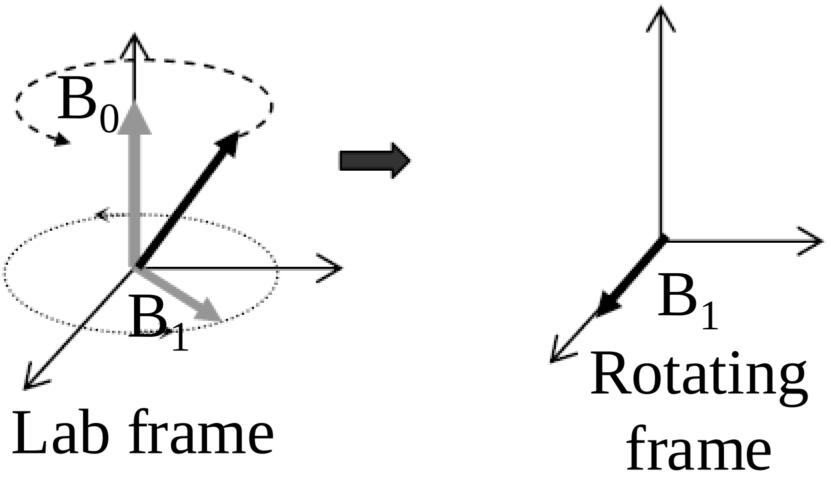
Lec 11

(MRI: B_1 field)

What do we see if we are sitting on the rotating frame?

B_1 is constant.
B_o vanishes.



What happens to magnetization in the rotating frame?

Bloch equations

- Used describe the time evolution of “magnetization”

- Phenomenological equations

Time derivative of a vector (**A**) in lab (fixed) frame

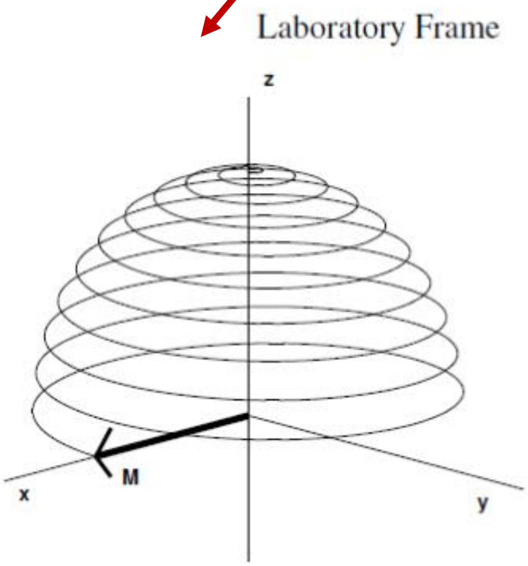
$$d\mathbf{A}/dt = D\mathbf{A}/Dt + (\boldsymbol{\omega} \times \mathbf{A})$$

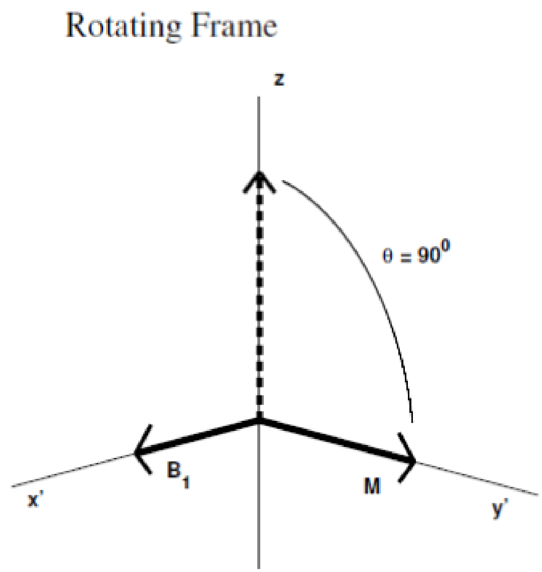
Describes motion of the rotating frame relative to lab frame.

Describes motion of vector in the rotating frame.

