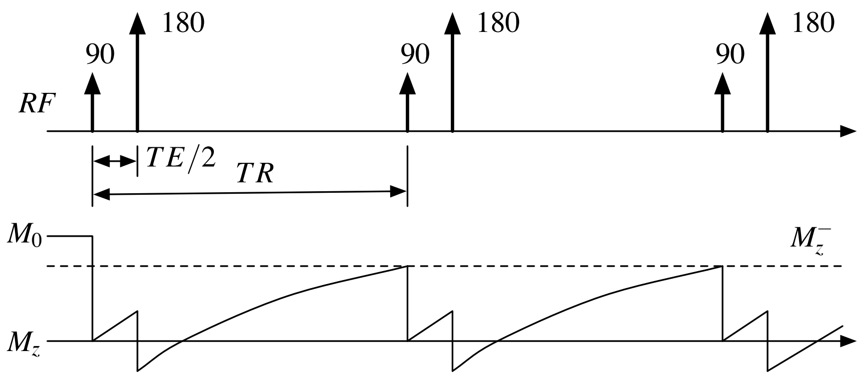
EE225E/BIOE265 Spring 2014 Miki Lustig
Principles of MRI

Assignment 9

Due Friday April 11th, 2014, Self Grading Due Monday April 14th, 2014

1) In class when we presented the spin-echo saturation recovery pulse sequence, we assumed that the echo time TE was short relative to the repetition time T_R, so we could ignore it. This is not always a good approximation, particularly if we want to measure T_1.

   In fact, after the 90 there will be some M_z recovery. The 180 will invert this, and M_z will continue to recover until the next 90. Let M_z^- be the magnetization immediately before the 90.



   Assume that T_E is small compared to T_1, but not negligible, so that we can approximate

$$(1 - e^{-T_E/T_1}) \simeq T_E/T_1.$$

   This means that the M_z recovery curves are approximately linear within a time T_E after the 90.

   a) Find an approximate expression for the time when the magnetization cross the $M_z = 0$ axis.
   b) This might be called a T_1 echo. Why?
   b) Find an expression for M_z^- using what you found in (a).
   c) Compare M_z^- calculated using your expression and the expression ignoring T_E for the case where $T_R = 200$ ms, $T_E = 20$ ms, and $T_1 = 800$ ms. What is the percent error produced by neglecting T_E in this case?

2) Choosing Scan Parameters (We will cover material for this on Tuesday.)

   You are designing a pulse sequence to image the upper abdomen. The tissues of interest are

   – Liver, $T_1 = 600$ ms, $T_2 = 50$ ms.
   – Spleen, $T_1 = 1000$ms , $T_2 = 80$ ms.
   – Fat, $T_1 = 350$ ms, $T_2 = 60$ ms.
   – Gall Bladder, $T_1 = 2000$ ms, $T_2 = 300$ ms.

This will be a spin echo acquisition, where you have to choose the repetition time T_R, the echo time T_E. In addition, you can also add an inversion recovery pulse *if you need it*, and specify the inversion time T_I. Otherwise leave the T_I blank. The minimum T_E is 15 ms, and the minimum T_R is 20 ms.

In each case you only need to specify the scan parameters *approximately*. You only need reasonable values, not necessarily the optimum values. However, you need to describe the reasoning behind your choices.

a) Choose the scan parameters so that you have good contrast between liver and spleen, and low signal from the gall bladder.

$T_R =$	$T_E =$	$T_I =$

b) Choose the scan parameters so that you see only the gall bladder, with little signal from the other tissues.

$T_R =$	$T_E =$	$T_I =$

c) Choose the scan parameters so that the liver produces no signal at all, but the spleen is bright.

$T_R =$	$T_E =$	$T_I =$

3) Nishimura 7.3

4) In order to produce a very high resolution image of the brain, you specify a scan that provides 0.25 mm resolution over a 25.6 cm FOV. Unfortunately, the SNR is very low.

   a) You lowpass filter the image to increase the SNR, using an ideal lowpass filter in both x and y. If the resulting resolution is 0.5 mm in both x and y, what is the final SNR compared to the original image?

   b) How does this SNR compare to an image with 0.5 mm resolution, and the same total imaging time as the 0.25 mm resolution image? Assume the same A/D duration for each readout interval, and that the 0.5 mm scan averages to provide the same number of readouts.

