Stabilizing Transient-State TrueFISP

T-C. Chuang[1], T-Y. Huang[2], C-W. Ko[3], Y-J. Liu[4], C-Y. Chen[5], H-W. Chung[1,5]

[1]E.E., National Taiwan University, Taipei, Taipei, Taiwan, [2]E.E., National Taiwan University of Science and Technology, Taipei, Taipei, Taiwan, [3]Computer Science and Engineering, National Sun Yat-Sen University, Kaohsiung, Kaohsiung, Taiwan, [4]Automatic Control Engineering, Feng Chia University, Taichung, Taiwan, Taiwan, [5]Radiology, Tri-Service General Hospital, Taipei, Taipei, Taiwan

Introduction

Magnetization-prepared transient-state TrueFISP (FIESTA, Balanced FFE) sequences have been shown practical in different MR applications [1]. In all of these techniques, the NMR signal was acquired during the transition from the prepared magnetization to steady-state free precession. Thus, a good stabilization method to “catalyze” the initial signal oscillation under different off-resonance conditions and to ensure a smooth transition was required to get an image with fewer artifacts. Different methods have been proposed to suppress the initial oscillations, including 1) the popular half-angle-half-TR method (HAHT) [2], 2) the linear-ramp method (LR) [3], and more recently, 3) the Kaiser-Bessel window method (KBW) [4]. In addition to the requirement of conventional steady-state TrueFISP, the stabilization techniques for the transient-state TrueFISP (TS-TrueFISP) should be selected to minimally affect the initially prepared magnetization, which further implies the designated image contrast. Therefore, the stabilization method should be implemented with fewer RF pulses (reduce T1/T2 relaxation) and exhibit less oscillatory residues. In this study, we evaluated these three methods with transient-state TrueFISP by both simulation and phantom study.

Materials and Methods

Three stabilization methods have been implemented and simulated. **Figure 1** generally demonstrates the stabilization RF trains with N+1 flip angles ($\alpha_0, \alpha_1, \alpha_2 \ldots \alpha_N$) and the TrueFISP readout pulses with flip angle **α**. And three stabilization were designed according to the following formula (HAHT:$\alpha_0 = \alpha/2$, $\alpha_n = \alpha$, LR:$\alpha_0 = 0$, $\alpha_n = n$□$\alpha/(N+1)$, KBW: $\alpha_0 = 0$, $\alpha_n = KB(n)$□α. KB(n) denotes the Kaiser-Bessel window function with beta=5). The signal behavior of the three methods was computer-simulated by Bloch equation according to different off-resonance conditions. The stabilization performance was evaluated by the remaining perpendicular component [4] after the stabilization pulses. As for the experiment, 2D phantom images were acquired on 1.5T system (Siemens, Vision+) using three different stabilization techniques followed by TS-TrueFISP readout (TR/TE: 6.8/3.4 msec, Matrix:128x128). The off-resonance effect (0Hz/20Hz/40Hz corresponding SSFP angle:$0^o/49^\circ/98^\circ$) was created by manually adjusting the system frequency. The HASTE-type phase-encoding order was used for the TS-TrueFISP readout.

Results

Figure 2a shows the simulation results according to the following parameters. TR/TE: 6.8/3.4 msec, TS-TrueFISP readout flip angle **48^o** , HAHT: [$\alpha_0 \alpha_1 \alpha_2 \alpha_3 \alpha_4 \alpha_5$]=[24^o 48^o 48^o 48^o 48^o 48^o] (blue, dotted line), LR: [0^o 8^o 16^o 24^o 32^o 40^o] (green, solid line), KBW:[0^o 2^o 9^o 20^o 33^o 44^o](red, dashed line**),** **o**ff-resonance SSFP angle: $-360^o \sim 360^o$). **Figure 2b** shows the same results but the off-resonance range is limited at 100^o. Notice that KBW method (dashed line) shows overall better stabilization (smaller perpendicular component after stabilization.) **Figure 3** shows the TS-TrueFISP images from the phantom experiments with the same stabilization parameters as the simulation. Notice that, under different off-resonance condition (0Hz/20Hz/40Hz), less artifacts were shown in the images acquired with KBW stabilization method (the third row).

Discussion and Conclusion

The goal of this study was to select an efficient method, which suppressed the transient-state oscillation with fewer RF pulses as possible, for TS-TrueFISP applications. To simplify the comparison, in this abstract, the number of stabilization pulses was fixed at 5~6 pulses. From the simulation, all the three methods showed able to suppress the perpendicular component when the system was on resonance. Nonetheless, KBW method could efficiently suppress the perpendicular component under the wider off-resonance range (-100^o <SSFP angle<100^o). The phantom experiment showed consistent results with the simulation. All of the three methods showed good performance to stabilize the initial oscillation when the system was on resonance and furthermore, fewer image artifacts were found at off resonance when the KBW method was applied. Notice that, for the stabilization, only 5-6 pulses were used in this study. This suggested that KBW method was a suitable solution for fast stabilization but didn’t suggest it is the best solution for all the stabilization applications. Different stabilization requirements may be achieved by the same framework as digital filter design strategy we demonstrated. In conclusion, KBW method can efficiently suppress the transient signal oscillation under wider off-resonance condition. Combined with KBW method, TS-TrueFISP can be more robust to acquire images with fewer artifacts.

References

1. Sheffler K, MRM 45:1075 2. Deimling M., SMR 1994 3.Nishimura DG., ISMRM 2000 4.Le Roux P., JMR 163:23

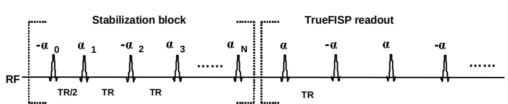

Figure 1. Stabilization pulses and TrueFISP readout pulses

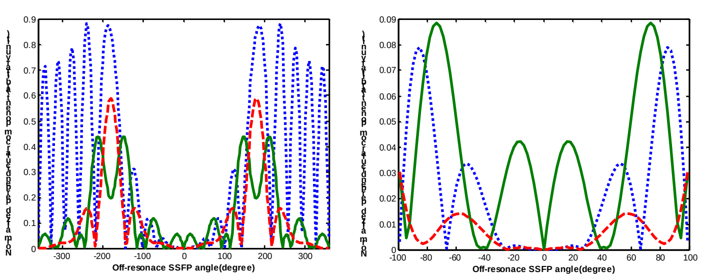

Figure 2 (a:left, b:right) Simulation results. HAHT: blue, dotted line; LR: green, solid line; KBW: red, dashed line. Notice that KBW method showed better stabilization at -100^o < SSFP angle <100^o

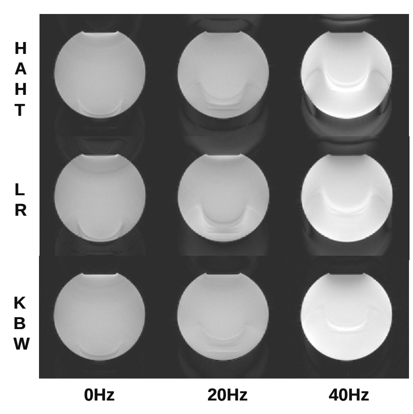

Figure 3. TS-TrueFISP images with different stabilization methods. Fewer artifacts were found in images acquired with KBW method.