Fast fat suppression RF pulse with insensitivity to B1 inhomogeneity: H-Sinc

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Introduction: Robust fat saturation pulse (fatsat) for magnetic resonance imaging (MRI) is important in clinical applications. With a 1.5-T or higher MRI scanner, an adiabatic inversion pulse is used for reducing the residual fat shown on an image caused by B1 inhomogeneity [1]. Since this pulse is a 180°-one, a long inversion recovery time (TI) is required resulting in a dead time of the measurement. So, we developed a new fast fat suppression radio frequency (RF) pulse called H-Sinc, which excites at a flip angle (FA) near 90° and is insensitive to B1 inhomogeneity. In other words, H-Sinc is a fast fat suppression pulse that does not require TI. The excellent fat suppression potential of H-Sinc is described in this article.

Method: H-Sinc is composed of three sinc-type RF pulses with different FAs (Fig.1). The longitudinal magnetization excited by three RF pulses (FAs are α1, 2, and 3 respectively) is shown by formula (1).

$$Mz = M(0) * \cos(B1_{local}/B1_{mean}\cdot\alpha1) * \cos(B1_{local}/B1_{mean}\cdot\alpha2) * \cos(B1_{local}/B1_{mean}\cdot\alpha3) * \exp(-\tau1/T1) + (1-\exp(-\tau1/T1)) * \cos(B1_{local}/B1_{mean}\cdot\alpha2) * \cos(B1_{local}/B1_{mean}\cdot\alpha3) * \exp(-(\tau2+\tau3)/T1) + (1-\exp(-\tau2/T1)) * \cos(B1_{local}/B1_{mean}\cdot\alpha3) * \exp(-\tau3/T1) + (1-\exp(-\tau3/T1)). \quad (1)$$

Mz: longitudinal magnetization, M(0): Initial magnetization, and T1: T1 value of fat, $B1_{local}/B1_{mean}$: B1 inhomogeneity

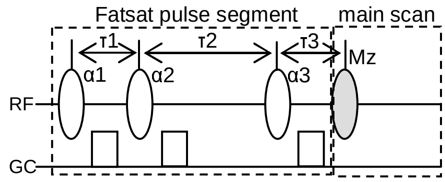
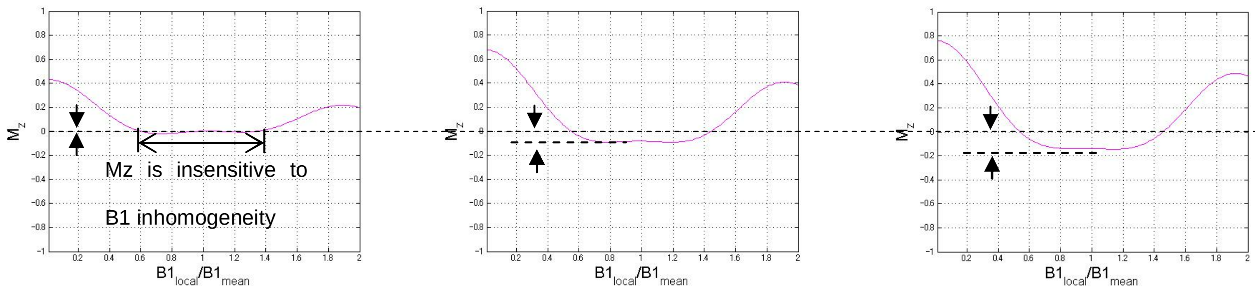


Fig.1 Diagram of H-Sinc pulse

We analyzed this formula and the combination of αi (i = 1-3), where Mz was maintained at almost zero and varied little even if the values of $B1_{local}/B1_{mean}$ fluctuated. The net flip angle of H-Sinc was obtained by varying τ2 between the second and the third pulse. The adjusted pulse was applied to 3D-TIGRE (T1 gradient echo) and 2D-FSE sequences. We made MRI scans of the abdomen and breasts of a volunteer (Permission was obtained by informed consent). Scan parameters were as follows. 3D TIGRE, TR/TE/FA = 4.7 ms/1.7 ms/12°, thickness = 6 mm, slice encode = 32 (double reconstruction: 64), Frequency# = 224, Phase# = 224, rapid factor = 1.8, and scan time = 23 s; 2D-FSE and TR/TE/FA = 5500 ms/93 ms/90°, thickness = 8 mm, MS = 18, Frequency# = 256, Phase# = 192, Inter Echo Time = 8 ms, Echo Train Length = 30, and scan time = 23 s. Imaging was performed on a 1.5-T MRI scanner (Echelon, Hitachi Medical Corporation) using an 8-element torso coil and a 7-element breast coil.

Results: The best FAs were α1 : α2 : α3 = 1 : 0.66 : 1.54. As for this combination of FAs, Mz was maintained at almost zero for the B1 inhomogeneity of ±40%. Figure 2 shows simulated results of B1 inhomogeneity versus Mz for different τ2 at; (a) τ2 = 17 ms (corresponding to 90°), (b) τ2 = 47 ms (95°), and (c) τ2 = 67 ms (100°). From experiments, an optimal FA was around 95° (τ2 was 47 ms) for body fatsat. Thus, the total time of the fatsat pulse segment was 80 ms, which was less than half of the 170-ms TI required for the adiabatic inversion pulse. The images of fat suppression using the H-Sinc on an abdomen and on breasts are shown in Fig. 3. Fat suppression was consistent over all slices.



(a) τ2 = 17 ms (corresponding to 90°) (b) τ2 = 47 ms (95°) (c) τ2 = 67 ms (100°)

Fig.2 Simulated results of B1 inhomogeneity versus Mz for different τ2

Conclusion: We developed a new fast fat suppression RF pulse called H-Sinc, which is insensitive to B1 inhomogeneity. Since H-Sinc can induce an arbitrary flip angle and does not require TI, it shows faster fat suppression than that of the adiabatic inversion pulse.

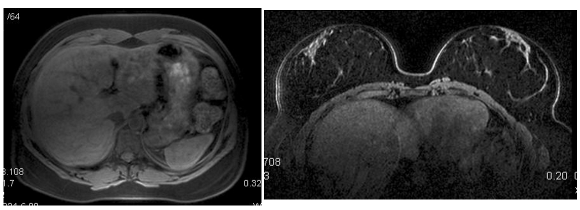

(a) Abdominal (b) Breast image

Fig.3 The result of fat suppression by H-sinc

Reference: [1] Daniel Rosenfeld, et al., MRM37: 793-801 (1997)