Pulse Programming Bootcamp
Day 3: Corrections and Compensations

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Pulse Programming Bootcamp 2005

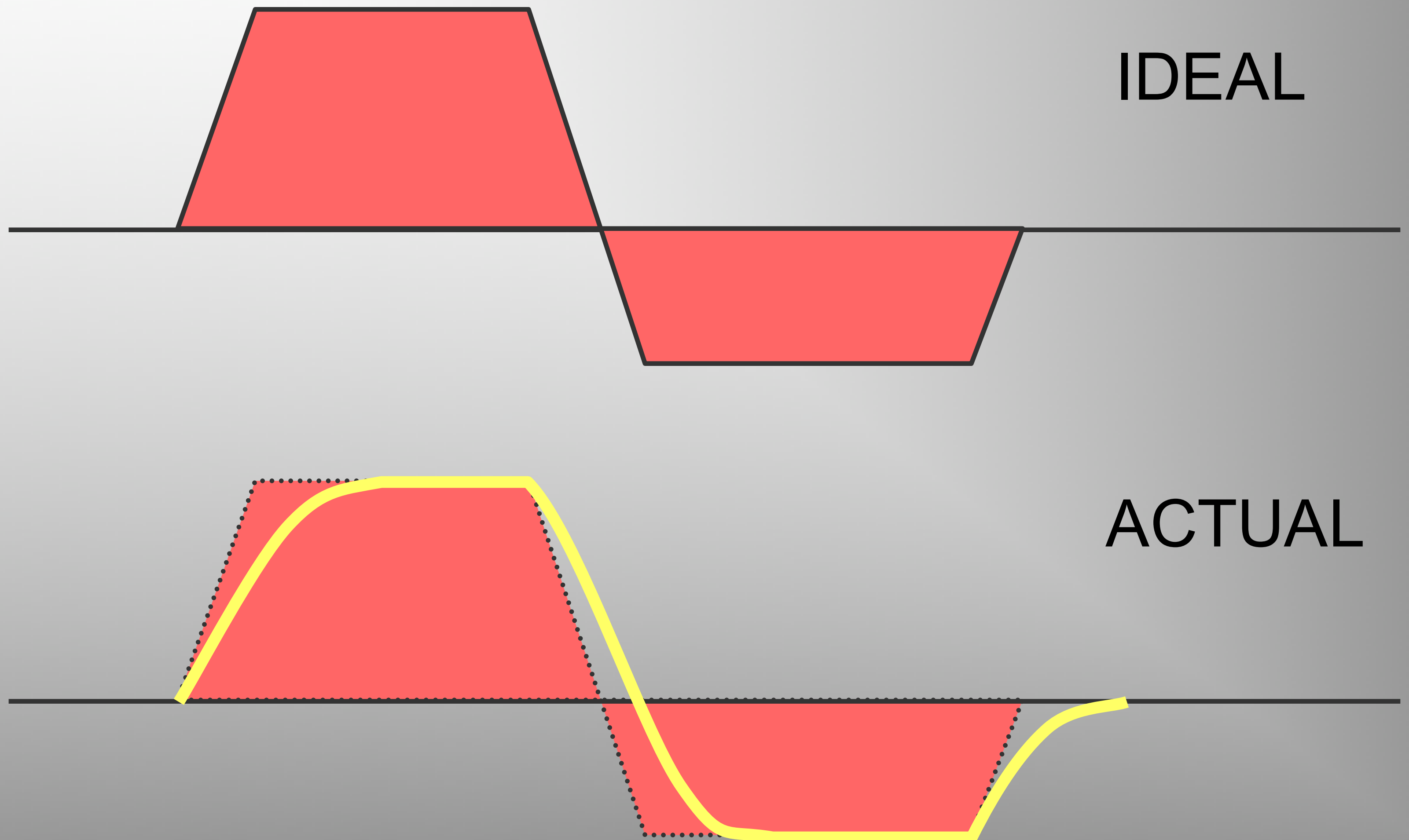
Caltech Brain Imaging Center

California Institute of Technology

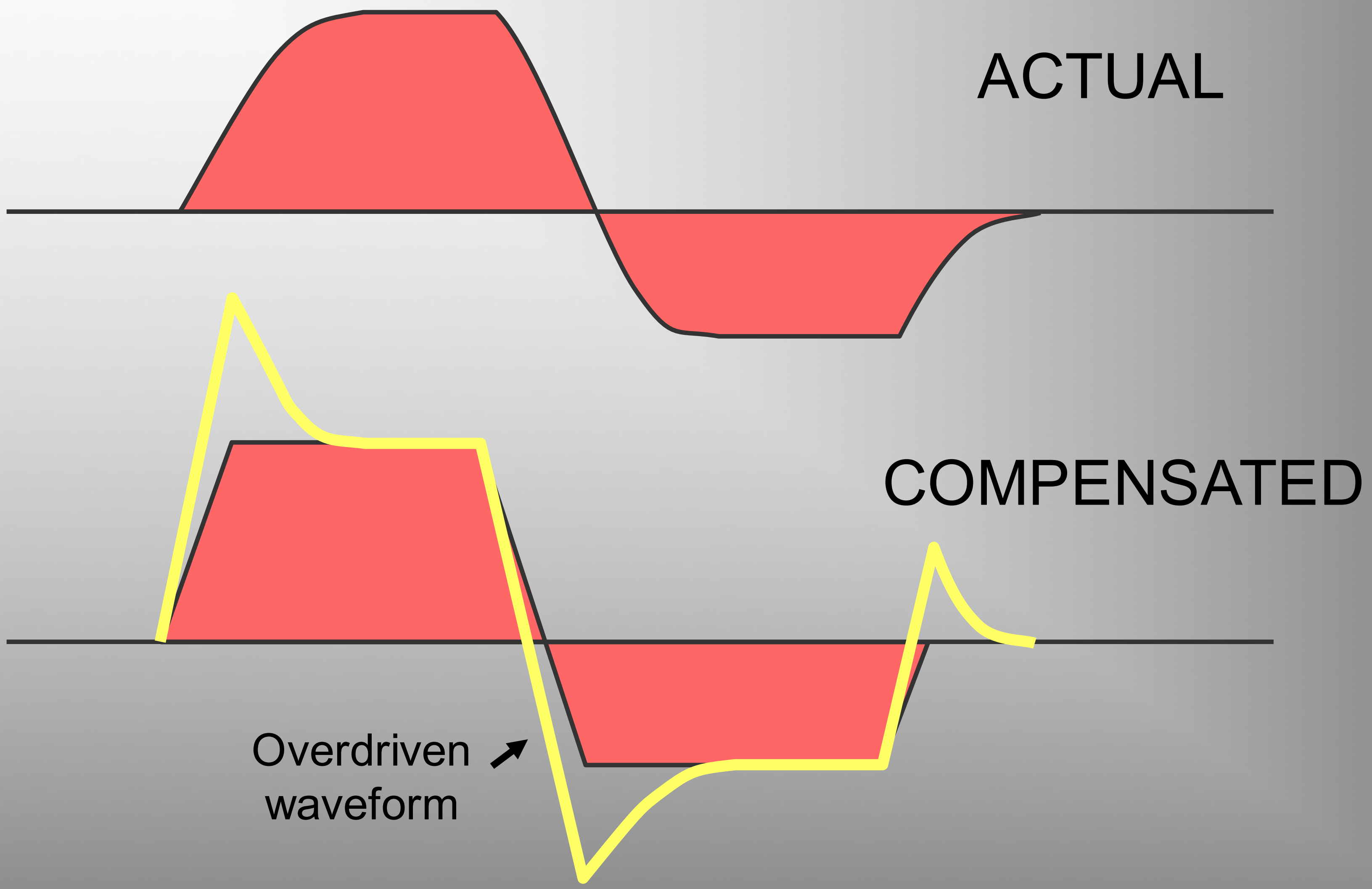
