MRI Lab 2   6.S03 – Spring 2015
Spin echoes and projection imaging

1. Spin Echoes

1.1 Find f_0, transmit amplitudes, and shim settings

In order to acquire spin echoes, we first need to find the appropriate scanner settings using the **FID GUI**. This was all done last week, but these calibration settings should be rechecked before each experiment.

- Insert full water tube (phantom #1) into RF coil. Run FID GUI sequence, by clicking on the "FID_GUI" software interface as you did last week. When you insert or remove phantoms, be careful not to displace the copper-covered coil holder within which the phantom test tube is placed. It is a good idea to remove and insert phantoms by holding the coil cartridge steady by one hand and use the other to position the phantom in the coil

- Use the frequency finder in the software ('find center frequency" box) or check the **6.S03_2015_MRI_Lab_Frequency_and_Shim_Settings.pdf** document on MITx to find the correct Larmor Frequency for your magnet and use this value for "Frequency (MHz)" field in the FID_GUI. Without a correct center frequency you may not see a proper signal (at least an SNR of ~200)

- If you don't see a frequency peak, try a reset on the medusa console. If that doesn't work, then try power cycling. Spend no more than 10 mins on getting a proper signal. If you can't, ask for help from the staff.

- If the peak is not centered at 0 Hz, adjust the system console frequency f_0 ("Frequency (MHz)") until it is. Record this f_0 frequency:_____

- Stop any ongoing runs, checking the "flip angle calibration" box in the FID_GUI and then click "Run Scan" again. Recall from MRI Lab #1:

    a. The 90° flip angle occurs when amplitude of the FID signal is maximized.

    b. The 180° flip angle occurs at the first minimum after the first maximum.

    c. Sometimes there will be a second maximum because a 270° rotation is achieved.

- Record the 90° transmit amplitude:_____, Record the 180° transmit amplitude:_____ Enter the 90° transmit amplitude value into the FID_GUI field "RF TX amplitude (0 to 1)" and use it for the rest of the lab.

- In the GUI, change the current offsets (mA) of the x, y, z gradient coils to apply linear shim fields along each direction. Refer to the document **6.S03_2015_MRI_Lab_Frequency_and_Shim_Settings.pdf** for a good start on the shim values. Try to further increase the magnitude of the frequency peak (i.e. make the line as narrow as

possible, equivalently increase the peak) by adjusting these values. You may want to set the number of repetitions to a high enough number so that you don't have to hit run scan every time. Once you optimize the shims, you may or may not have to update the system console frequency to center the frequency peak at 0 Hz. **Save your best shim settings using the "Save shim settings" button**. Also record your center frequency, in some cases with shimming the center frequency may shift slightly.

Record the currents (mA): X shim:_____ Y shim:_____ Z shim:_____

Center frequency f_0: _____

1.2 Acquire Spin Echoes

- Stop any ongoing scans in the FID_GUI and close this window. Now open the "Spin echo GUI" through the software interface.

- Enter your optimal f_0 "Frequency (MHz)", transmit amplitudes "RF 90 deg amplitude" and "RF 180 deg amplitude", and shim settings (use the "load shims" button) into the GUI. Make sure the acquisition type is set to "Spin Echo". Click "Run Scan".

- Sketch the magnitude of the acquired signal (blue trace) on the empty plot below, and on your sketch, mark:

    a. At what time point is the 180° RF pulse applied?

    b. At what time point does the spin echo occur?

    c. Which aspect of the plot corresponds to T_2^* decay? Which aspect of the plot corresponds to T_2 decay?

