Rad229 – MRI Signals and Sequences

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Lecture-14A — Magnetization Preparation

Magnetization Preparation and Fat Suppression

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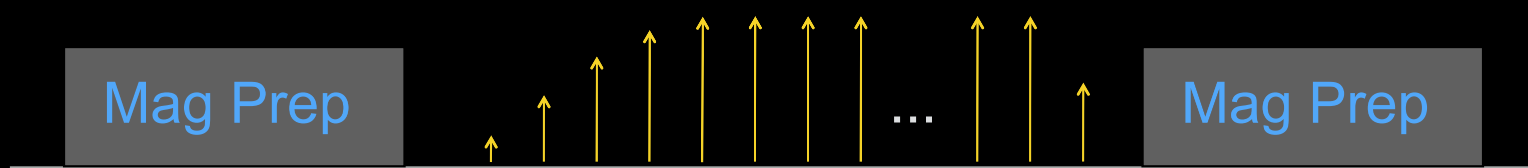
Learning Objectives

- Explain the role of magnetization preparation
- Draw a sequence showing the mag-prep and acquisition blocks
- Compare how different acquisition blocks fit with mag-prep
- Explain and compare saturation and inversion for nulling
- Justify why fat-suppression is used and describe three approaches to fat suppression

Magnetization Preparation Sequences

- Acquisition method may not give desired contrast
- “Prep” block adds contrast (and/or encoding)
  - MP-RAGE = Magnetization prepared rapid acquisition with gradient echo (Mugler, ~1990)
  - Inversion-recovery (IR) prep for T_1 contrast
  - Fat saturation
  - T_2-preparation
  - Diffusion-weighted imaging

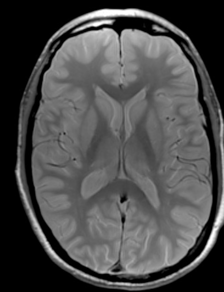


Acquisition Sequence

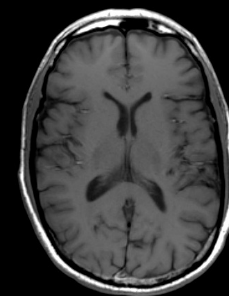
Magnetization preparation alters the contrast of an acquisition sequence

Basic Contrast of Sequences

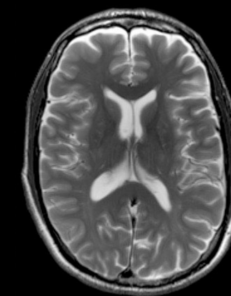
- Spin Echo
  - PD, T1, T2
- Gradient Echo
  - bSSFP, Gradient-Spoiled, RF-spoiled
- Magnetization Prepared:
  - Additional or improved contrasts
  - 3D imaging
  - Improved efficiency



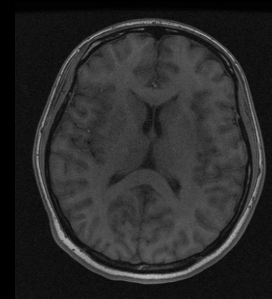
PD-weighted



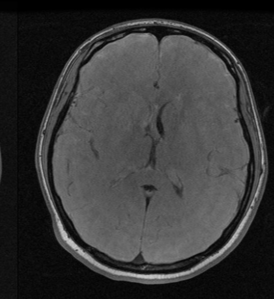
T_1-weighted



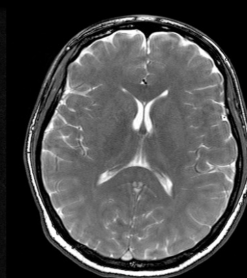
T_2-weighted



RF-Spoiled
T_1-weighted



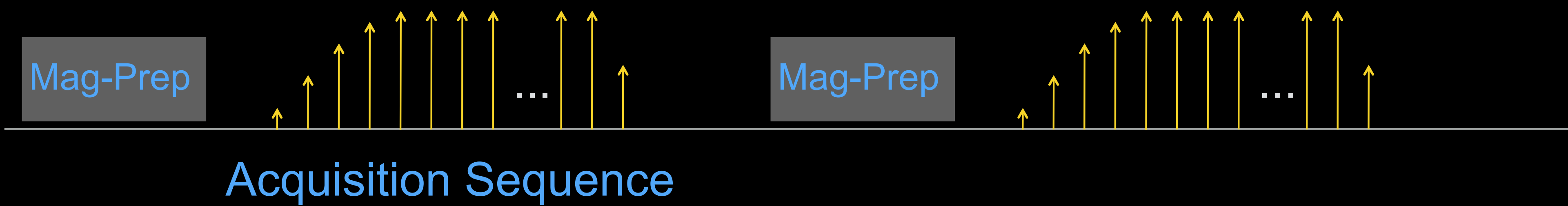
Gradient-
Spoiled



Balanced
T_2/T_1 Weighted

Common sequences have certain contrasts with some limitations

Mag-Prep Sequences: General Considerations

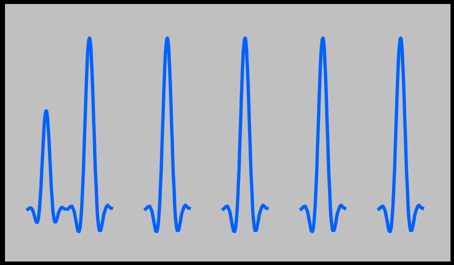


- Mag-Prep frequency (contrast vs efficiency)
- Acquisition block length (contrast wears off vs efficiency)
- Transitions/Transients? Necessary to avoid artifacts
- Mag-Prep for one slice or many slices?

