Inverted Double Half RF Pulse for Long T2 suppression in Ultrashort Echo-Time Imaging

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Introduction

Imaging of short T_2 species generally uses half RF pulse excitation to achieve ultrashort echo times(UTE) [1]. Two excitations with the slice-select gradient of opposite polarity are applied and the MR signals are added to form the desired slice profile. However, the half pulse is very sensitive to gradient imperfections such as eddy-current distortions [2]. Each half pulse excitation individually is not very selective, and excites signal far from the intended slice location. In the presence of eddy currents, the magnetization from out of the slice does not cancel appropriately. Also, the signal in UTE images is often dominated by long T_2 components, which need to be suppressed to enhance the contrast of the short T_2 species. Some approaches to long T_2 suppression include magnetization preparation (usually non-selective excitation followed by dephaser) or multi-echo techniques to subtract the long T_2 signal [3]. The purpose of this work is to develop an RF pulse that does slice selective long T_2 suppression while exciting short T_2, thus making short T_2 imaging and quantitation less sensitive to eddy currents.

Method

The inverted double half RF pulse (IDHRF) proposed here consists of a pair of half pulses of opposite polarity in each excitation as shown in Figure 1. Each excitation produces a half-sinc weighting in k-space for short T_2. However the preceeding opposite polarity half pulse is seen by long T_2 spins, resulting in zero flip angle. Solving the Bloch equation numerically for short T_2 (1ms) and long T_2 (100ms) provides a simulation of the slice profiles as a function of T_2. (Figure 1b)

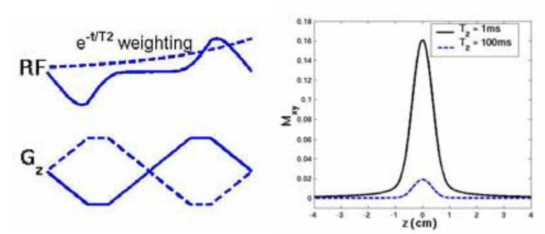

Figure 1: (left) inverted double half RF pulse with slice select gradient. (right) simulated slice profile for combined excitations.

Experiments were performed on a 0.5T GE Signa SP interventional MR scanner. A spherical phantom with a long T_2 (~100ms) was imaged with a radial acquisition (TE =150µs) with both the half pulse and the inverted double half pulse. The slice profile and the free induction decay(FID) signal was also measured with both pulses.

Results

Figure 2 demonstrates the effectiveness of the inverted double half pulse in the presence of eddy currents. The half RF pulse has tails that extend far from the desired slice, while the inverted double half RF suppresses signal from long T2. In the presence of eddy currents, the slice selectivity of the half pulses vary over time, so that the half RF FID demonstrates an oscillating behavior. The FID for the inverted double half RF decays without oscillation, or has oscillations of much smaller magnitude.

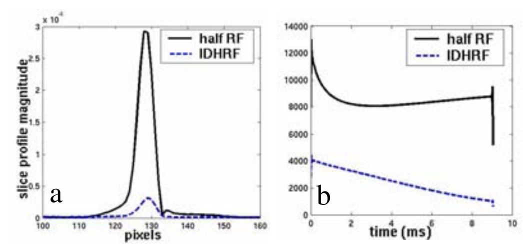

Figure 2: (a) slice profile magnitude and (b) FID, T2=100 ms

Figure 3 shows images of a phantom for the half RF and the inverted double half pulse. A sphere containing doped water (T2 ~100ms) was placed next to a gel phantom containing vials with T_2 values ranging from 0.5ms to 20ms. With the inverted double half pulse, the long T_2 signal is suppressed, which improves contrast for shortest T_2. To demonstrate the problem of out of slice signal due to eddy current distortions corrupting R_2* measurements, the short T_2 phantom was imaged with a long T_2 phantom (a cylinder with doped water) placed next to it in the slice select direction (Figure 4). R_2* maps were obtained from images at echo times of 0.1, 0.4, 0.7, and 1.0 ms. The half pulse R_2* image has significant signal outside the short T_2 phantom. The arrow shows where the out of slice long T_2 signal corrupts the R_2* measurement of the short T_2 vial. The out of slice signal is greatly reduced in the case of the inverted double half RF pulse, giving cleaner R_2* measurements.

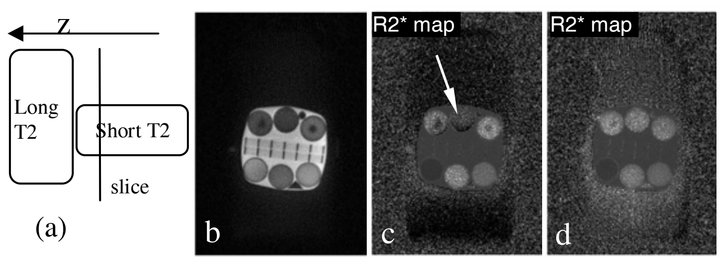

Figure 4: (a) phantom setup. (b) half RF magnitude image and (c) R2* map. (d) R2*map with inverted double half RF shows reduced out of slice signal.

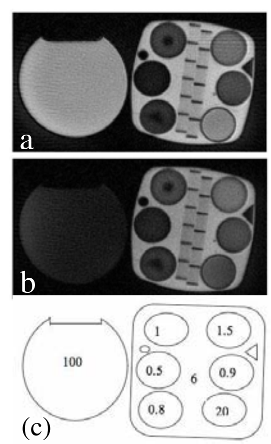

Figure 3: Phantom images with (a) half RF, (b) inverted double half RF. (c) Line diagram showing T2 (ms) values in phantom (TE=150µs)

Discussion

The inverted double half pulse improves slice selectivity of half pulses in presence of eddy currents by suppressing the long T_2. This is important when T_2* measurements may be contaminated by out of slice signal due to eddy current distortions. In addition, suppressing the large signal from the long T_2 components can provide dynamic range for the short T_2 components.

References

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[2] Wansapura J *et al* [2001], MRM,46:985-992
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