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MP 710: Advanced MRI

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**Homework 2**

**1. In the absence of an external magnetic field, a bulk object exhibits no net nuclear magnetism because:**

**(a) Nuclear magnetic moments for all nuclei are zero.**

**(b) Nuclear magnetic moments cancel out each other.**

**(c) The bulk magnetization vector is too small to be detected.**

**(d) All of the above.**

**Explain your answer.**

**B.** In the absence of an external magnetic field, the nuclear magnetic moments are not 0. In fact, the magnitudes of the magnetic moments are known but the direction (and hence the magnetic moment vector) is completely random and unknown due to thermal random motion. Due to this randomness, a large sum of magnetic moments in a bulk object will cancel each other, and no net nuclear magnetism will be observed.

**2.** **What is the primary function of the oscillating field.**

The primary function of the oscillating field is to tip the net magnetization vector into the transverse plane so that an MR signal can be obtained. More specifically, when the oscillating field is applied orthogonal to the direction of the magnetization vector , this causes a torque to be applied to and (according to the right hand rule) tips in a direction orthogonal to both and .

**3. Why does a spin system often have more than one resonance frequency? If you place a cup of water in a perfectly homogenous magnetic field, do you expect to detect more than once resonance frequency from the protons? Why?**

Spin systems often have more than one resonance frequency because spins are usually attached to macromolecules (like the hydrogen in fat or in water). These macromolecules cause local differences in the B-field which cause them to precess slightly faster or slower. This is known as chemical shift.

It is expected that there are different resonance frequencies for protons in water when imaging. Due to the magnetic field gradients applied when imaging, water in one region of the cup may experience a different magnetic field than another region. Since the Larmor frequency of the spins are linearly dependent on the strength of the external magnetic field, spins in different regions of the cup will precess at different frequencies due to the gradients. Additionally, if there are impurities in the water, some spin isochromats around these impurities may precess slightly faster or slower due to potential local shielding of the B-field from the impurity.

**4. Given a fixed flip angle, the larger the the stronger the needed because a stronger force is required to flip a larger . True or false? Explain your answer.**

**False.** If we look at the equation that describes how influences in the rotational frame:

it is apparent that there is no dependence of on flip angle.

**5. Briefly discuss how one can selectively elicit the NMR phenomenon from one spin system of a biological sample (such as protons) without affecting the others (such as 31P)?**

Due to the varying g-factors inherent to different non-zero nuclear spin systems, one would expect varying gyromagnetic ratios associated with those spin systems. For nuclei such as 31P, the gyromagnetic ratio is lower than that of 1H. Thus, different spin systems have different precessional frequencies for a given magnetic field and must be excited exactly at these frequencies. This is why we can excite only hydrogen and avoid excitation of other nuclei.

**6. The bulk magnetization of a proton spin system is flipped 90˚ by a rectangular RF pulse of width 1.0 ms.**

**(a) What is the magnitude of the field required?**

From above:

Since this is a rectangular pulse, integration turns into simple multiplication:

Solving for :

**(b) How many precession cycles take place in the laboratory frame during the pulse, assuming = 0.5, 1.0, and 1.5T respectively.**