Title: MRI Acquisition Simulator

OVERVIEW: Implement software that will simulate the data acquisition of a virtual MR scanner. MRI data collection occurs in the frequency-domain or the k-space. The real and the k-space are Fourier pairs; you go from one to the other by forward or inverse Fourier transform (FT). Matlab has the FFT function that is a fast FT algorithm; also refer to the FT course lecture. For your project you will start with an original image and you will generate its k-space with FFT. Then you will investigate different paths of digitizing those data. The way we scan the k-space is like following a road; and we call it “k-space trajectory”. Your aim will be to assess what kind of images we can get using:

- different k-space trajectories or k-space collection strategies
- collection “portions” of the k-space

Your test/validation phantoms will be the ones shown in the figure below.(phantom 1 and 2). The phantom is a circle with intensity of 0.5. Inside will have structures (in phantom one is a rectangular) and in phantom 2 are a series of smaller circles with decreased diameters). Those structures with intensities of 1.0 (so, those structures should appear brighter relative to the background tissue).

Test the following two acquisition trajectories to sample the k-space of your phantoms: one (left) is the Cartesian (or 2DFT spinwarp) and the other (right) is radial. For those cases change and study the effect on the reconstructed images of different data acquisition parameters:

Cartesian: number/density of horizontal lines,
density of points within a line, swapping the horizontal and the vertical lines, the width of the acquisition matrix
Radial: number of radial lines, points along each line

SPECIFICS:
1. Develop the different functions/code to perform all necessary calculations for:
   - Generate the phantoms and their corresponding k-space
   - operation of the scanner by selecting different acquisition schemes
   - sample the data with a specific trajectory
   - image reconstruction
   - image analysis
2. Implement a GUI that combines those pieces of code and performs the different tasks.
3. Test/validation phantoms: From this GUI you should be able to change the matrix size and the dimensions of those embedded structures.
4. Systematically study your code using the two phantoms. Suggestion: make the phantom with very high resolution 4Kx4K matrix size, this will give you a better results. Why?
5. For this project you will ignore T1, T2 effects. You will assume that your TR is infinity and your TE is zero.
6. Image Analysis: Implement code for three types of image analysis:
   - Signal Intensity (SI) and Contrast (relative signal intensity differences between two regions). These quantities should be reported as numbers and you will use them to investigate whether your calculations are correct (how? e.g. is the beam attenuation correctly calculated?)
   - Signal Intensity (SI) profiles: Generate graphs of the signal intensity vs. position along a specific direction. You will use those graphs to investigate for potential artifacts. You must be able to compare the profile of both your original object (phantom) and your image (the output of your virtual scanner). So, you can arrange to view two or more profiles in the same figure-graph.
7. The scanner part of the GUI should allow you to change the different acquisition schemes (a simple solution is with pull down menus). Add a run button to activate the acquisition. In the output do not forget to add appropriate comments that list the parameters you used (Matlab gives you some good options for this)
8. Using the test/validation phantom investigate the effect of changing acquisition parameters. In all cases the “ground truth” is your original phantom! You will compare the images generated by your code relative to this phantom! Use the different tools in section 5 to investigate how your scanner works. Compare the image and the validation phantom for different acquisition parameters:
   - How the edges of the rectangular structure the first phantom are appear in the image? Any improvements?
   - In the phantom with the circular structures, what is the effect on them?
   - What is the overall image impression?
   - What parameters give you the best possible image?
   - Add a time parameter and (e.g. this will be the duration of data acquisition per horizontal line for the Cartesian acquisition, and per radial line for the radial
acquisition) and investigate how “the longer the acquisition time the better the collected images”