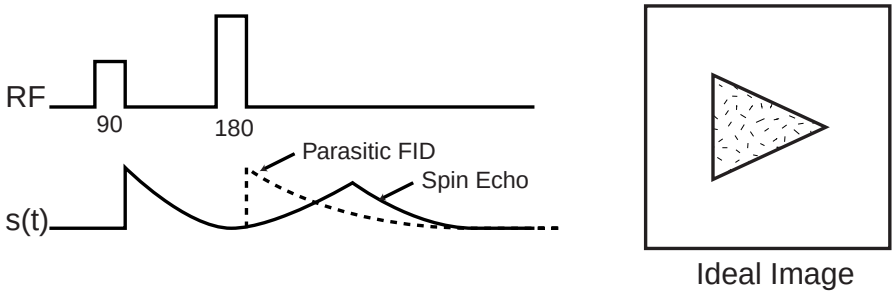
EE225E/BIOE265 Spring 2013 Miki Lustig
Principles of MRI

Assignment 8

Due Wednesday April 10th, 2013

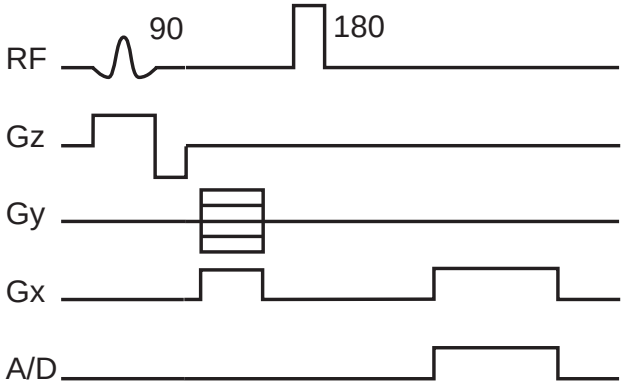
1. Nishimura 7.1

2. In a spin-echo pulse sequence the 180° pulse refocuses the magnetization produced by the 90° excitation. Since the 180° is never perfect, it will will also excite magnetization. This produces additional signals, as is shown on the left below:

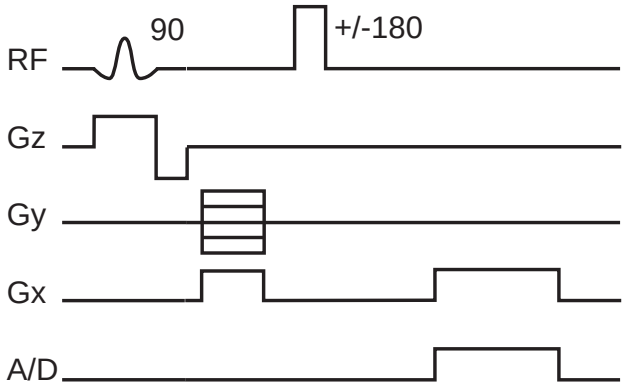


These signals, called "parasitic" FID's, will produce image artifacts that depend on the acquisition method. In each of the examples below, draw (i) where the parasitic FID ends up in k-space, and (ii) the image artifact it produces. Assume that the ideal image is as shown above on the right, and that signal only comes from the excited slice.

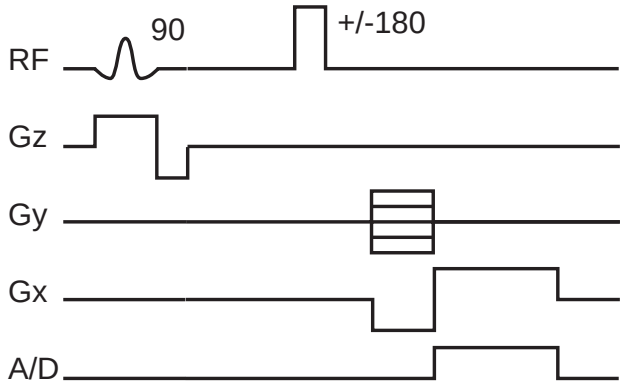
a) In this case the phase encode and the readout dephaser are before the 180.



b) The same pulse sequence as in (1), with the addition that the 180 is inverted every other phase encode step.



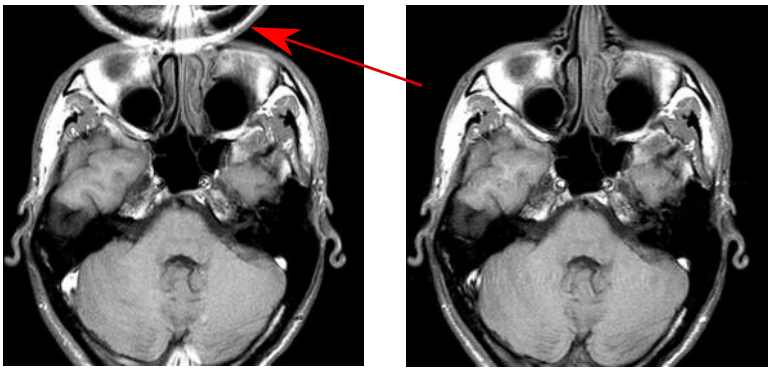
c) The same pulse sequence as in (2), with the phase encode and readout dephaser after the 180.



