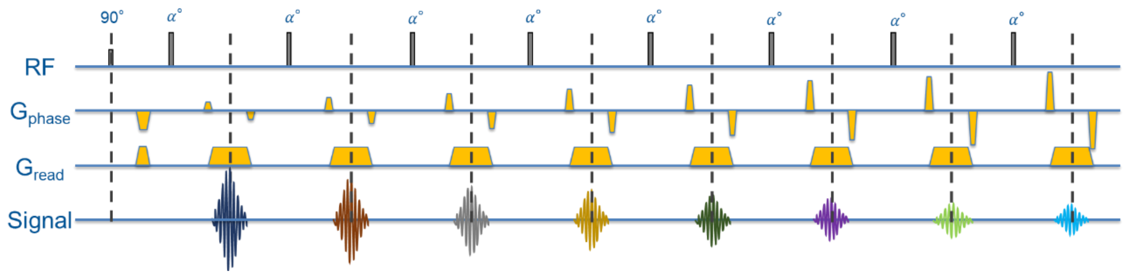
Homework #2

BME 599: Advanced Topics in MRI

Due 10/26/23 at 11:59PM 😊

Submission Instructions: Please submit a report and associated source code to the class Github page at https://github.com/orgs/UMICH-BME-AdvMRI. Please include all figures, and indicate which file was used to generate each figure in the report.

PROBLEM 1: Extended phase graphs. Shown below is a sequence diagram of a fast spin echo (FSE) with its first 8 refocusing pulses within one repetition time (TR). Each RF pulse is designated as a delta function, so you do not need worry about the slice profile. Refocusing pulses are spaced 5*ms* apart (echo spacing).



a. Please write a function using EPG to simulate spin echo train echo amplitudes for a sequence with $90°_x$ excitation, followed by refocusing pulses of $[\alpha+(90-\alpha/2)]_y$, α_y, α_y,… for 64 echoes for T1 = [200:100:1500] ms, and T2 = [50:30:300] ms

i. Simulate echo amplitudes with α = 180°, and plot amplitudes with five different T1 and T2 combinations

ii. Simulate echo amplitudes with α = 120°, and plot amplitudes with five different T1 and T2 combinations

iii. Simulate echo amplitudes with α = 60°, and plot amplitudes with five different T1 and T2 combinations

b. Plot 4 contour plots signals vs T1 and T2 for the 6th, 16th, 32nd, and 48th echoes using various α

c. Discuss the contrast you get with different flip angles.

PROBLEM 2: Single and Multiple Spin Echo Sequences. In this problem, you will simulate spin-echo images with single and multiple echoes.

a. Single-echo spin echo. The file *brain_maps.mat* on Canvas contains simulated T1, T2, and M0 maps from an axial slice in the brain. You will use these tissue property maps to simulate a single-echo spin echo sequence to create three images: T_1-weighted, T_2-weighted, and proton density weighted. Use a $90°_x$ excitation followed by a $180°_y$ refocusing pulse. You can choose to use either a Bloch equation simulation or extended phase graphs. *For each contrast weighting, choose an appropriate TR and TE (justify your reasoning!), simulate the spin dynamics, and display the image.*

b. Fast spin echo. Now let's speed things by sampling multiple echoes after each excitation. Use an FSE sequence with TR = 3 seconds, echo spacing (ESP) = 5 ms, and echo train length (ETL) = 32. Assume a $90°_x$ excitation followed by multiple $180°_y$ refocusing pulses.

i. First, let's investigate the signal behavior for a few T1 and T2 combinations. Simulate 5 TRs of the sequence. For the last TR, plot the transverse magnetization as a function of the echo time for the following (T1,T2) combinations: (1000,50), (1000,100), (2000,50), and (2000,100) ms.

ii. Using the brain T1, T2, and M0 maps, simulate an FSE sequence to create an image, as in Part A. With FSE sequences, the k-space filling order affects the contrast weighting. Choose a k-space filling order to obtain an image with an effective echo time (TE_{eff}) of 80 ms. *Display the image. Also draw a diagram showing the k-space filling order and explain how you chose this filling order. What would be the total acquisition time for this scan? How does this compare to the acquisition time for a single-echo spin echo scan with equivalent image contrast?*

iii. Now simulate FSE images with effective echo times of 40 ms and 120 ms. *Display each image. Also draw a diagram for each case showing the k-space filling order*.

iv. Simulate images with TE_{eff} = 80 ms and different ETL of 16, 32, 64, and 128. *Display the FSE images with different echo train lengths. Also display a single-echo spin echo image with TE=80 ms for comparison. What happens to the image as the ETL becomes longer? Why does this occur?*

c. BONUS: You should have seen that the image quality becomes worse at very high ETL. *Can you think of a strategy to improve image quality even with very long ETL? Test out your strategy by simulating an image with same FSE scan parameters as above with ETL=128.*