Spin echoes and projection imaging
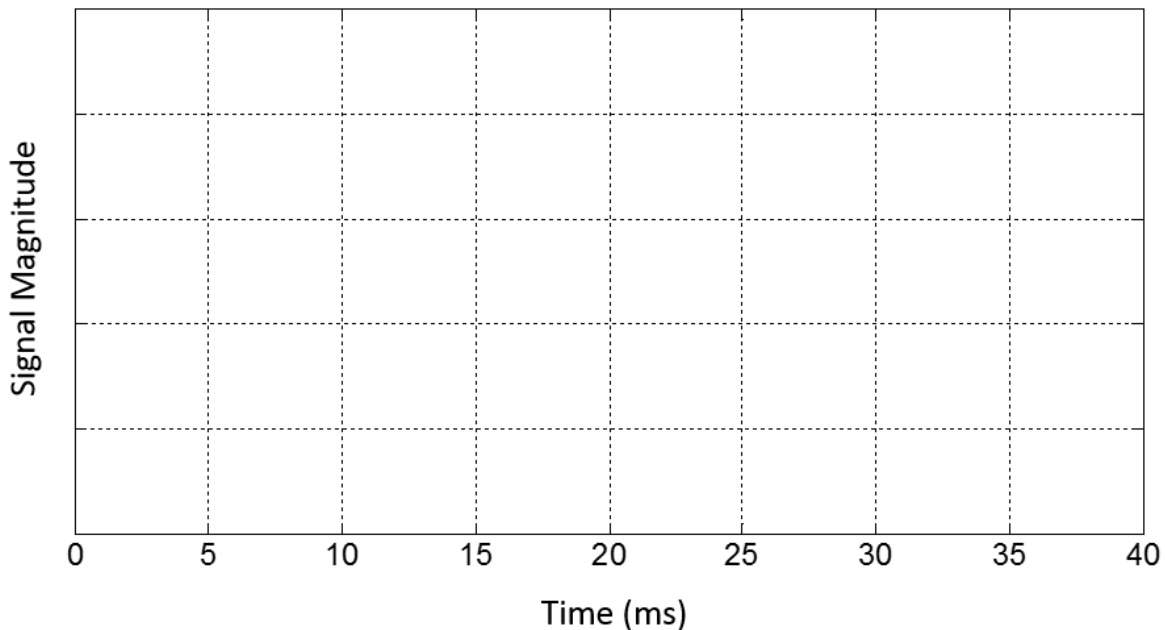
- Stop the scan and click the "zero shims" button so that no shim fields are applied. How does the acquired signal change?

- Try adjusting the echo time (TE), for instance increase TE from 30 ms to 200 ms. How does the acquired signal change?

Checkoff 1. Explain to a staff member:

- What you see in the spin echo sketch and relate this signal to what is physically happening to the spins?

- How does the acquired signal change when using the optimal shim settings versus when there are no gradient shim fields applied (the shims are zeroed)?

- How does the acquired signal change when TE is increased or decreased?

    (Hint: The spin echo sequence refocuses T_2* spin dephasing, but there is also signal decay with a longer time constant, T_2)

2. One-dimensional projections

The goal of this part of the lab is to learn about 1D projection imaging, and you may find it helpful to refer back to the prelab during this section.

2.1 Small Cylinder Phantom and projections

- Continue using "Spin echo GUI", but change the readout time and TE back to the default settings (TE = 30ms and readout = 20ms). The full water phantom (phantom #1) should still be in the RF coil.

- To turn on a gradient current (and therefore add a linear gradient field to the z-directed B0 field), choose "projection along X", "projection along Y" or "projection along Z" as the "acquisition type". The <u>frequency</u> domain signal is now a ***projection*** of the phantom onto the spatial axis in which you apply the gradient field.

MRI Lab 2   6.S03 – Spring 2015
Spin echoes and projection imaging

> ***Check yourself 1.*** Look at the signals before and after turning on the gradient field. When you turn the gradient on, the frequency domain signal should look wider. This is because the gradient causes some spins to precess off-resonance, so the field distribution (and therefore the frequency distribution) becomes much wider when the x-gradient is on.
>
> **What happens to the time-domain signal when you turn the gradient on? Does this make sense?**

- We need to make sure that the phantom is centered on the gradient coils. To do this turn on the Y gradient by choosing "projection along Y", this creates a field gradient along the bore of the magnet, i.e. in the orientation of the long axis of the glass tube that holds the sample. Gently adjust the coil position in or out of the bore, until the projection is centered around 0 kHz in the frequency domain. To adjust the position of the phantom in the coil, you need to first relax by a few turns the fastening screw that secures the coil box. Once you have adjusted the coil position, tighten the screw that holds the coil so that it does not slip out of place during the rest of your experiment
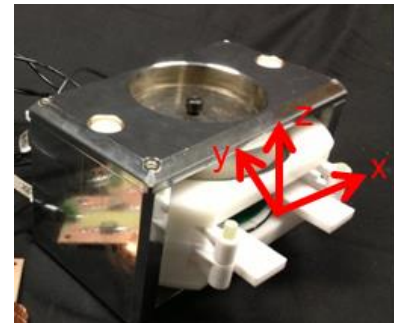
Fig 1: Gradient field directions in magnet. The z axis points towards the top pole of the static magnet, which is the large metal piece that you see when you take the lid off the system. The y axis is oriented along the long axis of the glass tube that holds the phantom, and the x axis points in the horizontal direction orthogonal to z and y. The origin of this coordinate system is at the center of the main magnetic field where we slide the phantom at the end of the glass tube.

