Single-sided Quadratic Phase Outer Volume Suppression Pulses

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Introduction: Quadratic phase outer volume suppression (OVS) pulses are used for single-shot fast spin-echo cardiac imaging (1), as well as for clinical spectroscopic imaging studies of brain and prostate cancer (2). The quadratic phase contributes to an even spread of energy and a low peak RF power (1). In order to further flatten out the energy spread and to lower the peak RF value, we propose designing single-sided quadratic OVS pulses, which will retain the sharp transition at the edge of the ROI, while increasing the transition width at the other edge of the passband, thus extending the frequency band over which the phase is quadratic.

Pulse Design: Following the weighted least squares algorithm outlined in (1), we design a feasible quadratic phase FIR filter that is flat in the passband, has a sharp magnitude transition at one edge, and a low peak value in the time domain. Then, the forward SLR transform is applied to the filter to obtain a low peak RF power B_1 pulse (3). Letting the phase be quadratic in the passband results in a small peak value for the FIR filter (1). Increasing the band of frequencies over which the phase is quadratic will result in an even lower peak RF value. As we only care about the high selectivity at one edge of the profile, we relax the constraints in the 'don't care' area beyond the second edge, where the magnitude is irrelevant, hoping to get additional quadratic phase accrual. The target of the weighted least squares procedure is an ideal quadratic phase filter, with a magnitude response dictated by the profile magnitude constraints, and a phase response that is quadratic over the passband and the 'don't care' region.

Procedure: We designed several sets of double-sided and single-sided quadratic phase OVS pulses, each for a different time-bandwidth product. The target profile for all pulses had a passband and stopband ripple of 1%, and the goal was to compare the selectivity and peak RF power of the single-sided versus the double-sided pulses.

Results: The figures to the right show the profiles and RF pulses for TBW of 18 and 32. The TBW 18 single-sided pulse achieved the same selectivity of 17 as the double-sided pulse, and the passband and stopband ripple were within the target variation of 1%. As expected, the single-sided VSS pulse was able to achieve a lower peak RF power. Compared to the double-sided peak RF value of .15 G, the single-sided pulse was 10% lower, with a peak RF value of .135 G, as can be seen in Figure 2. The reduction in peak RF is even greater for higher time-bandwidth products, as can be seen from the TBW 32 pulse that shows a 20% improvement, while keeping the same selectivity and ripple.

Discussion: Single-sided quadratic phase OVS pulses buy us reduced peak RF values at the expense of sacrificing symmetry and relaxing the magnitude constraints in the transition band at one of the profile edges. The reduction of peak RF power increases with the time-bandwidth product.

References:

[1] LeRoux et al. JMRI 8: 1022-1032 (1998)
[2] Tran et al. MRM 43 : 23-33 (2000)
[3] Pauly et al. IEEE Transactions on Medical Imaging 10: 53-65 (1991)

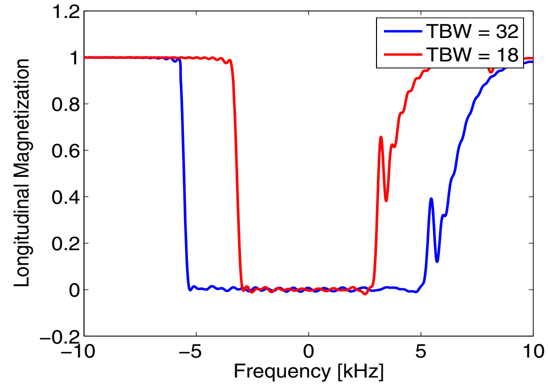

Figure 1: Single-sided saturation profiles for two pulses with different TBW products. At the left edge both profiles retain the high selectivity of double-sided OVS pulses, while keeping the ripple below 1%.

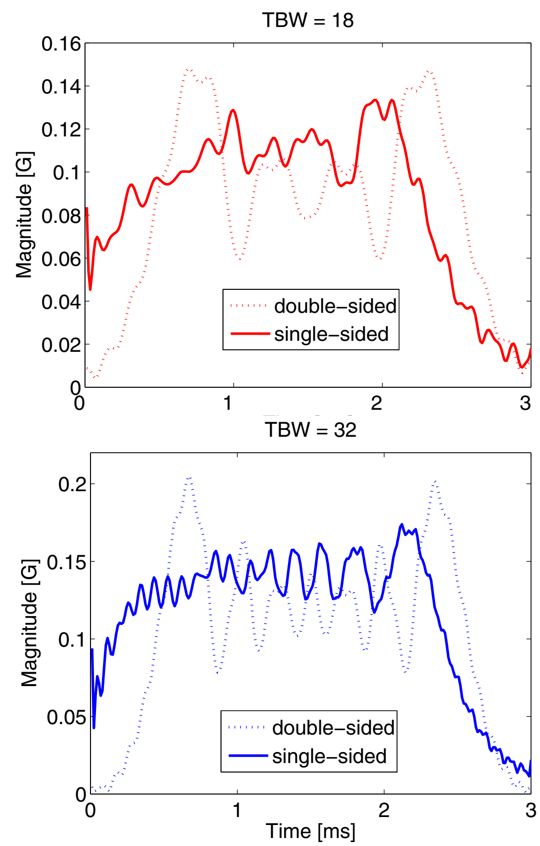

Figure 2: The solid line single-sided pulses have lower peak RF values compared to the double-sided ones. Note how the percent difference increases with TBW – for TBW=18, the peak RF is 10% lower, for TBW = 32, the reduction is 20%.