Bioengineering 278  
Magnetic Resonance Imaging  

Winter 2011  
Lecture 1  

Topics:  
- Nuclear magnetization  
- Spin excitation  
- The NMR signal  

Spins  

- Mass  
- Spin  
- Charge  

Angular Momentum  
Magnetic Moment  

Hydrogen Nucleus = Proton  

Boltzmann Distribution  

down\_spins  
up\_spins  

\( E = \mu_z B_0 \)  

\( \Delta E = \gamma h B_0 \)  

\( E = -\mu_z B_0 \)  

\( \frac{(down\_spins)}{up\_spins} = e^{-\Delta E/kT} \)  

Ratio = 0.99998 at 3T!  

Corresponds to an excess of about 20 up spins per million.
Equation of Motion for Magnetization Vector $\mathbf{M}$

Bloch Equation:

$$\frac{d\mathbf{M}}{dt} = \mathbf{M} \times \gamma \mathbf{B} - \frac{M_z \hat{i} + M_y \hat{j}}{T_2} - \frac{(M_z - M_0) \hat{k}}{T_1}$$

Solution:

$$M_z(t) = M_0 + (M_z(0) - M_0)e^{-t/T_1}$$
$$M_{xy}(t) = M(0)e^{-j\omega_0 t}e^{-t/T_2}$$

$$\omega_0 = \gamma B$$

Relaxation: Z-component

$$M_z(t) = M_0 + (M_z(0) - M_0)e^{-t/T_1}$$

Relaxation: Transverse Component

$$M = M_x + jM_y$$

$$\frac{dM}{dt} = \frac{d}{dt}(M_x + jM_y)$$

$$= -\left(j\omega_0 + 1/T_2\right)M$$

$$M(t) = M(0)e^{-j\omega_0 t}e^{-t/T_2}$$

$$\omega_0 = \gamma B$$
RF Excitation

Bloch equation says that magnetization will precess around the applied field.

$B_1$ radiofrequency field tuned to Larmor frequency and applied in transverse ($xy$) plane induces nutation (at Larmor frequency) of magnetization vector as it tips away from the $z$-axis.

- lab frame of reference

http://www-mrsrl.stanford.edu/~wro/defense/animations/

An NMR Experiment