Harvard-MIT Division of Health Sciences and Technology
HST.584J: Magnetic Resonance Analytic, Biochemical, and Imaging Techniques, Spring 2006
Course Directors: Dr. Bruce Rosen and Dr. Lawrence Wald

HST.584 / 22.561 – Problem Set 2

Due: Mar. 1 / 2006 in class

1) Perform the following experiment: A 90^o pulse with B_1 along the x' axis rotates **M** to the y' axis (rotating frame here!). As soon as the pulse is completed, change the *phase* of the RF by 90^o so that B_1 now lies along the y' axis also. Since B_1 and **M** are collinear, no torque is exerted on **M**, and it remains along the y' axis. In the absence of B_1 we know that M would decay due to both T_2 and inhomogeneities in B_o (ΔB_o). If we set $B_1 >> \Delta B_o$, the effective field $B_{eff} \cong B_1$, and the effects of inhomogeneities are eliminated.

This experiment (called "spin locking") does not eliminate decay of **M** entirely. Because in the rotating frame, B_1 plays the role of the fixed field, relaxation of **M** in the direction of B_1 (along y') is analogous in some ways to spin-lattice (T_1) relaxation. For this reason the kind of relaxation is called T_{1r}.

(a) Design a **simple** experiment to measure T_{1r}.
(b) In the limit of small B_1, what would T_{1r} approach? (In fact, the spin locking experiment is a good way of measuring this quantity in some circumstances).

2) In class we plotted T_1 versus correlation time τ_C. Given that T_2 relaxation depends on molecular motions at near zero spectral frequency, as well as motions at the resonance frequency, and given that the area of the spectral density curves is a constant, sketch a plot of $\mathbf{T_2}$ versus correlation time τ_C.

What does this look like for $T_C\omega << 1$? For $T_C\omega >> 1$?

What does this imply about the T_1 and T_2

3) Several different pulse sequences have been proposed to measure T_2 relaxation times, each with certain advantages and disadvantages. Two such sequences are as follows:

CP $90_x – t – 180_y – 2t – 180_{-y} – 2t\ldots$ (aka Carr-Purcell)
CPMG $90_x – t – 180_y – 2t – 180_y – 2t\ldots$ (aka Carr-Purcell-Meiboom-Gill)

Note that n spin echos occur at regular intervals separated in time by 2t.

(a) If the radio frequency pulses are perfect, will there be any differences in the echo signal as a function of time between these two pulse sequences?
(b) Assume that the RF pulses are imperfectly "tuned", such that the 180^o pulses applied above are in fact actually only 170^o B_1 pulses. For the CP pulse sequence, how will errors in the RF pulse angle propagate into a determination of T_2 (i.e. will the measured T_2 decay be higher or lower than the 'true' T_2)?
(c) How will the CPMG pulse sequence differ from the CP pulse sequence in its sensitivity to pulse angle errors such as discussed above (watch the B_1 phase in the rotating frame!)? Will even numbered echoes (2^{nd}, 4^{th}, etc) behave the same as odd echoes? Will errors be additive from one echo to the next? Why?
(d) How should one properly use CPMG data to calculate T_2 from spin echo amplitudes?