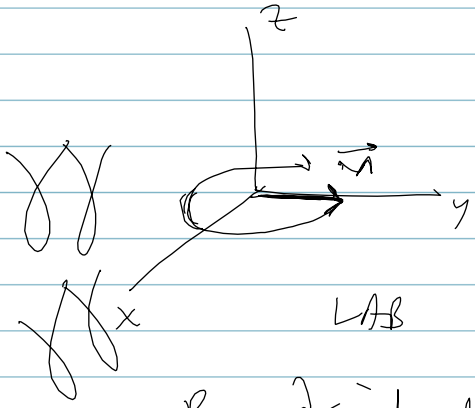
B_1 detection of signals

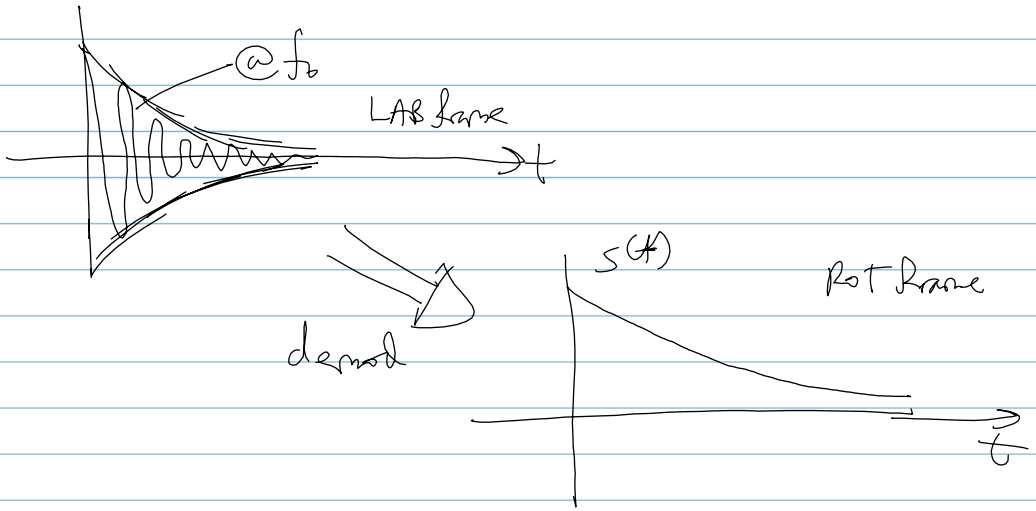


precessing $\vec{M}$

induce EMF in coil

$EMF = -\frac{d\Phi}{dt}$ ← flux

Received signal called "free induction Decay" FID



$\vec{M}$ returns to equilibrium $M_0\hat{k}$

transverse $M_{xy} \to 0$

longitudinal $M_z \to M_0$

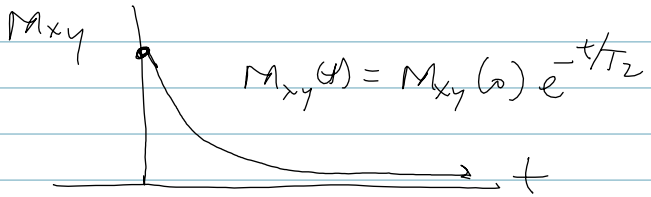
both are exponential

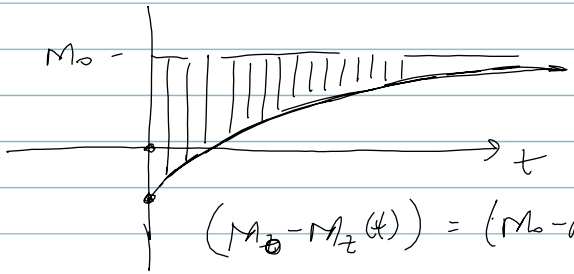
T_2

T_1

tissue dependent

time constants





$$(M_0 - M_z(t)) = (M_0 - M_z(0))\, e^{-t/T_1}$$

$$M_z(t) = M_z(0)\, e^{-t/T_1} + M_0\,(1 - e^{-t/T_1})$$

Relaxation Why?