5) Nishimura 7.10

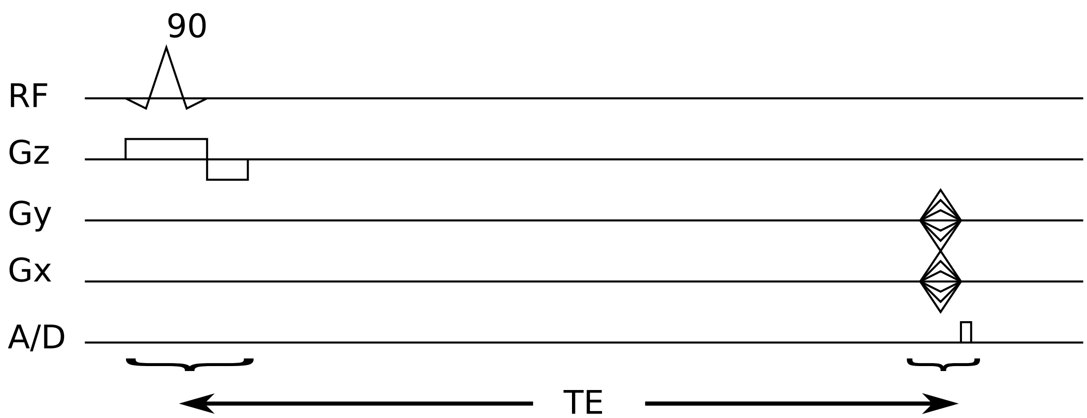
6) Consider the Hadamard encoding of two slices as shown in Fig. 8.2 in Nishimura. What is the relative SNR of the two slices compared to imaging two slices sequentially?

7) From Midterm 2014

Problem 1: Effects of Flow on Phase-Encoded Imaging

In this question we will consider several situations of flowing spins. We are going to make a few approximations.
1) The transverse magnetization decays completely and the longitudinal magnetization recovers completely between excitations. 2) The flow during gradient/RF pulses can be neglected, but there could be displacement between pulses that are separated considerably in time. 3) We assume stroboscopic acquisition, *i.e.,* a spin that moved from position (x_0, y_0) to (x_1, y_1) during a TR, in the next TR will also move from (x_0, y_0) to (x_1, y_1).

Consider the following phase-encoded only sequence, where for each TR a **single** point in k-space is acquired:



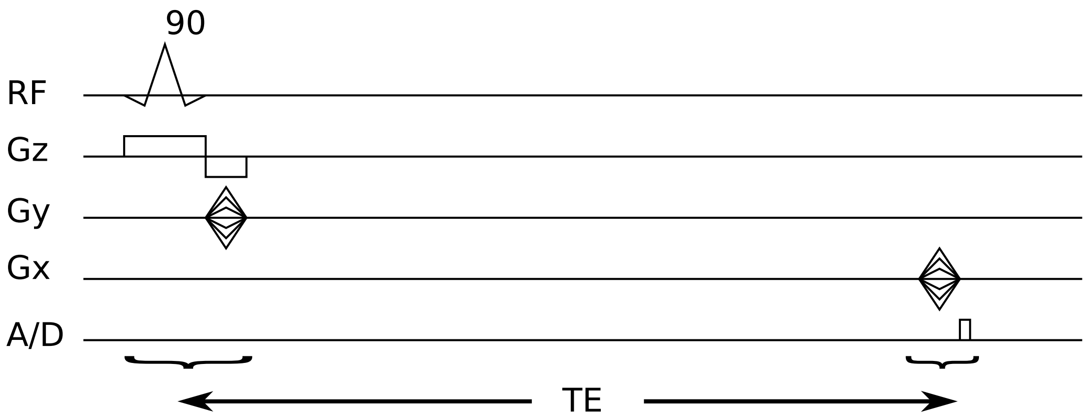
a) A spin with magnetization M_0 at position $\vec{r} = (x_0, y_0)$ has a velocity of $\vec{v} = (v_x, v_y)$. What is the received k-space $M(k_x, k_y)$ using the above sequence? Again, assume that the spin is not moving during the gradients/RF but is displaced between excitation and phase-encodes.

$M(k_x, k_y) =$

b) Now, consider two spins with magnetization M_0. Both spins are at iso-center $\vec{r} = (0, 0)$. However, one spin is static and the other is flowing at a velocity of $\vec{v} = (100, 100)$ cm/s. The spins are imaged with the above sequence with an echo time $TE = 10$ ms. Draw the resulting reconstructed image m(x,y). Don't forget to explain your answer and label axis and units.

