Rad229 – MRI Signals and Sequences

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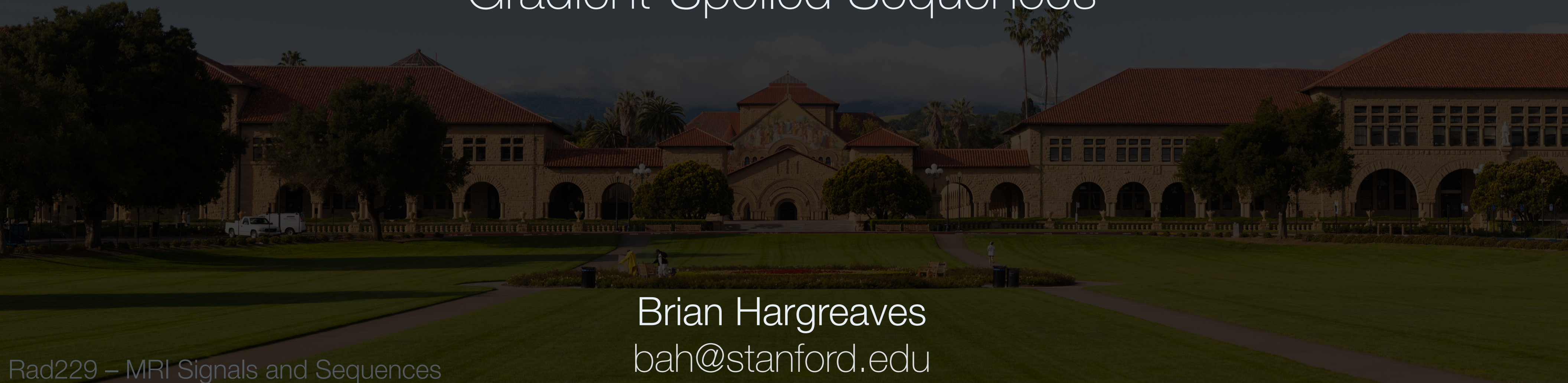
Lecture-9C — Gradient-Echo Sequences

Gradient-Spoiled Sequences



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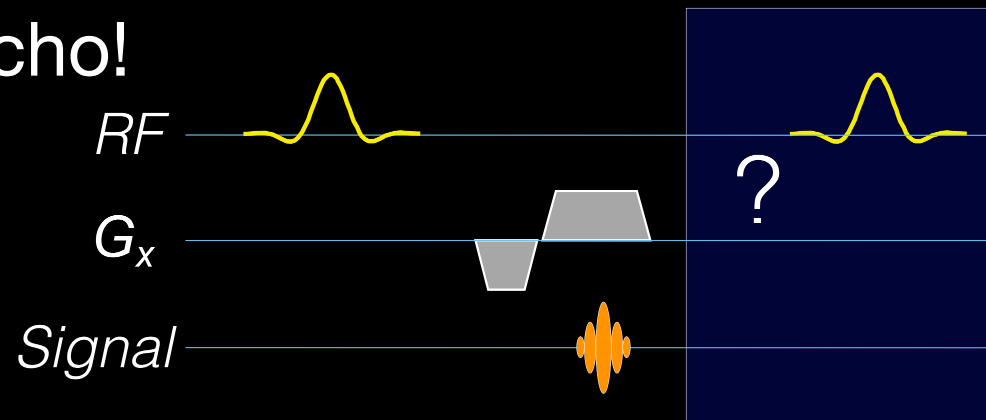
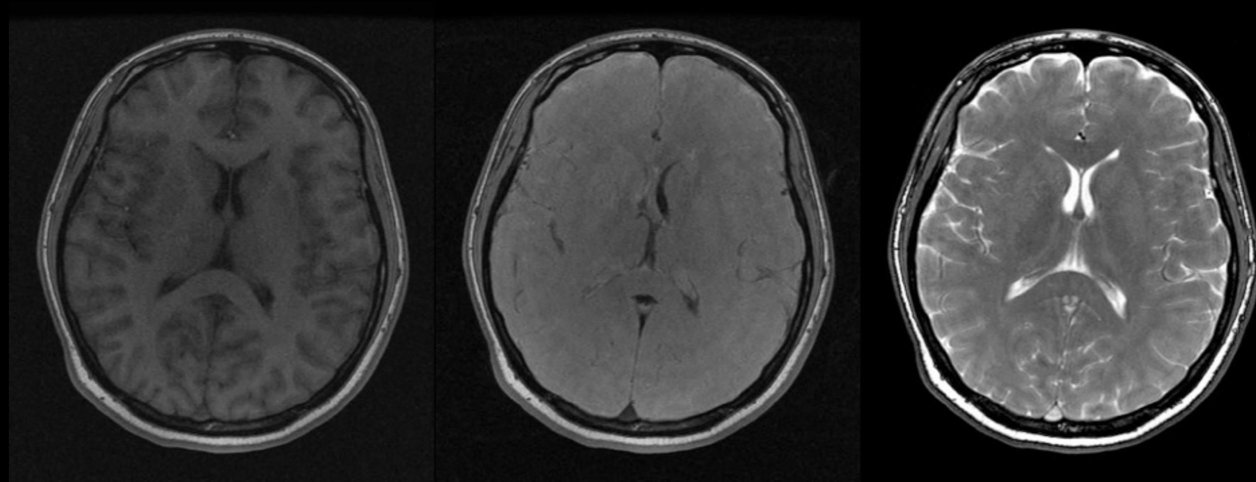
Learning Objectives

