Imaging Principles

M219 - Principles and Applications of MRI

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Course Overview

- 2023 course schedule
  - https://mrrl.ucla.edu/pages/m219_2023
- Assignments
  - Homework #2 is due on 2/15
- Office hours, Fridays 10-12pm
  - In-person (Ueberroth, 1417B)
  - Zoom is also available (https://uclahs.zoom.us/j/98066349714?pwd=cnVmV1J5QjR1d3I3cmJkQnVLSFZVZz09)

Combined B_0 and Gradient Fields

- Gradients contribute to the net B-field, but only along the z-direction

$$
\begin{aligned}
\vec{B}(\vec{r}, t) &= \left(B_0 + B_{G,z}\right)\vec{k} \\
&= \left(B_0 + \vec{G}(t) \cdot \vec{r}\right)\vec{k}
\end{aligned}
$$

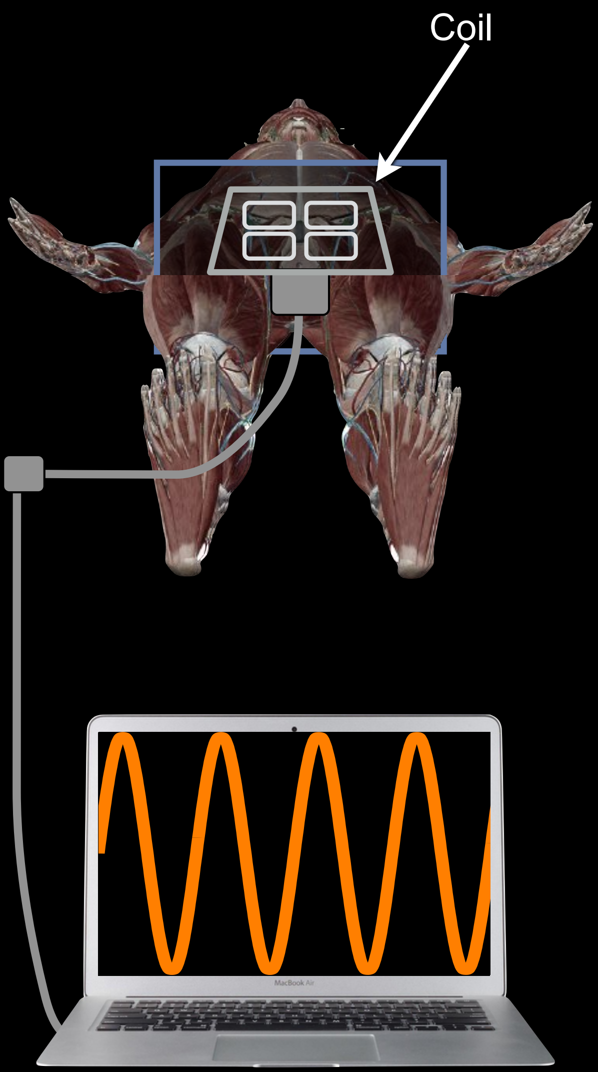
B-Field Assumptions in MRI

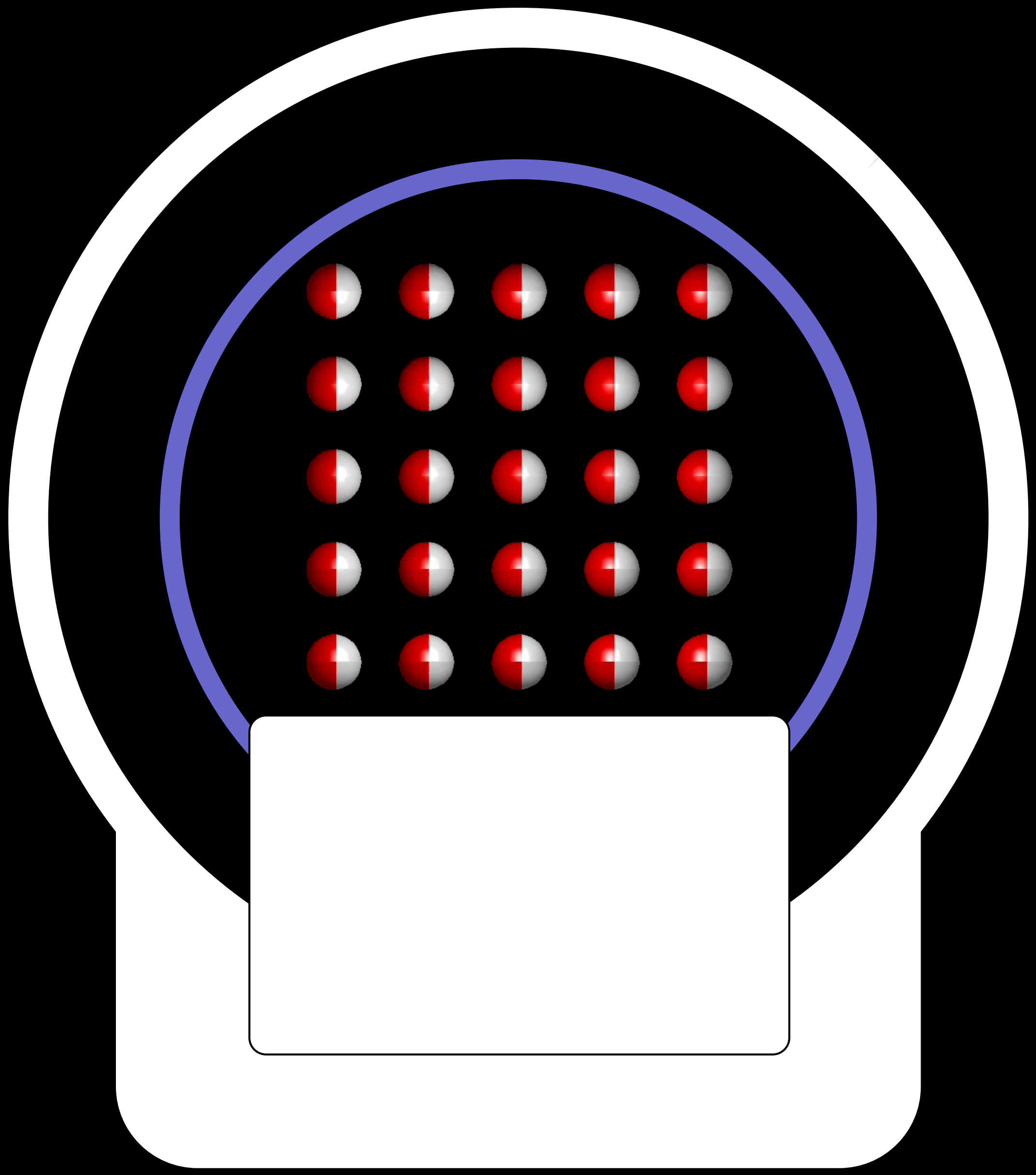
- **B_0-field is:**
  - Perfectly uniform over space.
    - "B_0 homogeneity"
  - Perfectly stable with time.
- **B_1-field is:**
  - Perfectly uniform over space.
    - "B_1 homogeneity"
  - Temporally modulated exactly as specified.
- **Gradient Fields are:**
  - Perfectly linear over space.
    - "Gradient linearity"
  - Temporally modulated exactly as specified

To the Board

How do we measure M_{xy}?

