A Spectral Spatial Fat Suppressing Pulse for Simultaneous Multi-Slice Excitation

Robert James Anderson[1], Benedikt Andreas Poser[1], and Victor Andrew Stenger[1]
[1] *Dept. of Medicine, University of Hawaii, Honolulu, HI, United States*

Target Audience: MR physicists and RF pulse design communities.

Purpose: Simultaneous Multi-Slice (SMS) imaging can reduce the volume imaging time of single-shot modalities such as EPI by factors of four or greater [1-4]. Typically SMS excitation is achieved using a multi-band (MB) or modulated single-slice pulse. Fat-suppressing (FatSup) spectral-spatial excitation pulses can be used to reduce time required to play out fat saturation [5]. Here we present two analytical SMS FatSup pulses based on MB and Power Independent Number of Slices (PINS) [6] designs. We show that good multi-slice selectivity and fat suppression is possible with pulses 5.3ms long at 3T.

Methods: Both MB and PINS, which is a series of non-selective pulses separated by z-blips, pulses can be made spectrally selective by repeating the pulse waveforms in time. The repetition rate is the frequency stop band f_s. The first FatSup method took a 1.3ms MB pulse (N=9, 5mm thick, Δz=2cm, f_s=770Hz) repeated five times. The second method repeated a 1.3ms PINS pulse five times (5mm thick, Δz=2cm, f_s=770Hz) as shown in Fig. 1 (a). Both were constructed in Matlab using a 180mT/m slew rate and 30mT/m peak gradient. Also shown are Bloch simulations of the excitation patterns (Fig. 1(b)). Note the line at -440Hz is where the fat signal falls in the stopband at 3T. Images of a water/oil phantom and a human brain were acquired on a Siemens 3T MRI scanner using a 32-channel head coil with the FatSup-MB and -PINS pulses. A blipped-CAIPI EPI sequence [4] was implemented with FOV/3 shift (nine 64x64 slices per 275ms TR, 33° FA, 25ms TE, 3.5x3.5x5mm^3 voxel size). A standard sinc without fat saturation was used to acquire 36 reference slices for a 3x4 sliceGRAPPA reconstruction kernel [7], as well as serve as an uncorrected standard.

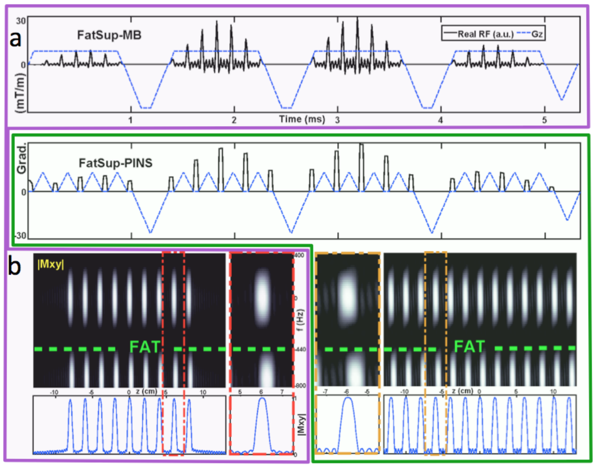

Figure 1. The FatSup-MB (**purple**) and FatSup-PINS (**green**) pulse sequences (**a**) and the corresponding Bloch simulations of their excitation patterns (**b**). The 3 T fat band at -440 Hz is not excited.

Results: It is seen that both FatSup pulses excite only water in the water/oil phantom, whereas the oil is blurred in the phase encoding direction in the standard sinc data, as indicated by the red arrow (Fig. 2). Fat in the neck and skull are suppressed across all nine slices in the *in vivo* data (Fig. 3).

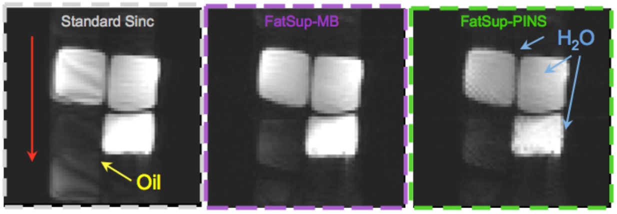

Figure 2. Comparison of the fat suppression effectiveness of the SMS FatSup pulses in a water (lower right & upper areas) and oil (lower left) phantom. The EPI-related fat blurring artifact is eliminated entirely.

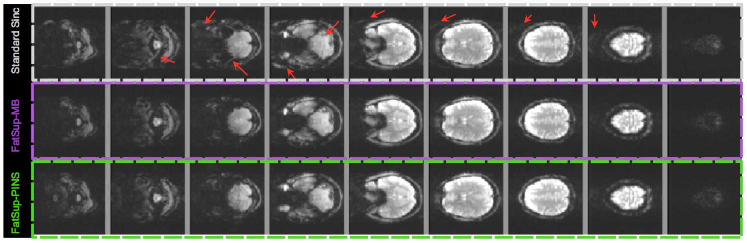

Figure 3. Nine simultaneous slices excited by sinc (top), FatSup-MB (middle), and FatSup-PINS. The the red arrows indicate the unsuppressed fat that is excited by the standard sinc pulse.

Discussion and Conclusions: Both FatSup pulses demonstrated that they are capable of sufficiently eliminating the unwanted fat signal across multiple slices in a volume. The standard Siemens 3T fat-saturating pulse is over 12ms in duration. By replacing it and the standard excitation pulse with a 5.3ms FatSup-MB or FatSup-PINS pulse, the time to acquire a single slice is reduced by roughly 10ms. In addition, the number of slices required to cover a volume is reduced by the SMS factor N, and thus significant gains in temporal resolution can be achieved. Here we demonstrated that N=9 is not unrealistic and that with the resultant TR of 275ms nearly four volumes per second is an attainable measurement rate. This would be particular useful to those interested in high temporal resolution fMRI studies.

References: [1] Larkman, D., et al., JMRI, 2001. **14**: p. 329. [2] Moeller, S., et al., MRM, 2010. **63**: p. 1144; [3] Feinberg, D., et al., PlosOne, 2010. **5**: p. e15710. [4] Setsompop, K., et al., MRM 2012. **67**: p. 1210. [5] Meyer, C. M. et al. MRM, 1990. **15**: p. 287. [6] Norris, D.G., et al., MRM, 2011. **66**: p. 1234. [7] Griswold, M.A., et al., MRM, 2002. **47**: p. 1202.

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