# LECTURE #8

## LAST TIME

TALKED ABOUT $T_2$ DECAY.

TWO EFFECTS:

↳) SIGNAL LOSS BY $e^{-\frac{TE}{T_2}}$

↳) APODIZATION BY $e^{-\frac{k_x}{\frac{D}{\gamma\pi}G_x T_2}}$

. (BLURRING IN READOUT)

TALKED ABOUT OFF RESONANCE SOURCES:

(1) MAIN MAGNET → NOT A BIG DEAL!

(2) MAGNETIC SUSCEPTIBILITY

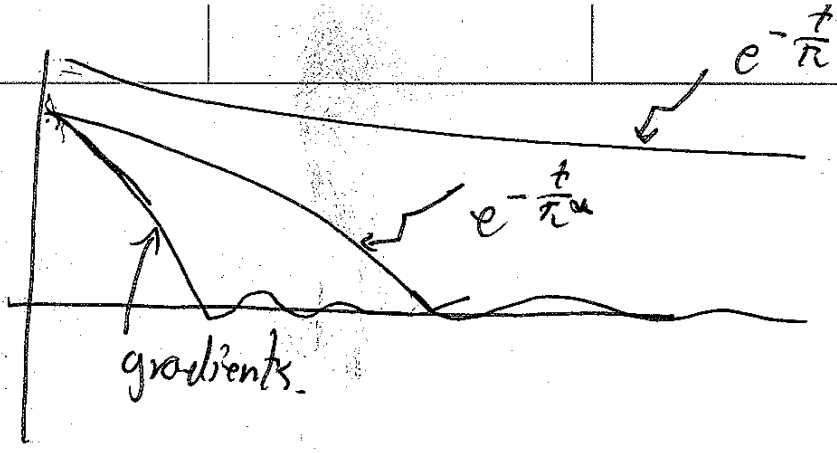
(3) CHEMICAL SHIFT

↳) INHOMOGENEITY IN A VOXEL LEADS TO DEPHASING AND SIGNAL LOSS.

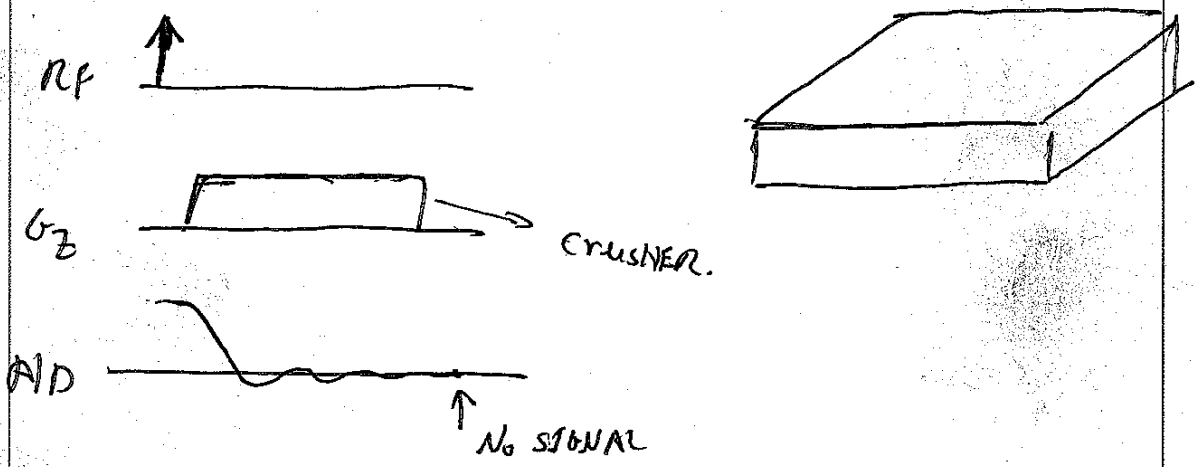
$$S(t)_{\text{VOXEL}} = \int_{\text{VOXEL}} m_{xy}(r,0)\, e^{i\omega_E(\vec{r})t}\, e^{-\frac{t}{T_2}}\, d\vec{r}$$

