

Off Resonance Effects

B_0 inhomogeneity
susceptibility differences
chemical shift

$$s(t) = \iint m(x,y) e^{-i\omega_E(x,y)t} e^{-i\gamma 2\pi(k_x(t)x + k_y(t)y)} dx dy$$

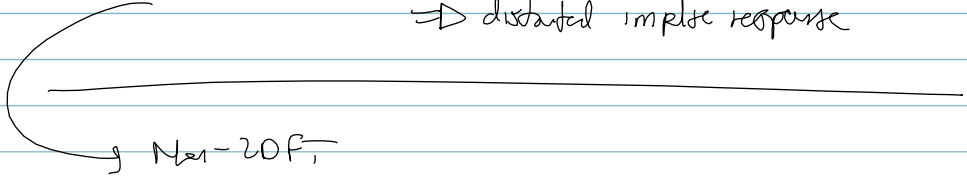
@ a given time

1) $e^{-i\omega_E t}$

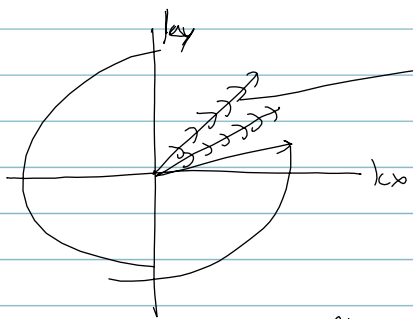
can create phase dispersion within a voxel \Rightarrow signal loss $T_2 \Rightarrow T_2^*$

2) $e^{-i\omega_E t}$

contributes phase error over kspace \Rightarrow distorted impulse response



ex) 2D PR



linear
phase error = $e^{-i\Delta k r}$

impulse response
= $\mathcal{F}_{2D}^{-1} \{ \}$

not a shift, but a blur

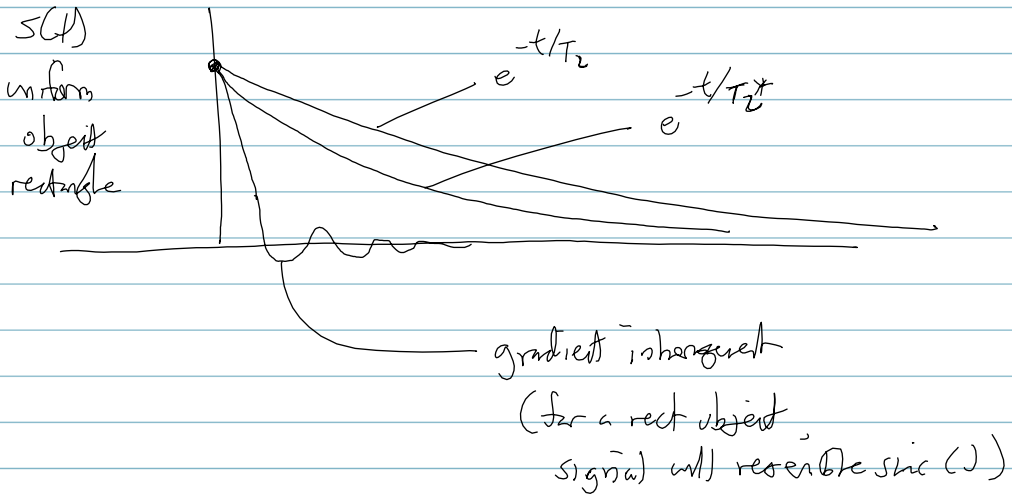
ECHOES

"undo dephasing"

$$s(t) = \iiint \underbrace{m(\vec{r})}_{\text{object}} e^{-i \underbrace{d(\vec{r}, t)}_{\text{phase}}} dx dy dz$$

$$d(\vec{r}, t) = \underbrace{\omega_E(\vec{r})t + \omega_{CS}(\vec{r})t}_{\text{no contrast}} + \underbrace{\gamma \left(\int_0^t \vec{G}(\tau) d\tau \right) \cdot \vec{r}}_{\text{contrast}}$$

