Binomial Pulse Suppression to Reduce Ghosting Artifacts in Transient-State bSSFP Imaging

Y-C. K. Huang[1], T-Y. Huang[2], T-C. Chuang[1], H-W. Chung[1,3], C-Y. Chen[3]

[1]Electrical Engineering Department, National Taiwan University, Taipei City, Taiwan, [2]Electrical Engineering Department, National Taiwan University of Science and Technology, Taipei City, Taiwan, [3]Department of Radiology, Tri-Service General Hospital and National Defense Medical Center, Taipei City, Taiwan

Introduction

Magnetization-prepared transient-state balanced steady-state free precession (TS-bSSFP) sequences have been shown to possess the potential of carrying various contrasts [1]. For such kind of transient-state imaging, the NMR signals are acquired during the transition from the prepared magnetizations to the steady state. A good stabilization method for such special images is needed to reduce ghosting artifacts due to initial signal oscillations at various off-resonance conditions. A previous study comparing three stabilization methods [2] showed that the Kaiser-Bessel window method (KBW) [3] exhibited better stabilization performance near 0° SSFP angle. However, signal oscillations from off-resonance spins near ±180° SSFP angles are still prominent. In this study, we present a method to suppress off-resonance ghosting using a binomial composite RF pulse with spoiler gradients applied preceding the KBW stabilization methods. We evaluated the effects using both computer simulation and phantom studies.

Materials and Methods

The signal intensities (SI) evolutions were numerically simulated using the Bloch equation with different off-resonance conditions, assuming no transverse magnetizations remained following spoiler dephasing. For the experiment, 2D images of water phantoms doped with $MnCl_2$ at different concentrations were acquired on a 1.5T system (Siemens Vision Plus, Erlangen, Germany) with or without the binomial off-resonance suppression, followed by the KBW stabilization technique (preparatory RF flip angle: [0° 2° 9° 20° 33° 44°]) [3], and then TS-bSSFP readout ensued (TR/TE: 6.46/3.23 msec, Matrix: 256x256, flip angle 48°). The binomial composite pulse used a 1-TR-(-3)-TR-3-TR-(-1) (90° flip angle) design to selectively excite off-resonance spins to achieve sharp frequency response near ±180° off-resonance regions, followed by spoiler gradients in three channels to dephase the off-resonance signals. Off-resonance condition (70Hz, corresponding to an SSFP angle of 163° for TR=6.46 msec) was intentionally created by manually adjusting the system frequency. The HASTE-type phase-encoding order was used for TS-bSSFP readout.

Results

Figure 1 displays the simulation results as the evolution of signal amplitudes as a function of time (horizontal axis) at different off resonances (vertical axis; expressed as SSFP angles [4]). Parameters used for simulation were chosen to be consistent with the experimental settings. Note from Fig.1c that even with KBW stabilization, signal oscillations near 180° were still prominent. With binomial pulse suppression, the oscillations reduced (Fig.1d), corresponding to a decrease in N/2 ghost amplitude. **Figure 2** shows the TS-bSSFP images from the $MnCl_2$. Notice from the brightened images that the ghosts outside the phantom were substantially reduced for the image *with* the binomial scheme, as compared to that *without* using binomial suppression pulse.

Discussion and Conclusion

Results from this study show that the ghosting artifacts from spins exhibiting ±180° SSFP angle could be prominent in TS-bSSFP imaging, which could nevertheless be suppressed using the binomial composite RF pulse applied preceding the stabilization method and SSFP readout. The suppression is flexible, meaning that its frequency spectrum can in theory be adjusted according to the specific experimental conditions, and not necessarily confined to the TR setting as demonstrated in this study. Note that although the experiments performed in this study used the KBW scheme for stabilization, the binomial suppression pulse also works for other stabilization methods such as half-angle-half-TR or linear ramping. In fact, for stabilization methods showing inferior performance to KBW, the effects of binomial suppression would be more prominent. In conclusion, the binomial scheme combined with a stabilization method effectively reduces signal oscillation and thus decreases ghosting due to off resonance, which assists TS-bSSFP in the acquisition of images without interference by ghosting artifacts.

Reference

1. Scheffler K, *MRM* 2001; 45:1075 **2.** Chuang TC, *ISMRM* 2005 **3.** Le Roux P, *JMR* 2003; 163:23 **4.** Hennig J, *MRM* 2002; 48: 801.

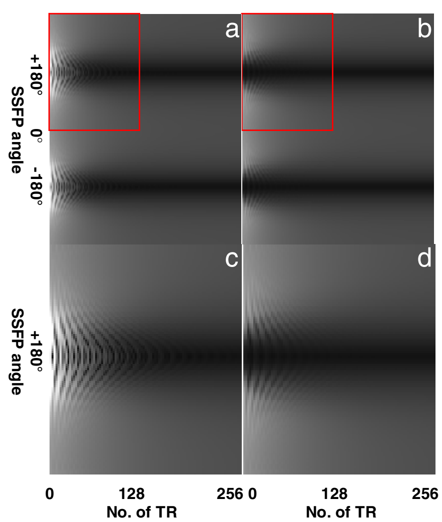
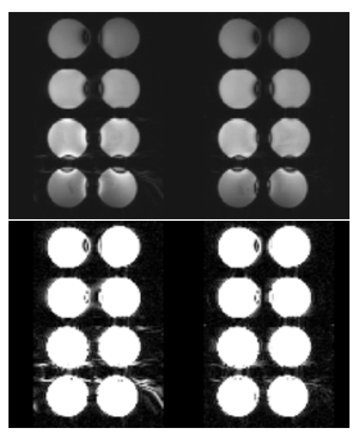


FIG. 1. Computer-simulated SI as a function of time at various off-resonance frequencies. Grayscale values represent the absolute SI ranging from 0 (black) to 1 (M_0). (a) *Without binomial* and (b) *with binomial* demonstrate signal evolution, whose zoom-in versions are shown in (c) & (d), respectively, for spins with SSFP angles near +180°.



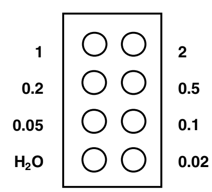


FIG. 2. Phantoms with different concentrations (in mM) of $MnCl_{2\ (aq)}$ showed strong susceptibility effect that caused various off-resonance conditions. Left column: *without binomial* and right column: *with binomial* are displayed for comparison. Original image (upper row) and brightened image (bottom) for a better visualization.