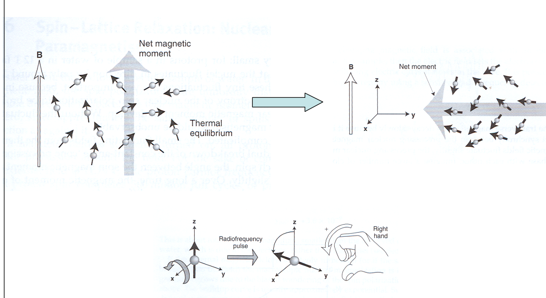
Bioengineering 280A
Principles of Biomedical Imaging

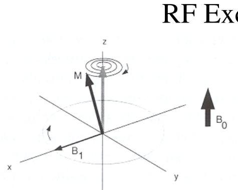
Fall Quarter 2005
MRI Lecture 4

RF Excitation



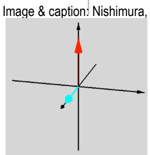
From Levitt, Spin Dynamics, 2001

RF Excitation



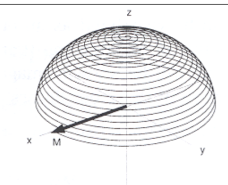
At equilibrium, net magnetizaion is parallel to the main magnetic field. How do we tip the magnetization away from equilibrium?

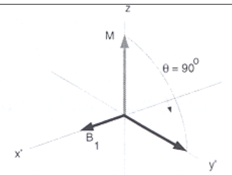
Image & caption: Nishimura, Fig. 3.2



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.eecs.umich.edu/%7Ednoll/BME516/

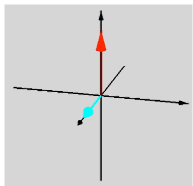




a) Laboratory frame behavior of **M**

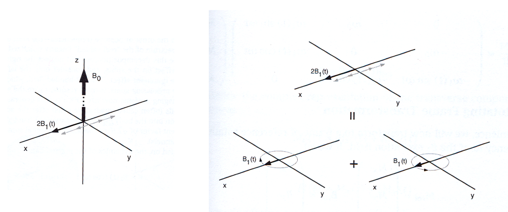
b) Rotating frame behavior of **M**

Images & caption: Nishimura, Fig. 3.3



Thomas Liu, BE280A, UCSD, Fall 2005

http://www.eecs.umich.edu/%7Ednoll/BME516/



$$\mathbf{B_1}(t) = 2B_1(t)\cos(\omega t)\mathbf{i}$$
$$= B_1(t)\left(\cos(\omega t)\mathbf{i} - \sin(\omega t)\mathbf{j}\right) + B_1(t)\left(\cos(\omega t)\mathbf{i} + \sin(\omega t)\mathbf{j}\right)$$

Thomas Liu, BE280A, UCSD, Fall 2005

Nishimura 1996

Rotating Frame Bloch Equation

$$\frac{d\mathbf{M}_{rot}}{dt} = \mathbf{M}_{rot} \times \gamma \mathbf{B}_{eff}$$

$$\mathbf{B}_{eff} = \mathbf{B}_{rot} + \frac{\omega_{rot}}{\gamma}; \quad \omega_{rot} = \begin{bmatrix} 0 \\ 0 \\ -\omega \end{bmatrix}$$

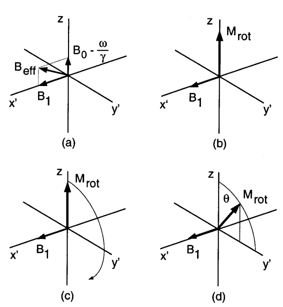
Thomas Liu, BE280A, UCSD, Fall 2005

$$Let\ \mathbf{B}_{rot} = B_1(t)\mathbf{i} + B_0\mathbf{k}$$

$$\begin{aligned}\mathbf{B}_{eff} &= \mathbf{B}_{rot} + \frac{\omega_{rot}}{\gamma} \\ &= B_1(t)\mathbf{i} + \left(B_0 - \frac{\omega}{\gamma}\right)\mathbf{k}\end{aligned}$$

