

MRI – 2D Imaging

1. Acquiring and reconstructing 2D images

1.1 Preparing to image (find f_0 , TX amplitudes, coil position, and shim settings)

In order to acquire spin echo images, we first need to find the appropriate scanner settings using the **FID GUI**. This was all done in the previous weeks, but these calibration settings should be found before each experiment.

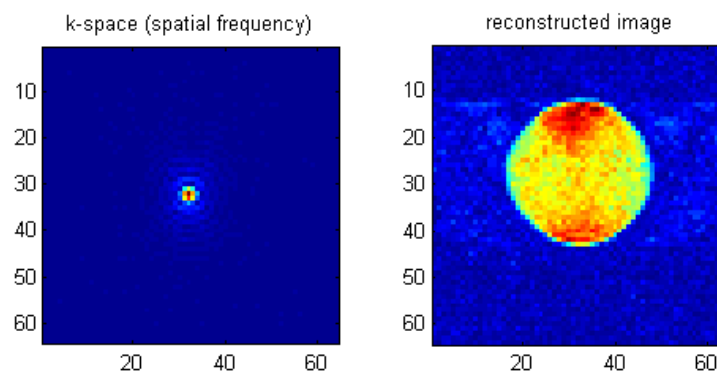
- Make sure to set the MATLAB path, by adding the “MRI_Lab” folder (including subfolders) to the path.
- Insert full water tube (phantom #1) into coil. Run FID GUI sequence, by typing “FID_GUI” into the command window. Look on your cart for a piece of paper with the recorded Larmor Frequency for your 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 adjust the coil position inside the magnet, to maximize 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 by checking the “flip angle calibration” box in the gui. Record the 90 degree TX amplitude: _____, Record the 180 degree TX amplitude: _____
- We need to make sure that the RF coil/phantom is centered in the gradient coils by looking at the 1D projection. Make sure the FID GUI is stopped. Run the Spin Echo GUI, but typing “SE_PROJ_GUI” into the command window.
- Enter your f_0 , and TX amplitudes into the GUI.
- Turn on the Y gradient by choosing “projection along Y” as the acquisition type, this creates a field gradient along the bore of the magnet.
- Click “Run Scan”, and adjust the coil position until the projection is centered around 0 KHz in the frequency domain.
- **CAUTION!** Once the copper clad sample holder is in the right place, be sure not to move it when replacing phantoms!
- Go back to the FID GUI. Find the best shim settings for this coil position. Save your best shim settings by clicking the “save shims” button.
Record the currents: xshim: _____ yshim: _____ zshim: _____

1.2 Acquire and reconstruct full water image with 2.56 cm FOV

Our sampling dwell time is 32us and our phase encode blip duration is 2ms. We want a 2.56 cm field of view for our image and 128x128 points in our image.

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- Use “IMAGING_GUI_1” for this part.
- Enter your f_0 , TX amplitudes, and shim settings (use the “load shims” button) into the GUI.
- Enter the correct matrix size and the gradient values you calculated in the pre-lab to acquire the k-space data for your image.
- The output data is a 128x128 matrix that holds the complex valued k-space (spatial frequency) data. Save this file.
- Write a matlab script that:
 - Reconstructs the image
 - creates a figure that shows 2 images: the kspace image and the reconstructed image. It should look similar to the figure below.
 - The following matlab commands will be useful for this: *abs*, *fft2*, *fftshift*, *imagesc*, *subplot*
- Save the reconstructed kspace and image figure for the checkoff.



1.3 Acquire and reconstruct full water image with the wrong values of G_x (readout) and G_z (phase encode).

- Repeat part 1.2, but set the G_x gradient to 2x the correct value. What happens?
- Take yet another image with both G_x and G_z set to 2x of the correct value.
- What happens in terms of Δk , FOV and the properties of the FT?

1.4 Acquire and reconstruct full water image with 1.5cm FOV (using the GUI)

Now that we know you are able to calculate the gradient strength for a desired FOV, we will let a GUI do that for you. This GUI will show a reconstructed image, but only the k-space data will be saved.