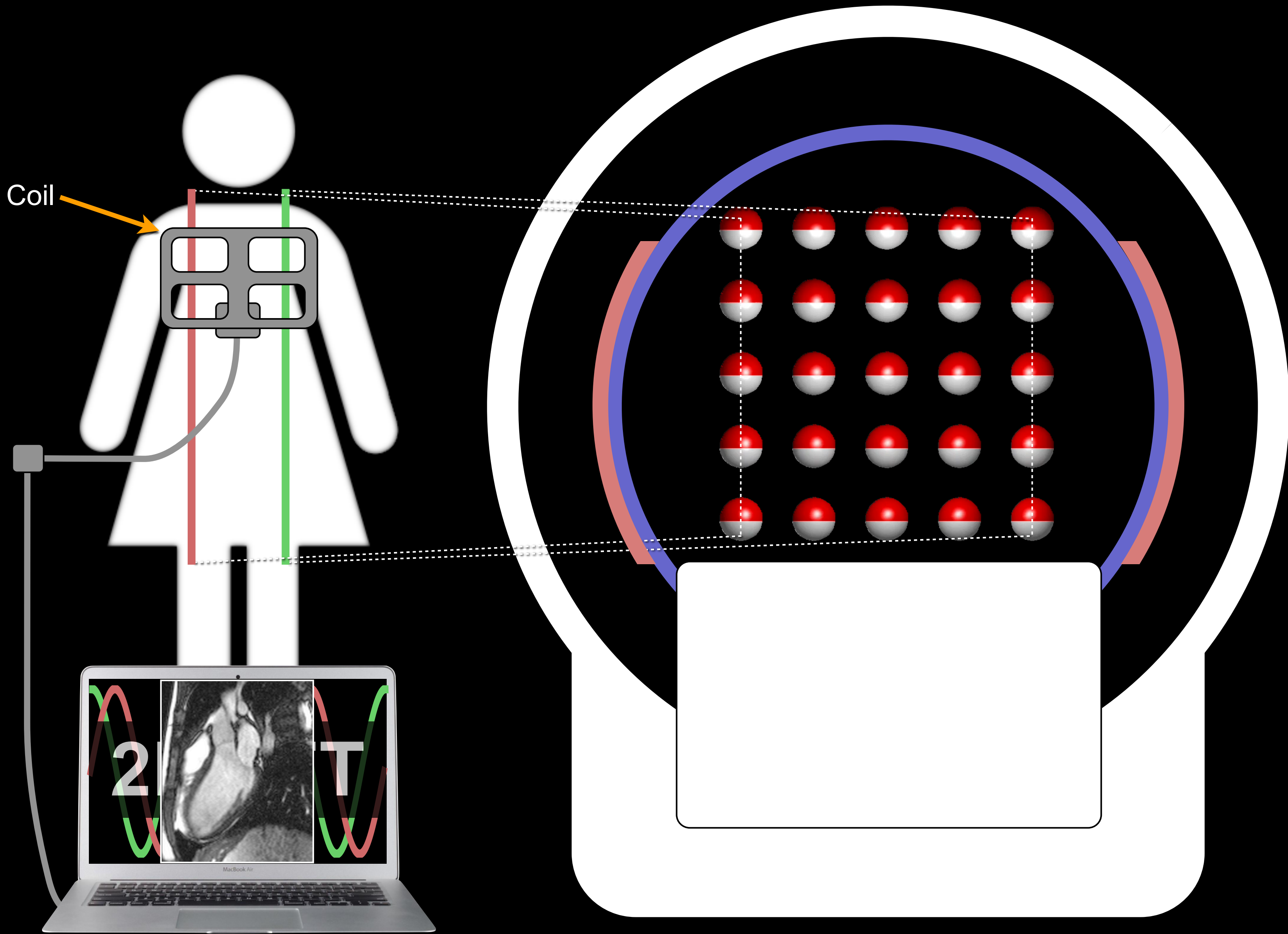
Faraday's Law of Induction





Precessing spins *induce* a current in a nearby coil.

Faraday's Law of Induction



The trick is to encode spatial information and image contrast in the echo.

