$B_1$ detection of signals

\[ \mathbf{M} \]

intercept $\mathbf{E}_{\text{MP}}$ in $\mathbf{a}$

$\mathbf{E}_{\text{MP}} = -\frac{\partial \mathbf{F}}{\partial \mathbf{y}}$ 

Recived signal called "free induction decay" FID

$\text{LAB}$

$\text{Rot. Frame}$

$S(t)$

depend
\[ M \text{ returns to equilibrium as } M_0 \]

- Transverse \( M_{xy} \rightarrow 0 \)
- Longitudinal \( M_z \rightarrow M_0 \)

Both are exponential:

\[ T_2 \]
\[ T_1 \]

Tissue dependent

Time constant

\[ M_{xy}(t) = M_{xy}(0) e^{-t/T_2} \]

\[ M_0 - M_z(t) = (M_0 - M_z(0)) e^{-t/T_1} \]

\[ M_z(t) = M_z(0) e^{-t/T_1} \]

\[ + \text{ other terms} + M_0 \ 1 - e^{-t/T_1} \]
Relaxation: Why?

\[ T_1 = [\text{spin-lattice}] \]

Fluctuating fields, motional of dipole exchange @ \( T_2 \)

100 ms to 5 sec

Paramagnetic agents can shorten it.

6H chelates (often used)

\[ T_2 = \text{all of both + spin-spin dephasing phenomenon} \]

After 90° flip \( (\rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow) \)

\(
\begin{align*}
&\text{a field of neighboring spins} \\
&\text{off resonant condition}
\end{align*}
\)

\( \text{spread in freq and phase at microseconds} \)

\( \text{dephasing} \) \( (\rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow) \)

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

$T_2 \sim$ largely independent of $B_0$

solid: $T_2 < 1 \text{ ms}$

liquid: $T_2 \approx T_1 \approx 3 \text{ s}$

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**Basic NMR experiment**

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

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**Problem:** How do we make an image??

RF sensitive to entire volume

$\begin{align*}
\mathbf{B}(0) & \sim (G_x \mathbf{x} + G_y \mathbf{y} + G_z \mathbf{z}) \cdot \hat{k} \\
G_x &= \frac{dB_z}{dx} \\
|G| &\leq 4 \text{ G/cm} \\
\text{hardware limit} &\leq 40 \text{ MT/m}
\end{align*}$
\[ B_z = B_0 + G_x x \]

\[ f(x) = \frac{g}{\text{dt}} (B_0 + G_x x) \]

\[ = f_0 + \left( \frac{g}{\text{dt}} G_x \right) x \]

**CW signal - temporal frequency maps to spatial position**

- **x**
  - object \( \Delta x = 2 \text{ cm} \)
  - \( G_x = 0.5 \text{ cm}^{-1} \)

\[ \Delta f = \frac{g}{\text{dt}} G_x \Delta x = \frac{1}{12} \text{ Hz} \]

\[ \left( 4.9 \pi^2 \frac{\text{sec}^2}{\text{cm}^2} \right) \left( 0.5 \text{ cm}^{-1} \right) \left( 20 \text{ cm} \right) \]

- \( f \) enable selective excitation
  - \( G_z \)

**envelope slice/ slab excitation**

- \( B_1 \) with an envelope

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2D imaging

1. Selectively excite a slice $B_1$, Gz
2. Record signals $r_{encode x y}$, Cx, Gy
3. Wait for relaxation

RF

Gz

Gy

Cx

DAQ

5-10 ms
1-3 ms

20 ms to 1 sec

288
286