- Open the GUI: “IMAGING_GUI_2” via the command window.
- Enter your f_0 , TX amplitudes, and shim settings (use the “load shims” button) into the GUI. Choose “spin echo imaging” as the acquisition type. Choose FOV in both directions to be 1.5 cm.

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- Click the “Run Scan” button. You will see lines of k-space appear. You will also see the reconstruction of whatever kspace data you have so-far.
- Save you data for this full water phantom (phantom1) (you will use this data later)
- Use your matlab script to plot the kspace image and reconstructed image.
- Save your figure.

1.5 Acquire and reconstruct mystery phantom image

- Find your mystery phantom that you used in the last lab, and insert it into the coil.
- Acquire k-space data for this phantom, the same way you did in part 1.4. (You should double check that it is centered in the y gradient, and that your f0 has not drifted)
- Verify the cylinder configuration that you deduced from the projection data.

Check off 1: Explain/Show to a staff member:

- Show your kspace and reconstructed images from section 1.2 to a staff member. The full water phantom has ~1cm diameter. Does your image appear to have the correct FOV?
- Show your kspace and reconstructed images from section 1.3 to a staff member. What happens in terms of Δk , FOV and the properties of the FT?
- Show your kspace and reconstructed image from part 1.4 to a staff member. Does the FOV look correct?

2. k-space Manipulation

2.1 Filtering

K-space is the 2D spatial frequency domain. To apply a low pass filter to the 1.5cm FOV image you saved, you can zero points in the high spatial frequency regions. To apply a high pass filter to the image, you can zero points in the center of k-space (low spatial frequency region). This abrupt windowing will cause truncation artifacts (a smoother window would be preferred). Example filters are shown in the figure below. The filters are a matrix of the same size as the data, but consist only of 1s and 0s. To apply the filters, they are multiplied point-wise with the k-space data. Most of the energy is in the center of k-space, so the high-pass filter must be small. The high pass filter in figure 1 has 3x3 zeros. (appendix may be helpful for this part)

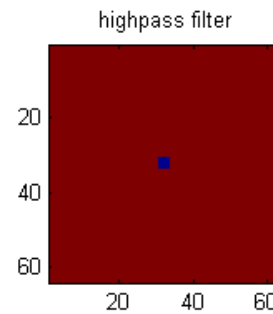
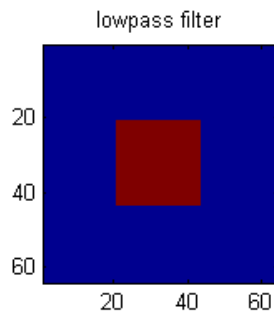
- Apply a simple box-car low-pass and high-pass filter to the full-water phantom data.
- Use your matlab script to create figures with the filtered k-space image, and the resulting reconstructed image.

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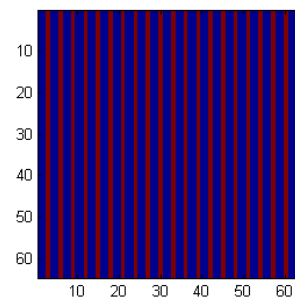
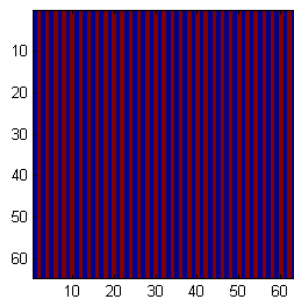
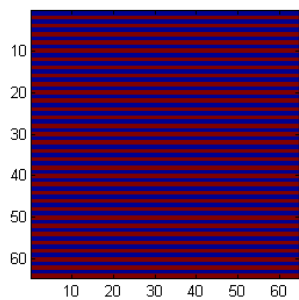
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- Save your figures.



2.2 Undersampling k-space

Let's see what happens if we undersample k-space. Instead of acquiring undersampled data, we can throw away data that we already have. We can create "mask" matrices (like those below) that consists of 1s and 0s and multiply it with our kspace data to simulate undersampling. Point-by-point matrix multiplication in matlab is with the `.*` operator.