Basic Detection Principles

Magnetic Flux Through The Coil – *Reciprocity*

$$\Phi\left(t\right) = \int_{object} \vec{B}_r\left(\vec{r}\right) \cdot \vec{M}\left(\vec{r}, t\right) d\vec{r}$$

Eqn. 5.38

↑ Magnetic Flux ($\Phi(t)$)

↑ Coil Sensitivity ($\vec{B}_r(\vec{r})$)

↑ Bulk Magnetization ($\vec{M}(\vec{r},t)$)

What happens if the coil has poor sensitivity?

What happens if the coil's sensitivity is perpendicular to the bulk magnetization? How would that happen?

Basic Detection Principles

We get here

$$S(t) = \int_{\text{object}} M_{xy}(\mathbf{r}, 0) e^{-i\gamma \Delta B(\mathbf{r}) t} d\mathbf{r}$$

From Here

$$V(t) = -\frac{\partial \Phi(t)}{\partial t} = -\frac{\partial}{\partial t} \int_{object} \vec{B}(\vec{r}) \cdot \vec{M}(\vec{r}, t)\, d\vec{r}$$

with 25 pages of Math!

Basic Detection Principles

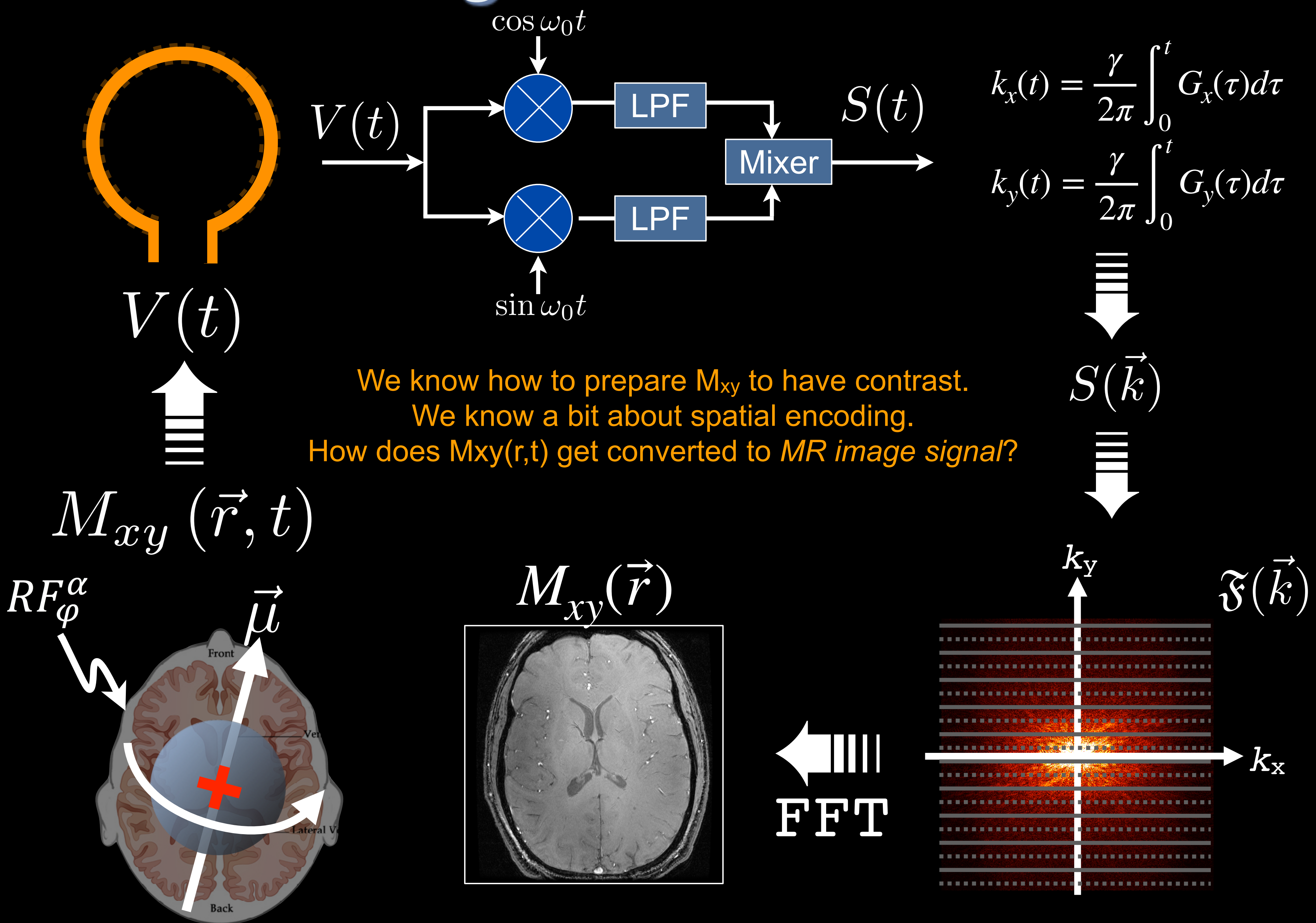
$$S(t) = \int_{\text{object}} M_{xy}(\mathbf{r},0)e^{-i\gamma\Delta B(\mathbf{r})t}d\mathbf{r}$$