- Explain the gradient-spoiled signal relative to bSSFP
- Explain reversed gradient-spoiling and double-echo in steady-state
- Use EPG simulations to calculate gradient-spoiled signals

Outline: Gradient Echo Sequences

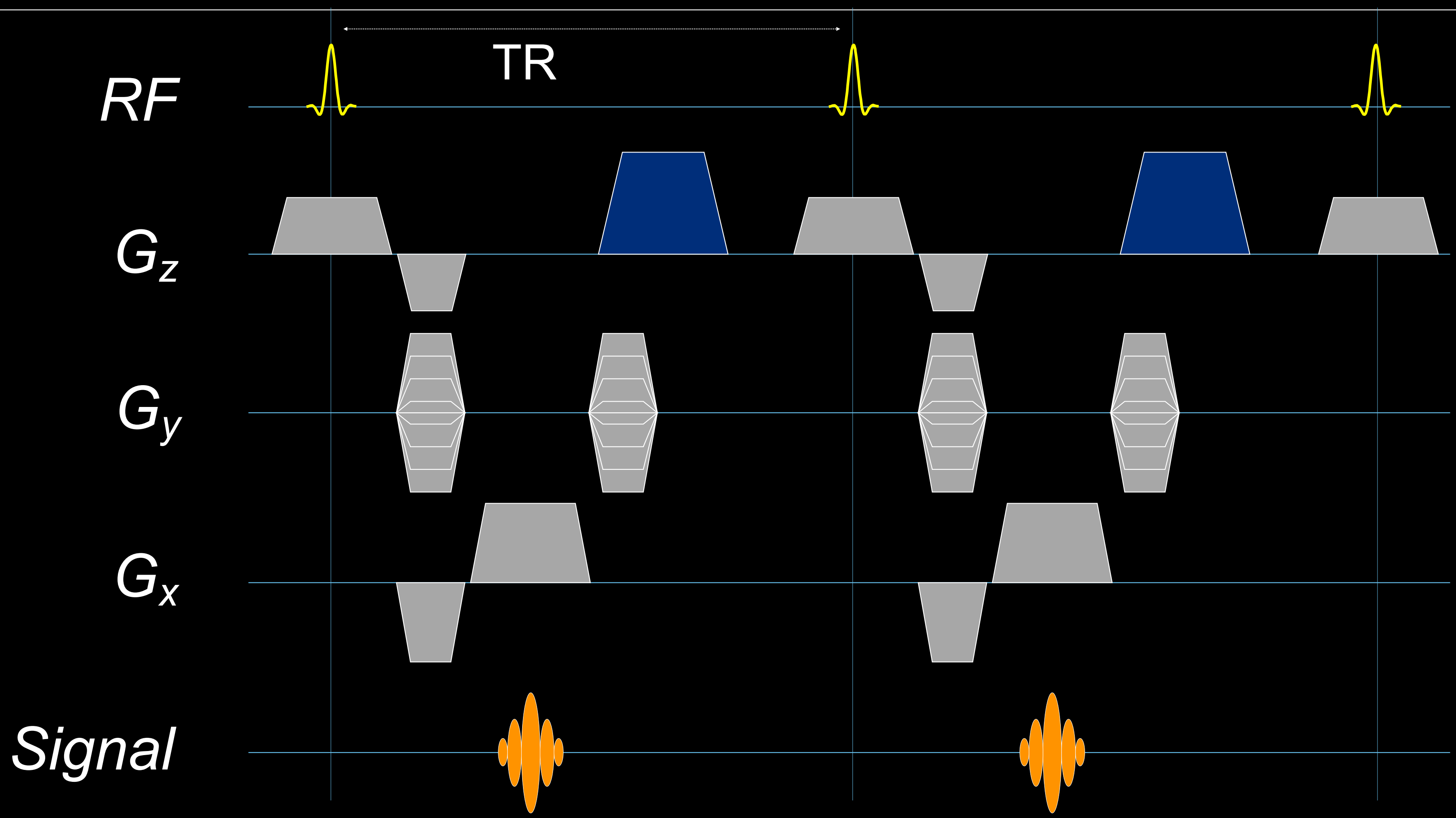
- Gradient Echo = No spin echo!
- Spoiling Types
- Properties