Magnetization preparation alters the contrast of an acquisition sequence

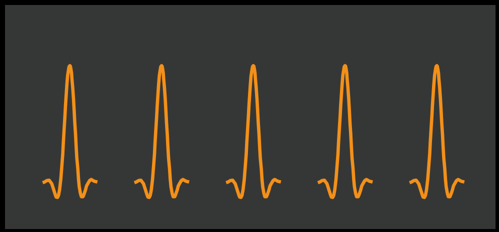
Common "Acquisition" Sequences

- Consider readout robustness, efficiency, RF power
- Consider transitions and signal recovery



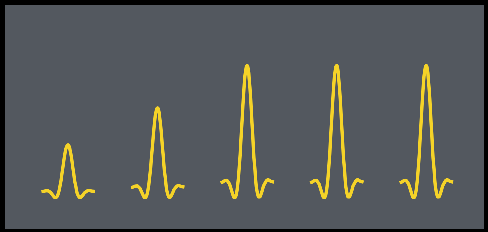
Spin-echo Train:

+ Robust to B_0
+ Simple transition
+ No recovering "leakage"
= Moderately time efficient
= Good signal efficiency
- High RF Power



Gradient or RF-Spoiled

+ Robust to B_0
- Some oscillation
- Some recovery / contrast loss
+ Time Efficient
= Moderate signal efficiency
+ Low RF Power



Balanced SSFP

- Sensitive to B_0
- Transient Oscillation
- Some recovery / contrast loss
+ Time Efficient
+ Signal Efficient
= Moderate RF Power

Different acquisition sequences have numerous characteristics to consider when combining with magetization preparation

Saturation or Inversion Nulling

- Eliminate the signal from something
  - Chemical species (fat suppression, water suppression)
  - Regions of image
- Advantages
  - Minimal cost (example, can do short TE)
  - Increase dynamic range for desired signal
  - Reduce artifacts from suppressed signal
- Disadvantages
  - Exciting unwanted signal - it can come back!
  - Disturb/reduce the desired signal

Saturation or nulling preparations excite unwanted signal to zero-out Mz prior to imaging

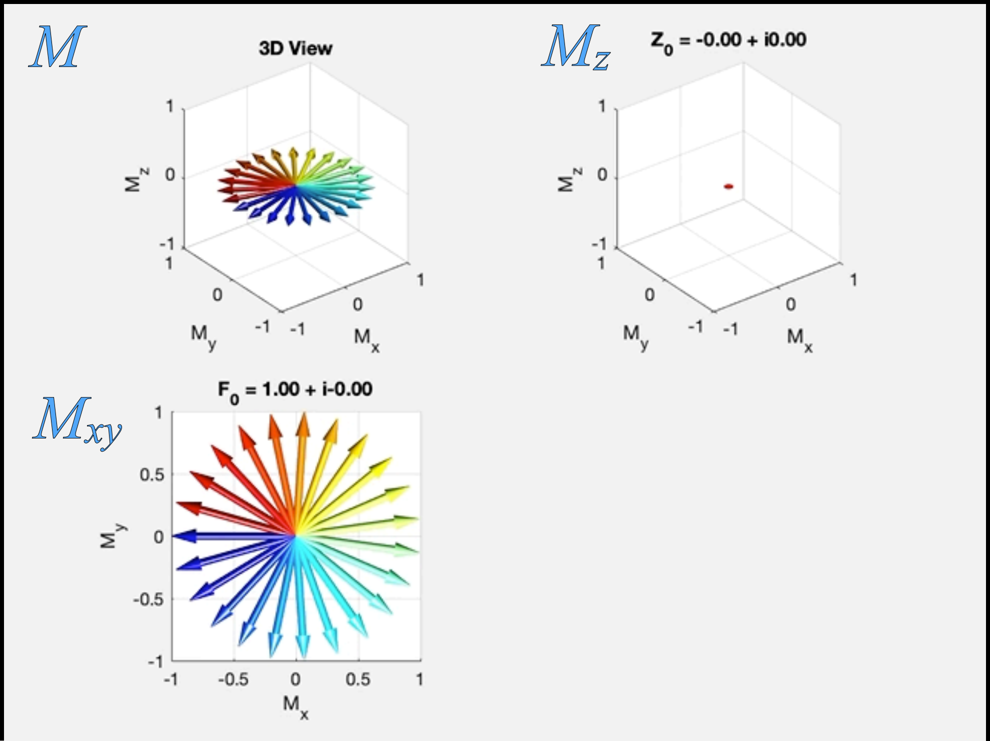
Saturation vs Inversion Nulling

- Saturation: tip ~90° followed by dephasing
  - Aims to leave M_z=0 for all T_1
  - ΔB_0 or ΔB_1^+ leaves non-zero M_z
  - Often spatially or spectrally selective
- Inversion: tip 180°, wait for null-point (M_z=0)
  - Selective based on T_1
  - Adiabatic improves ΔB_1^+ robustness
  - May be frequency/spatially selective
- Combination: Often used!

