M219, Winter 2018

Homework Assignment #4

Due Thursday, March 15th by 11:59pm

Late assignments will be discounted by $e^{-t/\tau}$, where $\tau = 72$ hours. For all problems – Clearly state the value of all constants and free variables that you use, show your work, and provide units. This is not a group assignment. 15 points.

1 Bloch Simulator (10 points)

Your goal for this question is to create your own Bloch simulator and use it to understand a pulse you have not seen before.

A. What is the required B_1 field strength (in Gauss) required to produce a 90°flip angle with a 100 μs hard RF pulse? [1 points]

B. The pulse from Part 1A will tip a water proton 90°, but now we would like to know how a fat proton will behave, given that it is not resonating perfectly in sync with the RF pulse. To do this you will create your own Bloch simulator. We will ignore relaxation and gradients in this problem, so the two main factors affecting our simulated spins are the applied B_1 field, and the chemical shift of fat. Provided with this HW are two functions: *rot_b1.m* and *rot_chemshift.m*. These functions rotate the magnetization vector $\vec{M}$ around the x axis and z axis, respectively. The functions *rot_b1.m* and *rot_chemshift.m* are incomplete in one critical line, calculating the amount to rotate for a given time duration (dt). Determine the correct rotation in radians for each function. [1 point]

C. Now use the corrected functions to simulate the RF pulse from Part 1B applied to a fat spin (chemical shift=3.5 ppm, B_0=1.5T). Start your simulation with $\vec{M} = [0, 0, 1]$. Discretize the pulse into dt = $1\mu s$ time steps and apply the two operators to the current $\vec{M}$. What is the resulting $\vec{M}$? What is the realized flip angle for the fat spin? [2 point]

D. Now, instead of a single 90°RF pulse, apply two 45°RF pulses (still 100 μs hard rf pulses) with some delay time between them. Evaluate delay times between 1-3 ms. Plot M_{xy} (y-axis) vs. delay time (x-axis) for both water and fat spins and include in your submission. [2 point]

E. You should have found a delay time that minimizes fat signal ($M_{xy} \approx 0$) while maintaining the water signal (If you do not see this effect then something has gone wrong with parts 1A-1D). What is the value of this optimal delay time, and describe how the fat signal is being nulled by this set of RF pulses. [1 point]

F. Now test a range of chemical shifts (-3.0 to 8.0 ppm, use at least 200 steps) with the pulse sequence from Part 1D and the optimal delay time described in Part 1E. Plot M_{xy} (y-axis) vs. chemical shift (x-axis) and include it in your submission. [2 point]

G. Based on what you have learned, what might be the clinical usefulness of using this pulse instead of a regular 90°RF pulse? [1 point]

2 Image Reconstruction (5 points)

For this problem you may need to be familiar with the fft2.m, fftshift.m, ifft2.m, and ifftshift.m function.

A. The file *dataset1.mat* contains a set of k-space data for an eight coil acquisition. Reconstruct any two coil images and figure of the images. [1 point]

B. Create a sum of squares coil combination of the dataset. Compare the result to a more simple approach to coil combination where the coils are simply averaged together. Make a figure showing both results. Describe any differences? [1 point]

C. Reconstruct a coil combined image from the k-space data found in *dataset2.mat*, note that there are 16 coils in this dataset (use all coils). [1 point]

D. Datasets 1 and 2 contain the same amount of noise, yet they appear different, locate and describe the cause. *Hint:* The coil maps used to create these datasets are also loaded with the *.mat files. [1 point]

E. Reconstruct a coil combined image from the k-space data found in *dataset3.mat*. [1 point]