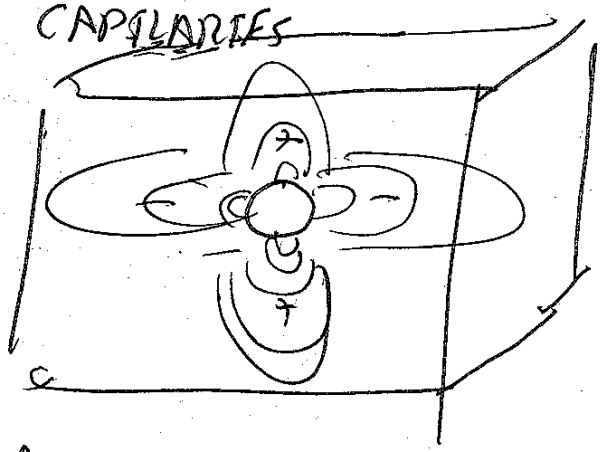
$$\simeq \left[\int_{\text{VOXEL}} m_{xy}(r,0)\, d\vec{r}\right] e^{-\frac{t}{T_2^{eff}}}$$

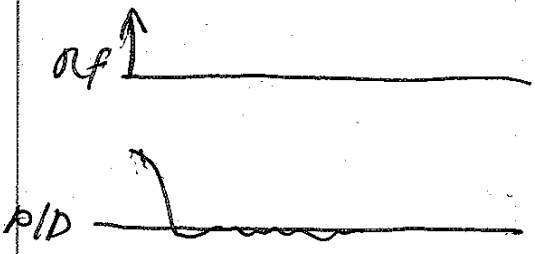
$$\frac{1}{T_2^{eff}} = \frac{1}{T_2} + \frac{1}{T_2'}$$



