Lab 8   6.S02 – Spring 2013
MRI – Projection Imaging

1. Spin Echos

1.1 Find f0, TX amplitudes, and shim settings

In order to acquire spin echos, 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 found before each experiment.

- Insert RF coil into magnet bore. Insert full water tube (phantom #1) into coil. Run FID GUI sequence, by typing "FID_GUI" into the command window. Make sure to set the MATLAB path, by adding the "MRI_Lab" folder (including subfolders) to the path. Look on your cart for a piece of paper with the recorded Larmor Frequency for your magnet; type this into the GUI for frequency.

- Set the # of repetitions to a high number (so it runs over and over). Reach in and slowly adjust the coil position inside the magnet. Take the sample out to make sure the signal fully goes away. Position it for maximum signal.

- Adjust the system console frequency f_0, until the peak is centered at 0 Hz. Record this f_0 frequency:_____

- Find the RF TX amplitude that corresponds to a 90° flip angle and a 180° flip angle. You can do this by stopping the run, checking the "flip angle calibration" box in the gui then starting again. This steps thru the amplitude of the RF excitation pulse and plots the amplitude of the FID as it goes. It steps from 0W power to ~1W. The 90° flip angle occurs when amplitude of the FID signal is maximized.   The 180° flip angle occurs at the power of the first minimum after the first maximum. Sometimes there will be a second maximum because a 270deg rotation will be reached.   Record the 90 degree TX amplitude:_____, Record the 180 degree Tx amplitude:_____

- In the GUI adjust current offsets to x,y,z gradient coils to apply linear shim fields. Try to increase the magnitude of the frequency peak (thus make the line as narrow as possible.) Save your best shim settings by clicking the "save shims" button.
     Record the currents: xshim:_____ yshim:_____ zshim:_____

1.2 Acquire Spin Echos

- Make sure the FID GUI is stopped. Run the Spin Echo GUI, but typing "SE_PROJ_GUI" into the command window.

- Enter your f0, TX amplitudes, and shim settings (use the "load shims" button) into the GUI. Make sure the acquisition type is set to "Spin Echo". Click "Run Scan"

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- Sketch the real part of the acquired signal (green trace), note that the 180° pulse is applied at 15ms:

- Stop the scan and click the "zero shims" button. How does the acquired signal change?
- Try adjusting the echo time (TE). The readout time also needs to be increased when you increase TE. Try readout = 300ms and TE= 150ms. How does the acquired signal change?
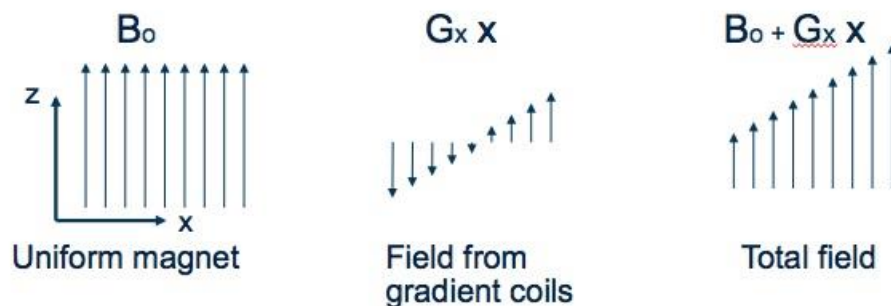
Check off 1: Explain to a staff member:

- What is seen in the spin echo sketch (what is physically happening to the spins?)
- How does the acquired signal change when the shims settings are loaded versus when the shims are zeroed?
- How does the acquired signal change when TE is increased or decreased?
  (Hint: the spin echo sequence refocuses T2* spin dephasing, but there is also signal decay with a longer time constant, T2)

2. 1D Projections

The goal of this lab is to learn about projection imaging. i.e. what happens when you record a signal with a linear gradient field present:

$$\vec{B}(x, y, z) = B_0\,\hat{z} + G_x x\,\hat{z} \quad \text{where } G_x \text{ is defined as } G_x = \frac{\partial B_z}{\partial x}$$

Bo	Gx x	Bo + Gx x
Uniform magnet	Field from gradient coils	Total field

Then: $$\omega(x, y, z) = \gamma B_0 + \gamma G_x x$$

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So we see that the frequency of precession is now dependent on location, with the spins at x=0 precessing at the old frequency of gamma*B0.   Let k = 1/2π γG$_x$ t and then the phase relative to the spin at x=0 becomes:

$$\Delta\varphi(\vec{r}, t) = 2\pi\,\vec{k}(t)\cdot\vec{r}$$

$$M_{xy}(t) = M_0 e^{-2\pi j\,\vec{k}(t)\cdot\vec{r}}$$ Eq. 10

Since the detection coil simply adds all the signals from inside the coil:

$$S(t) = \int \tilde{M}_{xy}(x)\,e^{-j\gamma G_x\,x\,t}\ dx$$ Eq. 13

where $$\tilde{M}_0(x) = \iint M_{xy}(x,y,z)\,dy\,dz$$ Eq. 12

 Since k and t are proportional (k = 1/2π γG$_x$ t) we stop thinking about the acquisition being as a function of t and start thinking of it as a function of k.