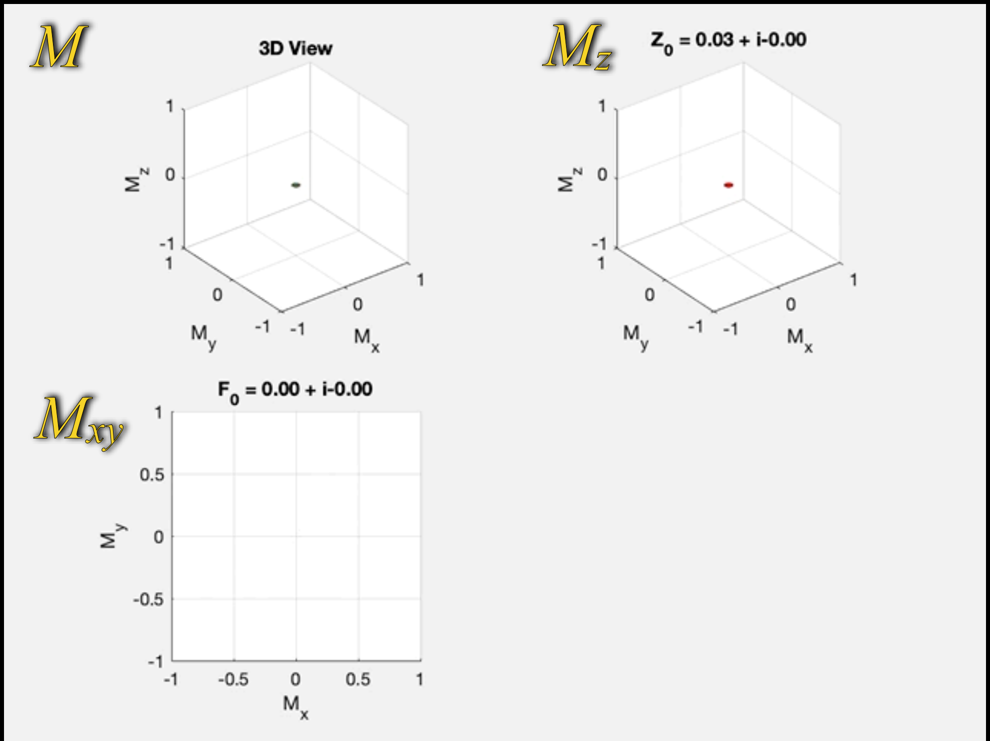
Saturation and Inversion pulses both aim to null M_z

Saturation vs Inversion Nulling: Dynamics

Saturation: tip ~90° followed by dephasing



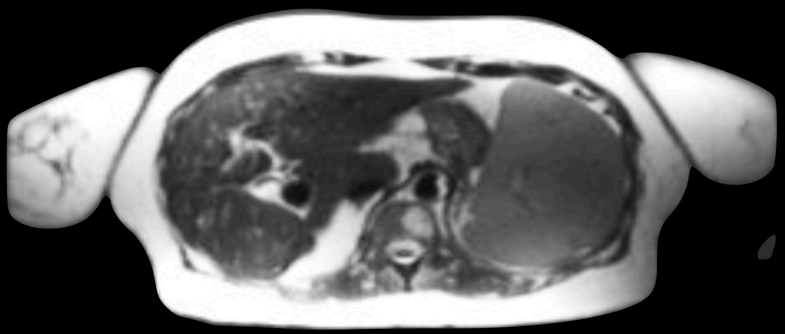
Inversion: tip 180°, wait for null-point (M_z=0)

