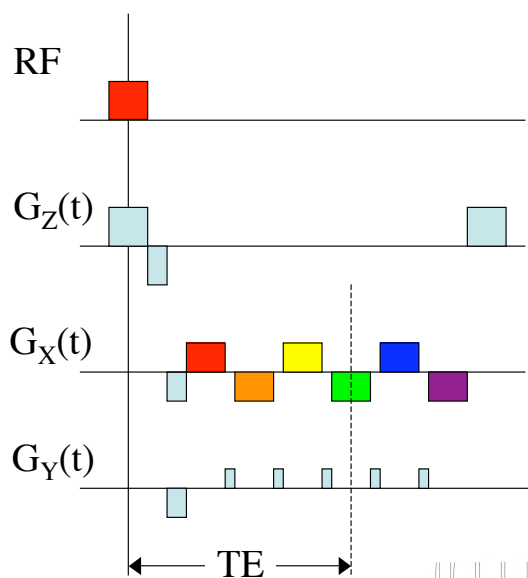Bioengineering 208
Magnetic Resonance Imaging

Winter 2007
Lecture 4
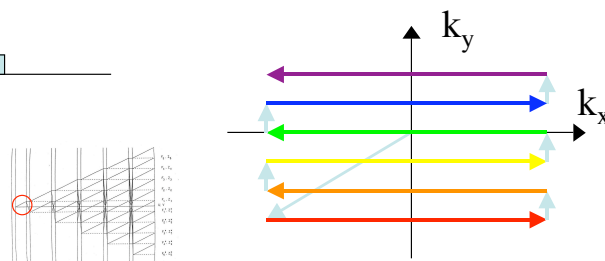
- • Echoplanar Imaging
  - – Pulse Sequence
  - – Nyquist Ghosts
  - – Off-Resonance Effects
  - – T_2* Blurring

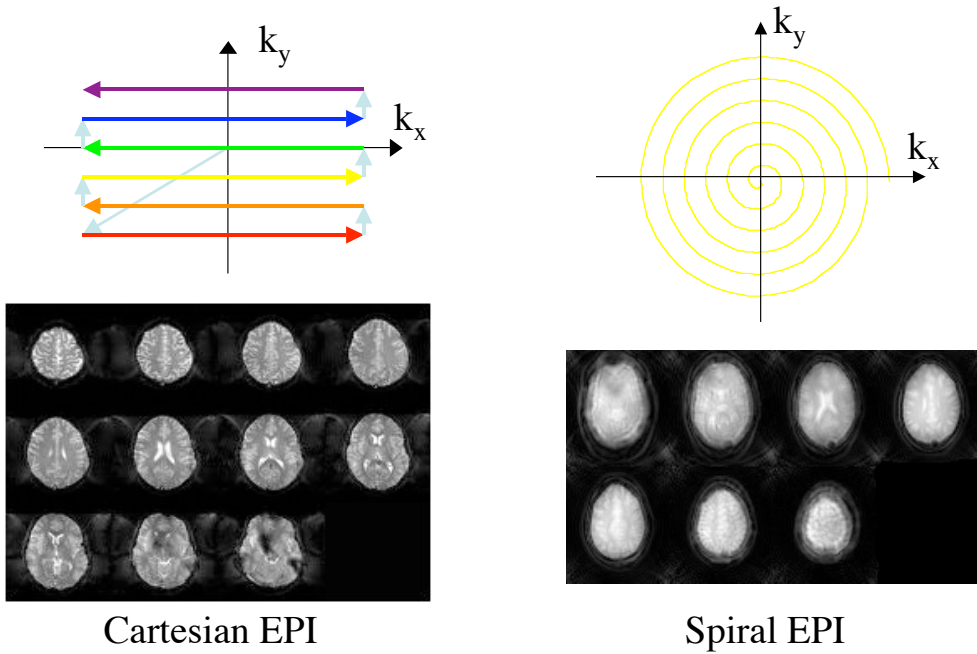# Echoplanar imaging sequence

RF

$G_Z(t)$

$G_X(t)$

$G_Y(t)$

TE

•Multiple lines of K-space with one excitation
•Allows for "snapshot" imaging
•K-space coverage limited by gradient hardware and T_2*
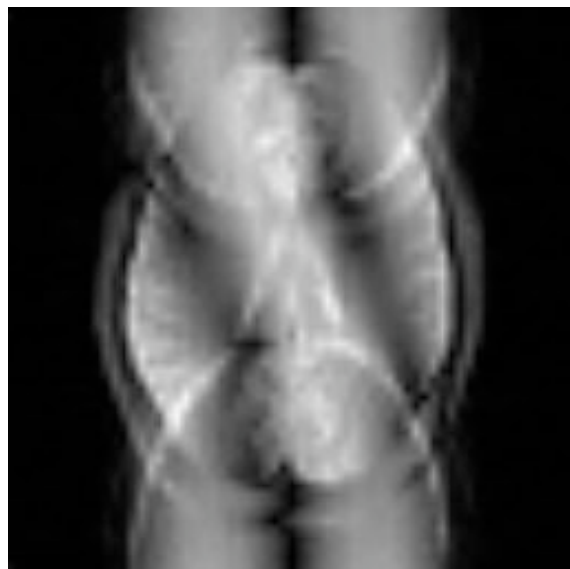•Main Applications:
 •BOLD fMRI
 •Diffusion
 •Freezing motion

k_y

k_x

The EPI Family

Cartesian EPI

Spiral EPI

NYQUIST GHOST

NYQUIST GHOST

FT(rows)

Magnitude   Phase

NYQUIST GHOST

Magnitude   Phase

FT (columns)

NYQUIST GHOST

Phase

REAL

REAL

REAL

IMAG.

