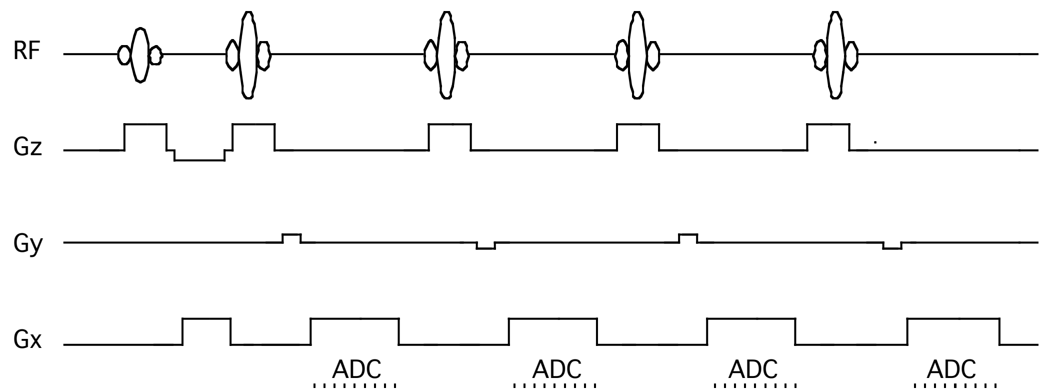
BIOEN 6401 Medical Imaging Systems
Homework #3
Due Monday, October 14, 2019

State all assumptions and show all your work

1. A fast spin-echo (FSE) sequence, also known as turbo spin-echo (TSE) or rapid acquisition with refocused echoes (RARE) sequence, employs a series of 180° RF pulses to generate multiple echoes from each excitation. By sampling the k-space with fewer excitations and repetitions, the scan time is shortened. Consider the diagram below showing a single repetition of a sequence that acquires 4 echoes for each excitation (i.e., "echo train length" or ETL of 4):

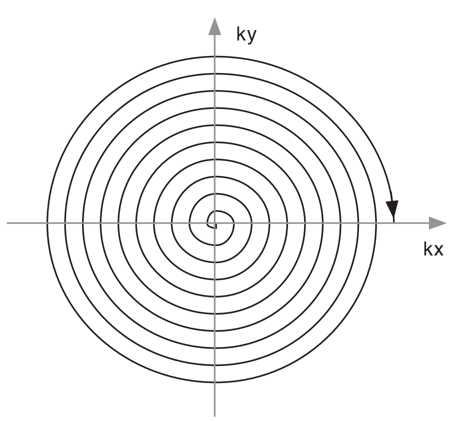


   (a) Manually sketch the k-space trajectories of a single pass of the FSE sequence shown above. Use dashed and solid lines to denote k-space positioning and data sampling, respectively. Label all pertinent features clearly.

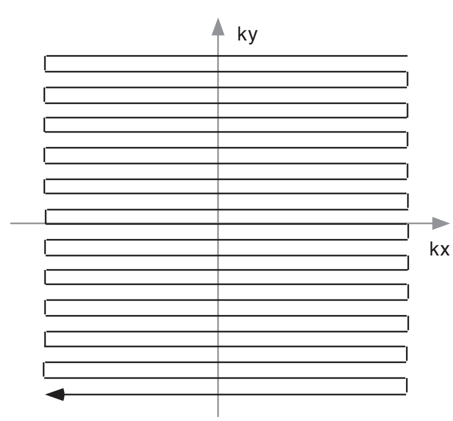
   (b) Modify and sketch the G_y gradient waveform such that the k-space lines are located in the same half of the k-spaced, and are traversed successively from the center outward.

2. For each of the following "single-shot" k-space trajectories:

(A)



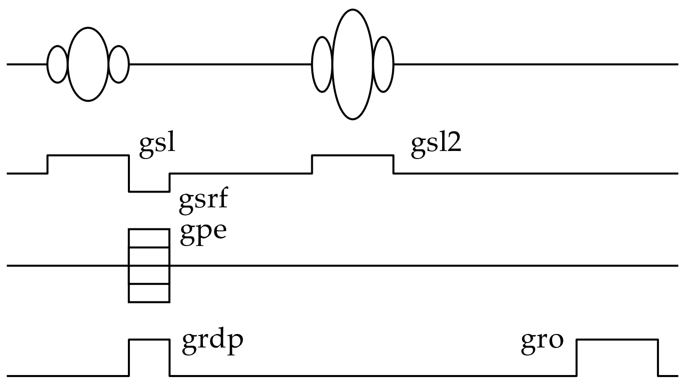
(B)



(a) Manually sketch the first 5 cycles of the post-excitation frequency and phase-encoding gradient pulse waveforms needed for the specified k-space trajectory.

(b) To verify your answers above, use Matlab to generate and plot the gradient waveforms and corresponding k-space trajectories. Include both your plots and Matlab codes.

3. Consider the idealized spin-echo pulse sequence shown below, which is *not* drawn to scale. Using 1.0 ms for the width of all gradient pulses except for gsl, gsl2 and gro:



(a) Compute the amplitudes of the slice-selective excitation (gsl), slice-selective inversion (gsl2) and refocus (gsrf) gradient pulses needed to generate a 1.0 mm-thick slice using a 4.0 ms-long modulated sinc pulses (with 1.0 ms center-lobe width). Suppose the slice thickness for the 180° RF pulse is to be twice as that of the 90° RF pulse. Use gauss per centimeter (G/cm) as unit for all gradient amplitudes.

(b) Compute the readout (gro) and read-dephase (grdp) gradient pulse amplitudes required to form a 20.0 cm FOV, 192 × 192 matrix size image using a 50 kHz digitizer.

(c) Compute the initial and incremental phase encoding gradient (gpe) amplitudes.

4. A modified spin echo pulse sequence has the read-dephase pulse on the same side of the 180° RF pulse as the readout pulse:

(a) Sketch the equivalent modified spin echo pulse with exactly the same geometrical prescription (i.e., FOV, matrix size, etc.) as the traditional spin echo pulse in Problem 3.

(b) What are the minimum TEs achievable for the original and modified spin echo pulse sequences?

(c) Besides allowing resolution-independent quantification of T2, what is another advantage of the modified pulse sequence over the conventional version?

5. Continuing from Problem 3, suppose the scanner has been upgraded with the latest gradient set capable of 4.0 G/cm maximum amplitude in each direction:

(a) Suppose the same RF pulses and digitizer frequency are used. What is the shortest TE possible to achieve the same geometrical prescription (e.g., FOV, slice thickness, etc)?

(b) Alternatively, suppose we want to keep all timings constant. What is the best spatial resolution (i.e., smallest pixel size and slice thickness) achievable?