Ideal vs Actual Waveforms

Superconducting Magnet Cross-section

Gradient Eddy Currents



Eddy Current Compensation



Spatial Saturation

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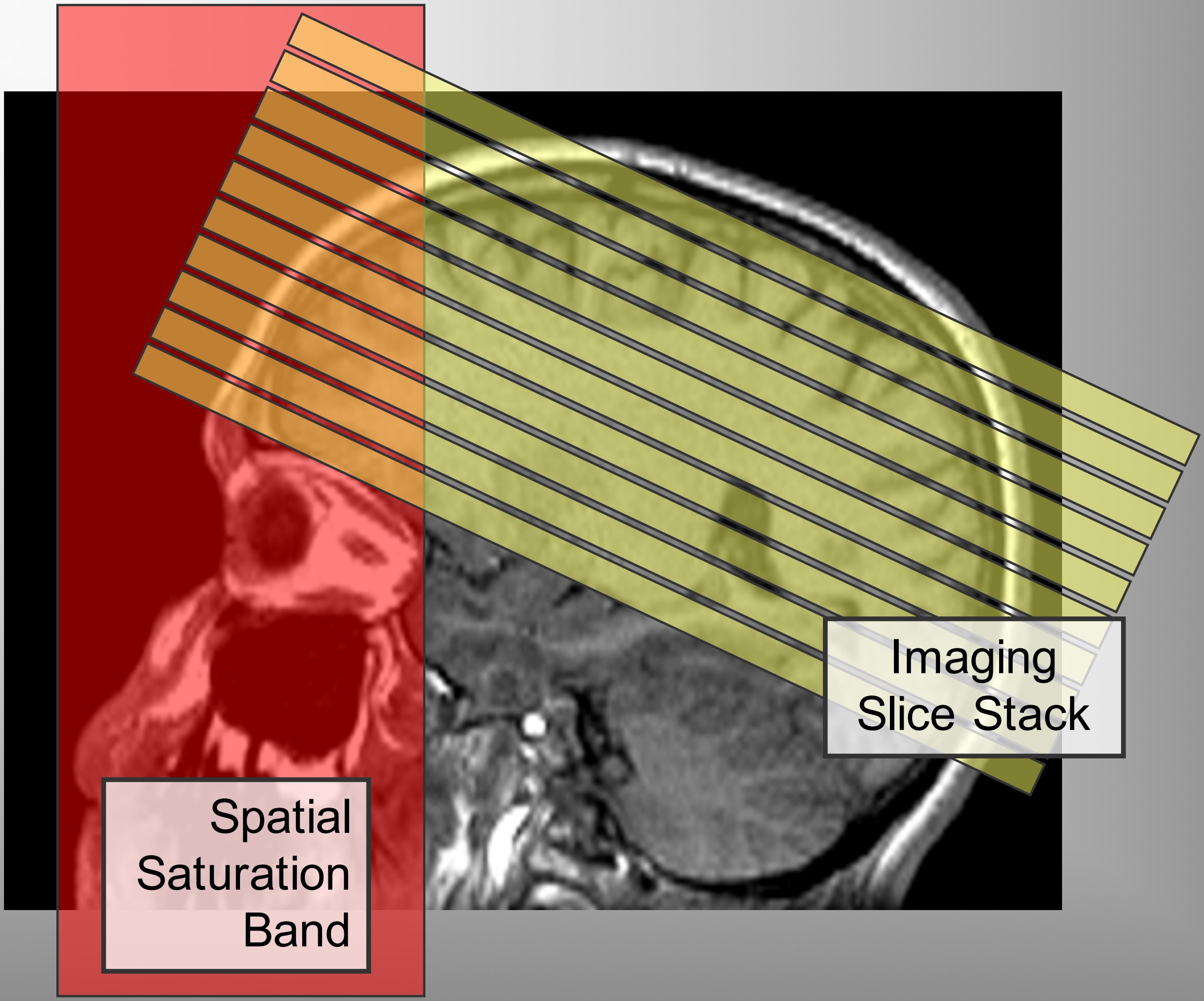
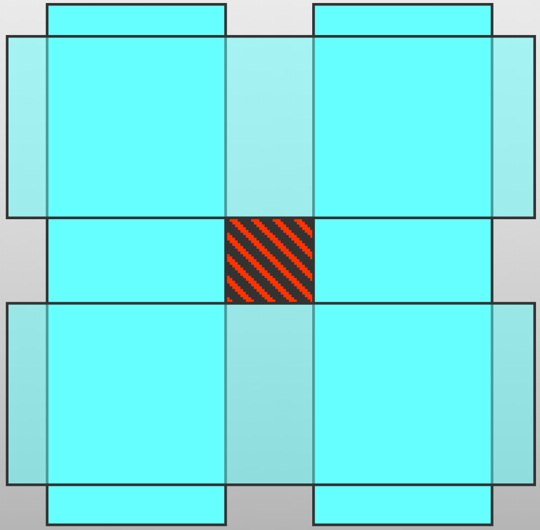
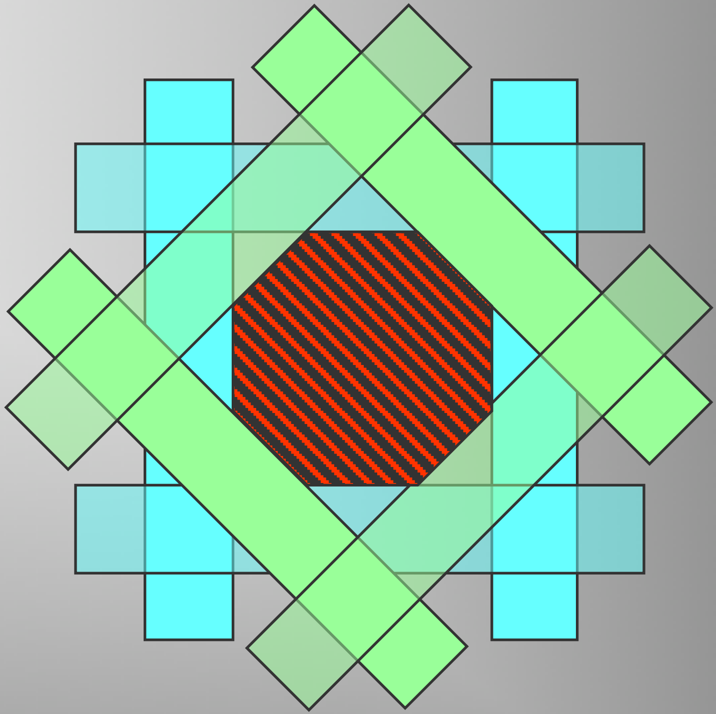