Contrast is based primarily on the end-of-TR action

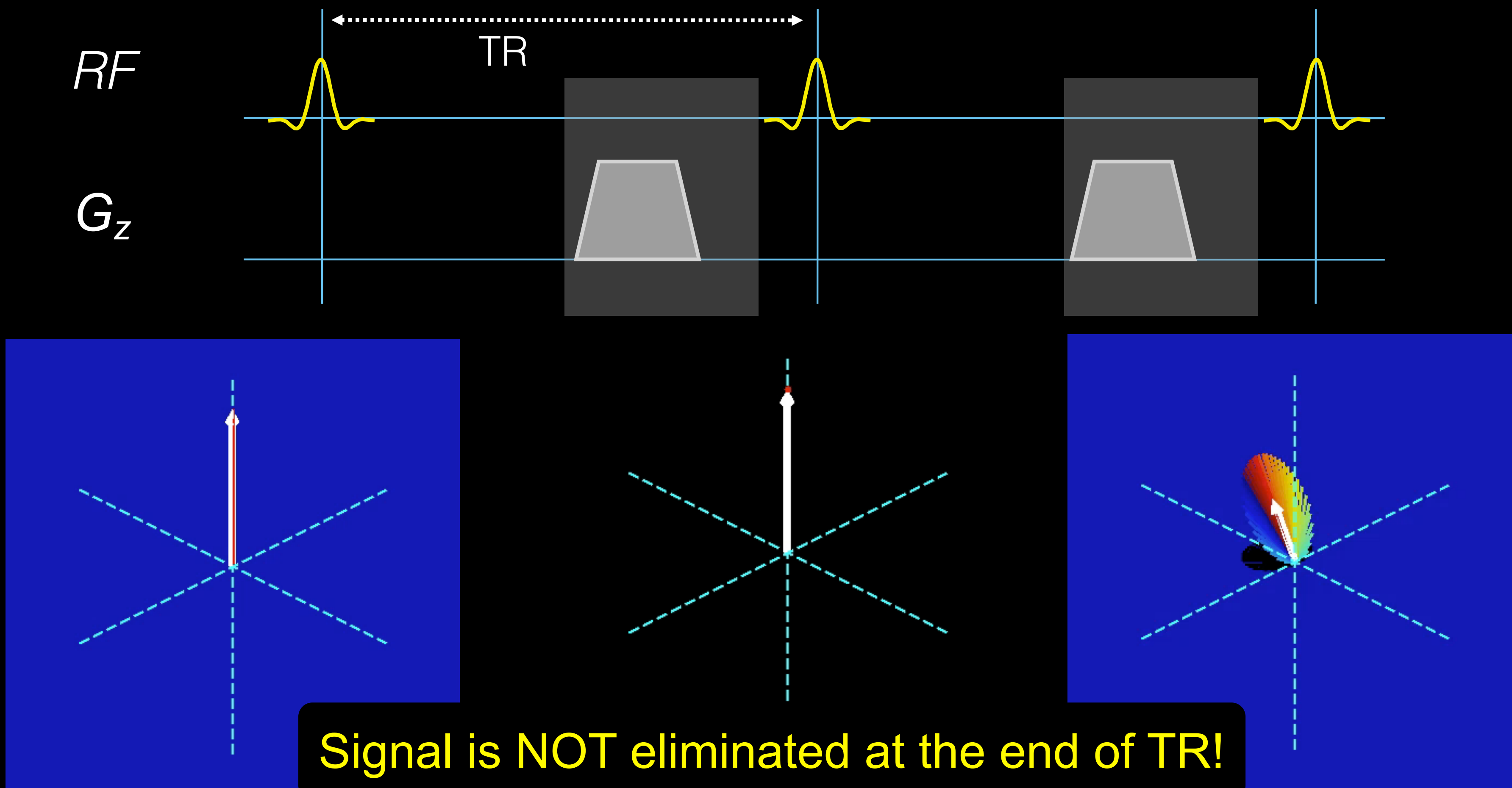
Gradient-Spoiled Sequences (GRE, FFE, FISP, GRASS…)



Gradient spoiling uses an unbalanced gradient at the end of the TR (Gx and Gz here)

Question 1: Constant Gradient vs Off-Resonance?

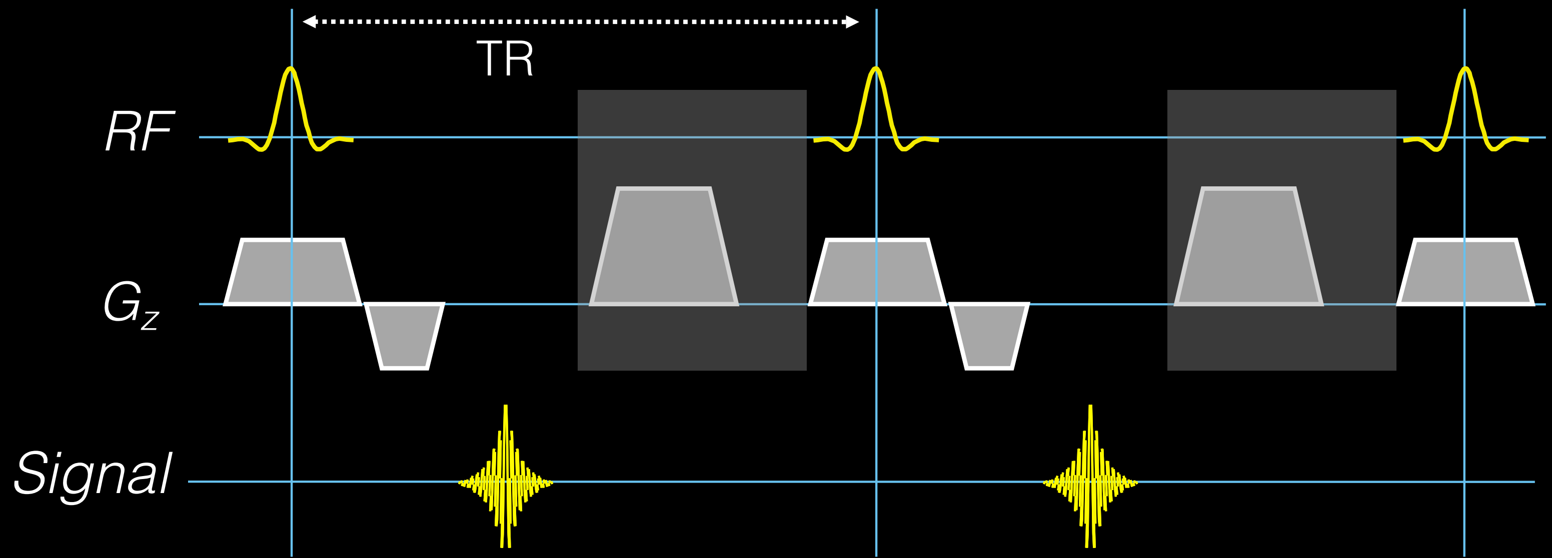
Gradient Spoiling



Signal is NOT eliminated at the end of TR!