T_1 — spin-lattice

↳ fluctuating fields, movement of dipoles
↳ exchange @ f_0

100 ms to 5 sec

paramagnetic agents can shorten T_1

Gd chelates often used

T_2 — all of above + spin spin
dephasing phenomenon

after 90° tip (→ → → → → → →)

↳ field of neighboring spins
↳ off resonant condition
↳ spread in freq and phase at microscopic level
↳ dephasing (→ ↘ → ↘ → ↘ →)

$T_1 \sim$ dependent on B_0 (longer at higher B_0)

$T_2 \sim$ largely indep of B_0

solids $T_2 < 1$ ms

liquids $T_2 \approx T_1 \approx$ 3 s → tissue

Basic NMR experiment

1. RF – excite sample
2. receive signal
3. wait for relaxation

Problem: How do we make an image??

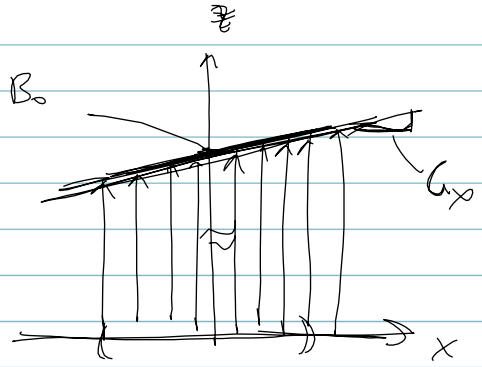
RF sensitive to entire volume

G gradient fields G_x, G_y, G_z

$$B = (G_x x + G_y y + G_z z)\hat{k}$$

$$G_x = \frac{dB_z}{dx} \qquad |G| < 4 \text{ G/cm}$$

hardware limit 40 mT/m



$$B_z = B_0 + G_x x$$

$$f(x) = \frac{\gamma}{2\pi}(B_0 + G_x x)$$

$$= f_0 + \left(\frac{\gamma}{2\pi} G_x\right) x$$

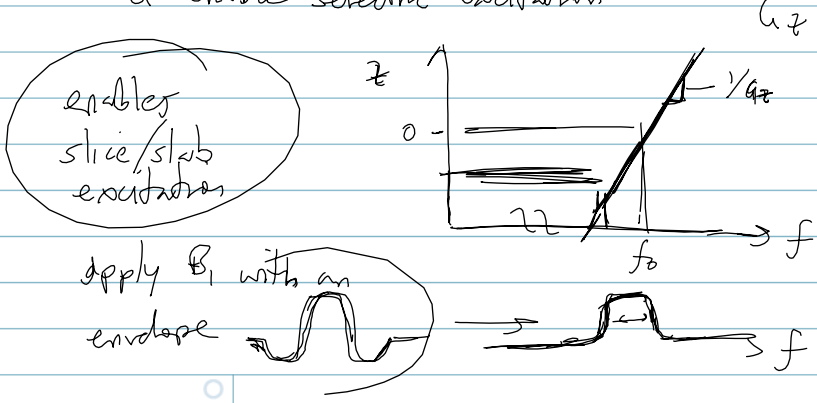
RCV signal — temporal frequency
maps to spatial position

ex) object $\Delta x = 20$ cm
$G_x = 0.5$ G/cm

$$\Delta f = \frac{\gamma}{2\pi} G_x \Delta x = 4257 \text{ Hz}$$

$$\left(4257 \frac{\text{Hz}}{\text{G}}\right)\left(0.5 \frac{\text{G}}{\text{cm}}\right)(20 \text{ cm})$$

G_z enable selective excitation



2D imaging

1. selectively excite a slice B_1 G_z
2. record signals, encode x, y G_x G_y
3. wait for relaxation