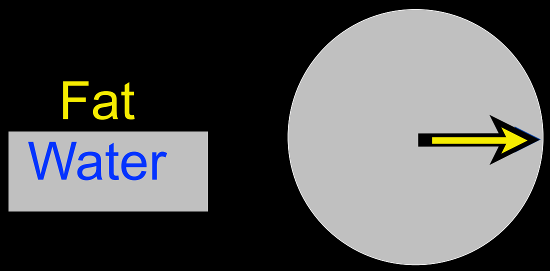


Saturation and Inversion pulses both aim to null M_z lec14_01.m and lec14_02.m

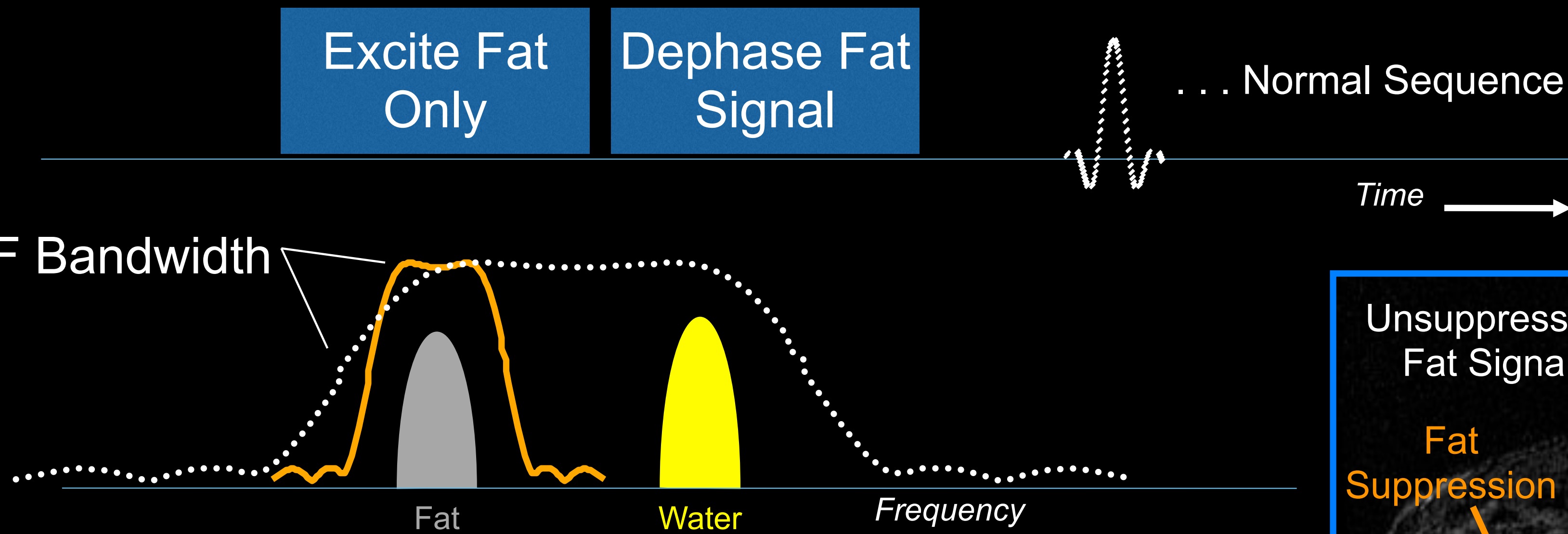
Fat in Magnetic Resonance

- Very prominent (subcutaneous, visceral, bone marrow, etc)
- Short T_1, about 250-400ms at 1.5T to 3T
- Moderate T_2, about 80ms
- Spectra:
  - Mostly -3.5ppm (mechanism)
  - Multiple peaks, including ~10% at water

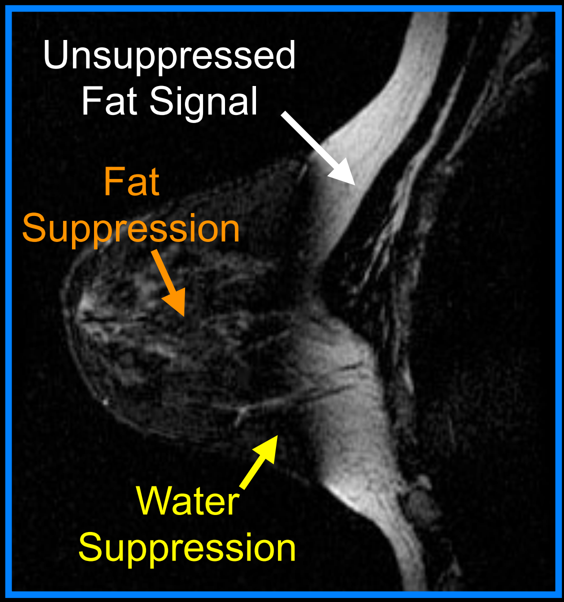




Fat Saturation

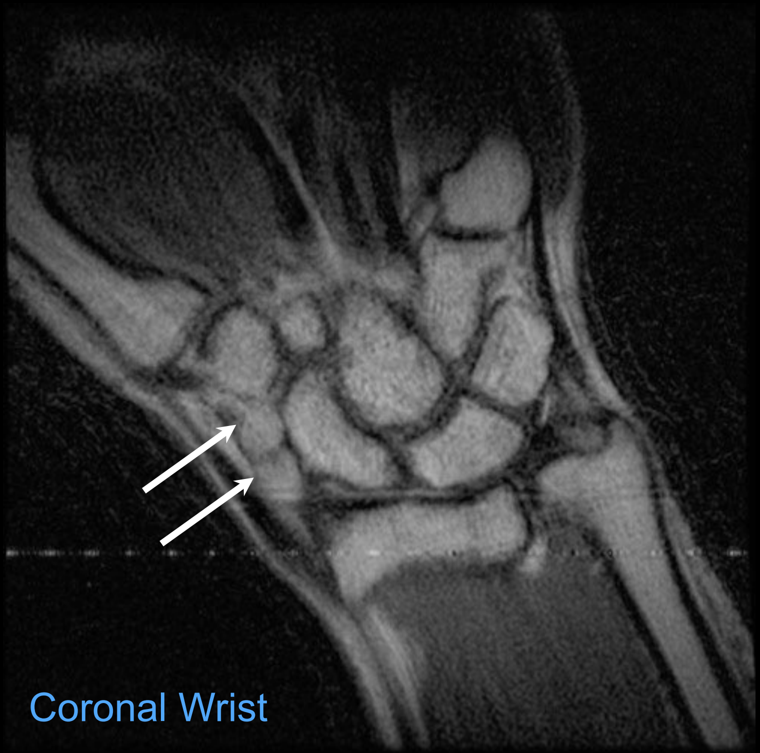


- Chemically-selective excitation
- Dephaser gradient
- Normal imaging sequence

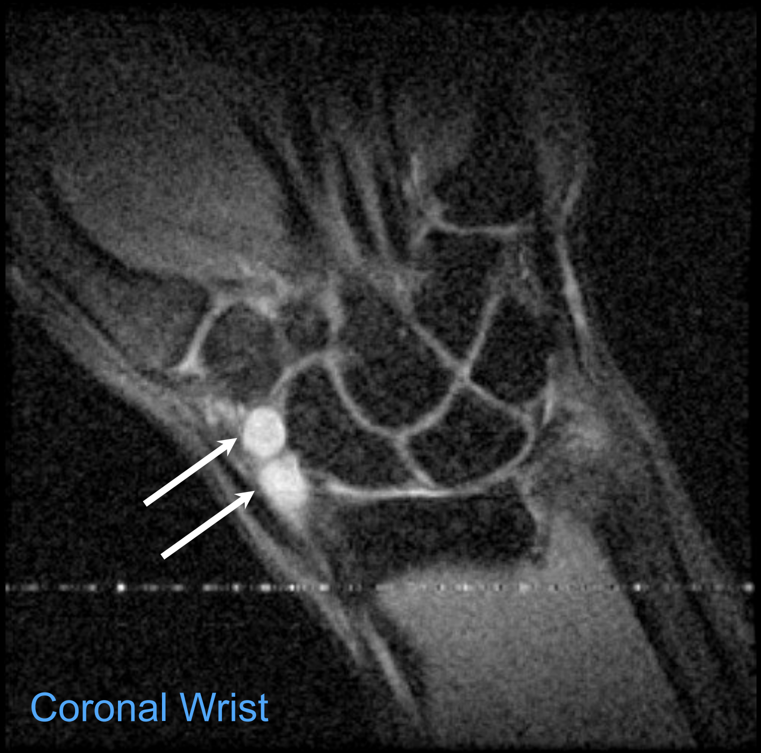


Fat Suppression: Contrast

PD FSE



Fat-Sat PD FSE



Radial cyst was otherwise iso-intense with bone marrow (fat)