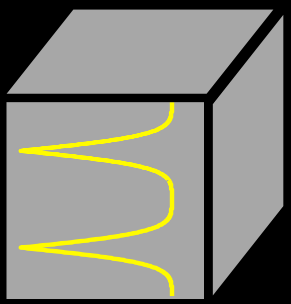
The gradient spoiler does NOT eliminate transverse magnetization, in the steady-state

Gradient Spoiling (GRE, FFE, FISP, GRASS)



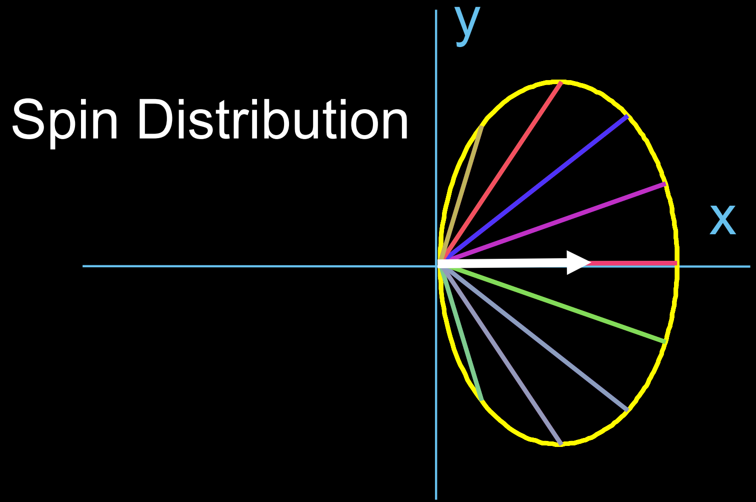
Precession across voxel dominated by spoiler:

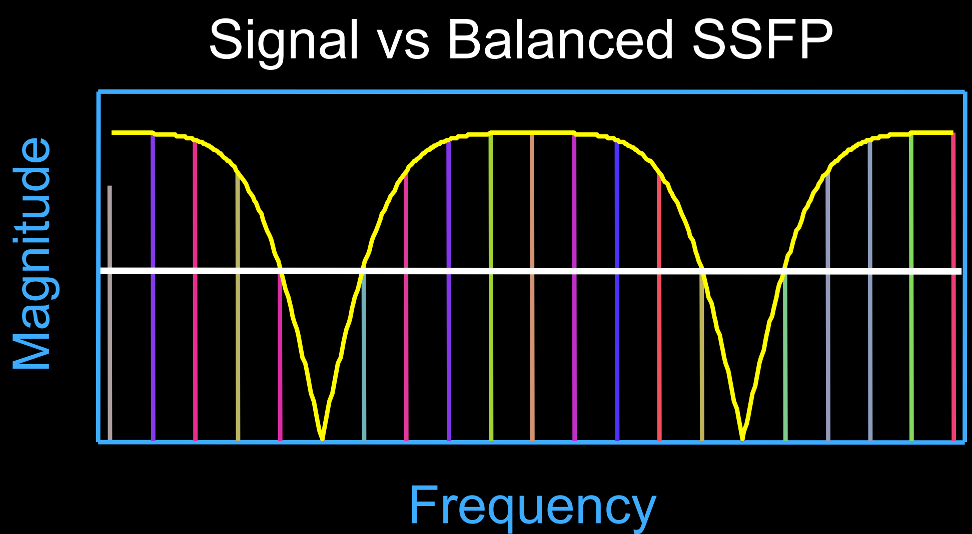
- Each spin has a different precession
- Average of balanced SSFP at start of TR!
- Perhaps some T_2 decay to TE



Gradient spoiling averages the bSSFP signal over frequency

Gradient-Spoiled Signal





- Lower signal than balanced SSFP
- Flat signal vs. frequency profile
- No dark band artifacts!
- GRE, FFE, FISP, GRASS

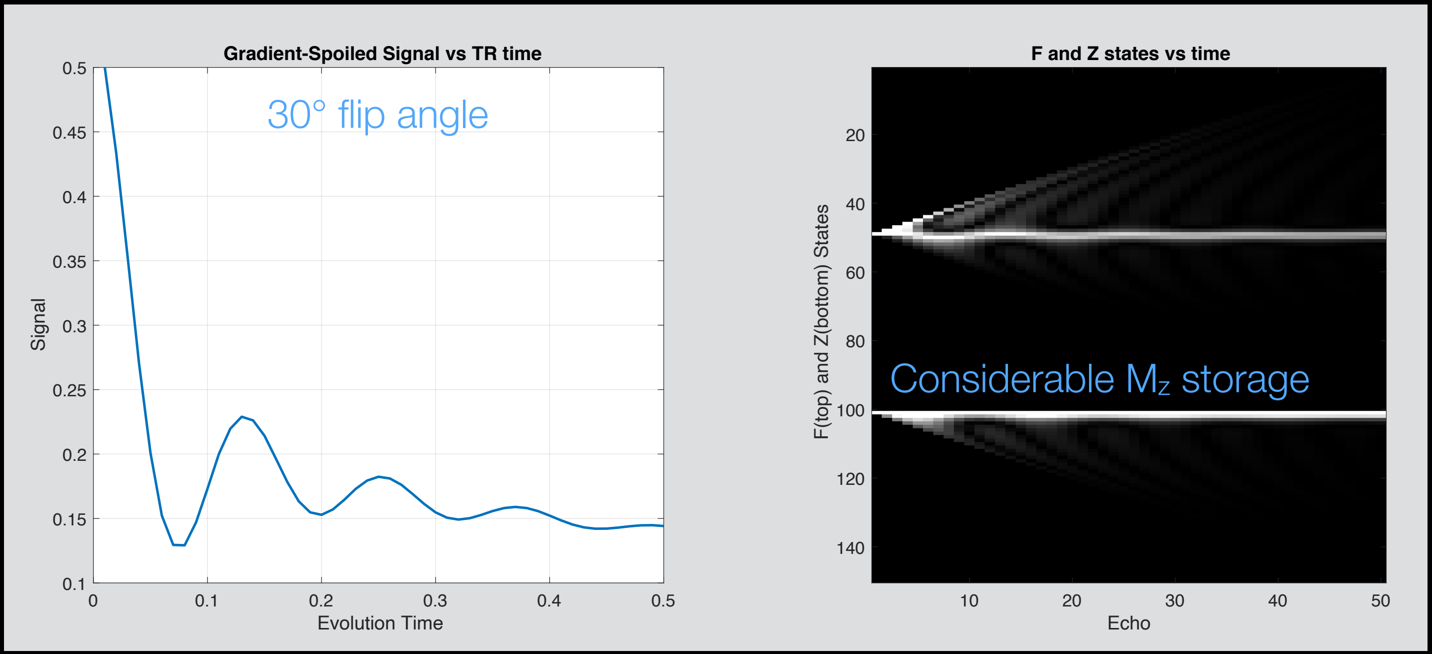
The signal is the complex average of the bSSFP signal just after the RF pulse