Outer Volume Suppression

Parallel saturation bands further suppress signal from outside of selected volume

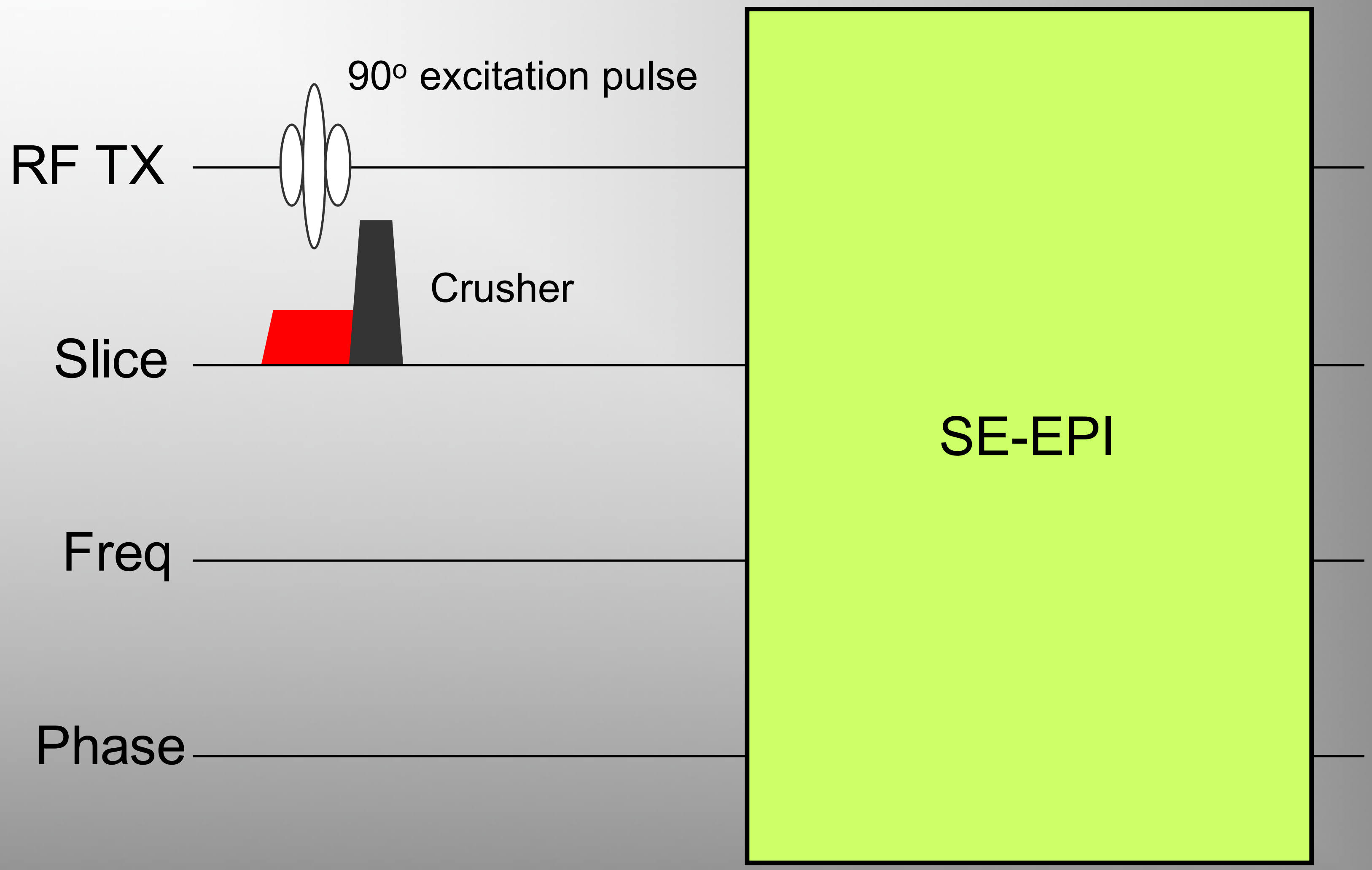


Single voxel OVS



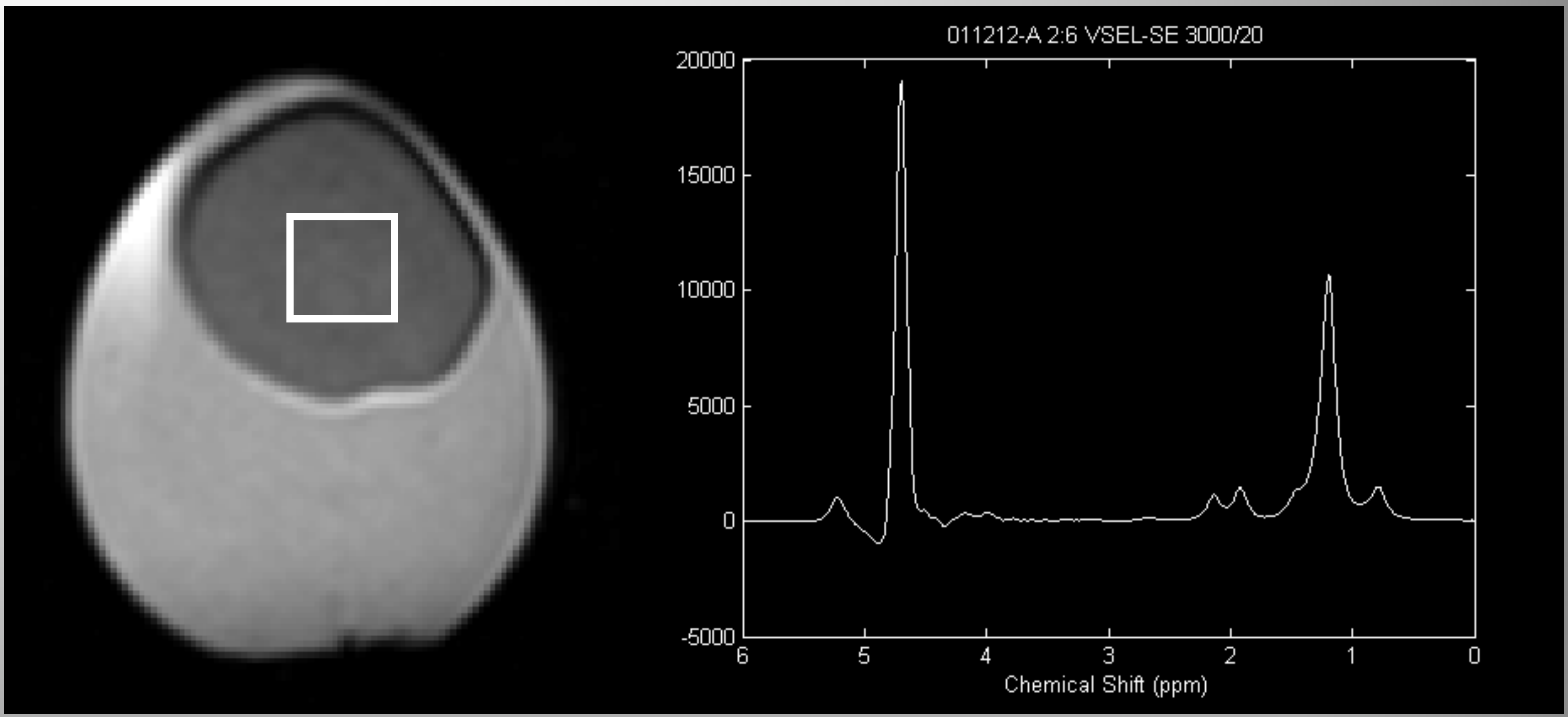
Scalp fat suppression pattern for CSI

Spatial Saturation Sequence



Chemical Shift Saturation

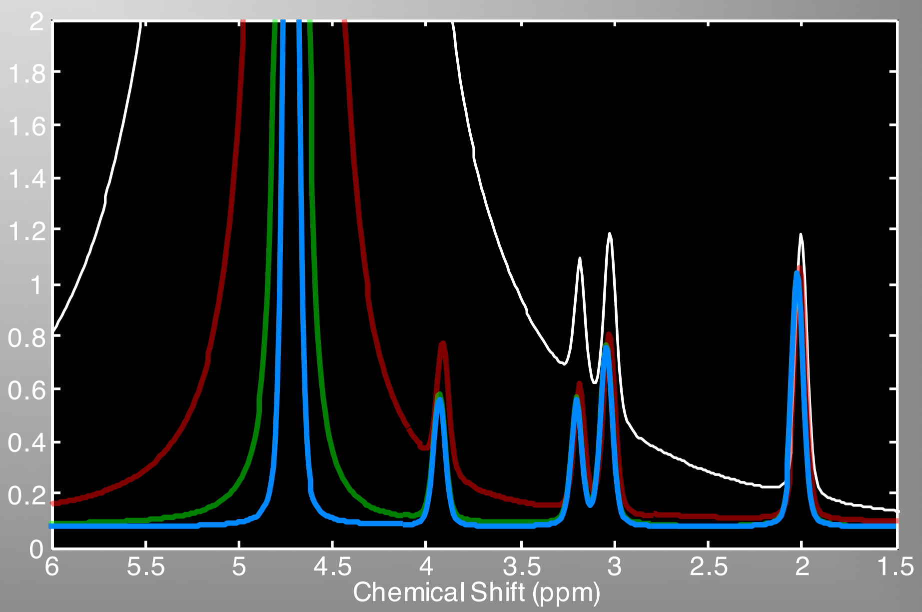