Time-derivative of magnetization

$$d\mathbf{M}/dt = D\mathbf{M}/Dt + (\boldsymbol{\omega} \times \mathbf{M})$$





$$D\mathbf{M}/Dt = d\mathbf{M}/dt - (\boldsymbol{\omega} \times \mathbf{M}) \text{ ----------- } (1)$$

We have already seen $d\mathbf{M}/dt = (\gamma\mathbf{M} \times \mathbf{B})$ --------- (2)

(Larmor equation)

From (1) and (2)

$D\mathbf{M}/Dt = \gamma(\mathbf{M} \times \mathbf{B}) - (\boldsymbol{\omega} \times \mathbf{M})$

$\Rightarrow D\mathbf{M}/Dt = \gamma(\mathbf{M} \times \mathbf{B}) + (\mathbf{M} \times \omega)$

$$\boxed{\frac{D\vec{M}}{Dt} = \gamma\vec{M} \times \left(\vec{B} + \frac{\vec{\omega}}{\gamma}\right)} \text{ ------------- (3)}$$

$$\boxed{\frac{D\overrightarrow{M}}{Dt} = \gamma\overrightarrow{M} \times \left(\overrightarrow{B} + \frac{\overrightarrow{\omega}}{\gamma}\right)} \text{ ------------- } (3)$$

Here, $\overrightarrow{B} = B_1\hat{\boldsymbol{x}} + B_0\hat{\boldsymbol{z}}$ ----- (4)

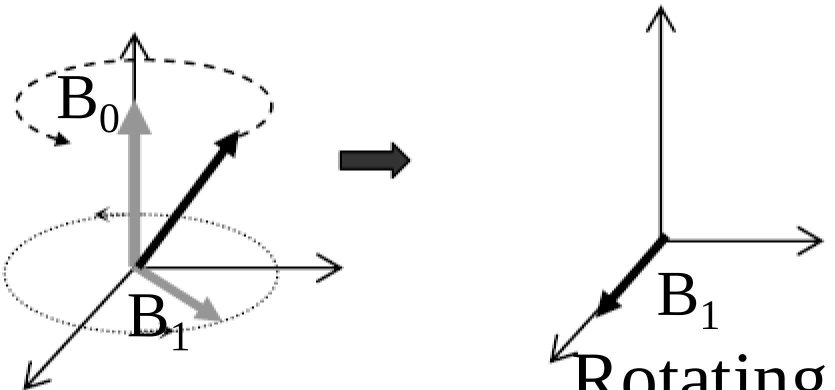
We choose, $B_0 = -\dfrac{\omega}{\gamma}$

$$\boxed{\frac{D\overrightarrow{M}}{Dt} = \gamma\overrightarrow{M} \times B_1\hat{\boldsymbol{x}}} \text{ ------------- } (5)$$

What magnetic fields do we see if we are sitting on the rotating frame?

B_1 is constant.

B_o vanishes.

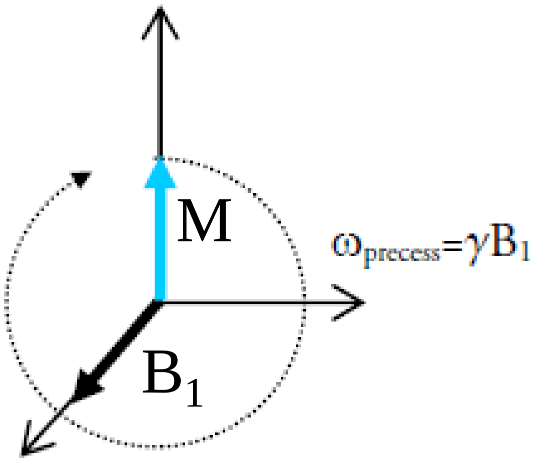


Lab frame

Rotating frame

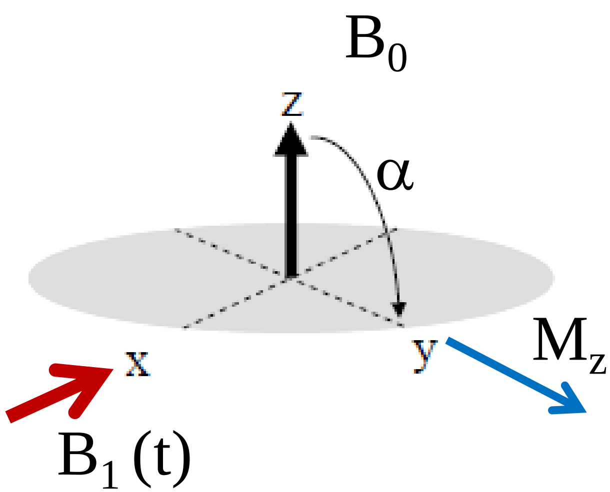
What happens to magnetization in rotating frame?

