Outer Volume Suppression in MRSI Using Equi-Ripple Designed Quadratic-Phase RF Pulses

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Introduction

MRSI is usually based on point-resolved spectroscopy (PRESS) localization and therefore the selected volume is cubic. Since regions of biological interest are rather ellipsoids or are located adjacent to fat tissue or air, outer volume suppression techniques were developed to overcome the geometric limits of PRESS MRSI. Conventional outer volume suppression (OVS) pulses based on amplitude modulation are not particularly selective and a lot of signal remains, contaminating spectra of interest. In 2000, very selective suppression (VSS) pulses developed by Le Roux [1] were successfully applied in brain and prostate MRSI [2]. VSS pulses are quadratic phase pulses designed based on a weighted least square FIR filter. A novel straight forward design method of quadratic-phase pulses based on the complex Remez algorithm was proposed by Schulte [3]. The resulting pulses have a sharper excitation profile and cause fewer errors in the transverse and longitudinal magnetization. In this work, the successful use of equi-ripple designed quadratic phase suppression (QPS) pulses for outer volume suppression in MRSI is demonstrated. Furthermore, the challenge of using multiple-outer volume suppression bands is discussed as well as the problem of significantly different T1 relaxation times, which is relevant for simultaneous suppression of fat and water.

Materials and Methods

All MRI and MRSI experiments were performed on a Philips 3T scanner (Philips Medical Systems, Best, The Netherlands). The novel quadratic-phase pulses are applied prior to PRESS-CSI excitation. Pulse duration and flip angle of each suppression band is separately adjustable. In MRI all suppression bands can be applied twice, in MRSI up to four times. In MRSI the flip angle of the same suppression band can be changed in different suppression band cycles.

Results and Discussion

The equi-ripple designed QPS pulses were successfully implemented and applied in MRI and MRSI. The excitation profile of the QPS pulses is sharper than that of conventional OVS pulses (Figure 1).

The use of multiple OVS bands leads to a gradually decreased suppression (Figure 2a) of the following suppression bands. This problem also occurs while using the novel QPS bands and is caused by progressing T1 relaxation. It can be solved by gradual adjustment of the flip angles (Figure 2b). Best results were achieved repeating the gradually adjusted QPS pulses twice (Figure 2c). The NAA metabolite maps in Figure 3 demonstrate that the new QPS pulses also lead to a better suppression profile in MRSI than conventional OVS pulses. Best results were achieved using 3 QPS cycles (Figure 3d). Wrong parameter adjustment leads to failure of the suppression (Figure 3f). This is especially important for *in vivo* fat suppression, as T1 relaxation times of fat and water are different. Hence, fat can not be suppressed well using the same parameters which were found best to suppress water. Figure 4 shows the comparison of spectra acquired without suppression bands and with the new QPS suppression bands adjusted to a flip angle of 90° and a pulse duration of 9 ms like in the previous examples. The ratio of fat to NAA, Choline and Creatine improved enormously using the QPS pulses, but not all fat disappeared from the spectra. Repetition of the suppression cycles improves the result (Figure 5b, c). An optimal flip angle for fat suppression is 105° (Figure 6).

Conclusion

High quality outer volume suppression can be achieved using QPS pulses. Gradually decreasing suppression in multiple suppression bands can be avoided by gradual flip angle adjustment of the single bands. Best simultaneous suppression of metabolites with different T1 relaxation times like fat and water can be achieved combining 2 to 4 cycles of QPS suppression bands with parameters adjusted to either metabolite in alternating fashion.

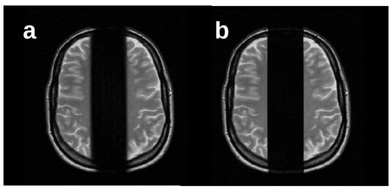

Figure 1: ***a)*** *conventional OVS;* ***b)*** *equi-ripple quadratic phase pulses*

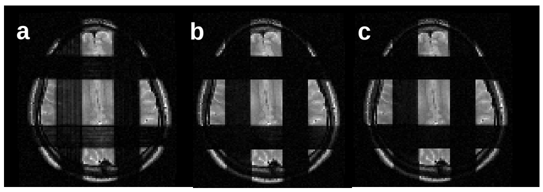

Figure 2: ***a)*** *conventional OVS;* ***b)*** *QPS 1 cycle;* ***c)*** *QPS 2 cycles, start angle 90°*

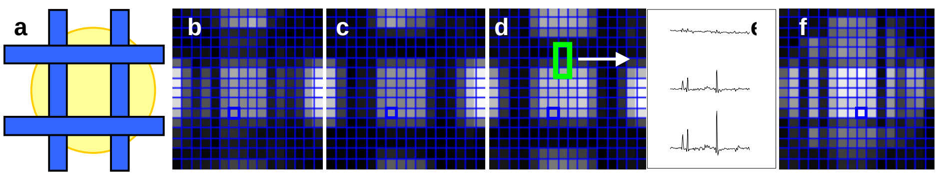

Figure 3: ***a)*** *setup of the suppression pulses;* ***b-d , f)*** *NAA metabolite maps;* ***b)*** *conventional OVS;* ***c)*** *QPS 1 cycle ;* ***d)*** *QPS 3 cycles (QPS flip angle 90°) ;* ***f)*** *QPS flip angle 130° ;* ***e)*** *spectra*

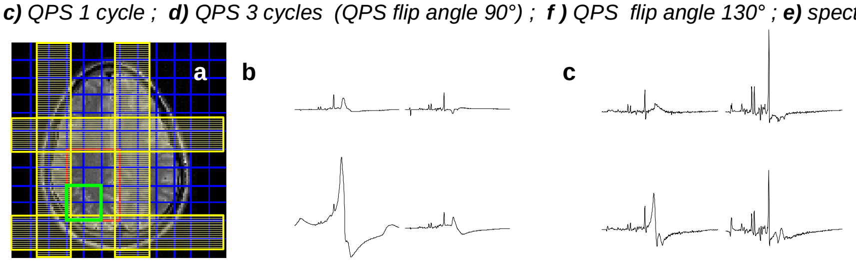

Figure 4: *Fat supression:* ***a)*** *setup;* ***b)*** *press w/o suppression bands;* ***c)*** *press with QPS (90°)*

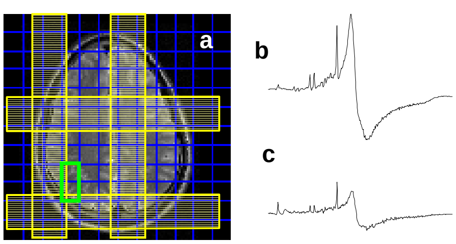

Figure 5: *Fat suppression:* ***a)*** *setup ;* ***b, c)*** *spectra of depicted voxels; QPS pulses 90°;* ***b)*** *1 QPS cycle ;* ***c)*** *2 QPS cycles*

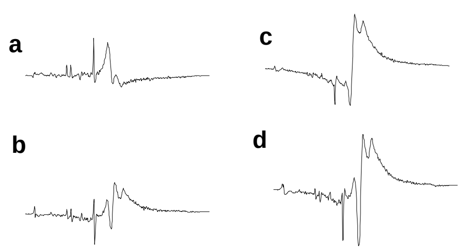

Figure 6: *Fat suppression: same setup as in Figure 5; flip angles:* ***a)*** *100°,* ***b)*** *110°,* ***c)*** *120°,* ***d)*** *130°*

[1] Le Roux P, et al., JMRI 1998 ; 8 :1022
[2] Tran TKC, et al., MRM 2000 ; 43 :23
[3] Schulte, et al., JMR 2004 ; 166 :2004