$$S(k) = \int \tilde{M}_{xy}(x)\,e^{-2\pi j k_x\,x}\ dx$$ Eq. 14

2.1 Small Cylinder Phantom

- Continue using SE_PROJ_GUI, but change the readout time and TE back to the default settings (TE = 30ms and readout = 60ms)
- To turn on gradient currents (and therefore add a gradient field), choose "projection along X, Y, or Z" as the "acquisition type". The frequency domain signal is now a **projection** of the phantom onto the gradient field.
- We need to make sure that the phantom is centered in 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. Adjust the coil position until the projection is centered around 0 KHz in the frequency domain.
- Remove the full water phantom, and insert small cylinder phantom (phantom #2). How do the projections change?

Fig 1: gradient field directions in magnet

- Go back to using the X or Z gradient. Try rotating the phantom inside the coil. Notice that width and basic shape of the projection does not change because of the geometry of the phantom (but it may shift in frequency if it's not in the center of the gradient).
- Plot the projection (frequency domain signal) in MATLAB. Use the fact that the cylinder is 4mm dia. to estimate the gradient field strength. Transform the x-axis to mm instead of Hz.
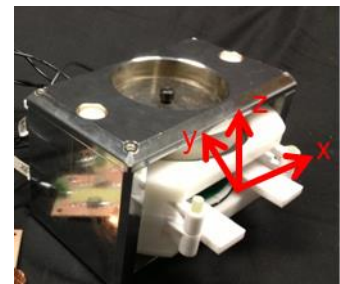
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Check off 2: Explain/show to a staff member:

- How does the time domain and frequency domain signal change when a gradient field is turned on?
- How does the 1D projection change with the full water phantom vs the small ball phantom?
- Show your projection plot to staff member. What is the calculated gradient field strength?

2.2 Two-tube Phantom

- Insert phantom #3, which consists of 2 capillary tubes filled with water.
- Turn on the X gradient, rotate the phantom until the 2 projections are collapsed into a single lump. Define this as the 0 degree position. You can decrease the field of view (FOV) to 1cm to "zoom in" (this increases the gradient field strength).
- Turn on the Z gradient, the 2 projections should be maximally separated. Why?
- Switch back to the X gradient. Save your time domain signal in this redefined 0 deg position. Now rotate the phantom by 45 degree increments from 0 to 180°, and save the signal from each rotation. (try not to move the coil while you are doing this)

Fig 2: Projection reconstruction plot

- Plot the projection (frequency domain signal) of the 0° rotation in MATLAB. Use this plot along with your gradient field strength estimate to determine the size of the 2 capillaries 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).
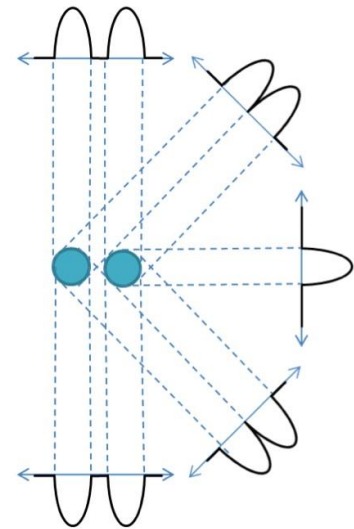
Check off 3: Explain/show to a staff member:

- Why does the X projection and Z projection look different?
- What angle collapses the spectral response?
- Show your 0 deg projection plot to staff member. What are the dimensions of this phantom in mm?
- Show your "projection reconstruction" plot to a staff member.

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2.3 Mystery Phantom

- Remove phantom #3 and insert a mystery phantom. The mystery phantom will include some unknown number and arrangement of capillary tubes. Record mystery phantom code _____
- Make whatever measurement you think needed to figure out the geometry of the mystery phantom.
- At home, figure out what the mystery arrangement of tubes is.
- *At home problem:* When you upload your checkoff sheet, also include a drawing of the estimated tube arrangement and justification of how this was determined.

3. Projection Reconstruction (at home - extra credit)

- Design a reconstruction method using MATLAB that allows you to form a 2D image with the recorded signals from 2.2 and 2.3.
- Upload your code, data, and 2D image to stellar

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Checkoff

Name: _____

	points	Staff Member Initials
Prelab	2	_____
Checkoff 1	2	_____
Checkoff 2	2	_____
Checkoff 3	2	_____
At home problem	2	

Scan and upload this sheet to the Stellar website prior to the due-date and time.