Magnetization (blue) precesses around B_1 with frequency $\gamma B_{1.}$



Tip angle (α)

- Tip angle (α): angle through which magnetization (M) is rotated by applying RF field.
- Depends on both B_1 and the duration of pulse (τ_{B1}).



$$\alpha = \omega\, \tau_{B1} = 2\pi\gamma\, B_1\, \tau_{B1}$$

$$\Rightarrow \tau_{B1} = \alpha / (2\pi\gamma\, B_1)$$

For a typical MRI scenario,

$B_1 = 10\mu T$, => $\tau \sim 0.5ms$

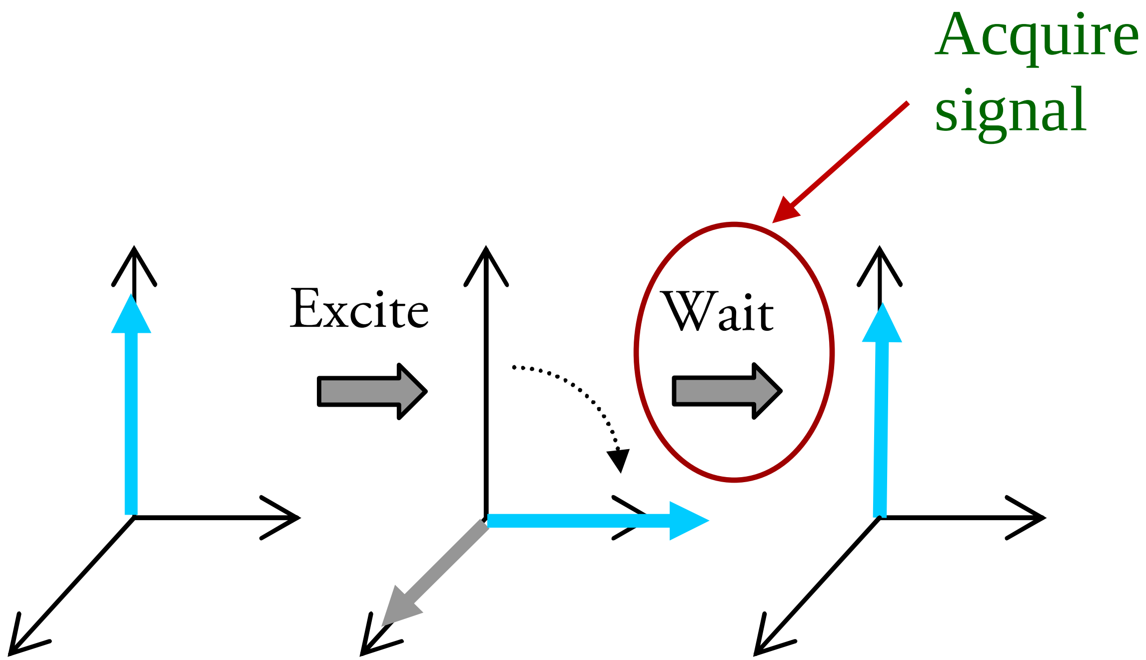
Typical pulses

- $\pi/2$ pulse leads to maximum transverse component of magnetization
- π pulse rotates magnetization from + z to –z. No transverse component.

What happens when RF-field is turned off?

- Magnetization returns to its equilibrium position along z-axis.
- We are interested in <u>how</u> it returns to equilibrium.
- This is when we measure the MRI signal (i.e. after RF field is turned off).

Relaxation



Relaxation of magnetization is measured after B_1 is turned off

Apply relaxation behaviour to magnetization components.

$$\frac{dM_z}{dt} = -\frac{(M_z - M_0)}{T_1}$$

$$\frac{dM_x}{dt} = -\frac{M_x}{T_2}$$

$$\frac{dM_y}{dt} = -\frac{M_y}{T_2}$$

- There are two relaxation times and they are different.
- Why is there no *Mo* in the equations for the transverse components?