Using Adiabatic Inversion Pulses to Suppress Long-T_2 Species in Ultra-short Echo Time (UTE) Imaging

P. E. Larson[1], J. M. Pauly[1], D. G. Nishimura[1], S. M. Conolly[2]

[1]Electrical Engineering, Stanford University, Stanford, CA, United States, [2]Bioengineering, University of California-Berkeley, Berkeley, CA, United States

Introduction:

Ultra-short echo time (UTE) imaging can visualize short-T_2 species that are normally invisible and has possible clinical applications [1-3]. Long-T_2 species will dominate the images unless they are suppressed. RF pulse methods of long-T_2 suppression have been used before [4], but they respond poorly to off-resonance and variations in RF power. We have investigated the use of adiabatic pulses to better suppress long-T_2 species.

Theory and Methods:

When amplitude-modulated pulses have a long duration and low amplitude, short-T_2 species are unaffected by the pulse [4]. Similarly, adiabatic pulses of sufficiently low amplitude and narrow bandwidth will not excite short-T_2 species. To minimize short-T_2 attenuation, a near minimum amplitude should be used. This requires a long duration to maintain adiabaticity for long-T_2 species.

Experiments were performed on a GE Excite 1.5T system. Inverted images were acquired by using an inversion pulse followed immediately by a dephaser and then a half-pulse excitation.

Results:

Figure 1 shows the T_2 profile of two 10 ms adiabatic sech inversion pulses with parameters shown. T_2s of a few hundred μs are not inverted, while T_2s near 100 ms are fully inverted. There is more short-T_2 attenuation during Inversion 2 because it has a wider bandwidth requiring a larger amplitude.

The figure 2 contour plots of M_Z show that RF amplitude variations of ±20% are tolerated by both inversion pulses, which is not true for amplitude-modulated pulses [5]. The wider bandwidth of Inversion 2 is shown.

Figure 3 shows phantom images using the Inversion 1 pulse. The short-T_2 phantom (0.35 ms) is unaffected by the pulse, the medium-T_2 phantoms (4 and 6 ms) have been nulled, and the long-T_2 phantoms (50 and 100 ms) are inverted. When the non-inverted and inverted images are combined, the long-T_2 phantoms are suppressed. The inverted image is also separated by phase into short **(3d)** and long **(3e)** T_2 images.

Discussion:

There are multiple possible techniques to remove long-T_2s using adiabatic inversted images. The images can be separated based on their phase to produce short and long T_2 images, as shown in figure 3d,e. Combining an inverted and non-inverted image will suppress long-T_2s, as shown in figure 3c. Inverted water and inverted fat images can be combined for long-T_2 and fat suppression. These combination techniques are SNR efficient because both images have short-T_2 signal. Image subtraction using a later echo only contributes noise to short-T_2s.

Conclusion:

Long adiabatic inversion pulses of low amplitude and bandwidth do not invert short-T_2 species and can be used in UTE imaging to suppress long-T_2 species. They are particularly robust to RF variations and also have reasonable off-resonance bandwidths. They can be used in multiple robust long-T_2 suppression techniques for UTE imaging.

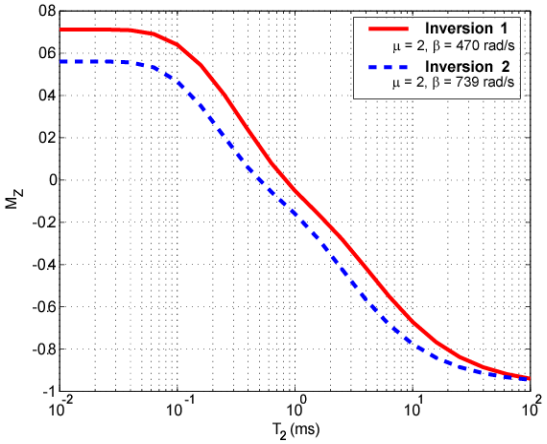

Figure 1: Plot of remaining longitudinal magnetization vs. T_2 after 10 ms adiabatic sech inversion pulses. Inversion 2 has a larger bandwidth and amplitude.

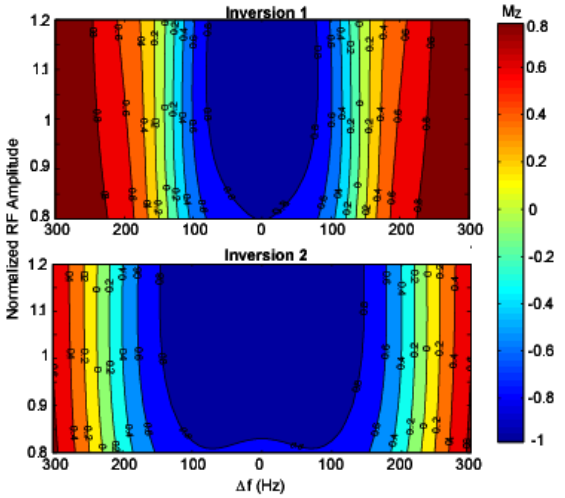

Figure 2: Contour plots of M_Z vs off-resonance at 1.5T and RF variations for T_2 = 100 ms. Both pulses can tolerate 20% RF power variations. Inversion 2 has a wider bandwidth, causing the attenuation in short-T_2 signal seen in Figure 1.

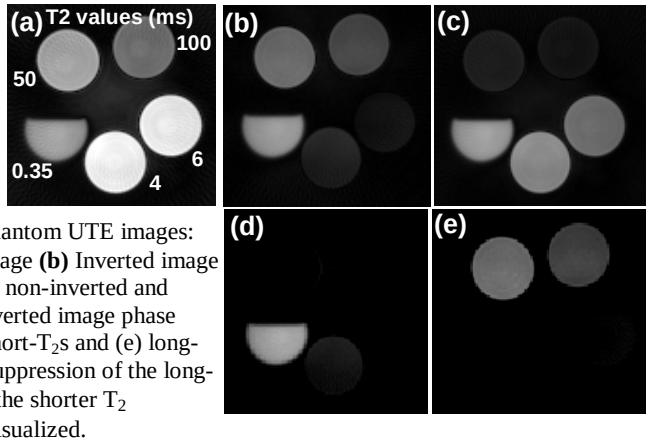

Figure 3: $MnCl_2$ phantom UTE images: **(a)** Non-inverted image **(b)** Inverted image **(c)** Complex sum of non-inverted and inverted images. Inverted image phase separated into (d) short-T_2s and (e) long-T_2s.There is good suppression of the long-T_2 phantoms while the shorter T_2 phantoms are still visualized.

References:

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