Off Resonance Effects

\[ S(t) = \iiint m(x,y) e^{-i \omega (x_{17} + \frac{1}{2} \gamma B_0 (x \cdot x + y \cdot y))} \, dx \, dy \]

1. \( e^{-i \omega t} \) can create phase dispersion within a voxel \( \Rightarrow \) signal gets \( T_2 = 1 T_2^* \)
2. \( e^{-i \omega t} \) contributes phase error over k-space \( \Rightarrow \) distorted image response

\[ e^{20 \rho R} \]

\[ \text{Key:} \]
\[ \text{phase error} = e^{-i \Delta \Phi} \]
\[ \text{impulse response} = 0 \text{ not a shift, but a blur} \]

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But for \( \text{"include dephasing\} \)

\[
S(t) = \iiint m(\vec{r}) e^{-i \int \vec{d}(\vec{r}, t) \cdot d\vec{x}} dt
\]

\( \vec{d}(\vec{r}, t) = \omega_E(\vec{r}) t + \omega_0(\vec{r}) t + \delta \int_0^t \omega_0(\vec{r}) d\tau \cdot \vec{r} \)

\( \text{no control} \)

\( \text{control} \)

inhomogeneous

\[
S(t) = e^{-\frac{t}{T_2}} e^{-\frac{t}{T_{2x}}}
\]

\( \text{gradient inhomogenous} \)

(for a rect object, \( \sigma \) will resemble \( \text{SIC} \))
1) GRADIENT ECHO

\[ \phi = \gamma \left( \frac{\Delta}{\gamma} \right) \cdot r \]

Gradient Echo occurs when \( \phi = 0 \quad \forall \, r \)
\[ \int \Delta \, dt = 0 \]

GE \quad gradient recalled echo
GRGE \quad gradient reversed echo

- echo "peaks" at the k-space origin

in 2DFT lingo

all considered 

a GE even if \( k_y \neq 0 \)
2. Spin Echo (SE)

Ignore $\ddot{\gamma}$

undo dephasing caused by $\omega_E$

-at time $t$ after excitation

$\phi(t, \gamma) = \frac{\omega_E(t) \gamma}{2}$

INEA

use an RF pulse to

flip phases at time $\gamma$

$180^\circ$ along $x$ or $y$

Relative phase after $180^\circ x$

a) $d = 0$

b) $\phi = \omega_E(t) \gamma$

c) $\phi = -\omega_E(t) \gamma$

d) $d = -\omega_E(t) \gamma + \omega_E(t) \gamma = 0$

Signal:

$s(t)$

$e^{-t/T_F}$

$e^{-t/T_2}$
$180^\circ$ pulse - spin echo pulse \( (M_{xy}) \)

\rightarrow \text{phasereversal}

"pancake dipole pulse"

\rightarrow \text{inversion} \( (M_z) \)

$180^\circ$ pulse affects k-space trajectory

\[ e^{i\theta} \rightarrow e^{i\theta} \]

before \hspace{1cm} after

\( k_y \)

\( k_x \)

\( (k_{x_0}, k_{y_0}) \rightarrow (-k_{x_0}, -k_{y_0}) \)

before \hspace{1cm} after
**NOTES**

- \( TE \) = gradient echo time \( \int G_x dt = 0 \)
- \( 2\gamma \) = spin echo time depends on timing of 90° & 180°
- usually set \( TE = 2\gamma \), max signal
- at \( TE \) signal amplitude \( e^{-\frac{TE}{T_2}} \) int \( T_2^* \)

- **SE** — pure \( T_2 \) weighting, bright signal (\( T_2^* \) pseudodielectric)
- **GE** — faster, no 180° pulse needed — shorter TE possible