$m(x, y)$

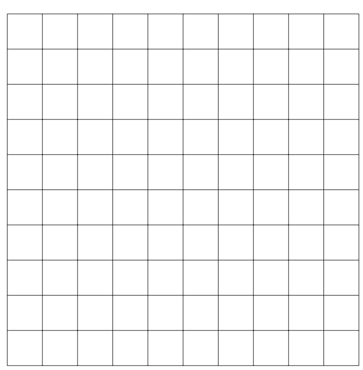
Now, consider the following modified phase-encoded only sequence, where for each TR a **single** point in k-space is acquired:



c) A spin with magnetization M_0 at position $\vec{r} = (x_0, y_0)$ has a velocity of $\vec{v} = (v_x, v_y)$. What is the received k-space $M(k_x, k_y)$ using the above sequence? Again, assume that the spin is not moving during the gradients/RF but is displaced between excitation and phase-encodes.

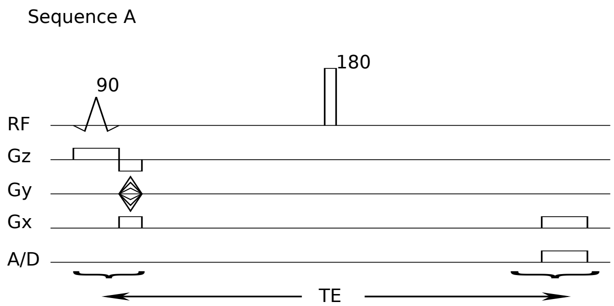
$M(k_x, k_y) =$

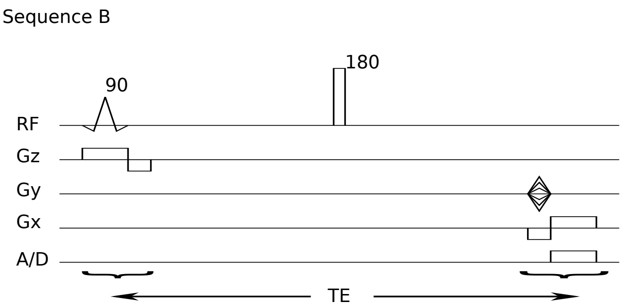
d) For the exact same setup as in part (b) where two spins with magnetization M_0 at iso-center $\vec{r} = (0, 0)$ where one spin is static and the other is flowing at a velocity of $\vec{v} = (100, 100)$ cm/s. What would be the resulting image if you scanned using the modified sequence and $TE = 10$ ms?



$m(x, y)$

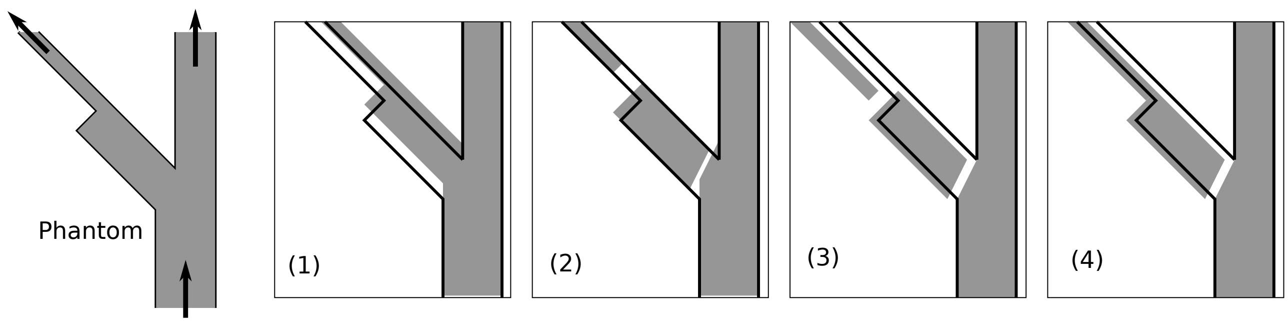
Now, consider the following two spin echo sequences:





These are used to image a flow phantom.

e) Here is the phantom and 4 possible resulting images. Match the two that are most plausible to be produced by the above sequences. Explain! We will assume that transitions in flow are abrupt and not smooth.



Sequence A: Sequence B: