BENG280A, Principles of Biomedical Imaging 11/17/13
Fall Quarter 2013

HOMEWORK #7

Due at 5 pm on Friday 12/06/13

Homework policy: Homeworks can be turned in during class or to the TA's mailbox in the Graduate Student Lounge. Late homeworks will be marked down by 20% per day. If you know that you need to turn in a homework late because of an emergency or academic travel, please let the TA know ahead of time. Collaboration is encouraged on homework assignments, however, the homework that you submit should reflect your own understanding of the material.

Readings: Read Chapter 6 and Sections 7.1 through 7.4.

For all problems, assume that $\frac{\gamma}{2\pi} = 4257 \text{ Hz/G}$

Problem 1

Upon finding out that you have taken BE280A, your boss asks you to design an MRI pulse sequence that "mimics" the k-space coverage of a CT system. Using the design parameters (e.g. FOV and beamwidth) from the midterm project, indicate how you would design a set of gradient waveforms that would provide this coverage. Specify how far out in k-space you will go and also how you will determine the appropriate sampling in k-space.

Problem 2

Do problem 4.3 from Nishimura (in other words, show that Eqn 4.15 is a solution to Eqn 4.14) ; In addition, use MATLAB to plot out the solution for initial conditions of (a) $M_z(0) = 0$; (b) $M_z(0) = -M_0/2$; and (c) $M_z(0) = -M_0$. Assume a T_1 of 1 second. For each of the initial conditions, determine the time at which the magnetization recovers to $0.95M_0$. Is this time the same for all initial conditions? – explain your finding.

Problem 3

Problem 7.3 in Nishimura.

Problem 4

You are asked to design an RF and gradient pulse sequence that achieves the following profile: $M_{xy}(z) = \frac{1}{4}\left(1+\cos(4\pi z)\right)^2$. The maximum available B_1 radiofrequency field is 0.2 Gauss and the maximum available gradient is 4 G/cm.

a) First compute the Fourier transform of the pulse profile. You may find it useful to use the convolution/multiplication theorem.
b) Next use the small tip angle approximation to determine the desired flip angles for each pulse. Compute the temporal width of each pulse required to achieve the desired flip angles, assuming that each pulse uses the maximum available B_1 field.
c) Derive a plot of the desired k_z versus time. Use this plot to design your gradient waveforms. Make sure to clearly label all amplitudes and timing parameters.
d) Draw a quiver diagram that shows the orientation of the spins from each RF pulse at the end of the pulse sequence. Discuss how the sum of the spin profiles achieves the desired overall profile. In specific, test out the locations where you expect the profile to equal 0, ½ or 1. Make sure to take into account the flip angles of the RF pulses that you used.

Problem 5
In this exercise you will experiment with how different imaging parameters alter the contrast of an image. First download the file BE280A08_hw6.mat from the course website. In this file you will find three matrices labeled csf, gm, and wm, which are the partial volume maps for cerebral spin fluid, gray matter, and white matter, respectively. Assume the values shown in the table below. Assume that your MRI system can have a minimum echo time (TE) of 3 ms and a maximum TR of 15,000ms. Finally, assume that you are using a saturation-recovery sequence. Come up with sequence parameters that yield proton-density, T1-weighted, and T2-weighted images and use the partial volume maps to generate corresponding images. For the T1-weighted image, choose parameters that maximize the contrast between gray and white matter -- you may want to use MATLAB to search over possible TR values.

Tissue	Proton Density	T1 (ms)	T2 (ms)
Csf	1.0	4000	2000
Gray	0.85	1350	110
White	0.7	850	80