Fat saturation can enhance visibility of other tissues

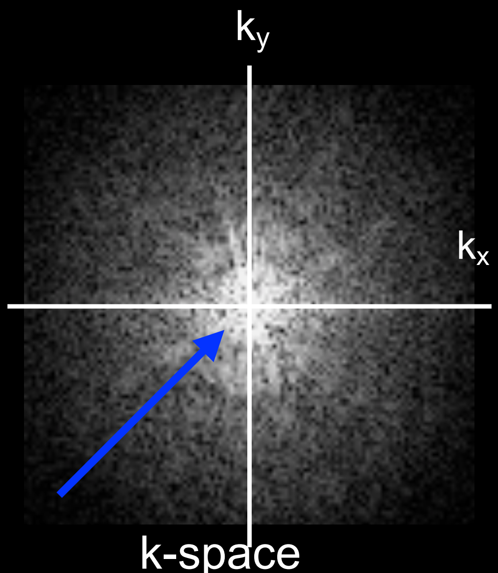
Fat Suppression: Reduce Artifacts

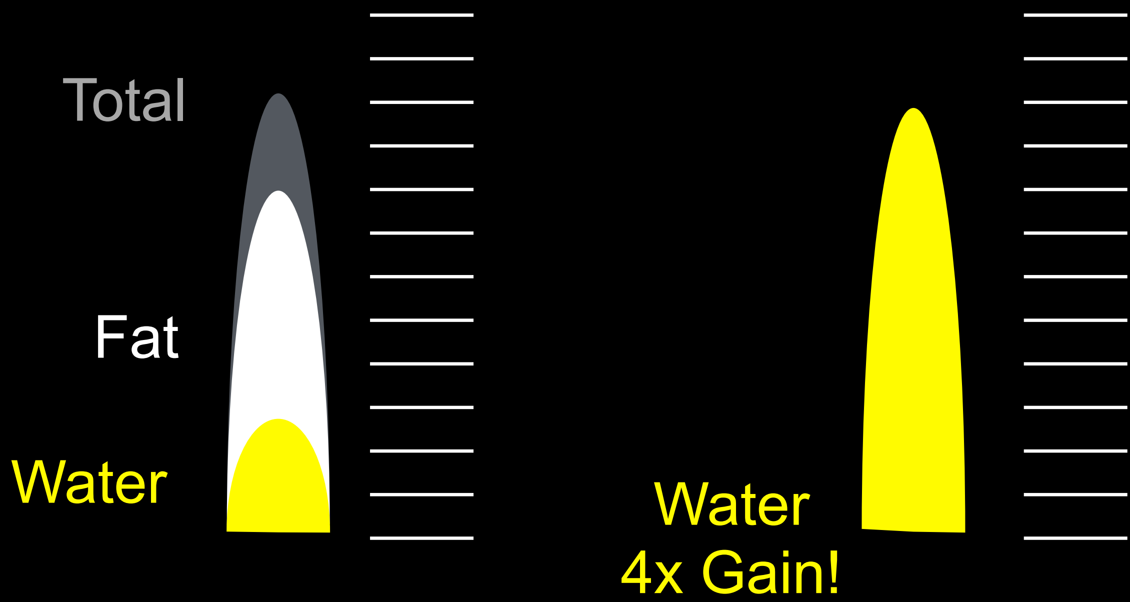
- Fat is displaced (chemical shift)
- Can overlap with other tissue
- Suppression avoids this

Prominent EPI Example

Fat can cause artifacts in images, so fat suppression can reduce artifacts

Fat Suppression: Dynamic Range

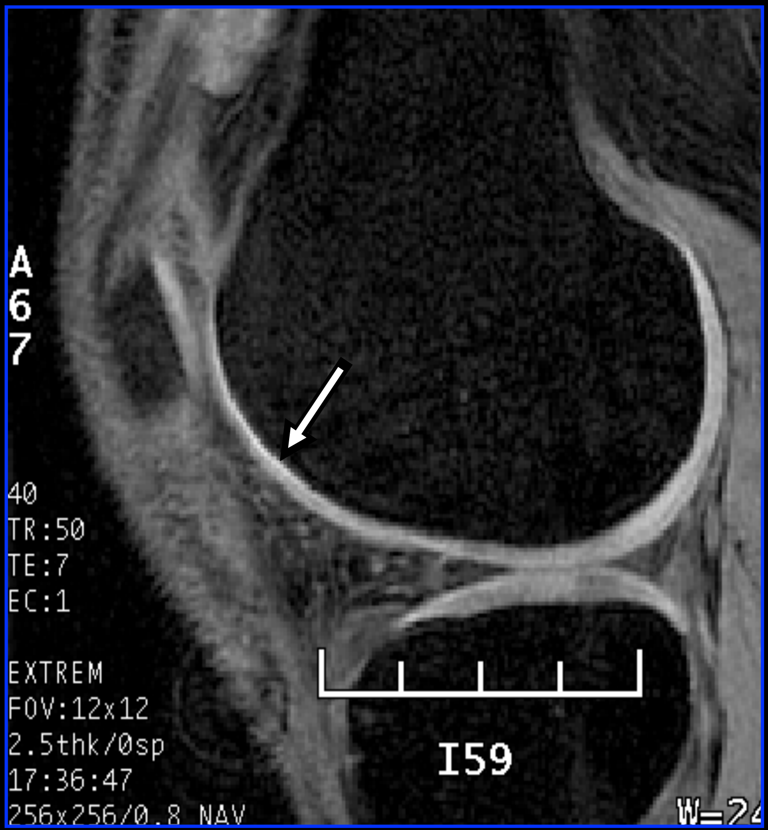




- Digitized signal, Quantized
- DC signal MUCH higher with fat
- "Use up" quantization steps

