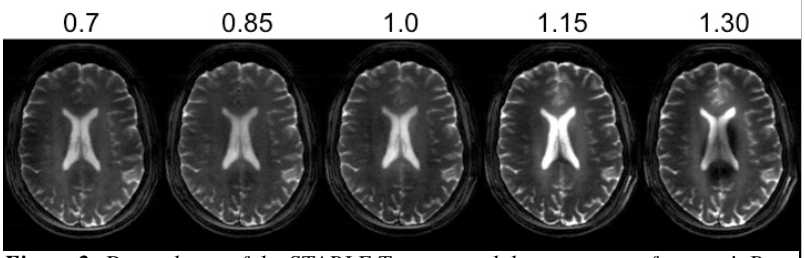

***Figure 2**: Dependence of the STABLE T_2-prep module to a range of transmit B_1 amplitudes (given as the ratio of applied B_1 to B_1 at adiabatic threshold).*

Results: Figure 1B shows that the mSTABLE preparation designed in this work behaves as a zero flip angle pulse within a 100 Hz frequency band and demonstrates good slice selectivity. Figure 2 shows the behavior of the STABLE T_2-prep as a function of B_1 amplitude. We found good immunity of T_2 contrast to B_1 variations within 30% of the adiabatic threshold value. For B_1 amplitudes over 30% of the adiabatic threshold, the larger nutation angles of the sub-pulses resulted in signal loss, which is consistent with the behavior described for STABLE in [4]. When comparing mBIR-4 and mSTABLE T_2-prep, we observed similar contrast (Figure 3A). In order to characterize the slice-selective nature of mSTABLE, we performed 3D axial acquisitions (16 slices of 2mm thickness each) while applying different amplitudes for the STABLE slice gradient. The 3D series were reformatted to a coronal orientation in order to visualize the effect of slice selection. Figure 3B shows that T_2 contrast can be obtained within a slice, while regions outside the selected slice appear as proton-density weighted and can thus be used in subsequent T_2-weighted acquisitions.

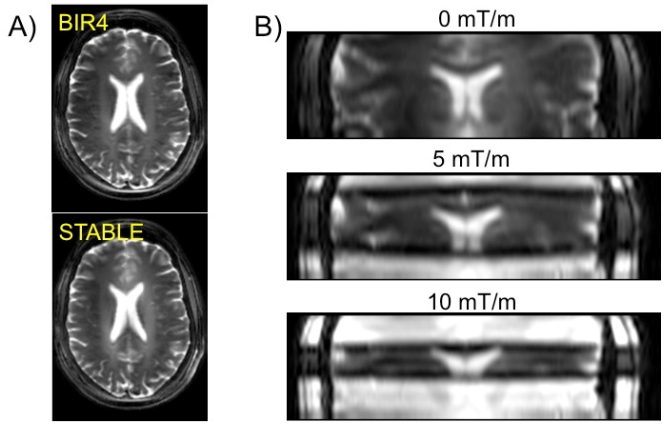

***Figure 3**: A) comparison of modified BIR-4 pulse (top) and modified STABLE T_2 preparation (bottom). B) 3D sagittal reformatted images showing slab-selective T_2 contrast as a function of the STABLE gradient amplitude (from top to bottom: 0, 5 and 10 mT/m).*

Discussion: We designed a novel T_2-prep module to perform slice- or slab-selective T_2 preparation while being relatively immune to B_0 and B_1 inhomogeneity at 7T and offering similar contrast to a BIR-4-based preparation. This enables the development of fast, interleaved 2D multi-slice or 3D multi-slab T_2-prepared acquisitions that provide improved SNR efficiency compared to standard acquisitions using non-selective T_2-prep modules. Our next step is to implement such a sequence.

Conclusion: T_2 contrast is essential for structural imaging and has strong diagnostic value. Because it employs fewer refocusing pulses, a T_2-prepared FLASH sequence has lower power deposition than a TSE acquisition (in our experience, 1.4 W/kg vs 7.0 W/kg for 2D TSE) and thus allows for whole brain coverage. Slice selectivity of the novel mSTABLE module can lead to the acquisition of high resolution whole brain isotropic T_2-weighted images with homogeneous contrast at ultrahigh field, within a clinically acceptable scan time.

References:

[1] Nezafat et al, MRM 61:1326–1335 (2009);
[2] Nguyen et al, proceedings ISMRM 2014, 0342;
[3] Balchandani et al, MRM 59:1072–1078 (2008);
[4] Balchandani et al, MRM 71:75–82 (2014).

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