Combined Excitation and Partial Saturation to Reduce Inflow Enhancement

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Introduction: Partially saturating an outer slab upstream can reduce inflow enhancement and pulsatile ghost artifacts by preparing flowing spins to a steady state before entering the imaging slab, while simultaneously dephasing their signal [1]. However, partial saturation requires another RF pulse and spoilers, and increases TR. Here, we present a short RF pulse that *simultaneously* excites the imaging slab while partially saturating and spoiling the outer slab [2]. This pulse was designed and demonstrated by phantom and in vivo experiments.

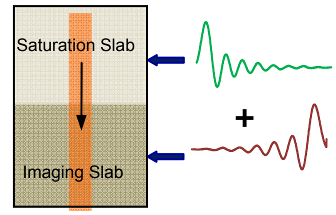


Fig. 1. Exciting the imaging slab and partially saturating the outer slab were performed by combining maximum and minimum phase pulses.

Methods: For the new RF pulse, one maximum-phase RF pulse and minimum-phase RF pulse were combined into one RF (Fig. 1) [3]. Using the maximum-phase RF pulse for the partial saturation slab provides gradient spoiling by the slab-select gradient itself. To provide sufficient gradient spoiling for a 3D slab, a high *time* x *bandwidth* (TBW) RF is necessary. After calculating beta polynomials for each slab and applying proper frequency modulation to locate the slabs, an inverse SLR transform was used to generate the composite RF pulse. To reduce the pulse duration, we applied the variable-rate selective excitation (VERSE) algorithm [4].

Here, an RF pulse was designed to excite a 12.8 cm-thick imaging slab that includes 32 sections with each 4 mm thickness and to partially saturate 13.8 cm-thick slab adjacent to the imaging slab. We assumed the imaging slab is located at the center. We used a flip angle of 20° and TBW = 96.

Experiments using this new RF pulse were conducted on a 1.5T GE scanner (GE Healthcare, Waukesha, SI) by replacing the standard RF pulse and slab-select gradient waveforms with the VERSE waveforms in a 3D RF-spoiled gradient sequence. A phantom experiment was conducted to measure the steady state signal profile across the slab direction by using the GE standard head coil and 25 cm long GE resolution phantom. For this demonstration, the slab-FOV included three times the width of the imaged slab. Inflow enhancement reduction by this pulse was tested in the femoral artery of a healthy volunteer using the eight-channel knee phased-array coil (MRI Devices Corp, Waukesha, WI), after obtaining informed consent.

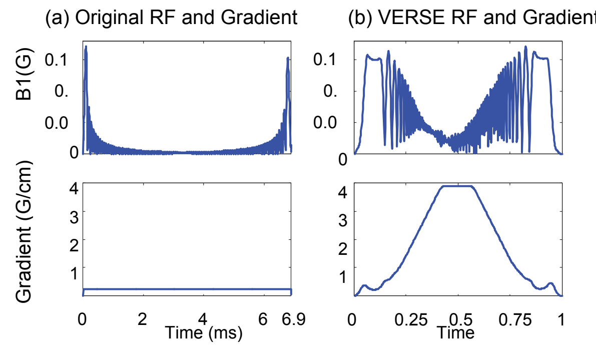
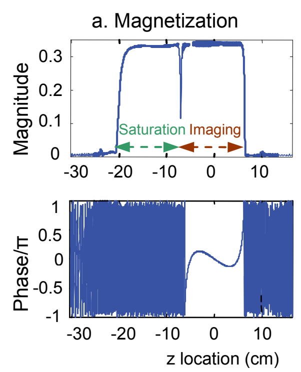


Fig. 2. (a) Original and (b) VERSE RF and gradient pulses. For the same peak RF amplitudes, the pulse duration decreases from 6.9 ms to 1 ms.

Results: The RF and gradient waveforms with and without VERSE are compared in Fig. 2. For the same peak RF amplitude of 0.17 G, the RF duration was reduced from 6.9 ms to 1 ms. The simulated magnetization profile using the VERSE excitation is shown in Fig. 3. As expected, this RF pulse excites both the imaging slab and partial saturation slab, but provides enough cycles of phase twist in the partial saturation slab, resulting in signal close to zero. The phantom experiment in Fig. 4 also confirms that the partially-saturated slab generates negligible signal compared to the imaging slab. Figure 5 shows an *in vivo* experiment with measured signal intensity changes through the femoral artery across the slab from the superior to inferior direction. Signal intensity changes from our pulse and a standard slab excitation pulse are compared. We can see that our pulse reduces inflow enhancement significantly and provides an almost uniform signal profile along the artery across the whole slab.



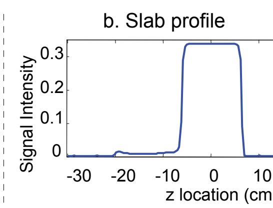


Fig. 3. (a) Magnetization profile and (b) net magnetization over each section from VERSE excitation. Due to enough cycles of phase twist in the saturation slab, net magnetization becomes close to zero.

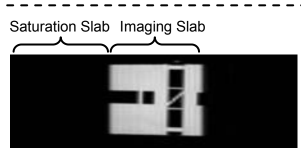


Fig. 4. Phantom experiment by encoding three times of slab thickness. The image is from coronal reformation to see the slab profile. The partial saturation slab was dephased almost perfectly.

Discussion: Partial saturation of an outer slab to achieve steady state in flowing spins was combined with an imaging slab excitation pulse. We utilized VERSE to provide enough spoiling gradient in the partial saturation region with a short RF pulse duration. Due to high sensitivity to timing in VERSE excitation, the gradient timing delay should be properly set for perfect signal elimination in the partial saturation region. By reducing inflow enhancement without any time penalty, this pulse can be useful for measurement of arterial input function with rapid temporal resolution. To conclude, we have designed and implemented an RF pulse that can simultaneously excite the imaging slab and partially saturate the outer slab to reduce inflow enhancement of the blood.

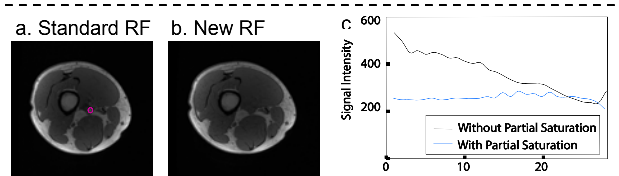


Fig. 5. (a-b) Axial leg images. The femoral artery (shown by the circle) with enhanced blood is seen in the slice (a) when partial saturation was not used. (c) compares signal intensity changes in that artery.

References

[1] Pang et al., 16th ISMRM, P2775, 2008.

[2] Cunningham et al., 11th ISMRM, P699, 2004.

[3] Staroswiecki et al., 17th ISMRM, P4506, 2009.

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