$$\begin{aligned}\text{If } \omega &= \omega_0 \\ &= \gamma B_0\end{aligned}$$

$$\text{Then } \mathbf{B}_{eff} = B_1(t)\mathbf{i}$$



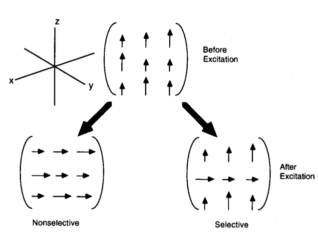
Flip angle

$$\theta = \int_0^{\tau} \omega_1(s)ds$$

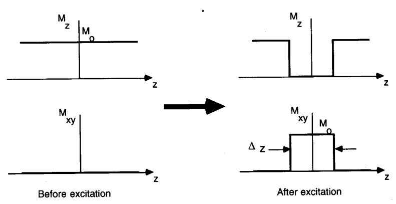
where

$$\omega_1(t) = \gamma B_1(t)$$

Nishimura 1996



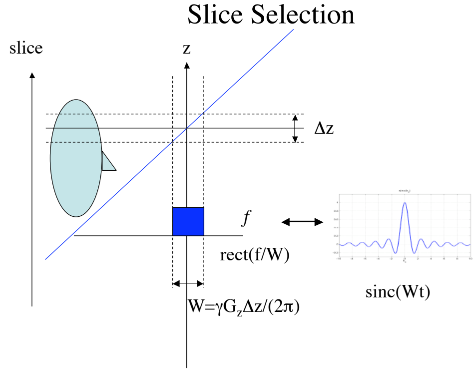
Nishimura 1996



Thomas Liu, BE280A, UCSD, Fall 2005

Nishimura 1996

Slice Selection



Thomas Liu, BE280A, UCSD, Fall 2005

$$Let\ \mathbf{B}_{rot} = B_1(t)\mathbf{i} + \left(B_0 + \gamma G_z z\right)\mathbf{k}$$

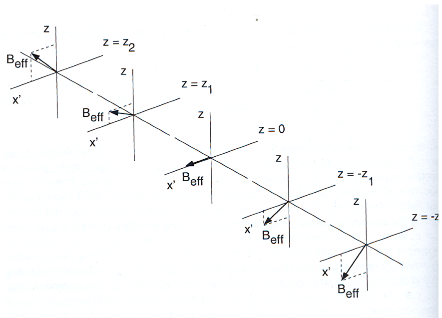
$$\mathbf{B}_{eff} = \mathbf{B}_{rot} + \frac{\omega_{rot}}{\gamma}$$

$$= B_1(t)\mathbf{i} + \left(B_0 + \gamma G_z z - \frac{\omega}{\gamma}\right)\mathbf{k}$$

If $\omega = \omega_0$

$$\mathbf{B}_{eff} = B_1(t)\mathbf{i} + \left(\gamma G_z z\right)\mathbf{k}$$

Thomas Liu, BE280A, UCSD, Fall 2005



Thomas Liu, BE280A, UCSD, Fall 2005

Nishimura 1996

Small Tip Angle Approximation

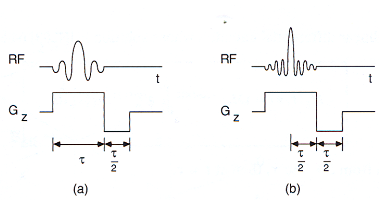
$$M_r(t,z) = jM_0 \exp(-j\omega(z)t)\int_0^t \exp(j\omega(z)s)\omega_1(s)ds$$

For symmetric pulse of length τ

$$M_r(\tau,z) = jM_0 \exp(-j\omega(z)\tau/2)\int_{-\tau/2}^{\tau/2} \exp(j2\pi f(z)s)\omega_1(s+\tau/2)ds$$

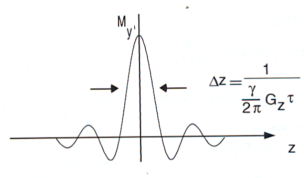
$$= jM_0 \exp(-j\omega(z)\tau/2)F\left\{\omega_1(t+\tau/2)\right\}\Big|_{f=-f(z)=-\frac{\gamma}{2\pi}G_z z}$$

Thomas Liu, BE280A, UCSD, Fall 2005



Thomas Liu, BE280A, UCSD, Fall 2005

Nishimura 1996



Thomas Liu, BE280A, UCSD, Fall 2005

Nishimura 1996