- Remove the full water phantom, and insert small cylinder phantom (phantom #2). How do the projections change?

- Now repeat the procedure on the small cylinder phantom with "projection along X" or "projection along Z". Try rotating the phantom inside the coil. Notice that the width and basic shape of the projection does not change because of the geometry (symmetry) of the phantom. (However, the projection signal may shift in frequency if it's not in the center of the gradient).

- Save the projection data along x or along z, and make sure to give it a name such as "*one_tube_projection*". Plot the frequency information of the projection data (after fft) in MATLAB. Use the fact that the cylinder is **4mm** in diameter to estimate the gradient field strength through the relationship you determined in Prelab problem #1. Transform the x-axis in your MATLAB plot to mm instead of Hz.

Checkoff 2. Explain to a staff member:

- How does the 1D projection change with the full water phantom versus the small cylinder phantom and why?

- Show your projection plot (the horizontal axis should be in mm) to a staff member. What is the calculated gradient field strength?

2.2 Two-tube Phantom

- Insert phantom #3, which consists of two capillary tubes filled with water. The capillary tubes are thin and there is not a lot of doped water inside them hence your signal will be noisier than before. You may need to increase the "number of averages" to see a decent signal, especially if your system's SNR is low.

- Turn on the X gradient using "projection along X", and rotate the phantom until the two projections are collapsed into a single hump. Define this as the 0 degree position. If you desire, you can decrease the field of view (FOV) to 1cm to "zoom in" on the object; but note that this will increase the gradient field strength.

- Without moving the phantom, turn on the Z gradient with "projection along Z". Now, the two projections should be maximally separated. Why do you think this is?

Fig 2: Projection reconstruction plot

- Switch back to the X gradient. Save your time domain signal in the identified 0° position. Now rotate the phantom from 0 to 180°, by increments of 45°, and save the signal from each rotation. **You will be using these data for the homework**. The tick marks on the phantom are 45° apart. (Try not to move the coil while you are doing this). Make sure to save a separate data file for each rotated position of the phantom.

- Plot the projection (frequency domain signal) of the 90° rotation in MATLAB. Use this plot along with your gradient field strength estimate from Checkoff #2 to determine the diameter of the two capillary tubes and the spacing between them.
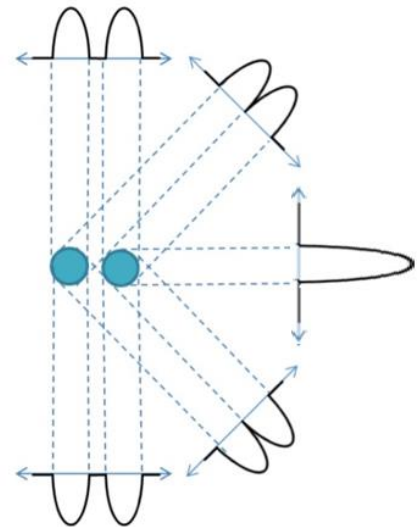
- Plot all of the projections in MATLAB. Create a drawing like Fig. 2 with your projections (doing this by hand is fine).

Drawing:

> ***Checkoff 3.*** Explain to a staff member:
>
> - Why do the X projection and Z projection look different?
>
> - Show your 90º projection plot to a staff member.   What are the dimensions of this phantom in mm?
>
> - Show your "projection reconstruction" plot to a staff member.

2.3 Mystery Phantom

- Remove phantom #3 and insert a mystery phantom (It is labeled as PH4 or Phantom 4). The mystery phantom will include some unknown number and arrangement of capillary tubes. Record mystery phantom code _____

- Make whatever measurement you think is needed to figure out the geometry of the mystery phantom, and save each acquisition as a separate data file.

- Figure out what the mystery arrangement of the tubes! Draw it here:

> ***Checkoff 4.*** Show a staff member a drawing of the estimated tube arrangement, and justify how you determined this mystery orientation within the phantom.