EE101 Homework 4

**Please submit it via Blackboard Due：December 8th 23：59**

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**Your name: Student ID:**

**Problem 1: (9 pts)**

(1) At room temperature of , if water is placed in a magnetic field with strength of , then what is the magnetization, , of the protons within this volume of water? (5 pts)

(2) If we want to improve the image SNR of an MRI scan, which two parameters could be changed? Please explain. (4 pts)

**Solution:**

(1) The net magnetization is defined as the sum of magnetic moment of nuclei involved. It is determined by the population difference of nuclei occupying the two energy levels, multiplied by the component of the magnetic moment for each nucleus.

And each water molecule () has 2 protons, so should be

At room temperature of , we have

(2) We could increase the intensity of MR signal by increasing the number of protons in the object () or improving the value of .

**Problem 2: (10 pts)**

There is an MRI scanner whose magnetic field has a strength of . Provided that the gyromagnetic ratio is .

(1) Assume the gradient along direction is . In order to get an image slice of thickness, what should the bandwidth, measured in , of the RF pulse be? ()

(2) If the gradient becomes , and the bandwidth of the RF pulse remains unchanged, then what will the slice thickness become?

**Solution:**

(1) The slice thickness is given by

Since we know , we can compute the bandwidth by

(2) From the formula in (1), we know that if the gradient becomes half the original, and the bandwidth stays unchanged, then the slice thickness will double, being in this case.

**Problem 3: (10 pts)**

**Choose** the correct option from (a) - (e) and **explain** why these options are correct or wrong. Water in tendons is bound very strongly and cannot diffuse freely. It produces very low MR signal intensity because:

(a) T1 is too short.

(b) T2 is too short.

(c) T2\* is very long.

(d) T2 is longer than T1.

(e) T2\* is longer than T2.

**Solution:**

Only **(b)** is correct *(2 pts)*. Very tightly bound tissue has a very short T2 and T2\* which produces a low signal intensity. Therefore, (b) is the only option that is correct. T2 can never be longer than T1 so (d) is incorrect, and T2\* can never be longer than T2 so (e) is incorrect. A short T1 gives a high MR signal, as does a long T2\*, so both (a) and (c) are wrong *(8 pts)*.

**Problem 4: (18 pts)**

Calculate the effects of the following pulse sequences on thermal equilibrium magnetization. The final answer should include x-, y-, and z-components of magnetization.

a) 90°x (a pulse with tip angle 90°, applied about the x-axis).

b) 30°y

c) 90°x 90°y (the second 90° pulse is applied immediately after the first).



**Fig1: Example of the magnetization after a 90°x pulse sequence**

**Solution:**

**Problem 5: (10 pts)**

A region of the brain to be imaged contains areas corresponding to tumor, normal brain and lipid. The relevant MRI parameters are:

Which type of weighted spin-echo sequence should be run in order to get contrast between the three different tissues? Explain your reasoning, including why the other two types of weighting would not work.

**Solution:**

We can draw up a table relating the image signal intensity to the three different parameters, proton density (), and .

表格

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Obviously, a proton-density weighted sequence would not work, since tumor and lipid would have equal signals. If we use a T2-weighted sequence, then we are guaranteed that the brain will have the lowest signal due to the combined effects of proton density and short T2. If we were to use a T1-weighted sequence, there is a chance that the higher signal from the brain due to a short T1 would cancel out the effect of lower proton density and produce no contrast. Therefore, ***T2-weighting*** should be used.

**Problem 6: (12 pts)**

Three MR images of the brain are acquired using identical parameters except for the TR and TE times. Three tumors (upper, middle and lower) are seen in one of the images but not in the other two, shown in Fig 2. If the values for all the tissues (tumors and brain) are less than , and the values are all greater than , please describe the *relative* values of proton density, and of brain tissue and the three tumors.

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**Fig 2. Three phantom MR images**

**Solution:**

(1) The image on the right is proton-density weighted due to the long TR and short TE. This shows that the ***proton density*** of the three tumors and the brain tissue are the same.

(2) The image in the center is ***T1-weighted*** due to the short TR and short TE. The top tumor shows the highest signal intensity, meaning that it has the shortest T1 value, followed by the brain, the bottom tumor and the middle tumor, which has the longest T1.

(3) Since only the TE changes from the image in the center to the one on the left, the associated signal changes are related to the ***relative T2 values***. The signal intensity of the top tumor decreases by the most with increased TE, meaning that it has the shortest T2 value, followed by the brain, the bottom tumor and finally the central tumor which has the longest T2.

**Problem 7: (15 pts)**

Consider the pulse sequence in Fig 3 (surface 2 equals two times surface 1). Draw the trajectory of k in the k-space.

图表, 箱线图

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**Fig 3**

**Solution:**

图示

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After two negative gradient of Gx and Gy, the initial point is on the left-down corner. The continuous Gy phase encoding gradient leads to continuous increase in ky direction, and the double length frequency encoding gradient shifts the point from the left to the right when the value is positive and from right to left when the value is negative. After this process, the k-space mapping is illustrated by the figure above.

**Problem 8: (16 pts)**

Determine whether each of the following statements is true or false, with one or two sentences of ***explanation***.

(a) A higher strength of the RF field from the RF coil means that the duration of the pulse decreases.

(b) A longer relaxation time means that the voltage induced in the RF coil lasts longer and so a larger MRI signal is achieved.

(c) One line of -space data acquired for each value of the phase encoding gradient corresponds to one line of the image.

(d) A short tissue indicates a slow spin-lattice relaxation process.

**Solution:**

(a) ***True***. For a given tip angle, consider the function: 𝛼 = 𝛾𝐵1𝜏𝐵1, the stronger the RF field, the stronger the 𝐵1, and so the shorter the RF pulse lasts.

(b) ***False***. Consider the function: , the MRI signal doesn’t depend on T1.

(c) ***False***. Every point and line in -space has an effect on the entire image, since -space data are inverse Fourier transformed to produce the image.

(d) ***False***. A short T1 means that it takes a shorter time for the spin system to resume to its thermal equilibrium state, corresponding to a faster relaxation.