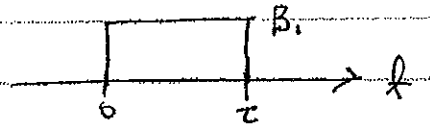
* Small tip-angle example

- consider a rectangular RF pulse (duration of τ)

$$B_1(t) = B_1 \cdot \Pi\left(\frac{t - \tau/2}{\tau}\right)$$

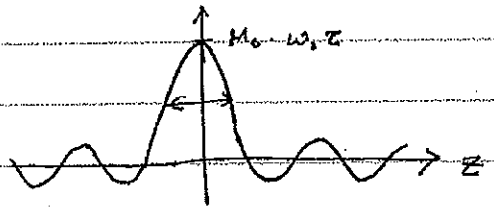


- $M_r(\tau, z) = i M_0 e^{-i w(z) \tau/2} \; \mathcal{F}_{1D}\left\{ w_1\left(t + \frac{\tau}{2}\right) \right\}\Big|_{f = \frac{\gamma}{2\pi} G_z \cdot z}$

$$w_1\left(t + \frac{\tau}{2}\right) = \underbrace{\gamma \cdot B_1}_{w_1} \cdot \Pi\left(\frac{t}{\tau}\right)$$

$$\mathcal{F}_{1D}\left\{ \Pi\left(\frac{t}{\tau}\right) \right\} = \tau \; \mathrm{sinc}(\tau \cdot f)$$

$$\Rightarrow M_r(\tau, z) = i M_0 \underbrace{e^{-i w(z) \tau/2}}_{\text{Canceled out by the refocusing pulse}} \cdot w_1 \tau \; \mathrm{sinc}\left(\tau \cdot \frac{\gamma}{2\pi} G_z \cdot z\right)$$



$$\Delta z = \frac{1}{\frac{\tau}{2\pi} \gamma \cdot G_z}$$

Echo → undo dephasing effects

$$S(t) = \iiint_V m(\vec{r})\, e^{-i\phi(\vec{r},t)}\, dV$$

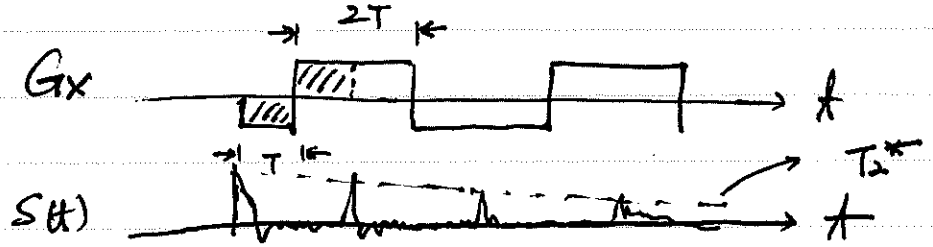
$$\phi(\vec{r},t) = \gamma \int_0^t \vec{G}(\tau)\,\vec{r}\, d\tau$$

(controlled by G)

① Gradient echo

$$\phi = \gamma \int_0^t G(\tau)\,\vec{r}\, d\tau = 0$$

(GE)



Gradient recalled echoes (GREs)

→ echo "peaks" when returns to k-space origin

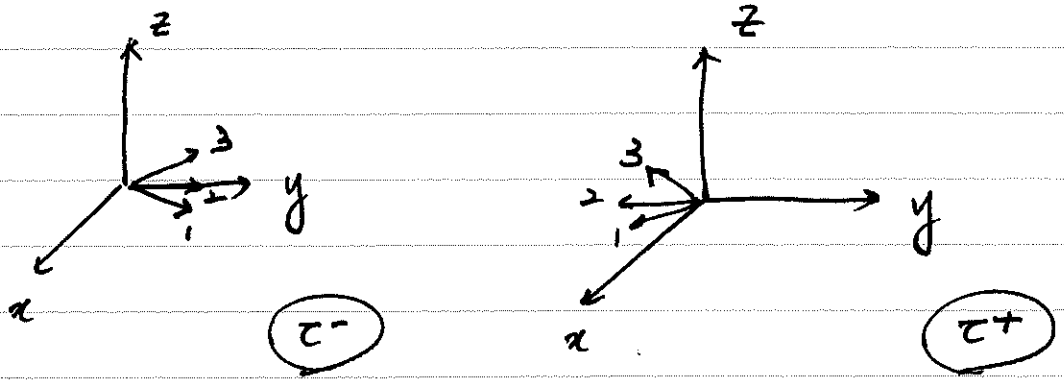
→ 2DFT with PE = 0

PE ≠ 0 still calls it a GRE when $\int G_x = 0$

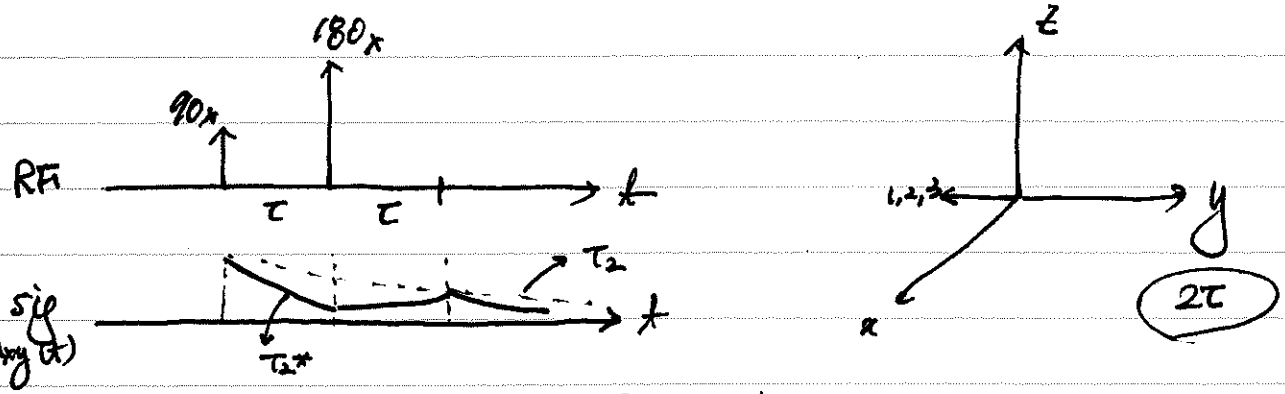
② Spin echo (SE)

- Ignore $\vec{G}$
- undo dephasing due to off-resonance

Idea Apply a 180° excitation at $t = \tau$ and see what happens



180° around x



⟹ Spins rephased formed "spin echo"