- Zero every other row in k-space (the size of the matrix should remain the same), and reconstruct the image with this k-space data.
- Zero every other column in k-space, and reconstruct the image with this k-space data.
- Zero 2/3 of the kspace columns. (mask matrix columns should be 1, 0, 0, 1, 0, 0...), and reconstruct the image with this k-space data.
- Use your matlab script to create figures with the undersampled k-space images, and the resulting reconstructed image.
- Save your figures

Check off 2: Show to a staff member:

- Show your filtered images to a staff member. Explain the effect of the filters on the reconstructed images.

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- Show your undersampled images to a staff member. Why is the image wrapped (aliased?)

3. Single-Shot 2D and 3D imaging

3.1 MIT Phantom

The MIT Phantom has three layers of plastic structures seen to the right. When we take a 2D image in the xz plane, we will get a projection thru the y direction since that direction is not encoded.



- Insert the MIT phantom. (double check that f_0 is still correct, and the phantom is centered in the y -gradient) You will continue using IMAGING_GUI_2 for this part.
- Choose the turbo spin echo option from the IMAGING_GUI_2. Set FOV to 1.5cm, and do 16 averages. Make sure you are imaging in the xz plane. Acquire an image.
- This sequence takes all of k -space in a single shot by doing 72 spin echos in a row (a single 90° excitation followed by 72 180° pulses). Thus it is a more efficient sequence and has higher SNR per unit time.
- Save your k -space data, reconstruct the image and save your figure in matlab.

Now we will switch to the 3D imaging GUI. In 3D imaging, the k -space matrix is now 3D. This sequence fills in one of the k_x , k_z planes per shot, and then steps thru the phase encodes in k_y .

- Open the GUI, by typing "IMAGING_GUI_3" into the command window.
- Set the number of "slices" to 16 (matrix in the y direction). This will give us 16 "slices" along the imaging FOV. If the FOV is 3cm, that should fully cover the distance along the tube seen by the RF coil (detector) and provide $\sim 1.875\text{mm}$ "slices". Hopefully, it will allow you to see the individual letters in the MIT phantom more clearly, since they will no longer be collapsed.
- Try some different FOVs and some averaging.

Check off 3: Show your results to a staff member

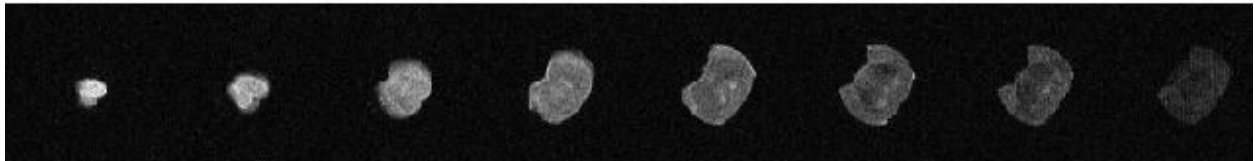
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4. Biological Samples

4.1 Mouse brain and/or heart imaging

- Switch to biological sample (mouse brain or mouse heart). Use your imaging expertise to try to get the best possible image.

axial slices or 3D volume acquisition



mouse brain acquired with a 3D TSE in about 3 minutes.

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APPENDIX:

In Lab 9, you will be required to perform matrix operations. The following MATLAB commands will come in useful:

```
>> zero_3by5 = zeros(3,5)    % create a 3x5 zeros matrix  
zero_3by5 =
```

```
 0  0  0  0  0  
 0  0  0  0  0  
 0  0  0  0  0
```

```
>> ones_3by5 = ones(3,5)    % create a 3x5 ones matrix
```

```
>> ones_3by5(:,k)          % select the kth column
```

```
>> ones_3by5(k, :)        % select the kth row
```

```
>> ones_3by5(k, 2:4)      % select elements (k,2) through (k,4)
```

These commands along with for loops will be useful in k-space manipulation.

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Checkoff

Name: _____

	points	Staff Member Initials
Prelab	2	_____
Checkoff 1	2	_____
Checkoff 2	2	_____
Checkoff 3	2	_____

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