Question 2: Gradient Spoiling and EPG

EPG Signal Calculation

- Simulate RF, relaxation, gradient
- Can plot signal evolution and coherence pathways

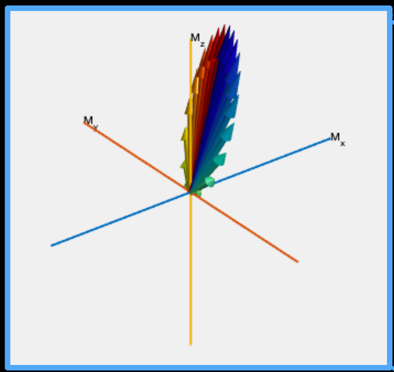
```
% epg_gradspoil.m:  Core loop
%
for n=1:N
  P = epg_rf(P,flipangle,pi/2);          % RF excitation
  s(n) = P(1,1);                         % Signal is F0 state.
  P = epg_grelax(P,T1,T2,TR,1,0,1,1);    % Spoiler, relaxation
end;
```



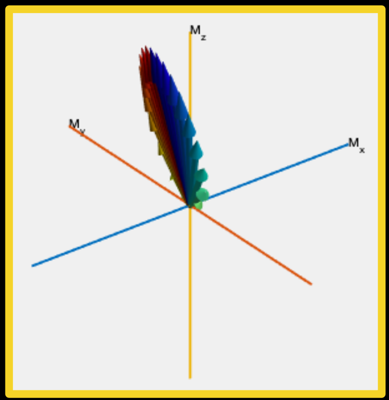
EPG coherence pathways reach a steady state   epg_gradspoil.m

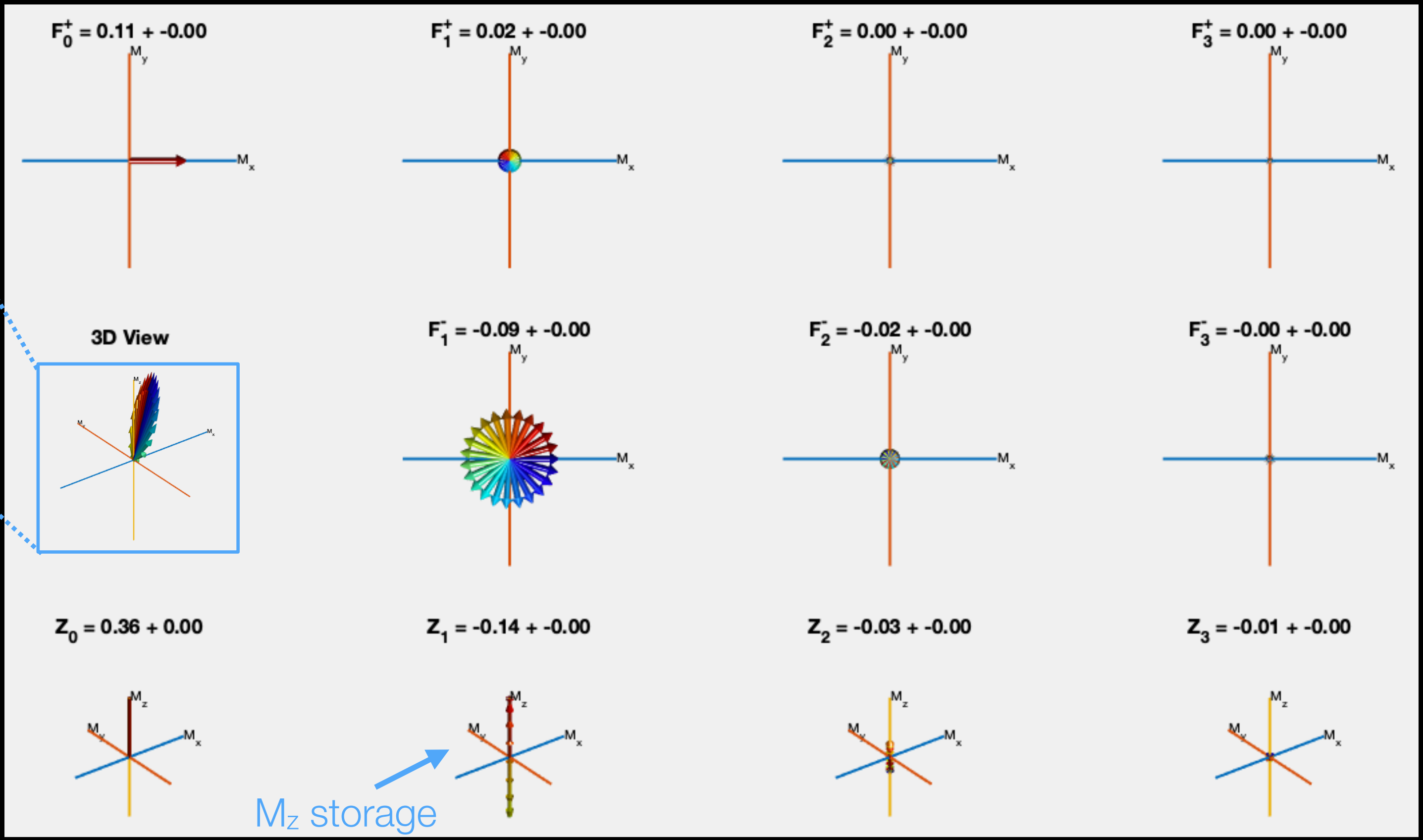
EPG Steady-State Gradient-Spoiled Signal

