MRI: Physical Principles and Applications: Mock Exam

Choose any 3 out of the following 4 questions. Each question is worth a third of your final exam's grade. Write your answers clearly and legibly. If you make any assumptions, state and justify them. Throughout the exam assume (as needed) that the field strength is 3T, and that the T_1s and T_2s of WM, GM and CSF are 1, 1.5 and 4 secs and 50, 100 and 200 ms, respectively. Good luck!

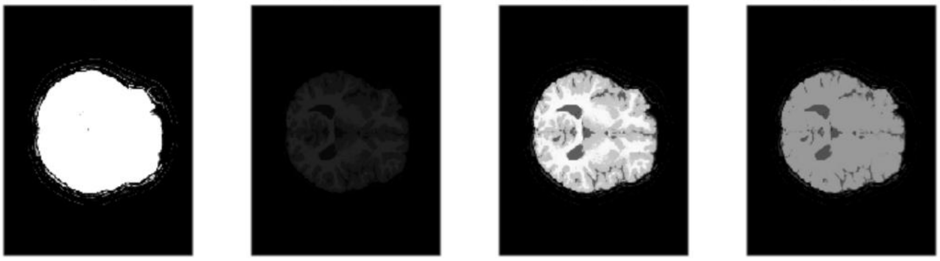
Question 1.

1. Explain qualitatively how spatial inhomogeneity of the main field B_0 affects the signal in a GRE experiment. How would that change in a spin echo experiment?
2. A single slice through the center of a brain is imaged with a spoiled GRE using the following parameters: TR=1 s, TE=50 ms, α=90°, dwell time 0.1 ms, readout time 20 ms (i.e. time during which you acquire with a readout gradient turned on), number of scans 200. What is the spatial resolution (i.e. [number of voxels] × [number of voxels]) of the final image? Assuming the brain is a sphere with a radius of 10 cm, what would your readout gradient have to be (in mT/m) in order to avoid aliasing?
3. Would you expect T_2^* (in a voxel) to increase, decrease or stay the same as you make the voxel smaller? Explain.

Question 2. A researcher is interested in obtaining a 2D spoiled GRE image of the human brain. To that end, the sequence is run with TE=1 ms, TR=6000 ms, flip angle α =90°, 256×256 resolution with a FOV of 256×256 mm^2 and a slice thickness of 5 mm. The image in Fig. 1a is obtained.

1. Why is there no contrast in the image?
2. To fix the issue, the researcher tries to rerun the sequence with TE=1 ms, TR=100 ms and the image in Fig. 1b is obtained, which shows contrast but very little signal. Explain the source of this signal loss.
3. To fix the issue, the researcher reruns with TR=1.2 s (Fig. 1c). How long will the sequence take?
4. In an attempt to introduce T_2-contrast, the researcher decides to switch out the sequence for a spin-echo sequence and reruns the sequence with TE=25 ms. However, the image in Fig. 1d is obtained which shows little contrast between WM and GM. Explain the researcher's way of thinking (i.e. why increasing TE might increase the contrast in general), and why it achieved the opposite result in this particular case.

Fig. 1a Fig. 1b Fig. 1c Fig. 1d



Question 3. For many applications it is beneficial to suppress signal arising from protons present in lipid molecules. One of the approaches is to apply a non-selective 180° pulse followed by a delay TI (inversion time) before executing pulse sequence (see Fig. A).

(a) Assuming fat T_1 to be 400 ms at 3T, to what value you would set TI to ensure that fat signal is fully suppressed, i.e., that its magnitude is equal to zero at the moment of starting to execute pulse sequence? Remember, that relaxation of z-magnetization can be described following equation: $M_z(t) = M_z(0)\, e^{-t/T1} + (1 - e^{-t/T1})\, M_{equilibrium}$

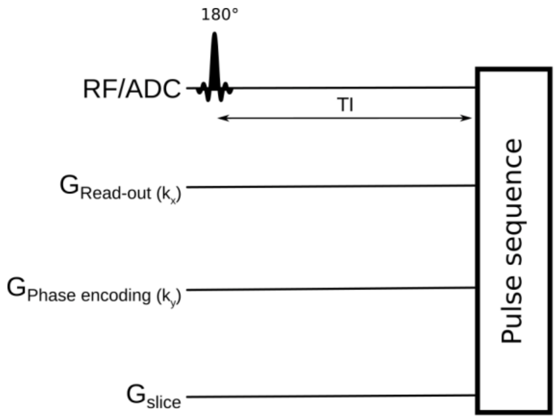


Fig. A. Fat suppression using non-selective 180° inversion pulse.

(b) By what amount will water magnetization have been decreased at the beginning of the pulse sequence, compared to a case when no fat saturation is performed? Assume T_1 of water to be 1.1 sec.

(c) Alternative technique to the previous fat suppression strategy in order to avoid decrease of water magnetization is application of a spectrally selective 90° excitation pulse addressing only lipid resonances followed by a spoiler gradient (see Fig. B). Assuming, that spoiler gradient amplitude is 5 mT/m, what should be its minimum duration to achieve full lipid signal dephasing along excited slice, given that its thickness is 5 mm?

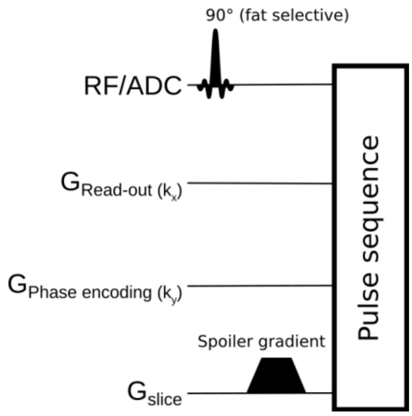


Fig. B. Fat suppression selective fat excitation followed by spoiler gradients.

Question 4. Classify the following as true or false, and explain your answer:

1. Increasing the density of your sampling in k-space increases the FOV.
2. The net effect of a positive gradient, followed immediately by a negative gradient (of equal duration and opposite magnitude) is exactly zero in the absence of motion and relaxation.
3. The only way to decrease the voxel size along the readout direction in a GRE experiment is to make the readout gradient stronger.
4. Larger molecules are expected to have longer T_1s compared to smaller molecules in the same environment (assume no chemical exchange or magnetization transfer take place).
5. If you want to excite a larger slice, you need to make the bandwidth of your excitation pulse smaller (all other things kept equal).