inhomogeneity

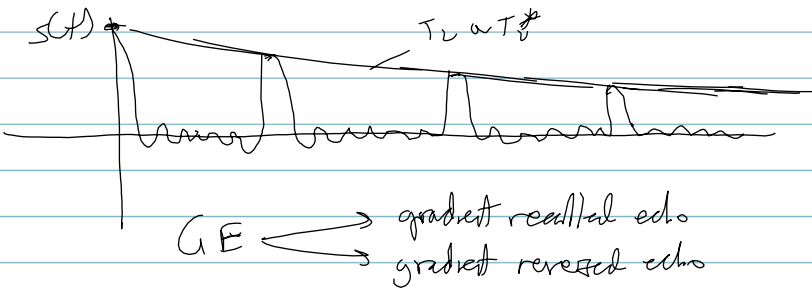
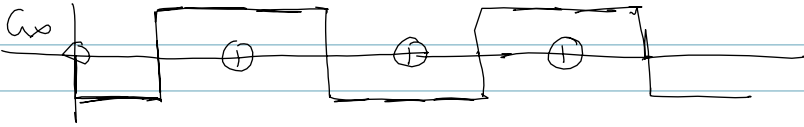


1) GRADIENT Echo

ignore E, CS
$$\phi = \gamma \left(\int_0^t \vec{A}(r) d\tau \right) \cdot \vec{r}$$

Gradient Echo occurs when $\phi = 0 \quad \forall \vec{r}$

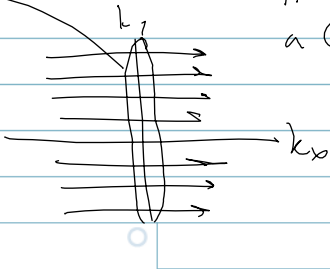
$$\int A d\tau = 0$$



• echo "peaks" at the k-space origin

• in 2DFT, blingo

all considered
GE



time when $k_x = 0$ is called
a GE even if $k_y \neq 0$

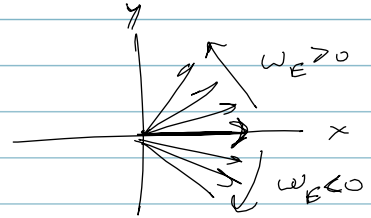
② Spin Echo (SE)