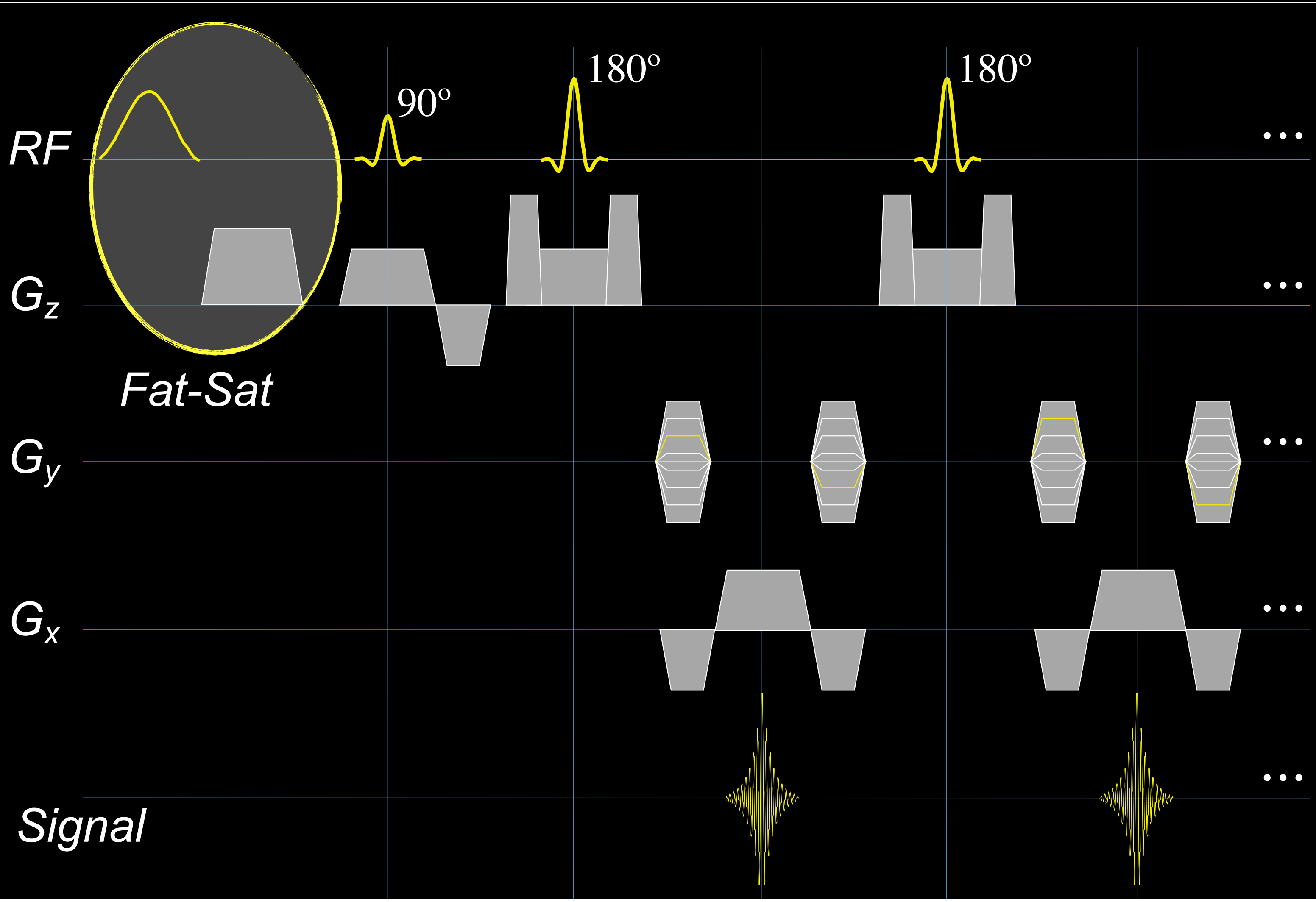
Suppression of one signal allows better dynamic range for other signals

Fat Suppression for Dynamic Range



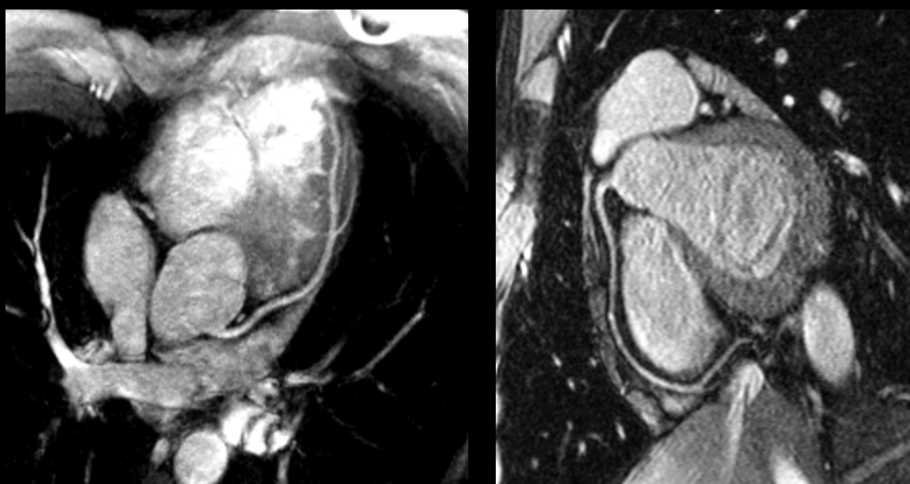
Fat-suppressed images have more gray-levels in the non-fat signal