3. MRI Artifacts and Debugging

In this question you will be given several pairs of images. The images may exhibit artifacts which will be indicated by arrows/circles. Answer the questions as best as you can. First describe the artifact and then provide as much information as possible on the source/s of the artifact and why it appears this way. There might be several possible right answers. A final answer without explanation will not be credited.

a) Example: What is the source of the artifact in the left image and what is the difference in the acquisition/processing of the two?



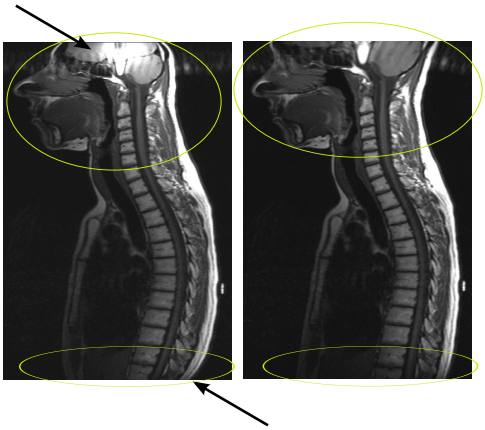
Solution:

The artifact in the image appears as the back of the brain aliasing over and wrapping to the front. This is typical when the prescribed FOV in the phase encode is smaller than the FOV of the object. In that case the sampling density does not meet the Nyquist rate. The phase encode is obviously Anterior-Posterior.

The image on the right does not exhibit aliasing. One way to avoid aliasing is to increase the number of phase encodes while keeping the resolution the same. The other way is to swap the readout and phase-encode directions. It seems that the latter approach of swapping the readout direction was used since the back of the skull as well as the nose are cropped. Choosing a larger FOV in the phase encode would have shown the entire nose and skull.

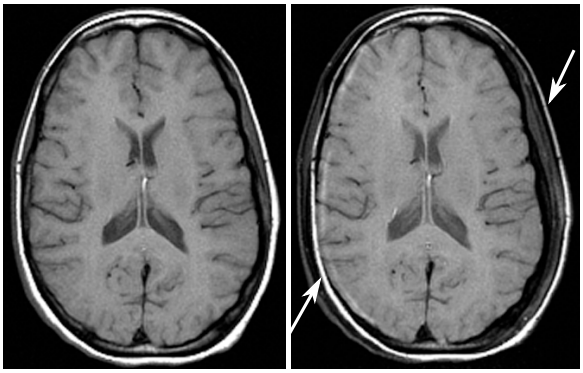
Source of Artifact: aliasing in the phase-encode direction (A/P) Difference: readout and phase encode directions swapped

b) What is the source of the artifact in the left image and what is the difference in the acquisition/processing of the two?



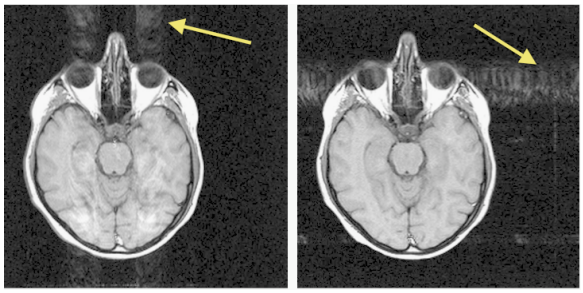
Source of artifact: Difference:

c) What is the source of the artifact in the right image and what is the difference in the acquisition/processing of the two?



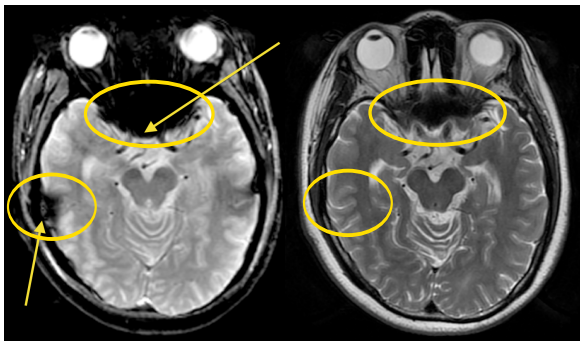
Source of artifact: Difference:

d) What is the source of the artifact in the two images and what is the difference in the acquisition/processing of the two?



