Homework 1: Multi-Dimensional RF Pulse Design

M229 Advanced Topics in MRI (Spring 2018)
Assigned: 4/12/2018, Due: 4/26/2018 at 5 pm by email

1. 2D EPI Pulse Design

Design a 2D separable EPI RF pulse using the method outlined in class.

a) Gradient Design

Design a blipped EPI trajectory with $k_{x,max} = k_{y,max} = 0.5$ *cycles/cm*, and nine lines ($L=9$). Assume the trapezoid ramps (τ_R) are 1/8 ms long, and the trapezoids themselves (τ) are 1 ms long. The blips are 1/4 ms long. What is the maximum amplitude of G_x and G_y?

Sample the RF and gradient waveforms at 5 us (200 samples per trapezoid and 25 samples per trapezoid ramp). Include a refocusing lobe at the end to bring the trajectory back to $k_x = k_y = 0$, using 1 ms trapezoids on x and y. Plot the gradient waveforms, G_x and G_y, with the axes labeled.

b) RF Pulse Design

Design the RF waveform with TBW = 4 for the subpulses, and the envelope. This will produce a 4 cm by 4 cm excited volume.

```
>> tbw = 4;
>> rf_fast = wsinc(tbw,samples);
>> rf_slow = wsinc(tbw,L);
```

Apply the “flat-top only design” (RF only played flat part), and use the RF waveform to be zero during the refocusing gradient. Scale the RF to a flip angle of 1 radian (i.e. sum(rf) = 1). Plot the RF waveform in Gauss.

c) 2D Bloch Simulation

Simulate the pulse over a sufficient range (e.g., -12cm to 12cm in x and y) at on-resonance. Plot the profile as an image using

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

and cross-section plots along x (M_{xy} vs. x) and y (M_{xy} vs. y)

```
>> subplot(211); plot(x,abs(mxy(:,round(length(y)/2))));
>> subplot(212); plot(y,abs(mxy(round(length(x)/2),:)));
```

2. Spectral-Spatial Pulse Design

True null and flyback designs are very closely related. Design both spectral-spatial pulses using the method outlined in class.

a) True Null Pulse Design

Design a true null spectral-spatial pulse, with a spatial TBW = 4 profile, and a spectral TBW = 4 profile. Assume the trapezoid ramps (τ_R) are 1/8 ms long, and also for convenience, assume the lipid null is centered at 250 Hz from water. How long is the trapezoid itself to make lipid nulling at 250 Hz?

Design for a 1 cm slice, and spectral passband of ±125 Hz. What is the maximum amplitude of G_z? What is the RF pulse duration? How many subpulses will be used?

Sample the RF and gradient waveforms at 5 us. Include a refocusing lobe at the end to bring the trajectory back to $k_z = 0$. Apply the "flat-top only design," and use the RF waveform to be zero during the refocusing gradient. Scale the RF to a flip angle of 1 radian. Plot the RF and gradient waveforms, with the axes labeled.

b) True Null Excitation Profile

Simulate the excitation profile over a sufficient range (e.g., -4cm to 4cm in z and -1000Hz to 1000Hz in frequency). Plot the profile as an image, and cross-section plots along z (M_{xy} vs. x) and frequency (M_{xy} vs. *frequency*).

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.

Characteristics of the Flyback Profile (Bonus Points)

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 is each spatial subpulse shifted in space, for a given frequency shift.