Quail Egg Yolk ^1H Spectrum



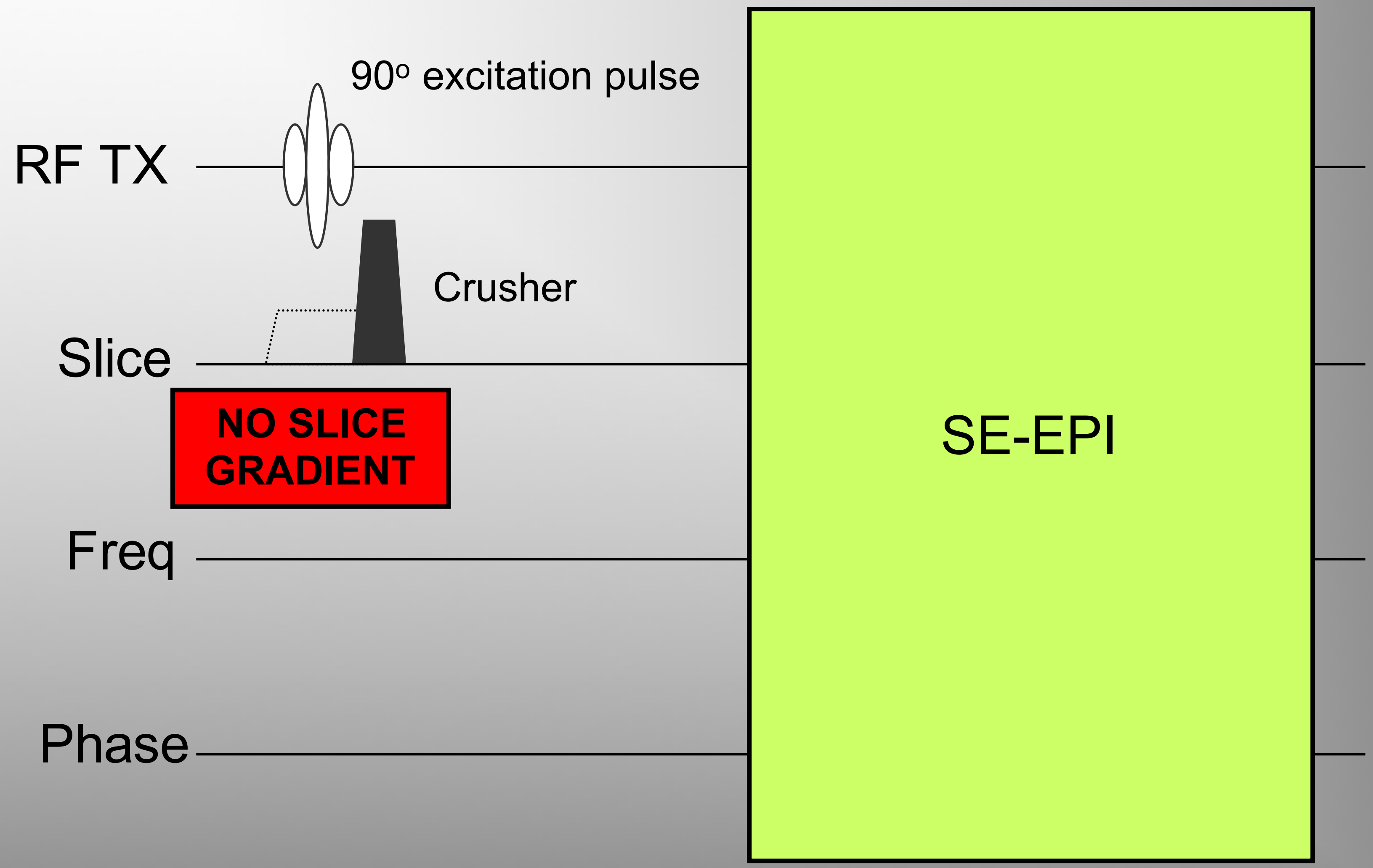
Voxel Dimensions : 5mm x 5mm x 5mm

CHESS Water Suppression

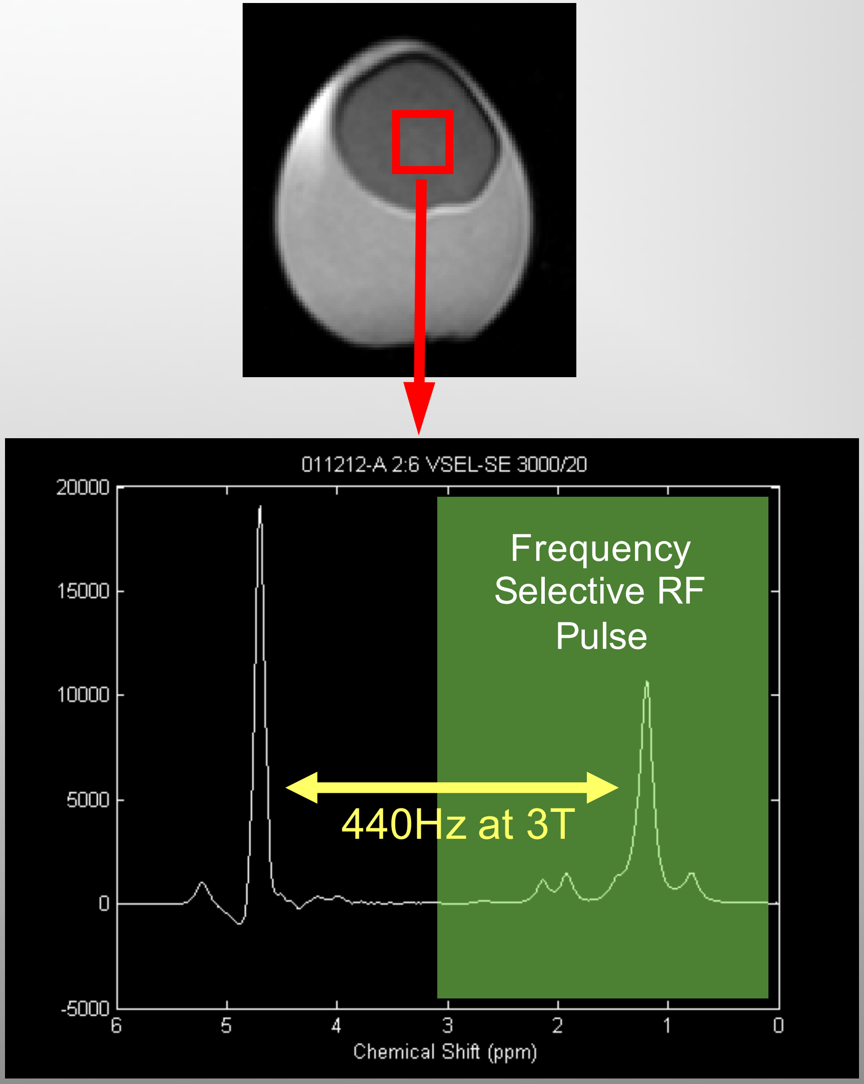
Narrow frequency band centered on water is repeatedly excited and spoiled. In this example suppression ratio is 90%/pulse (99.9% suppression after three pulses).

