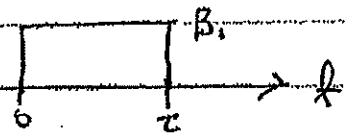


* Small tip-angle example

- consider a rectangular RF pulse (duration of τ)

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



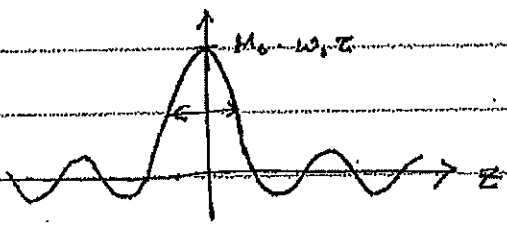
$$M_r(\tau, z) = \lambda M_0 e^{-\lambda W(z) \tau/2} \int_{10} \left\{ W_1 \left(t + \frac{\tau}{2} \right) \right\} \Big|_{f = \frac{\lambda}{2\pi} G_2 \cdot z}$$

$$W_1 \left(t + \frac{\tau}{2} \right) = \underbrace{\tau}_{W_1} \cdot B_1 \cdot \Pi\left(\frac{t}{\tau}\right)$$

$$\int_{10} \left\{ \Pi\left(\frac{t}{\tau}\right) \right\} = \tau \text{ SMC}(\tau \cdot f)$$

$$\Rightarrow M_r(\tau, z) = \lambda M_0 e^{-\lambda W(z) \tau/2} \cdot \underbrace{W_1 \tau}_{\text{canceled out}} \text{ SMC}\left(\tau \cdot \frac{\lambda}{2\pi} G_2 \cdot z\right)$$

Cancelled out by the refocusing pulse



$$\Delta z = \frac{1}{\frac{\tau}{2\pi} \lambda \cdot G_2}$$

②

Echo \rightarrow undo dephasing effects

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

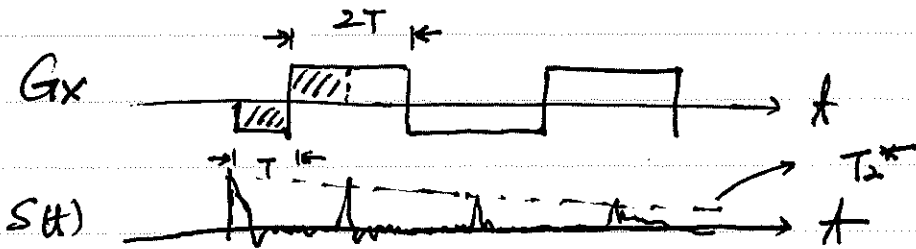
$$\phi(\vec{r}, t) = \gamma \int_0^t \underbrace{\vec{G}(\tau) \vec{r}}_{\text{controlled by } G} d\tau$$

controlled by G

① Gradient echo

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

$\underbrace{\hspace{10em}}_{GE}$



Gradient recalled echoes (GREs)

\rightarrow echo "peaks" when returns to
k-space origin

\rightarrow 2DFT with $PE = 0$

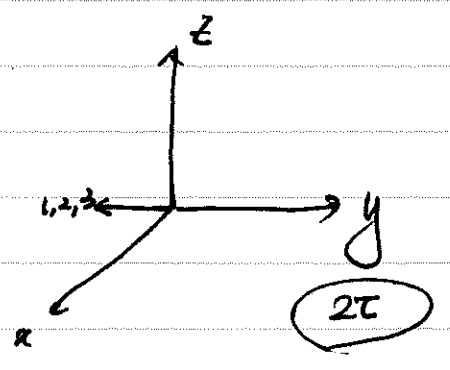
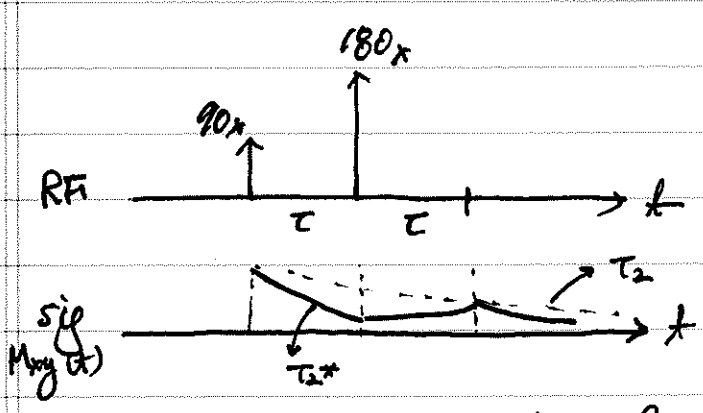
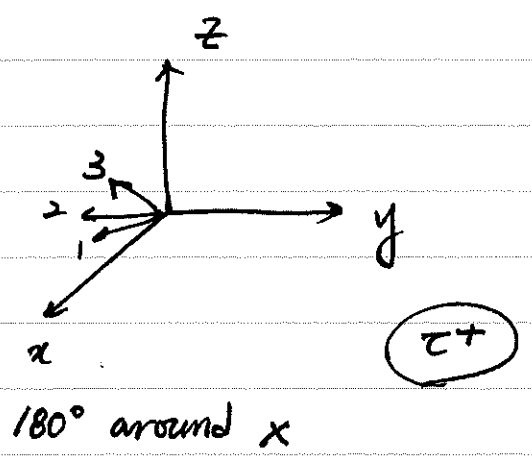
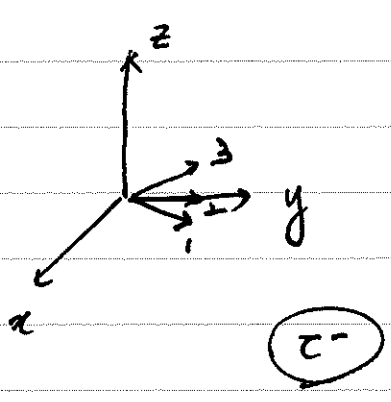
$PE \neq 0$ still calls it a GRE when

$$\int G_x = 0$$

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



\Rightarrow spins rephased formed "spin echo"