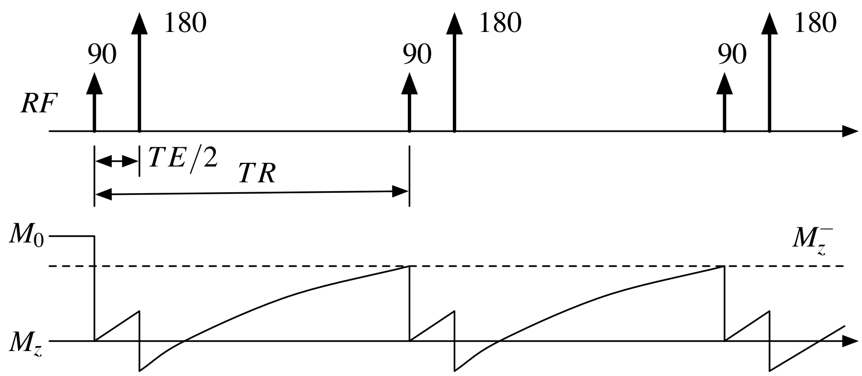
EE225E/BIOE265 Spring 2016 Miki Lustig
Principles of MRI

Assignment 9

Due Friday April 8th, 2016, Self Grading Due Monday April 11th, 2016

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

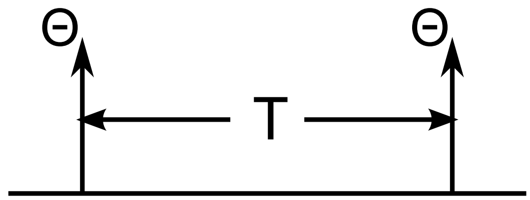
$$(1 - e^{-T_E/T_1}) \simeq T_E/T_1.$$

   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. Contrast Preparation:

Consider the following sequence of two θ degrees tip-angle RF pulses separated by T seconds.



a) Given that the equilibrium magnetization is M_0, derive an expression for the M_z component of the magnetization immediately following the second RF as a function of T_2, T, and θ. You can neglect T_1 recovery (since $T_1 \gg T$) and off-resonance.

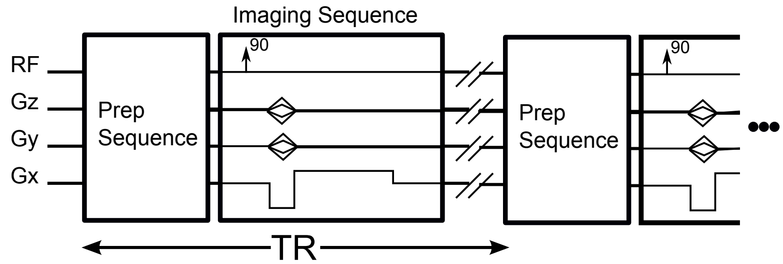
$M_z =$

b) Given $T = T_0$, find the flip angle θ for which the M_z component is zero for spins with a desired T_2 transverse relaxation value.

$\theta =$

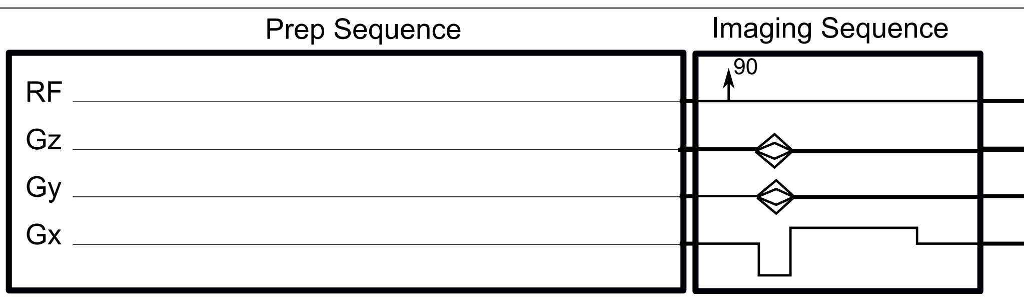
MR Angiography is an important tool in assessing vascular diseases in patients. Often, T_1 shortening Gadolinium contrast agents are used in combination with short TR sequences to increase the blood-muscle contrast. However, using Gadolinium based contrast agents can result in a life threatening syndrome, called NSF, in patients that have renal disease.

Consider the contrast preparation imaging paradigm below. For each preparation sequence a single phase encode is collected. Also, assume $TR \gg T_1$.



The T_1/T_2 of blood are 1000/220ms and the T_1/T_2 of muscle are 870/50ms. We would like to design a non-contrast enhanced preparation pulse that will ideally have good blood signal and no muscle signal at all. In addition, we would like the preparation pulse to not be much longer than 50ms.

c) Based on your previous derivations, design a preparation sequence that nulls the muscle signal while producing signal from blood. Draw the sequence pointing out the relevant parameters. (Extra points will be given for those coming with solutions that are insensitive to off-resonance). what is the blood M_z magnetization after the prep-pulse?



Blood $M_{zprep} =$

3) Choosing Scan Parameters

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.

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

4) Nishimura 7.3

5) 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.

6) You have a working 2DFT gradient-recalled echo pulse sequence that produces an image with an SNR_1 of 100. What is the new SNR_2 after you make *one* of the following changes. Add a brief explanation as well.

a) Double the TBW of the slice selective RF pulse, while the RF pulse duration and the slice select gradient remain the same.

$SNR_2 =$

b) Double the readout gradient strength, while keeping the A/D duration and sampling rate the same.

$SNR_2 =$

c) Double both the readout gradient strength and the sampling rate, while halving the duration of the A/D window. Assume the anti-aliasing filter bandwidth matches the sampling rate.

$SNR_2 =$

d) Double the number of phase encodes, while keeping the maximum phase-encode gradient amplitude the same.

$SNR_2 =$

7) Nishimura 7.10

8) 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?