## **MRI Project**
Due Date: Nov. 21, 2023

In this project you will implement a Bloch equation simulator to demonstrate the functioning of a spin-warp pulse sequence with slice selection in order to provide understanding of a) the behavior of magnetization in the presence of applied B fields, b) image acquisition methods and parameters, and c) slice selective excitation. We will use the following pulse sequence:
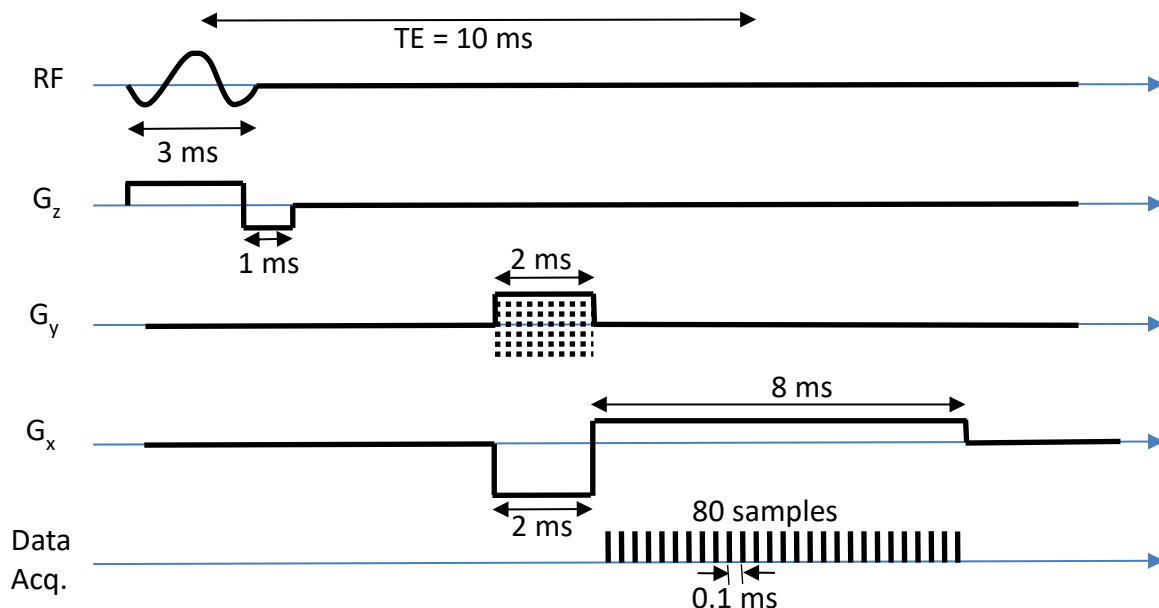
Other information: $FOV_x = 16$ cm. $FOV_y = 12$ cm ($N_x = 80$, $N_y = 60$). Slice thickness = 1 cm. Simulation step size $dt = 0.05$ms.

Assume you are working in the rotating frame, that is, use the rotation frame version of the Bloch equations. The object will consist of a number of discrete spins with associated locations (x,y,z) and relation parameters (T1, T2). These will be provided to you. You will need to calculate the amplitudes of all RF and gradient functions.

Administrative items:
- You may choose a partner for this project (or you may also work alone). You must choose a different partner than you had for the US project. If you are having problems locating someone to work with, please let me know. Please put your partner's name on your solutions. Each person must hand in their own solution.
- The partnering is not intended to be a "divide and conquer" approach – that is, you may not split up the problem and then share solutions. I expect you to do your own work, but when you get stuck, you may ask your partner or the instructor for help. Think of this as an exam, but one in which on may ask for help from one other person.
- Getting help from anyone other than the instructor or your partner or copying solutions (even from your partner) will be considered a violation of the engineering honor code.

- As before, you will be expected to hand in a report outlining your solutions. Please create a single pdf file with answers to questions below, all requested plots/graphs/images and at the end of the pdf file, please include copies of your final ".m" files. For each question/task please write 2 or 3 sentences about what you did, what equation you implemented, and about the appearance of the resultant images, etc.
- Title and label the axes or all plots and images.
- If you are having problems, please come and see Prof. Noll (or send e-mail) or the GSI.

QuestionsTasks:

1. Before using the large set of point objects in "object23.mat" we will start with a simpler case with a point object at (x,y,z) = (4,4,0) cm and (T1, T2) = (1000,100) ms. For this part, let all gradients be equal to zero. Simulate the magnetization for this spin in the presence of the 90 degree RF pulse. Plot Mx, My, and Mz vs. time.

2. Repeat 1. for (T1, T2) = (20,10) ms. Plot Mx, My, and Mz vs. time and describe the differences from part 1.

3. Let (T1, T2) = (1000,100) ms and add the z-gradient waveform. Plot Mx, My, and Mz vs. time and describe the differences from part 1.

4. Let the z position change to z = 0.2 cm. Plot Mx, My, and Mz vs. time and describe the differences from part 3. Repeat for z = 1.0 cm – this spin is outside of the slice.

5. Let (x,y,z) = (4,4,0) cm and (T1, T2) = (1000,100) ms and add the z and x gradients. You will need to determine the amplitude of the negative x gradient so that the samples are acquired symmetrically. Plot Mx, My, and Mz vs. time and describe the differences from part 3.

6. Extract the received signal at the desired sampling rate (remember, this is different than the simulation step size). Take the 1D inverse Fourier transform of this received signal and plot the magnitude (of the IFT) vs. spatial position. Remember that in imaging the 0 location usually is placed in the center of the plot, that is, you will need to use the fftshift functions in Matlab (or use the ift.m function provided).

7. Add the y gradient and step through all of the phase encodes. Create an image of real(M(kx,ky)) and imag(M(kx,ky)).

8. Reconstruct the image and create and image of abs(image(x,y)).

9. Repeat step 8., but set the y position of the spin to +10 cm. Describe what happens.

10. Modify the simulation to integrate the signal from the complex object in "object23.mat" Create images of abs(M(kx,ky)) and abs(image(x,y)).

11. Repeat step 10., but now modify B1 for a slice positioned at z = +1.0 cm. Describe what happens.

Parts 10. and 11. may run slowly (object23.mat has 2850 spins to be simulated), so it is important that you debug your simulation before getting to this part.