Observations

Detected signal is the vector sum of all transverse magnetizations in the “rotating frame” within the imaging volume.

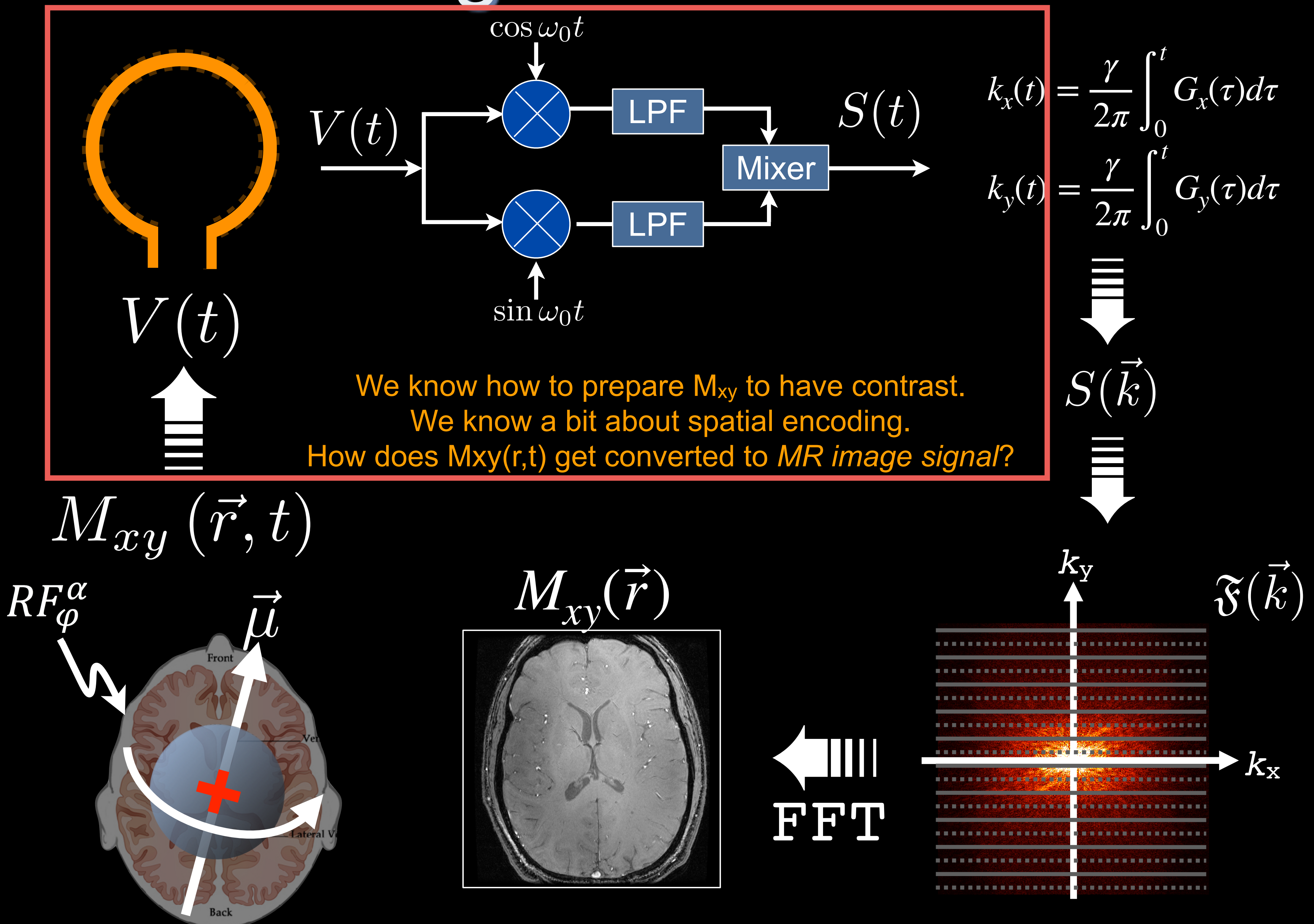
The Larmor frequency precession (Lab frame rotation) is necessary for detection, although only the baseband signal matters for imaging