After RF



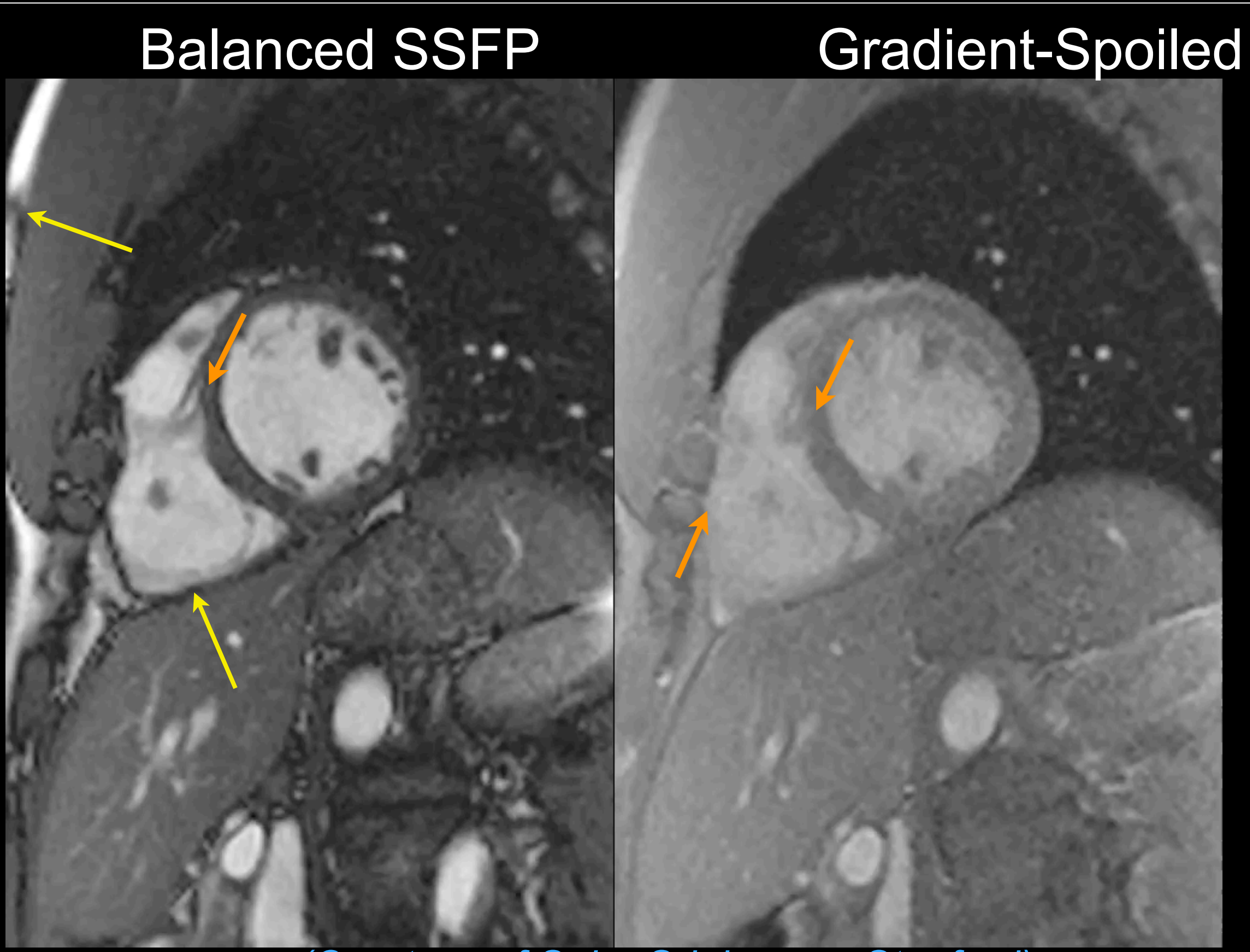
Before RF





Steady-state EPG states at TE=0 - advancing by 1 gradient shows states at end of TR

