Rad 229 Homework 7

Due Thurs, Nov 29, 11:59pm
(Email to bah@stanford.edu)

1 Spiral Waveform Design (E3.1)

Download **vds.m** from the class repository. Use a maximum gradient amplitude of 50 mT/m and sew rate of 150 mT/m/ms ("SR150") for this problem. Note that these are 5 G/cm and 15000 G/cm/s for the units of **vds.m**, which also accepts FOV in cm and k_{max} in cm^{-1}. Use a sampling period of 0.000004s, which is common on MRI scanners.

a. Design a trajectory with 20cm FOV, 20 interleaves, and 1mm resolution (using the default 0.004 ms sample spacing. Submit the resulting plot.

b. What is the trajectory duration? About what fraction of the waveform is slew-rate limited?

c. If we use just one interleaf of this trajectory as a single-shot acquisition, what are the resolution and FOV?

d. If our goal is to sample a low-resolution (2cm) image, how can we use this single-shot trajectory to achieve this? What is the resulting FOV?

2 Spiral Image Reconstruction (E3.2)

Download the file **spiral.mat** from the website. This is roughly a 188x188 matrix over 20cm FOV, with 9 spiral interleaves. Note that the spiral has been normalized for gridding already. Assume a sample spacing of 4 μs along trajectories.

a. Plot the spiral trajectory with `plot(ksp)`

b. Generate data for a square that is 300 $\times$ 300 pixels, using a sinc(k) type formulation. Grid to a 512x512 matrix and display the image. (Note that the object exceeds the FOV a bit.)

c. Repeat (b) but with a square that is 150 $\times$ 150 pixels. What happened?

d. Delay the samples by 1, 2, and 5 samples. Reconstruct the image for these 3 cases using the 150 $\times$ 150 square. Comment on what happened here.

e. Repeat (c) for off-resonance of 50 Hz, 100 Hz and 200 Hz, and comment on the outcome.

3 Spiral Duration (E3.3)

Use **vds.m** from the class repository. Use a maximum gradient amplitude of 50 mT/m and sew rate of 150 mT/m/ms ("SR150") for this problem. Note that these are 5 G/cm and 15000 G/cm/s for the units of **vds.m**, which also accepts FOV in cm and k_{max} in cm^{-1}. Use a sampling period of 0.000004s, which is common on MRI scanners.

a. Make a plot of trajectory length vs number of interleaves N (for N=[2,100]) for 20cm FOV, 20 interleaves, and 1mm resolution, with 0.004 ms sample spacing. On the plot, also include the minimum scan time, which is N*(trajectory length+ RF length), assuming a 1ms RF pulse duration.

b. Now consider the k-space area in cm^{-2} that is covered by the spiral to achieve 1mm resolution. If you assume that the sample spacing is perfectly uniform, with $\Delta k = 1/\text{FOV}$, both along and between trajectories, can you give an expression for the number of samples along an interleaf (and thus the trajectory duration) in terms of resolution, FOV and number of interleaves?

c. Add a comparison of the (approximate) trajectory length using the equation in (f) to the plot in (e). *What do you conclude from this comparison?*

4 Variable-Density Spiral (E3.4)

Use **exampleE3_spiral.m** for this question. Read over this example, whch is commented, to understand the steps.

a. Run the example function, which generates a spiral trajectory and k-space data, then grids and reconstructs the image, assuming 100Hz off-resonance. Show the final image, and explain why the edges are not as bright as the middle.

b. Assume that the sequence consists of an RF pulse of duration 1.5ms, and the readout. What is the total scan time for the example acquisition in (a), which has 30 interleaves?

c. Repeat part (a) and (b) but with 120 interleaves. Comment on differences in the image.

d. Modify the code in (a) to use a variable density. You pass FOV *polynomial coefficients* to **vds.m** as `[24 -12]`, which gives a density variation that drops linearly with k-space radius. Show the image, and repeat (b). Also describe any differences you observe in the image.

e. Now your task is to make the **best** image you can with a scan time of 0.4 seconds. You are free to change the number of interleaves, and the variable-FOV. You can also "oversample" by acquiring more interleaves than the number for which you designed the spiral. For at least 3 quite different designs, show the spiral trajectory, FOV function, number of interleaves, readout duration, total scan time and image. Try a range, so only one needs to be "best." Comment on the differences in your images for different designs.