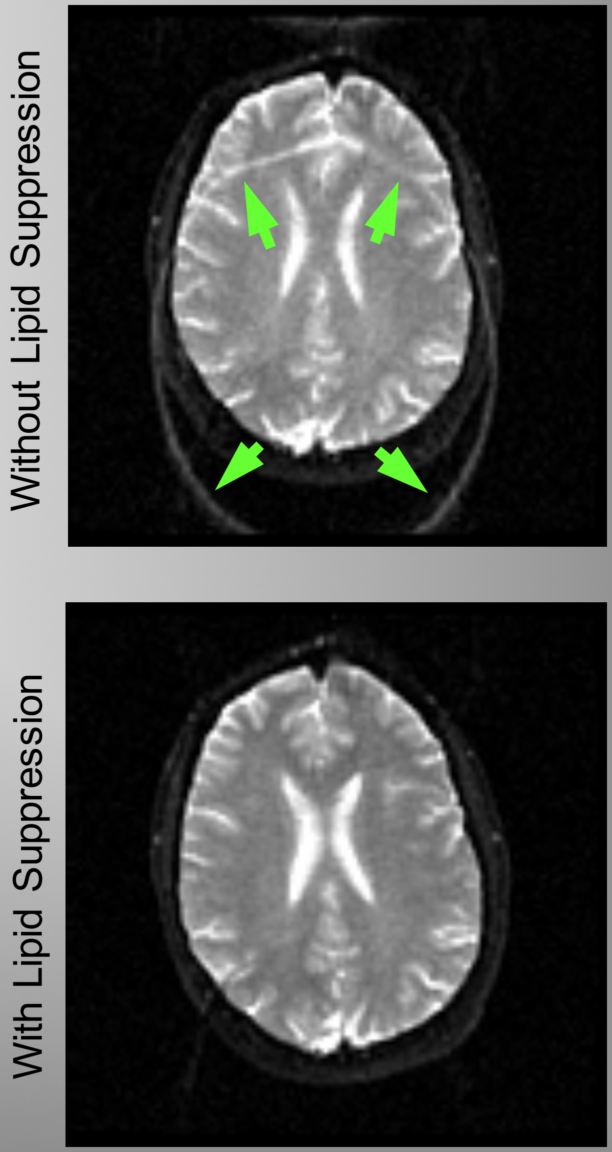


Chemical Shift Saturation Sequence

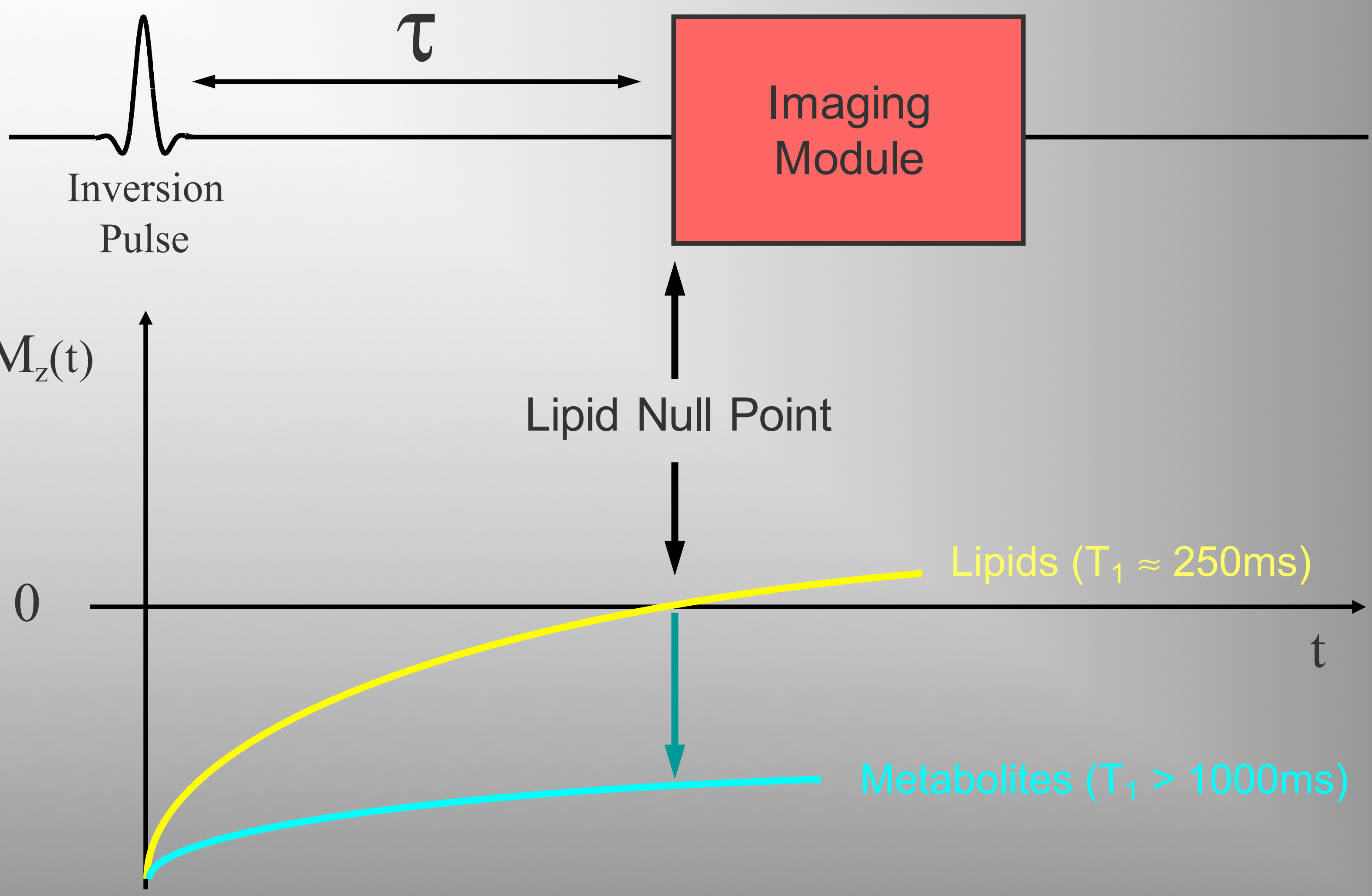