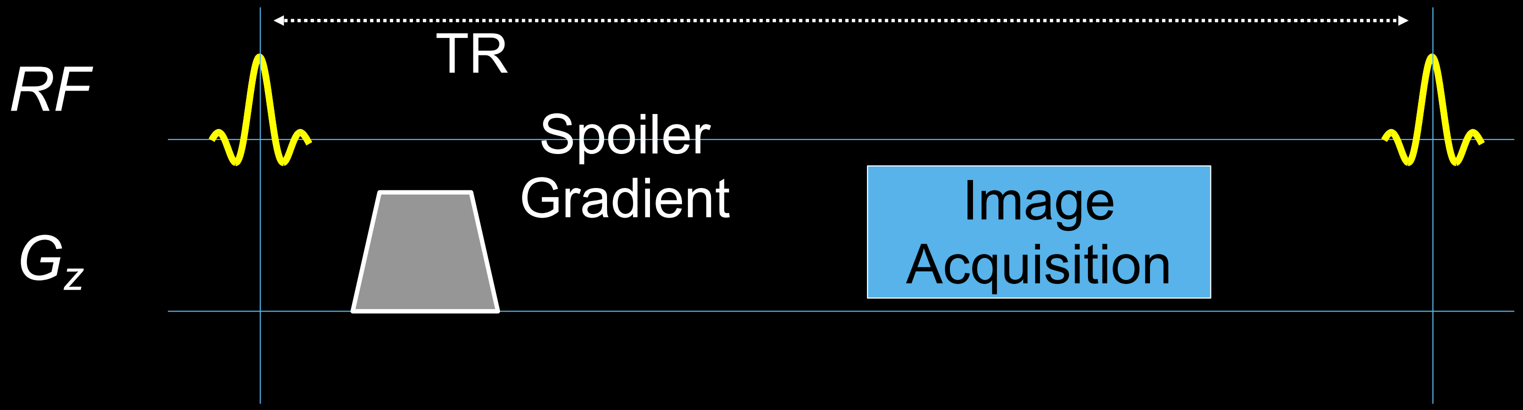
Gradient Spoiled vs Balanced SSFP



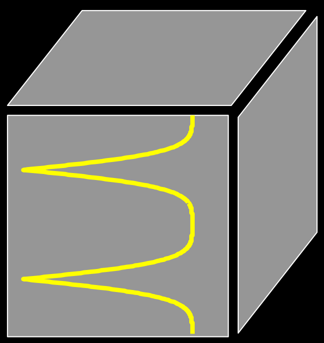
(Courtesy of Suba Srinivasan, Stanford)

bSSFP has higher signal, but some artifacts, compared to gradient spoiling

Reversed Gradient Spoiling

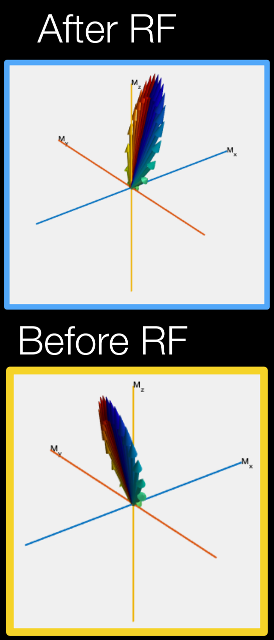


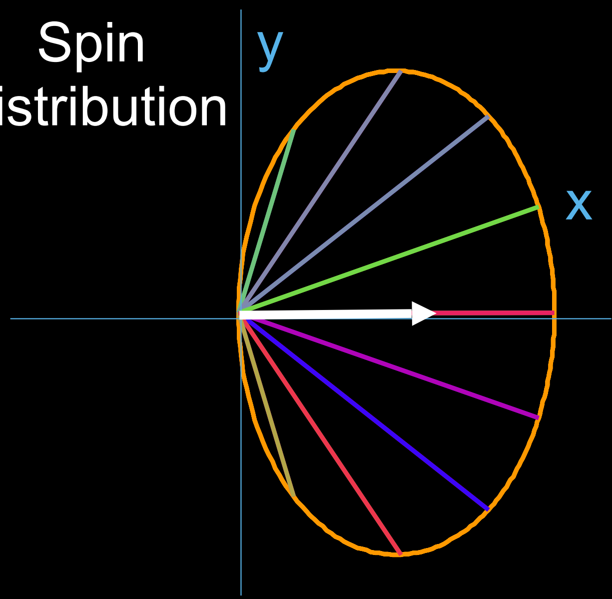
Same as gradient-spoiling, but
- Precession before imaging
  (bSSFP Signal at TE=TR)
- Some T_2 contrast