Fat-Saturated Spin-Echo

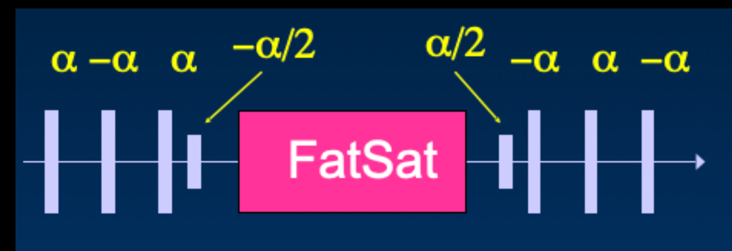


Fat-Saturated Balanced SSFP

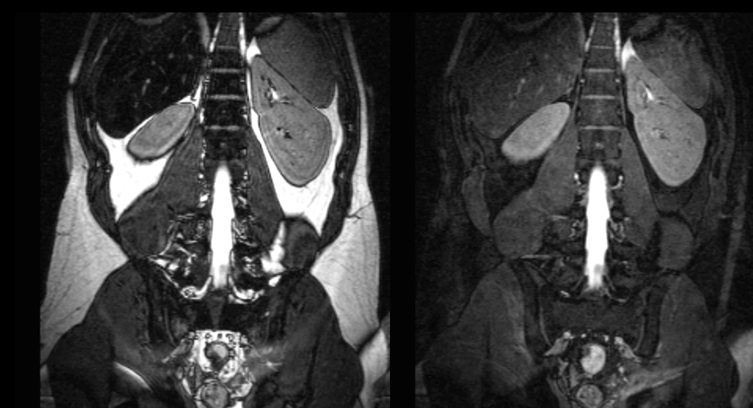
- Recall α/2 - TR/2 setup with bSSFP
- Allows efficient fat-saturation



(Courtesy Vibhas Deshpande, MRM 2000



No Fat-Sat With Fat-Sat



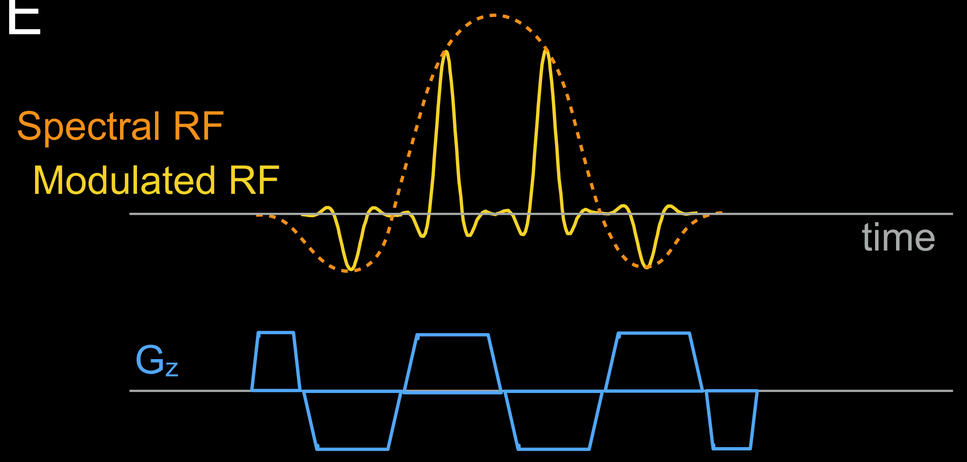
(Courtesy Klaus Scheffler, MRM 2001

Fat is bright on bSSFP, so magnetization preparation (including transition into/from steady state) is very useful

Question 1: Fat Saturation

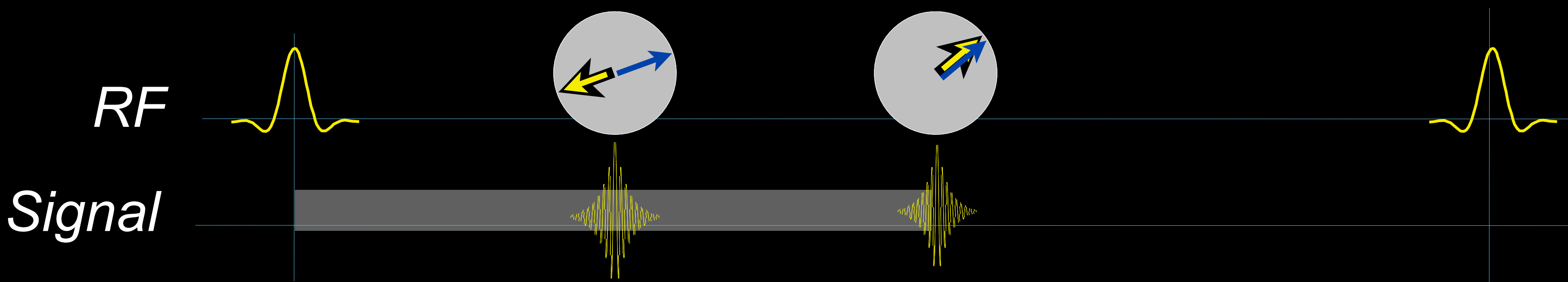
Water-Only Excitation: Spectral/Spatial Pulses