Lipid Suppression



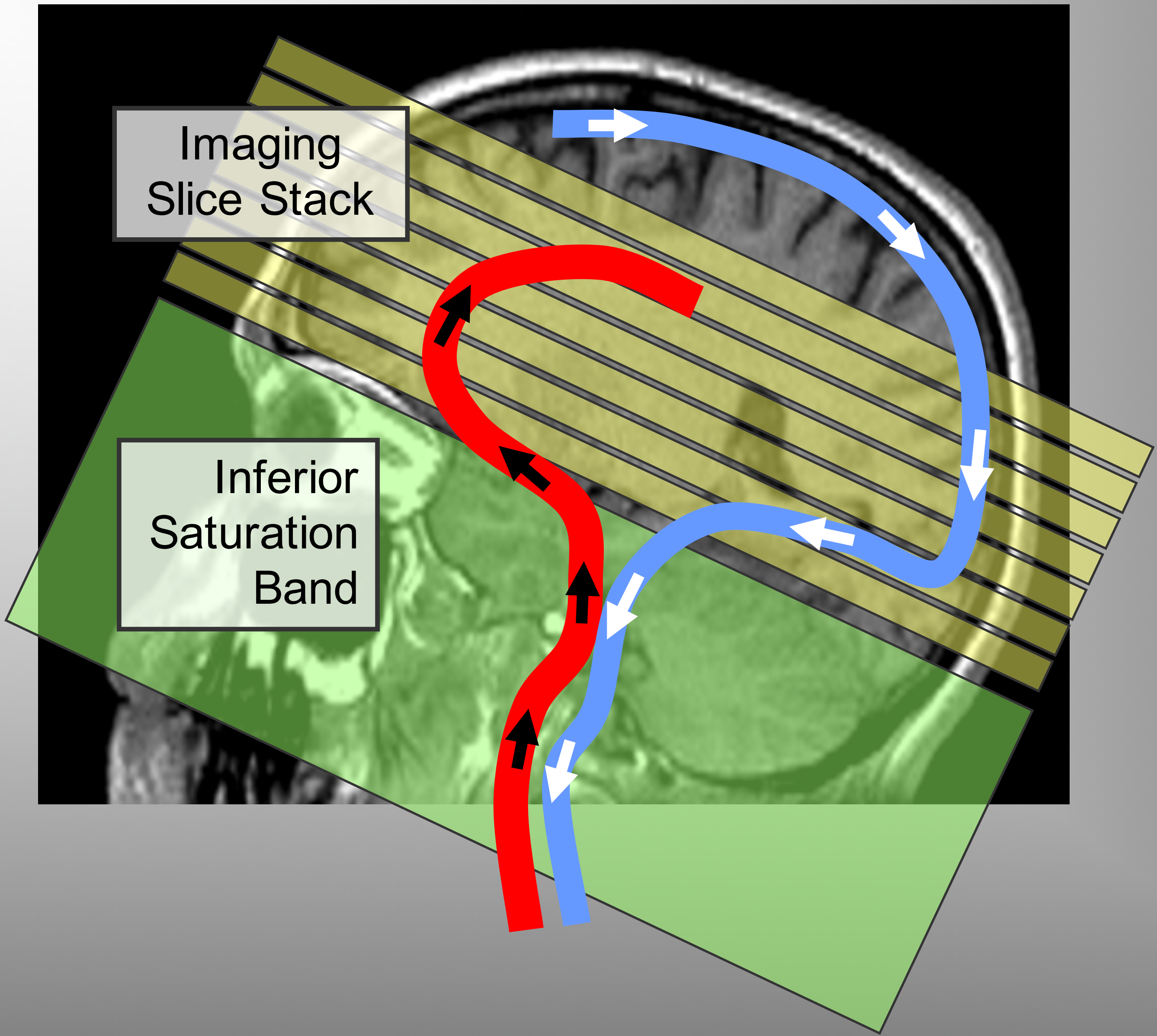


Short Tau Inversion Recovery (STIR)