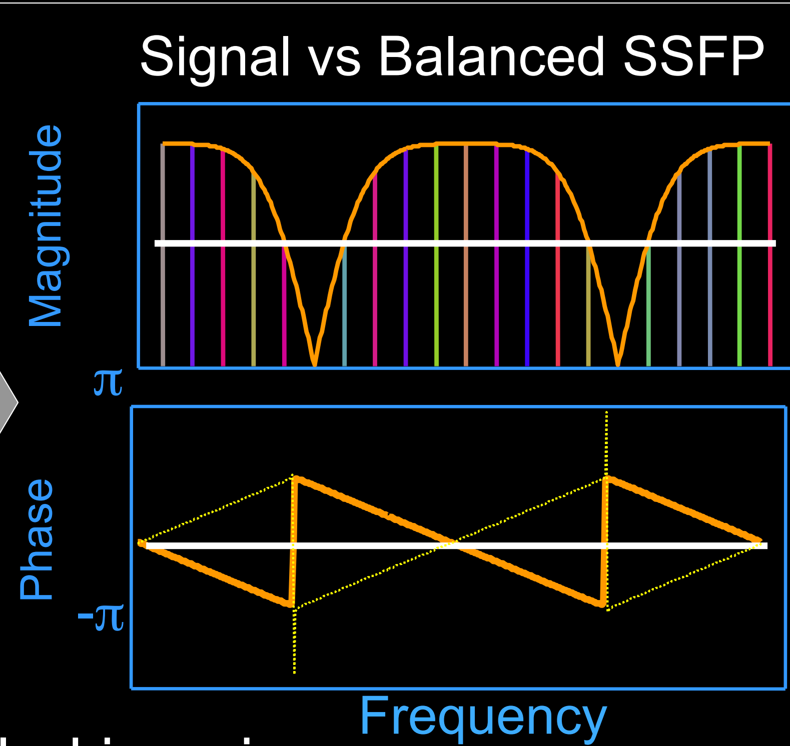


The spoiler gradient still has the effect of inducing off-resonance across the voxel

Reversed Gradient Spoiled Signal



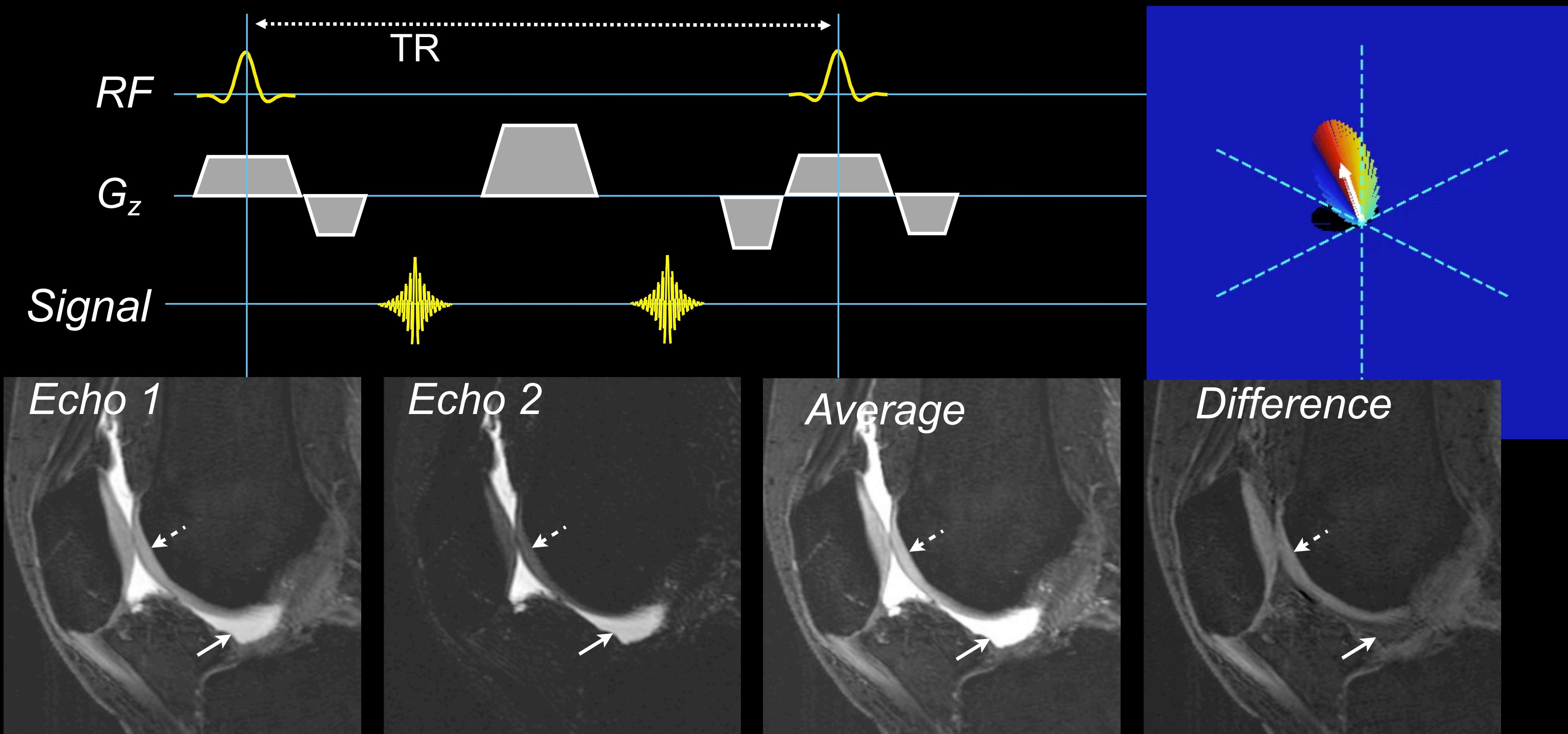




- Almost identical signal to gradient-spoiled imaging
- Flat signal vs. frequency profile, and more T2 contrast than GRE
- PSIF, CE-FAST, T2-FFE

Sampling after the spoiler gradient leads to a similar signal, with more T2 contrast

Double Echo Imaging: DESS/FADE



Double-Echo in steady state samples both before and after the spoiler

Question 3: Split-Spoiling

Question 3: (cont)

Gradient Spoiling: Summary

- Gradient spoiling averages the bSSFP magnetization
- Reduce sensitivity to off-resonance
- Can do reversed gradient spoiling or double-echo
- GRE gives T_2/T_1 contrast, lower signal than bSSFP

FFE, FISP, GRASS, GRE, FAST, Field Echo,
T2-FFE, PSIF, CE-FAST, SSFP(!)
FADE, DESS

Is there a way to get pure T1 contrast with gradient-echo imaging?

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