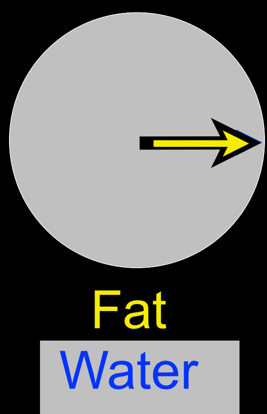
- Not really mag-prep(!)
- Spectrally-selective excitation takes ~8-12ms (1.5T) or ~4-6ms (3T)
- Modulate RF and use slice select gradient
- Water-only, spectral-spatial, binomial (1-2-1, 1-3-3-1, etc)
- More robust to ΔB_0 and ΔB_1^+ than fat-suppression
- Longer minimum TE

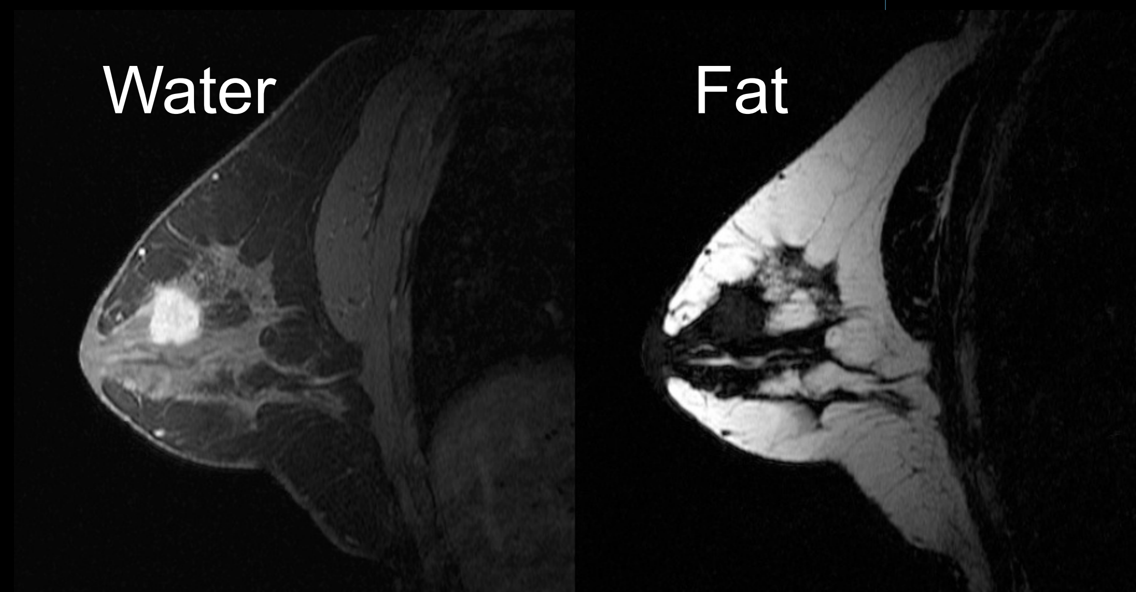


Water-only Excitatation selectively excites water but not fat, to suppress fat signal

Dixon-Based Imaging





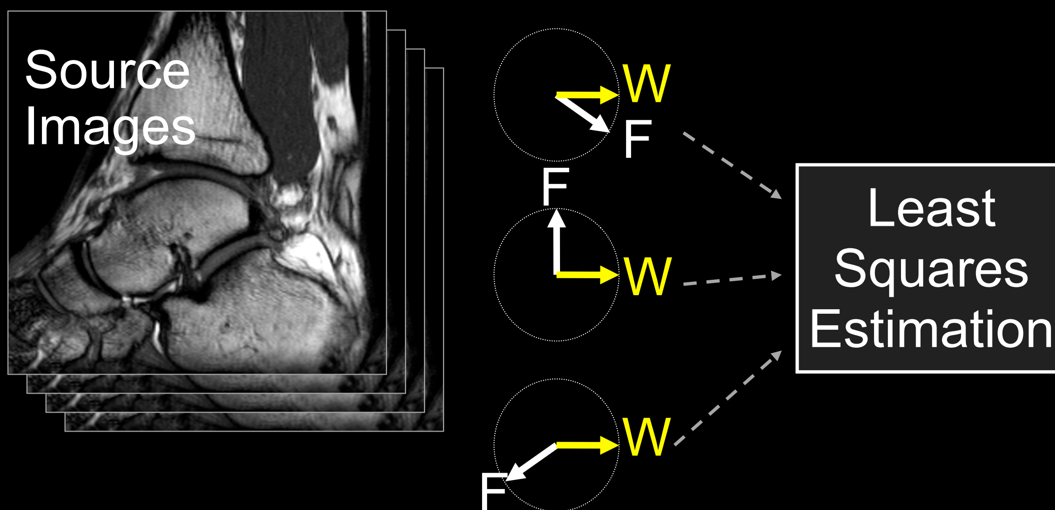


(Dixon 1984, Glover 1991)

Dixon imaging uses multiple echo times (TE) to separate fat and water signals

IDEAL Water-Fat Separation

(Reeder 2003, 2004)



- 3x Scan Time = 5 minutes
- SNR efficiency is preserved
- Post-processing can correct for large ΔB_0

Least-squares separation can be SNR-optimal, while multiple echoes add robustness to ΔB_0

Summary: Magnetization Preparation and Fat Suppression

- Modify contrast before an imaging sequence
- Pair magnetization prep with efficient acquisition
- Saturation vs Inversion for nulling
- Fat Suppression methods:
  - Fat saturation: remove the fat with saturation
  - Water-only excitation: do not excite fat
  - Dixon techniques: Multiple TEs to separate water/fat

What are other examples of magnetization preparation?

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