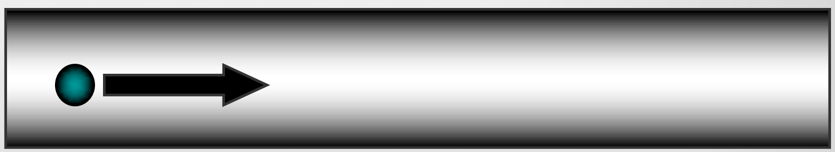
Flow Supression and Compensation

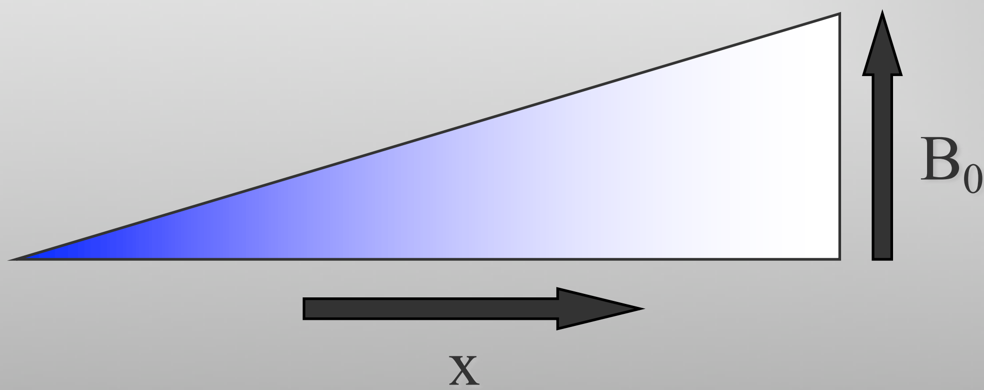
Inflow Saturation



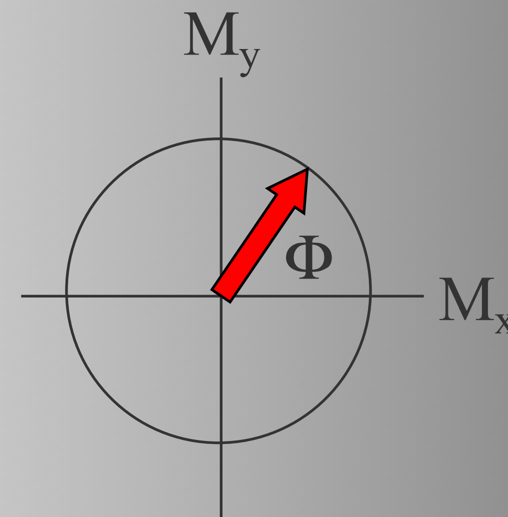
Motion in a Gradient

Constant fluid velocity in x





Constant field gradient in x



$$\Phi(T) = \gamma \int_0^T dt\, G(t)\, x(t)$$

$$= \gamma \int_0^T dt\, G v t$$

$$= \frac{1}{2} \gamma G v T^2$$

Principle of Moments

Expand position as a Maclaurin series:

$$x(t) = x(0) + x'(0)t + \frac{1}{2!}x''(0)t^2 + \ldots \frac{1}{n!}x^{(n)}(0)t^n + \ldots$$

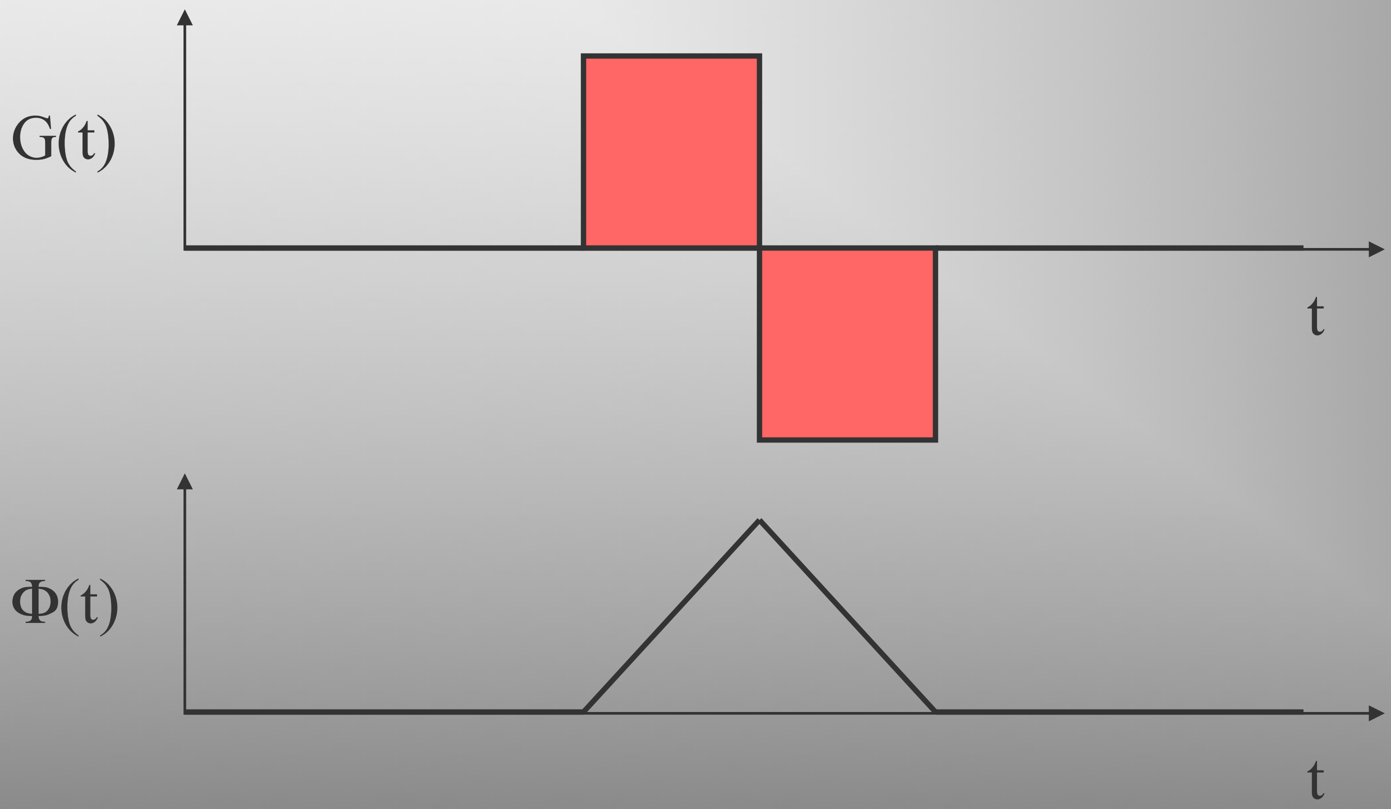
Substitute into phase equation:

$$\begin{aligned}
\Phi(T) &= \gamma \int_0^T dt G(t) x(t) \\
&= \gamma \left[x(0) \int_0^T dt G(t) + x''(0) \int_0^T dt G(t) t + x'''(0) \int_0^T dt G(t) t^2 + \ldots \right] \\
&= \gamma \left[x(0) m_0(T) + v(0) m_1(T) + a(0) m_2(T) + \ldots \right]
\end{aligned}$$

Where m_n is the n^{th} gradient moment.

