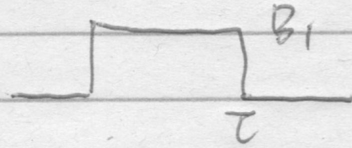
M229 Lecture5 2023.4.18

RF Pulses

Ex. 1



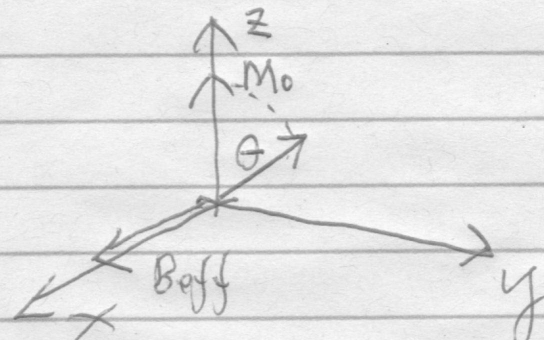
$B_1(t) = B_1, \quad 0 \le t \le \tau$

$$\vec{B}_{eff} = \begin{pmatrix} B_1 \\ 0 \\ 0 \end{pmatrix} \quad \text{on resonance} \quad B_0 - \frac{\omega_0}{\gamma} = 0$$

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

$$\Rightarrow \vec{M}_{rot}(t) = R_x(\underbrace{\gamma B_1 t}_{\text{"}\theta\text{"}}) \begin{bmatrix} 0 \\ 0 \\ M_0 \end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ M_0 \sin(\gamma B_1 t) \\ M_0 \cos(\gamma B_1 t) \end{bmatrix}$$



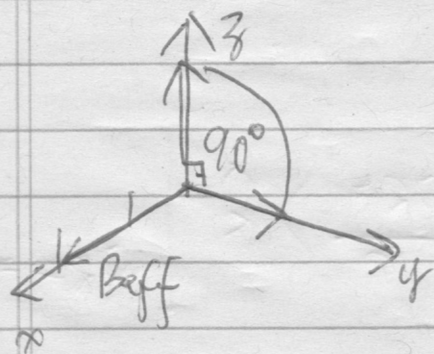
tip angle $\theta = \int_0^{\tau} \gamma \cdot B_1(t')dt' = \gamma B_1 \tau$

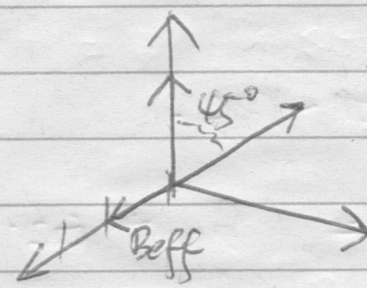
$\theta = 90^\circ = \frac{\pi}{2}, \quad \tau = 1\text{ms}$

$\frac{\pi}{2} = \gamma \cdot 1\text{ms} \cdot B_1 \Rightarrow B_1 \approx 0.06\text{G} = 6\mu\text{T}$

B_1 inhomogeneity

$B_1 \rightarrow 50\%$





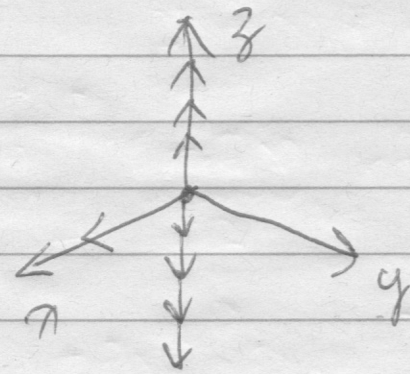
EX.2 NO RF pulse, G_z

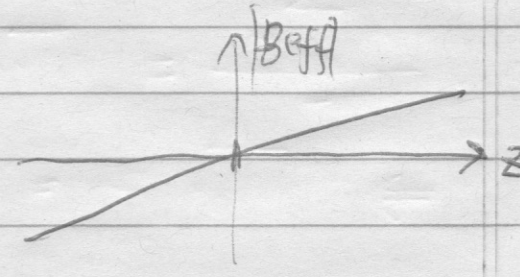
$$\vec{B} = (B_0 + G_z \cdot z)\,\hat{k}$$

$\vec{B}_{eff}$ at on-res.

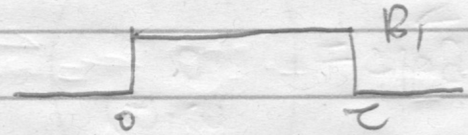
$$\vec{B}_{eff} = \left(B_0 + G_z \cdot z - \frac{\omega_{RF}}{\gamma}\right)\hat{k}\,\Bigg|_{\omega_{RF} = \omega_0}$$