ignore \vec{G}

undo dephasing caused by ω_E

- at time τ after excitation

$$\phi(\vec{r}, \tau) = \omega_E(\vec{r}) \tau$$



IDEA we use an RF pulse to flip phases at time τ

180° along x or y

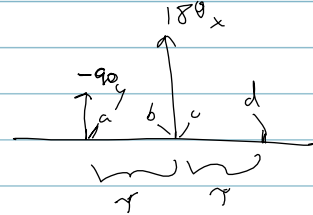
Relative phase after 180°

a) $d = 0$

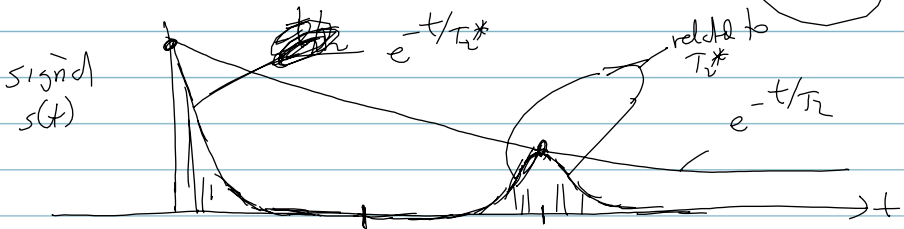
b) $\phi = \omega_E(\vec{r}) \tau$

c) $\phi = -\omega_E(\vec{r}) \tau$

d) $d = -\omega_E(\vec{r}) \tau + \omega_E(\vec{r}) \tau = 0$



SE

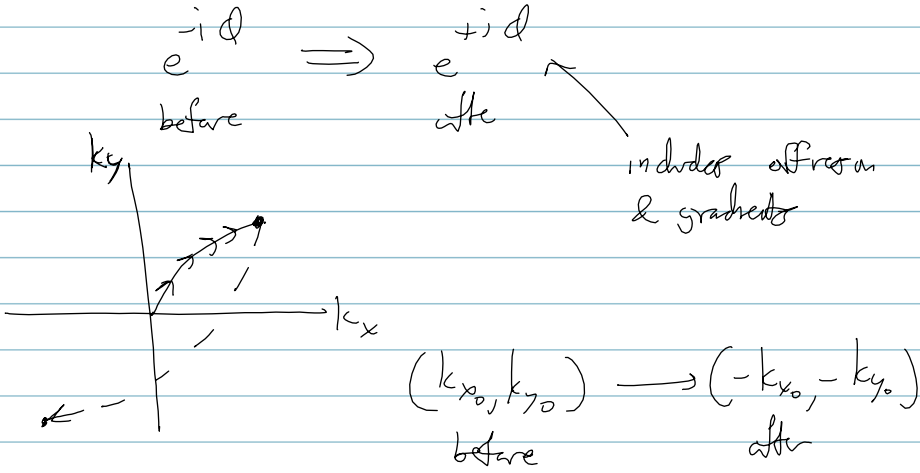


180° pulse → spin echo pulse (M_{xy})
↳ phase reversal
"pseudo flip pulse"

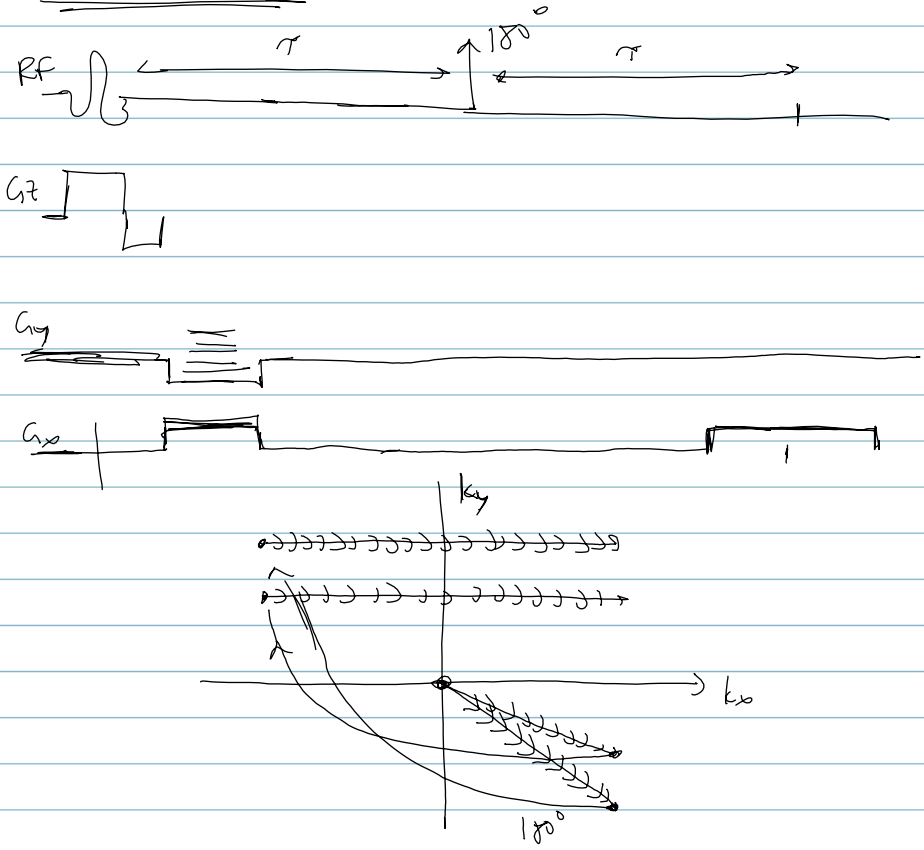
• inversion (M_z)



180° pulse affects k-space trajectory



2DFT w/ SE



NOTES

- TE = gradient echo time $\int G_x dt = 0$
- $2\tau =$ spin echo time depends on timing of 90° & 180°
- usually set TE = 2τ , max signal
- at TE signal amplitude e^{-TE/T_2} ← not T_2^*

① SE — pure T_2 weighting, coherent signal
(T_2^* problematic)

② GE — faster, no 180° pulse needed
— shorter TE possible