

Reduction of Slice Select Artifacts in Half Pulse Excitations used in Ultrashort TE (UTE) Imaging

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Introduction: Ultra Short TE (UTE) imaging is a method that can capture the signal from tissues with very short T2* relaxation times. There are two strategies employed to minimize the echo time in UTE: 1) radial sampling of k-space eliminates the need for a prewinder on the readout gradients and 2) a so-called “half-pulse” is used to obviate the rephrasing gradient after the slice select [1]. The excitation process can be considered as a deposition of RF energy in “excitation k-space.” Two repetition periods (TR) are needed for a full excitation. During the first half RF pulse, the RF envelope is played during the constant and decay ramps of a trapezoidal gradient, depositing RF energy in one side of excitation k-space. During the second half pulse, the RF remains the same but the polarity of the slice select gradient is reversed, depositing RF in the opposite half of k-space. In real space, the two RF excitation pulses excite profiles that are complex conjugates of each other and the even-real portion of the excitation add constructively while the odd-imaginary component cancels when signals from the two TR are combined.

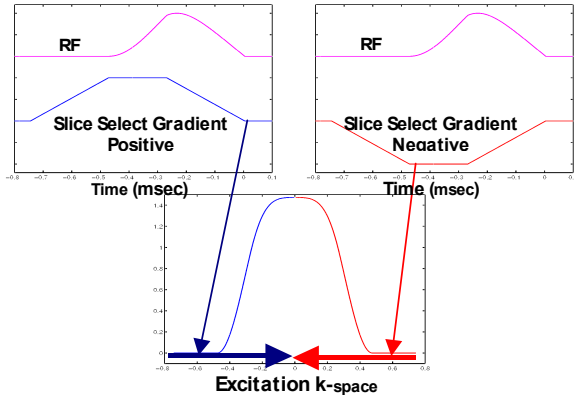


Figure 1: Excitation k-space description of the half pulse.

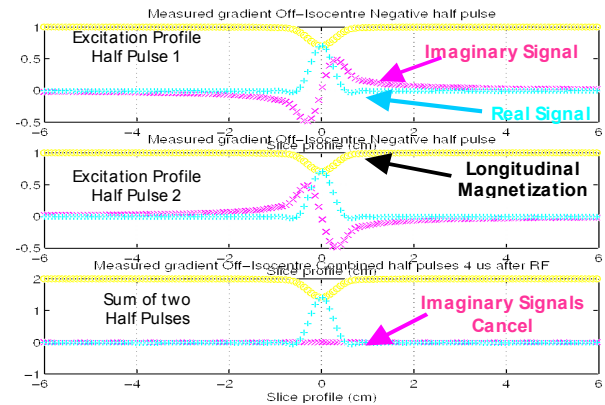


Figure 2: Excitation profiles in real space description of the half pulse.

Unfortunately, when these pulses are used experimentally, the gradients exhibit a non-ideal behavior with either overshoot or undershoot after the end of the final gradient ramp. This manifests itself in excitation k-space as a slight overlap or gap and since this affects the low regions of k-space, a low spatial frequency baseline can appear resulting in contamination of the signal from outside the desired slice. These errors in the gradient waveforms are of the order of 0.1% of the gradient amplitudes but affect the slice profiles. We compensate for these gaps or overlaps by changing the delay time between the RF and gradient, typically by 0-6usec. Furthermore, these errors are due to very small non-linear behavior of the gradient amplifiers and the out-of-slice contamination can vary greatly even when slice thickness varies only slightly. This correction works only for a given slice thickness.

Materials and Methods: Conventionally, slice thickness is controlled by adjusting the gradient strength. However, slice thickness can also be adjusted by keeping the gradient waveform constant and recalculating the RF envelope. By using a fixed gradient waveform, the delay compensation we make for under/over-shoot becomes a constant regardless of slice thickness. As the RF waveform is played on both the flattop and final ramp of the trapezoidal slice select gradient, compensation for the gradient ramp is achieved by using VERSE [2]. A Quality assurance phantom with very little signal in a slice of interest was used to visualize out-of-slice signal contamination.

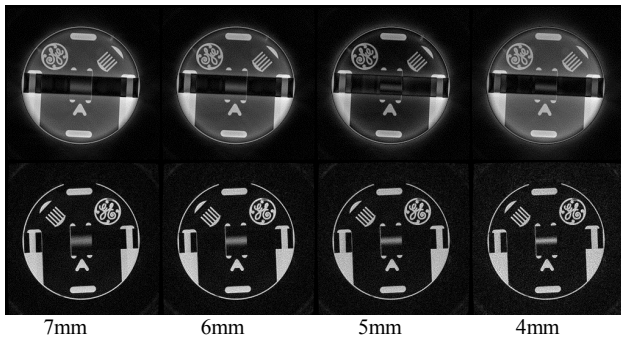


Figure 3: Slice thickness is adjusted in the conventional method of varying the gradient strength. Note that the out-of slice signal does not vary monotonically. For example the 5mm slice thickness shows very little out-of-slice signal whereas the 4 or 6 mm is very poor.

Figure 4: Slice thickness is adjusted by keeping the gradient waveform constant and recalculating the RF envelope. Note that the out-of slice signal remains small for all slice thicknesses.

Conclusion: Using a fixed gradient waveform and varying slice thickness by recalculating the RF envelope dramatically reduces the variability in the out-of-slice signal contamination due to gradient errors. By using a high slew rate, the duration of the RF pulse is always minimized and is critical in exciting the short T2* tissues. One drawback is this compensation cannot be used for oblique slices.

References: [1] Pauly J, et al. Proceeding SMRM 1989 p28; [2] Conolly, S, et al. J.Magn.Reson. 1988, 78:440-457