$$= G_z \cdot z\,\hat{k}$$





Ex 3   RF pulse + G_z

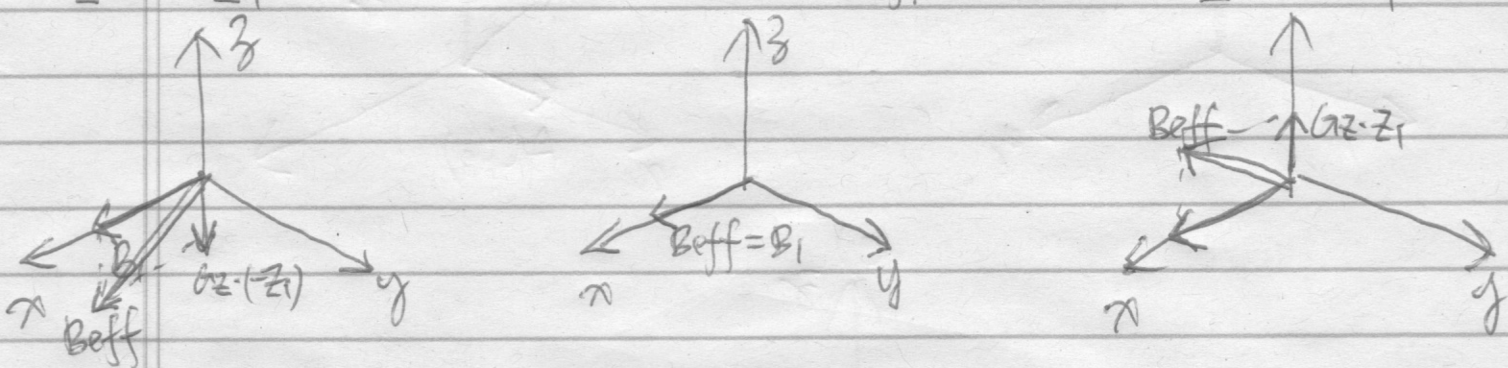


$$\vec{B}_{eff} = \left(B_0 + G_z z - \frac{\omega_{RF}}{\gamma}\right)\hat{k} + B_1 \hat{i}$$

on-res: $\omega_{RF} = \omega_0$

$$\vec{B}_{eff} = G_z \cdot z\,\hat{k} + B_1 \hat{i}$$

$z = -z_1$ $z = 0$: $\vec{B}_{eff} = B_1 \hat{i}$ $z = +z_1$

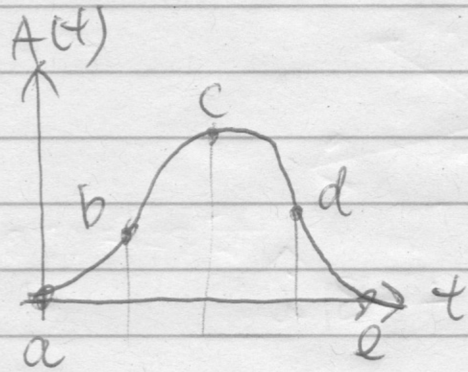


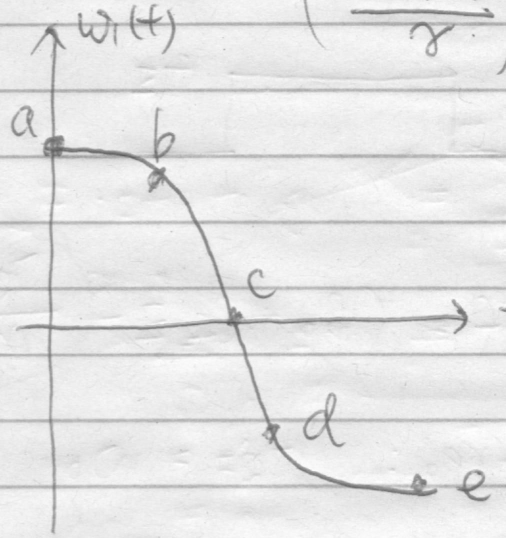
at z very far from B_0 center

Adiabatic RF Pulse

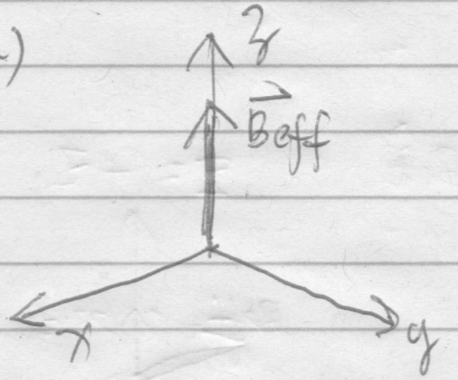
$$B_1(t) = A(t)\, e^{-i\omega_1(t)\cdot t}$$

$$\vec{B}_{eff} = \begin{pmatrix} A(t) \\ 0 \\ \frac{\omega_1(t)}{\gamma} \end{pmatrix}$$

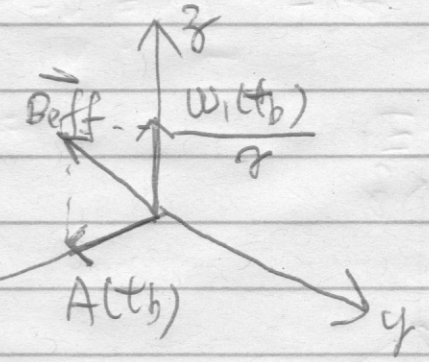




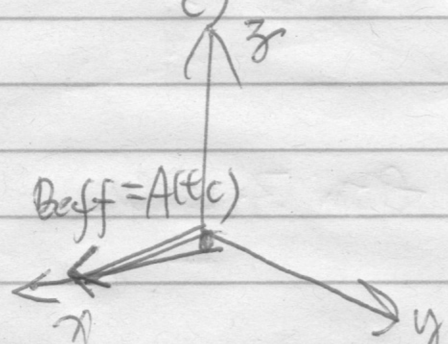
a)



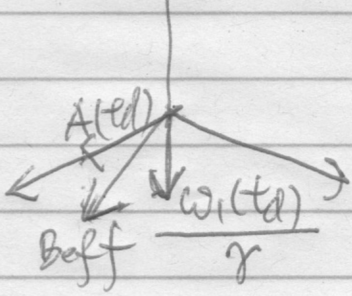
b)



c)



d)



e)