Improved Half RF Slice Selectivity in Presence of Eddy Currents with Quadratic Phase Saturation

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Introduction

Two dimensional imaging of short T2 species depends on the use of 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. The purpose of this work is to develop a simple robust method for accurate R2* quantitation in the presence of eddy currents using a quadratic phase (QP) RF saturation pulse.

Method

To suppress out of slice magnetization the saturation pulse should have high bandwidth and selectivity. QP RF pulses [3] distribute the RF energy more evenly over the pulse, compared to linear phase pulses. Thus they can achieve higher excitation bandwidth and improved selectivity, for a given max B1 amplitude and pulse duration. Using the Shinnar Le-Roux (SLR) transform [4], an RF pulse can be described by a pair of complex FIR filters. The complex Remez exchange algorithm is used to design the quadratic phase equi-ripple FIR filter coefficients [5]. The QP saturation RF pulse is cosine modulated to obtain two saturation bands on each side of the slice to be imaged. Figure 1 shows the QP RF pulse, designed for bandwidth=4kHz, fractional transition width(FTW)=0.15, B1max=0.158G, to achieve saturation bands 5cm wide, separated by 1.5cm, with a transition width of 2mm.

Experiments were performed on a 0.5T GE Signa SP MR scanner. The half RF pulse excitation with radial acquisition was used to achieve short TEs. The QP saturation RF pulse was phase cycled to effectively spoil the transverse magnetization. A spherical phantom with a long T2 (~100ms) was imaged with the half pulse with and without the saturation RF pulse, and the slice profile was measured. In the next experiment, out of slice long T2 phantoms were placed adjacent to the short T2 phantoms in-plane. In a third experiment, frozen tissue was imaged at echo times of 0.1, 0.4, 0.7, and 1.0 ms and R2* maps calculated.

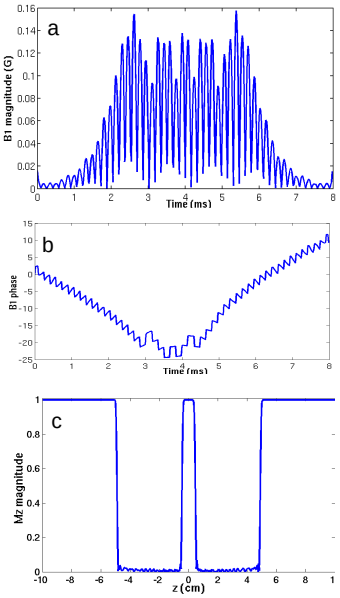

Figure 1: Cosine modulated QP RF magnitude (a), phase (b), and its simulated slice profile (c). RF BW=4kHz, FTW=0.15, B1max=0.158G, Sat bands 5cm wide, separated by 1.5cm, transition width=2mm, are placed both sides of imaging slice.

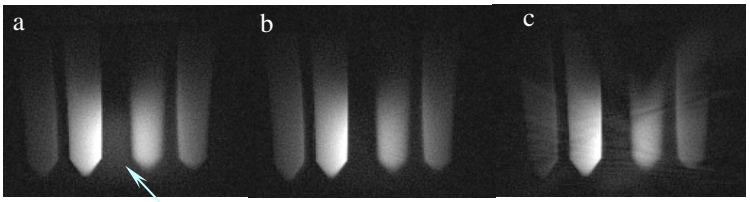

Figure 3: (a) half RF magnitude image without out of slice saturation (b) with QP saturation (c) without RF spoil (same gradient crusher used) . TE=190μs

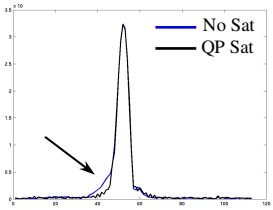

Figure 2: (a) measured slice profile magnitude of Half RF with (black) & without (blue) QP Saturation in slice direction. T2=100 ms, TE=150μs

Results

The effectiveness of the QP saturation bands in improving the slice profile of the half RF pulse is demonstrated in Figures 2 & 3. In the presence of eddy currents, the half RF pulse has tails that extend beyond the desired slice, which are suppressed by the saturation bands. In Figure 3, the half RF image has significant out of slice signal (arrow), which is greatly reduced with the saturation bands. Figure 3c shows the streak artifacts that result without RF spoiling the QP saturation pulse.

The frozen tissue experiments are shown in Figure 4. The out of slice signal is greatly reduced by the saturation bands, giving cleaner R2* measurements.

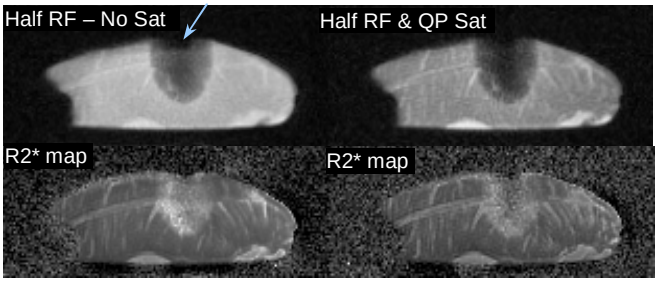

Figure 4: Magnitude & R2* images of ex-vivo frozen tissue, using half RF excitation without & with adjacent slice saturation. Arrow shows out of slice signal in case of no SAT bands.

Discussion

Using QP saturation RF with the half pulse can be an effective approach to improving the slice selectivity in the presence of eddy currents, by suppressing the out of slice signal. This is important when R2* measurements may be contaminated by out of slice signal due to eddy current distortions.

References

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Acknowledgements

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