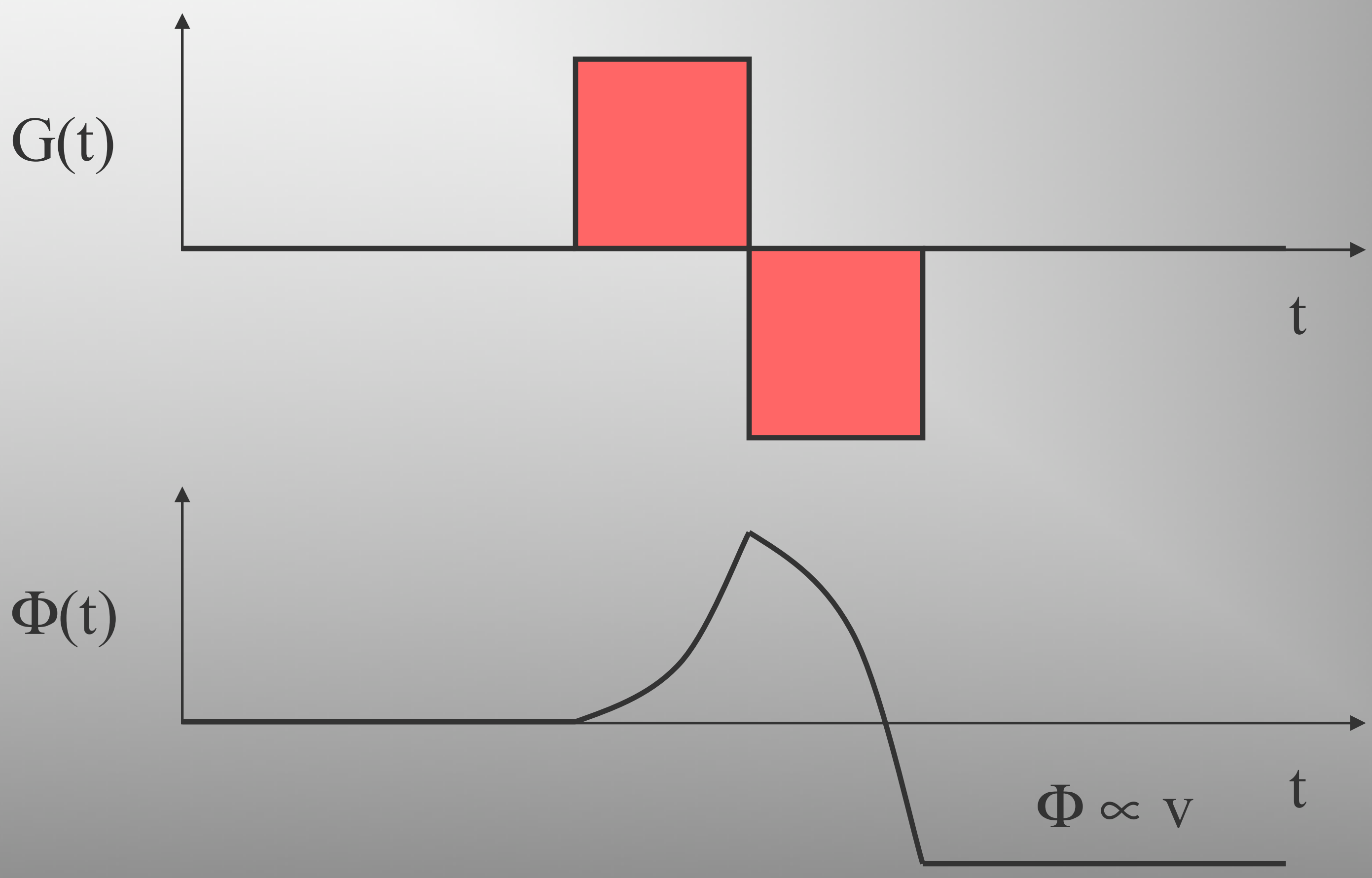
0^{th} Moment

- Area of gradient in pulse sequence diagram.
- Phase evolution of stationary spin.



1st Moment

- Phase evolution of spin with constant velocity.

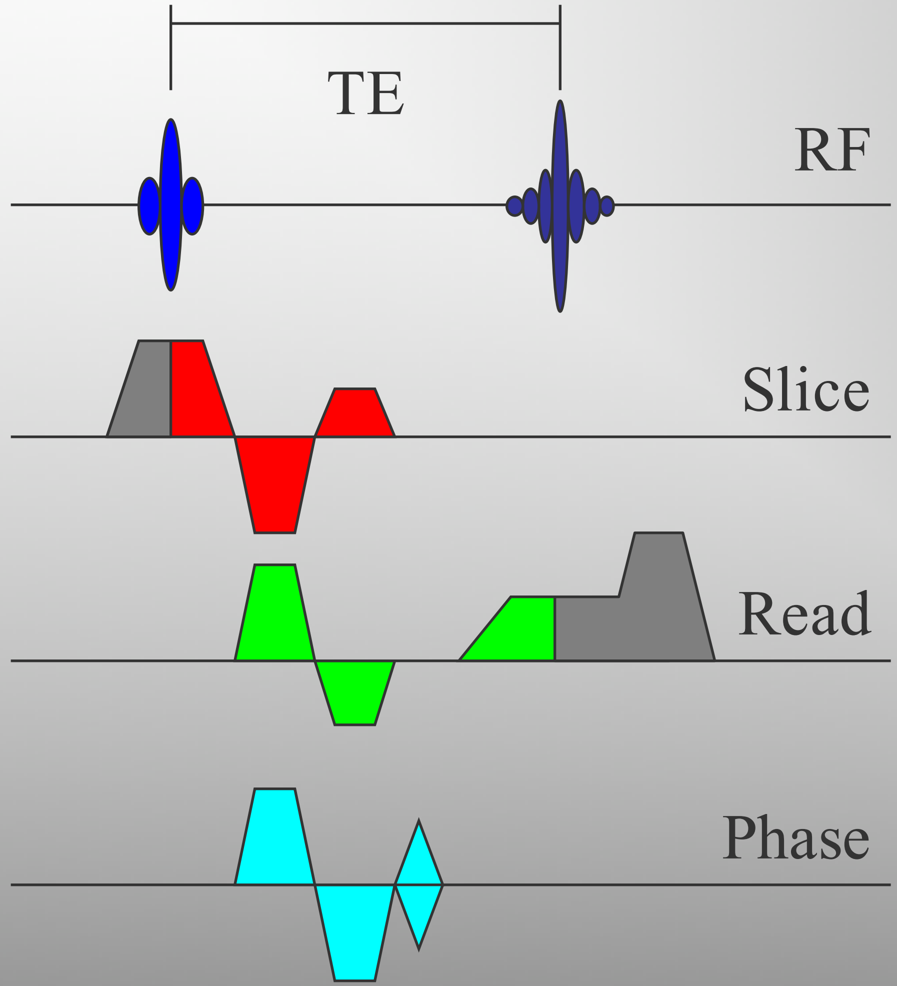


Motion Artifacts

CSF Pulsation Artifact

1. Which is the phase encoding direction?
2. How are the ghosts generated?
3. How can we eliminate this artifact?

Flow Encoding



Two degrees of freedom required to solve linear equations for gradient amplitudes and timings:

$$m_0(TE) = 0$$

$$m_1(TE) = \pi/(\gamma v_{enc})$$

Flow Compensation

- Special case of flow encoding:
- $v_{enc} = \infty$.
- $m_0(TE) = 0$
- $m_1(TE) = 0$

Gradient Calculation for Flow Compensation