Source of artifact: Difference:

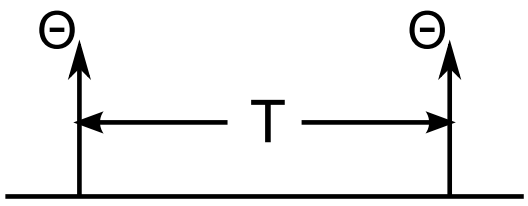
e) What is the source of the artifact in the left image and what is the difference in the acquisition/processing of the two? (Ignore the contrast difference between the two)



Source of artifact: Difference:

4. 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.

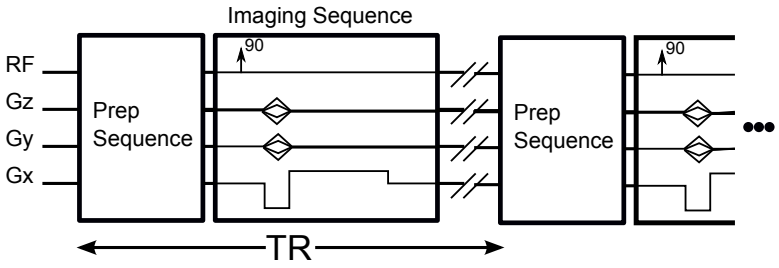
$M_z =$

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.

$\theta =$

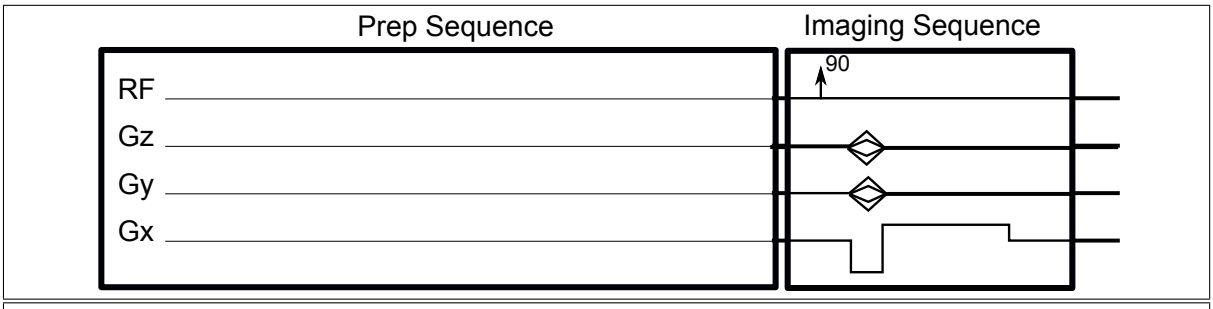
MR Angiography is an important tool in assessing vascular diseases in patients. Often, T_1 shortening Gadolinium contrast agents are used in combination with short TR sequences to increase the blood-muscle contrast. However, using Gadolinium based contrast agents can result in a life threatening syndrome, 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 $M_{zprep} =$

5. Consider the EPI and spiral trajectories in fig. 8.12 in Nishimura.

   a) Assume T ms readout gradients and that the gradients start 1ms from the peak of the RF excitation. What is the echo-time for EPI and what is the echo time for the spiral trajectory?

   b) What is the k-space weighting due to T_2^* decay in EPI and spiral for a gradient echo sequence. (Assume decay happens only in the slow direction.)

   c) How would your answer change if the sequence is a spin-echo. What's the problem for spiral spin-echo imaging?

6. **Matlab Simulation: 2DFT Spin-Echo Sequence**. In this exercise we are going to modify the sequence you designed in HW 5 Q6c to a spin-echo sequence. For that, we need to insert a 180° refocusing pulse. We are going to insert the refocusing pulse between the phase encodes (and the readout prewinder) and the readout.

   a) Modify the GRE sequence to be a spin echo sequence. Add an appropriate hard refocusing pulse and modify the gradient timings such that the echo-time is TE=6ms. In your design assume maximum $B1_{\max} = 0.16G$. Plot the pulse sequence diagram.

   b) Simulate the pulse sequence using the data from HW5. In the simulation make the refocusing pulse 170° to simulate B1 imperfection. In addition, to simulate off-resonance add a constant gradient field of 0.01G to Gy. (simply calculate the appropriate phase encode waveform and add 0.01 to it.) The constant gradient should be on through the entire pulse sequence! Reconstruct and plot magnitude and phase images. Can you see the effects of the parasitic FID from the refocusing pulse? do you see any phase due to off-resonance?

   c) Modify the sequence to overcome the artifact from the parasitic FID by chopping the refocusing pulse (±170°). Reconstruct magnitude and phase images. Comment on the artifact and also on the phase of fat and water.