

## EE469B: Assignment 4

Due Wednesday, Oct. 21

**1. True Null/Flyback Spectral-Spatial Pulses** True null and flyback designs are very closely related. In this problem we look at the properties of the flyback pulse sidelobe structure to predict the characteristics of the opposed sidelobe in the true null design.

**a) True Null Pulse Design** Design a true null spectral-spatial pulse, with a spatial  $SBW = 4$  profile, and a spectral  $TBW = 4$  profile. For convenience, assume the gradient slew rate is unlimited, so the gradient sublobes are perfect rectangles. Also for convenience, assume the lipid null is centered at 250 Hz from water. Design for a 1 cm slice, and spectral passband of  $\pm 125$  Hz. Sample the RF and gradient waveforms at 10  $\mu$ s. Plot the RF and gradient waveforms.

**b) True Null Excitation Profile** Simulate the excitation profile using the same method you used to simulate 2D spatial RF pulses in the previous assignment. The gradient waveform is scaled as usual. The spectral dimension is simulated with a constant gradient,

```
>> gy = 2*pi*dt*ones(1,length(rf));
```

The spectral profile will then be in kHz, if  $dt$  is in ms. Simulate the profile from  $\pm 1/(\Delta T)$ , the sampling frequency, and  $\pm 2$  cm. Plot the response as an image using

```
>> imshow(abs(mxy), [0 0.5]);
```

where the scale factor is included to make the sidelobes more apparent.

**c) Flyback Excitation Profile** Generate two flyback pulses, one by zeroing out the even subpulses, and another by zeroing out the odd subpulses. Double the amplitude of the remaining subpulses, so that the total flip angle remains the same.

Simulate these profiles, and plot the responses.

**d) Characteristics of the Flyback Profile** The flyback excitation profiles are inclined. Find an analytic expression for this angle in cm/kHz. Does it agree with your simulation?

*Hint:* How far does each spatial subpulse shift in space, for a given frequency shift.

**d) Opposing Null** In the small-tip-angle case we are considering here, the excitation profiles are linear functions of the applied RF. Hence, the true null profile from part (b) should be the same as the sum of the two flyback profiles of part (c), divided by 2.

Consider the opposed null in the true null design. Explain why it is the sum of the two  $1/(2\Delta T)$  sidelobes of the flyback profiles.

*Hint:* The second flyback pulse is shifted by  $\Delta T$  in time. What does that do to a sidelobe at  $1/(2\Delta T)$ ? Also, why isn't the cancellation perfect?

**2. Improved Opposed Null Design** Traditionally, the opposed null RF pulses are designed with water on resonance, and the opposed null on the lipid frequency. A better approach is to design the lipid stopband on resonance, and the passband where the opposed null would have been. The null is then perfect. The passband is degraded slightly, but not significantly.

**a) Conventional Opposed Null Design** Design an opposed null RF pulse for the parameters of problem 1, with the passband at 0 Hz, as usual. Reduce the spectral bandwidth to  $\pm 100$  Hz to keep the pulse from getting too short. Plot the pulse, and simulate and plot the excitation volume.

**b) Improved Design** Now alternate the signs of the RF subpulses, which modulates the passband to  $1/(2\Delta T)$ , and leaves the stop band on resonance. Plot the pulse, and simulate and plot the excitation volume.

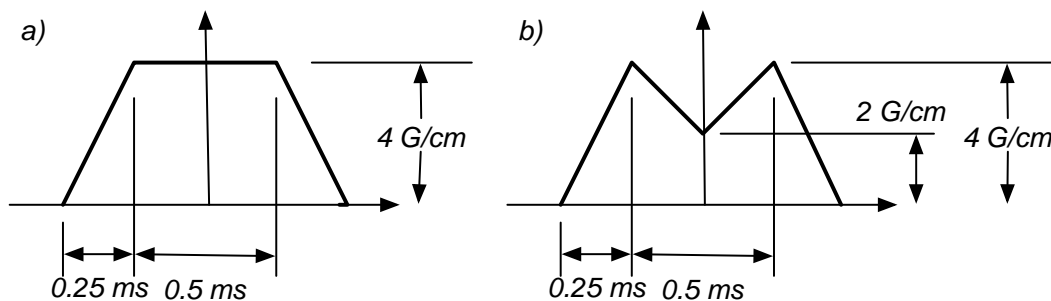
One place where this type of design is important is for 3T systems. At 3T the spectral separation of water and fat is twice that at 1.5T, so the subpulses have to be half as long. However, the gradient system performance is the same. Hence it is difficult to get enough gradient area for a true null design to reach 3 mm slices, which you would like for cardiac imaging. This technique solves this problem.

**3. Reduced Peak Power** The peak amplitude of the spatial subpulses can be a problem. One solution is to vary the gradient amplitude. Recall from the small-tip-angle solution, the RF waveform for a 1D pulse should be

$$\gamma B_1(t) = |\gamma G(t)|W(k(t))$$

Generate  $TBW = 4$ , flip angle  $\pi/3$  spatial subpulses for each of these subpulse gradients. Use the entire gradient waveform in either case. Find  $k(t)$  by numerically integrating  $G(t)$ . The samples of the windowed sinc  $W(k)$  are non-uniformly sampled. You can either compute these samples explicitly, since you have an analytic expression for  $W(k)$ , or you can sample  $W(k)$  uniformly, and interpolate, using the matlab command `interp1`.

Plot the RF pulses and gradients, and simulate the 1 D slice profiles.



How much has the peak power been reduced? How much has the slice thickness increased?

This is an example of variable rate excitation pulses, or the VERSE algorithm. Although we have based the development here on the small-tip-angle case, VERSE is a quite general result that holds for any RF pulse.