Signals in MRI



We know how to prepare M_{xy} to have contrast.
We know a bit about spatial encoding.
How does Mxy(r,t) get converted to *MR image signal*?

Signals in MRI



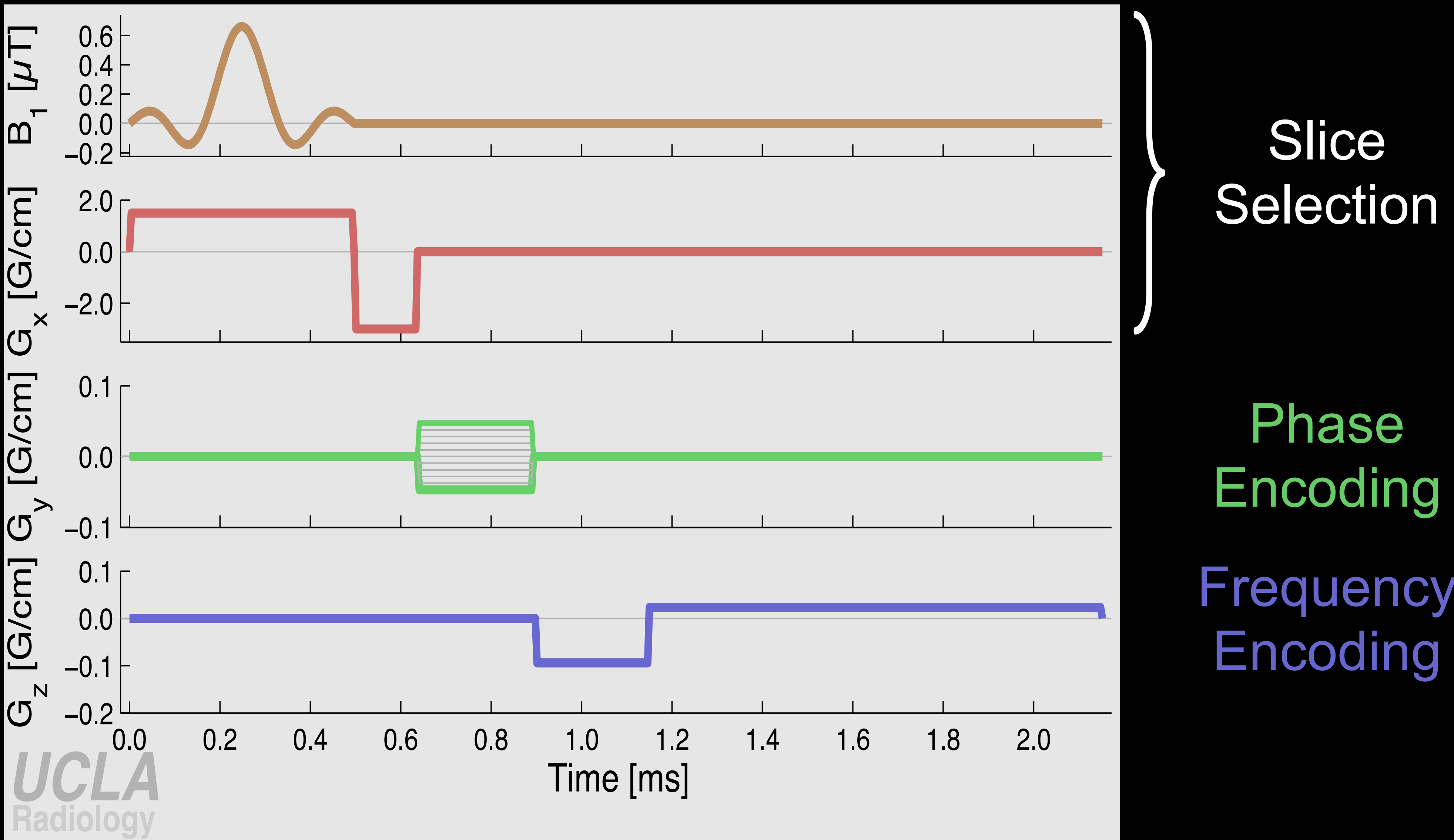
To the Board

Spatial Localization

Spatial Encoding

- **Three key steps:**
  - **Slice selection**
    - You have to pick slice!
  - **Phase Encoding**
    - You have to encode 1 of 2 dimensions within the slice.
  - **Frequency Encoding (aka *readout*)**
    - You have to encode the other dimension within the slice.

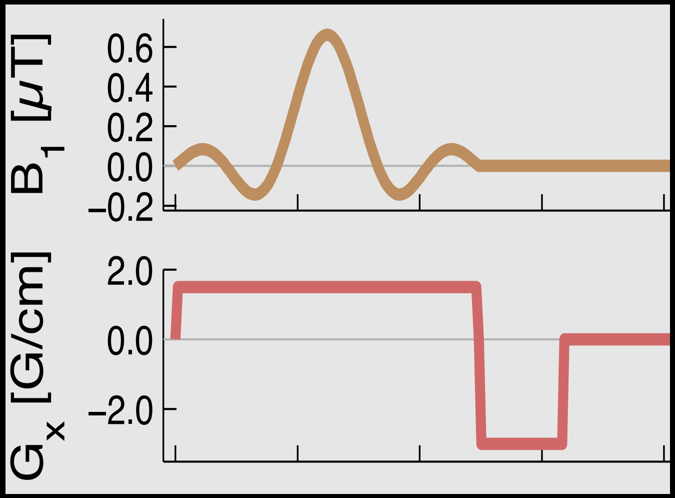
3 Steps for Spatial Localization



Pulse Sequence Diagram - Timing diagram of the RF and gradient events that comprise an MRI pulse sequence.

Slice Selection

- Consists of:
  - RF (B_1) Pulse
    - Contains frequencies matched to slice of interest
  - Slice selection gradient
    - Constant magnitude
  - Slice re-phasing gradient
    - Increases SNR
    - Re-phases spins within slice
    - AKA “slice refocusing gradient”



- Permits exciting the slice of interest.

Questions?

- Related reading materials
  - Nishimura - Chap 5

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