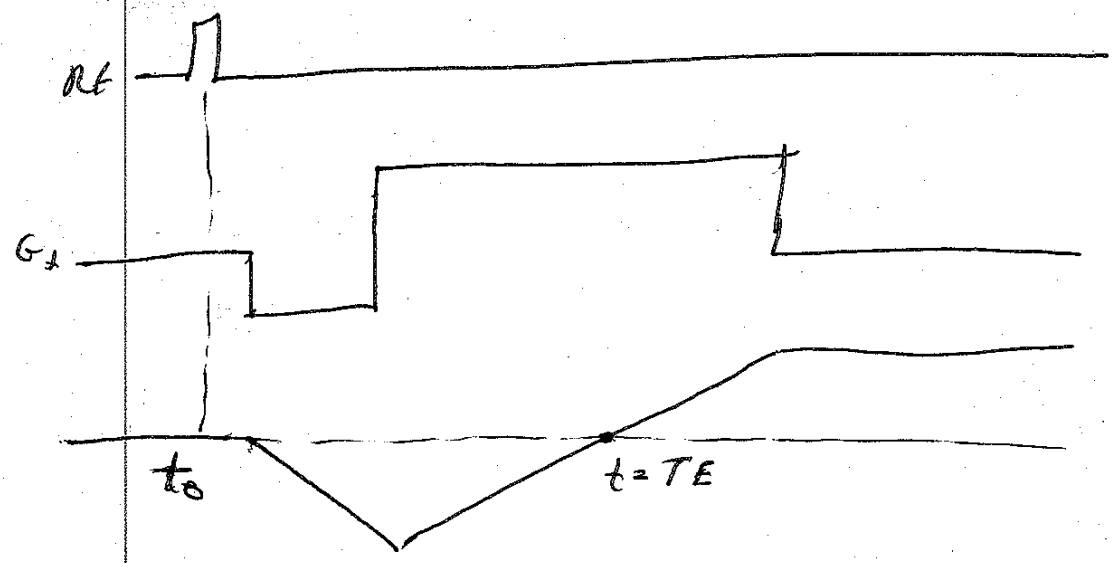

gradients act as $T_2^*$ source



# OFF-RESONANCE EFFECTS ON IMAGING




DURING READOUT

$$k_x(t) = \frac{\delta}{2\pi} G_x (t - TE)$$

AND

$$t = \frac{k_x}{\frac{\delta}{2\pi} G_x} + TE$$

THE TRANSVERSE MAGNETIZATION IS

$$m_{xy}(\vec{r}, t) = m_{xy}(r, 0)\, e^{-i\omega_E(\vec{r})\, t}\, e^{-\frac{t}{T_2(\vec{r})}}\, e^{-i2\pi k_x(t) x}$$

NEGLECTING $T_2$ AND SUBSTITUTING FOR $t$.

$$m_{xy}(\vec{r},b) = m_{xy}(\vec{r},0)\, e^{-i\omega_E(\vec{r})\left(\frac{k_x(b)}{\frac{\gamma}{2\pi}G_x} + TE\right)} \cdot e^{-i2\pi k_x(b)x}$$

$$x' = x + \frac{\omega_0(r)}{\gamma G_x}$$

$$= m_{xy}(r,0)\underbrace{e^{-i\omega_E(r)TE}}_{\text{DEPHASING}(T_2^{eff})}\underbrace{e^{-i2\pi k_x(b)\left(x - \frac{\omega_E(\vec{r})}{\gamma G_x}\right)}}_{\text{DISPLACEMENT}}$$

A SPIN AT: $x' = x + \underbrace{\frac{\overbrace{\omega_E(r)}^{\text{FREQ.}}}{\gamma G_x}}_{(\text{FREQ/cm})}$ $\qquad \omega_E(\vec{r}) = 0$ ON-RESONANCE

PRODUCES THE SAME SIGNAL AS A SPIN AT

$x$ AND $\omega_E(\vec{r})$ SHIFTED → OFF RESONANCE

EXAMPLE

$$\frac{\gamma}{2\pi}G_x = 1\ \frac{kHz}{cm}$$

$$E(\vec{r}) = 3\ mm \qquad \omega_E(r) = 2\pi \cdot 1200\ Hz$$

$$\Delta x = x' - x = \frac{\omega_E(r)}{\gamma G_x} = \frac{2\pi\,(1200\ Hz)}{2\pi\,(1\ kHz/cm)} = 0.2\ cm.$$

AT $\Delta x = 1\ mm$ THIS IS 2 PIXELS!

## OFF-RESONANCE ~~AMT~~ IN SPIN-WARP (2DFT)

MODEST SPATIAL DISTORTIONS (few-pixels)

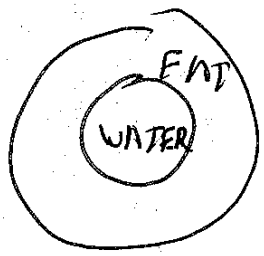
RELATIVELY BENIGN ARTIFACT

REDUCED WITH LARGE $G_x$

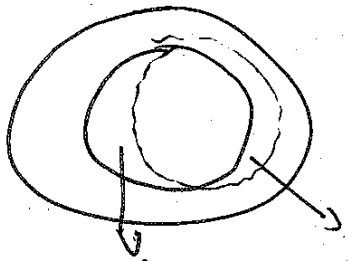
## CHEMICAL SHIFT

$$\frac{\omega_f}{2\pi} = \frac{\omega_w}{2\pi} - 220\ Hz \quad @\ 1.5T$$

FAT IMAGE IS DISPLACED FROM WATER




TRUE




IN PRACTICE, FAT/WATER SHIFT LIMITED TO 2 VOXELS

LIMIT R/P LENGTH.

@ 1.5T

$$2 \cdot \frac{1}{(220\ kHz)} = 9.1\ ms \quad \text{R/D TIME}$$

TYPICAL: 8 ms.