On the generation of Half-Sinc pulses for optimal excitation profile

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Introduction

It has been noted in a number of reports[1] that the response of species with rapid T2 decay to excitation pulses (or inversion pulses, for that matter) is more complex than for their longer-lived counterparts. More specifically, it has been shown that even for infinite TR, the nominal flip angle that produces the greatest amount of signal is not 90 degrees but an increasingly smaller fraction of 90 degrees that decreases with the product of T2×B1, where T2 is the transverse decay constant of the species, and B1 is the amplitude of the RF pulse.

In this work, we look at the case of slice selective half-sinc pulses, and whether the same trends can be seen in the off-resonance case. Also, the number of side lobes to generate an optimal excitation profile was investigated, since, unlike the case of longer T2, using more side-lobes does not necessarily result in a better profile.

Methods

Half-sinc pulses for selective excitation in UTE imaging were generated with 50 us resolution. For simulation purposes, the maximum B1 amplitude of the pulses was set to 25 uT. A slice-selective gradient was then calculated to generate an excitation over an arbitrary 4.5 mm. A simulation based on the Bloch equations was then implemented over each 50 us time interval to generate the spin response across a vector in space, spanning three times the excitation profile to capture excitation response outside the slice. This procedure was repeated for a range of roughly 30 T2 relaxation times spanning from 0.05 to 5 ms. All these curves were then generated for the case of 13 different nominal flip angles, ranging from 25 to 90 degrees. Only the final Mx magnetization was utilized for analysis, as the alternating gradient and summation method commonly used with UTE results in complete cancellation of the rotationally symmetric My. The same curves as described above were also performed with half-sinc pulses modified at its terminus to extend to the edge of slice-select gradient's downward ramp.[2]

An arbitrary method was chosen to evaluate the degree and quality of the resulting excitation profiles, which involved a summation of the Mx excitation within the slice band, subtracted by the magnitude summation of the signal outside. This method was chosen as it did not require any assumptions about the ideal nature of the excitation profile.

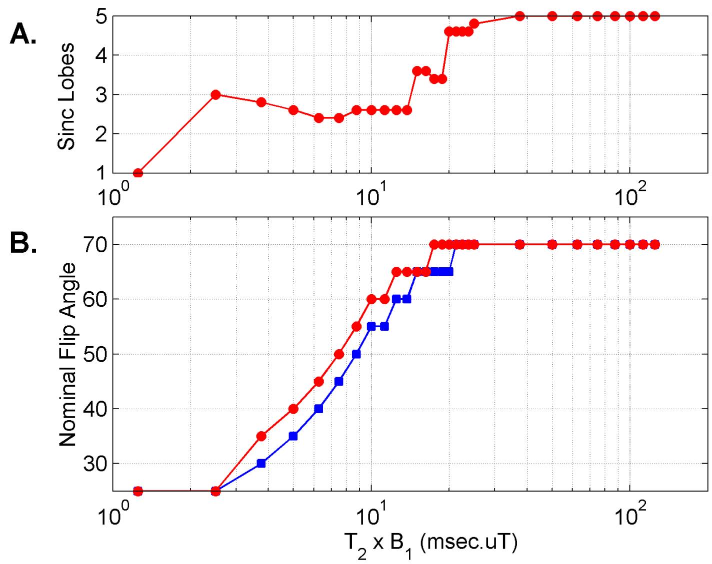

Figure 1. The number of half-sinc lobes (**A**), and the nominal flip angle (**B**), of the pulse that was found to generate the optimal slice excitation profile. **B** contains both nominal flip angles for simple half-sincs (circles) and half sincs treated to extend to the end of the slice-select gradient ramp-down (squares).

Results and Discussion: Counter to intuitive reasoning when dealing with longer T2 materials, adding extra lobes on the selective sinc does not always result in a better slice profile. In fact, doing so can often cause the amount of excitation produced by the pulse to be degraded. This can be explained by the fact that the higher frequency side-lobes are low amplitude, and during these low amplitude intervals the relaxation processes are occurring at a faster rate than excitation from B1. Therefore much of the transverse signal generated here will be lost. However, longitudinal relaxation will not be occurring as quickly, resulting in lost Mz signal that can no longer be transformed into transverse signal by the remainder of the pulse. This trend can be seen in Figure 1A, where species with shorter T2s were excited more optimally with fewer lobes. Although the plot is ragged (reflecting the algorithm's difficulty in identifying the best excitation profile), the trend is clear. Figure 1B displays the nominal flip angle that was found to be optimal for generating excitation profiles. A small lag can be seen between the unmodified sincs (circles) and the modified (squares). This is reasonable in that the mean B1 of the pulse will be marginally lower.

Conclucsions: A model has been generated to assist in the prediction and optimal implementation of half sinc pulses for UTE imaging. Although sinc pulses have disadvantages when it comes to excitation of short T2 materials, they will continue to have a role, if for no other reason their ease of implementation.

References: 1. Robson et al, NMR Biomed 19:765, 2006 2. Conolly et al, J Magn Reson 78:440, 1988