Reduced Field-of-View RF Pulse Designs with Fat-Suppression

K. Sung[1], K. S. Nayak[1]

[1]Electrical Engineering, University of Southern California, Los Angeles, CA, United States

Introduction: In many imaging applications, only a fraction of the entire field-of-view (FOV) is of clinical interest. By exciting only the region of interest, the FOV can be reduced (to increase acquisition speed) without causing aliasing artifacts [1,2]. In this work, we present time-efficient 2D spatially selective RF pulse designs which limit the excited FOV in 2D imaging with or without fat suppression. This pulse was tested in-vitro and in-vivo at 3T.

Methods: 2D RF pulses were designed with the excitation k-space framework developed by Pauly et al [3,4]. Excitation pulses were used to excite a thin slice (5mm) along z and the desired excited region (10cm) along an in-plane direction (y). In order to minimize the total duration, a time-bandwidth product of two was used for the individual subpulse (z-direction) and a minimum-phase FIR filter design using least-squares is applied to determine subpulse weightings (y direction). A fly-back design (RF is only transmitted during positive gradient lobes) was chosen to simplify off-resonance effects. Fig 1 illustrates one such minimum-phase reduced-FOV (rFOV) excitation pulse. In fly-back 2D-EPI RF design, off-resonance creates a linear phase primarily along k_y resulting in an excitation profile shift along the y direction. The phase difference between adjacent subpulses is, $\phi_{off} = 2\pi\Delta f_{off}T_{RF}$, therefore the linear phase along k_y can be eliminated by adjusting the time between subpulses (T_{RF}) so that $\phi_{off} = 2\pi$. This requires $T_{RF} = 2.27$ms at 3T. The excitation profiles for fat and water will be the same (Fig 2a and b). When fat-suppression is desired, we propose making $\phi_{off} = \pi$ instead of 2π. The excitation profile for fat will be shifted by half of the excitation FOVy while the required T_{RF} becomes halved (1.14ms at 3T). To suppress the fat signal, the excitation FOVy must be increased by adding more subpulses so that shifted profile does not overlap with the physical object (Fig 2c and d). The net pulse duration is approximately the same. Fig. 2 contains excitation profiles comparing 2π and π methods with and without off-resonance (-440 Hz).

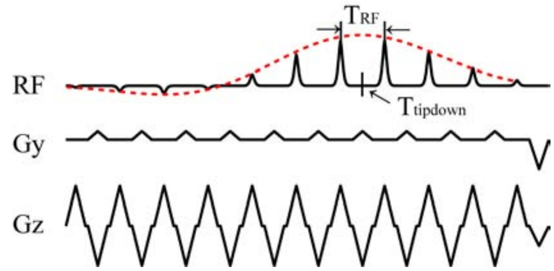

Fig. 1: rFOV excitation pulse. Pulse duration is 12.5ms with 5 mm slice thickness. Note that T_{RF} was set to have a π phase difference between subpulses with a chemical shift. TE starts from $T_{tipdown}$.

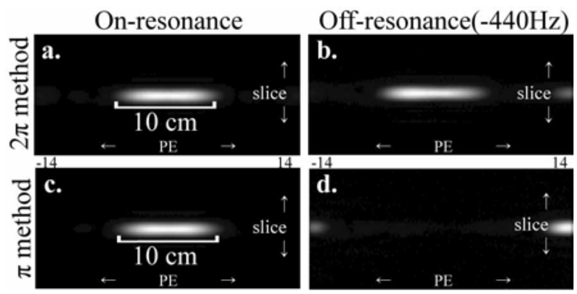

Fig. 2: Experimentally measured excitation profiles on-resonance (left) and -440 Hz off-resonance (right) for 2π method (top) and π method (bottom).

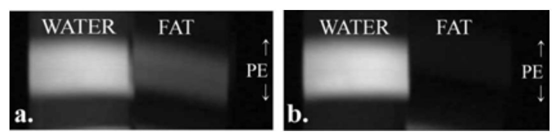

Fig. 3: rFOV fat-water phantom validation for (a) 2π and (b) π method.

Results: Experiments were performed on a GE Signa EXCITE HD 3.0T system with gradients supporting 40 mT/m and 150 T/m/s. Excitation pulses were inserted into 2DFT and variable density spiral sequences. The overall excitation pulse durations that include refocusing gradient lobe were 13ms and 12.5ms for 2π and π methods, respectively. Fig 3 illustrates the fat-water phantom validation. The excited PE profile is comparable for fat and water with the 2π method (Fig. 3a) and fat is adequately suppressed using the π method (Fig. 3b). In-vivo experiments to study the performance of these approaches were performed on healthy volunteers. Cardiac-gated interleaved spiral imaging within a breath-hold was performed. Fig 4 shows an example of the rFOV excitation pulse in cardiac imaging at 3T. The imaging FOV was 30 cm and the width of the chest was assumed to be 20cm as the desired excited region was set to 10cm.

Discussion: The small width and sharp edge of the PE profile requires a large number of RF subpulses which prolongs the echo-time (TE). The long TE results in a loss in signal from T_2 or T_2* decay. Utilizing minimum-phase design both reduces the total RF pulse duration and shortens TE. The TE times for the 2π and π methods with spiral acquisition were 4.4ms and 4.3ms, respectively. Other schemes that reduce pulse length such as gaussian weighting (more points in the center of k-space) and blipped-planar k-space trajectory can still be applied.

Conclusion: We have demonstrated a new RF pulse design that can limit the excited FOV with fat-suppression. Our goal is to use these pulses in conjunction with single-shot EPI readouts for high temporal resolution cardiac imaging.

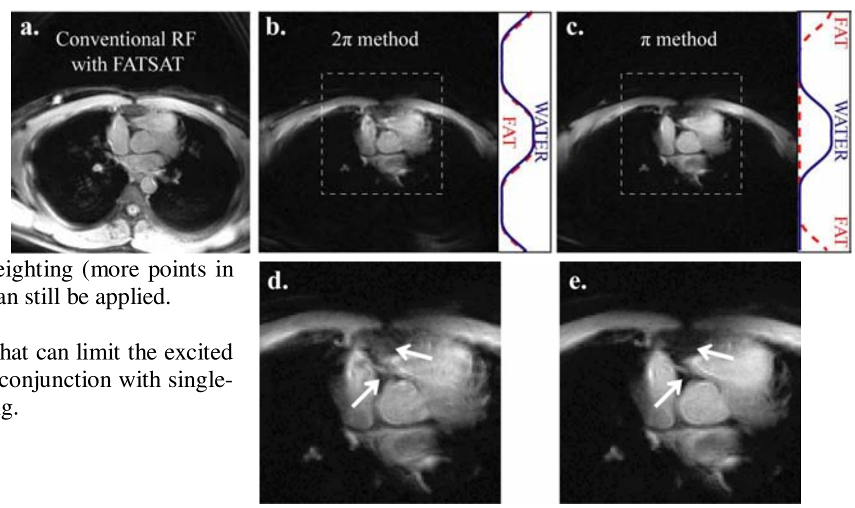

Fig. 4: rFOV in cardiac imaging at 3T. Conventional slice-selective RF with fat-saturation pulse (a), 2π method (b), π method (c), and magnified views over the heart for 2π (d) and π method (e). White arrows identify areas of fat. Note that fat signal appears blurred due to the spiral acquisition (b and d).

References

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