IMAG.

IMAG.

TIMING ERRORS

EPI

SPIRAL

TIMING ERRORS

EPI

SPIRAL

0   24μs

SKIP a BLIP (or two)

Redundant line
collected twice:
once in each
direction

Use measured time
shifts to correct data
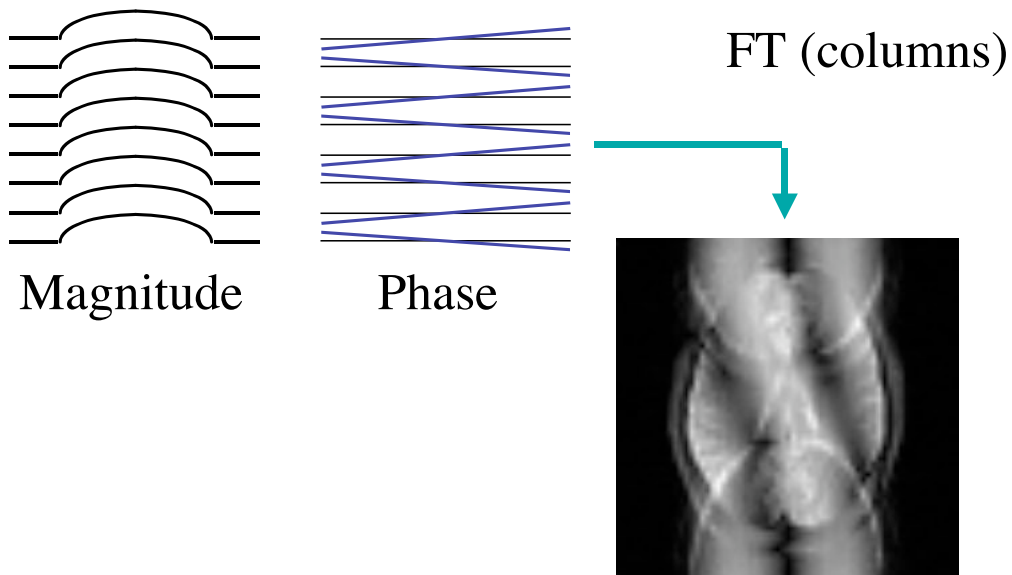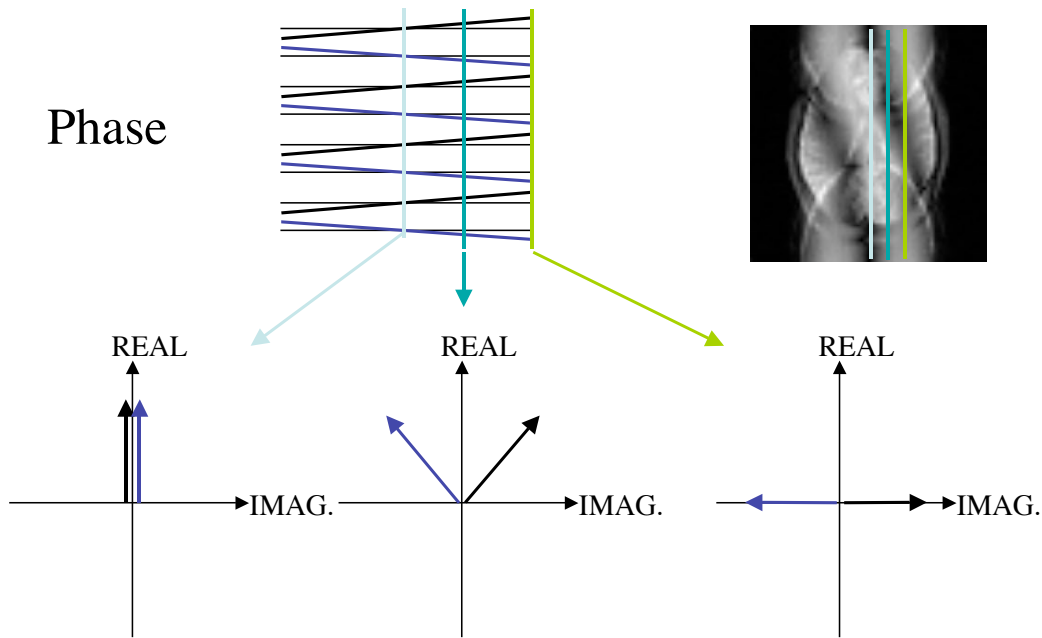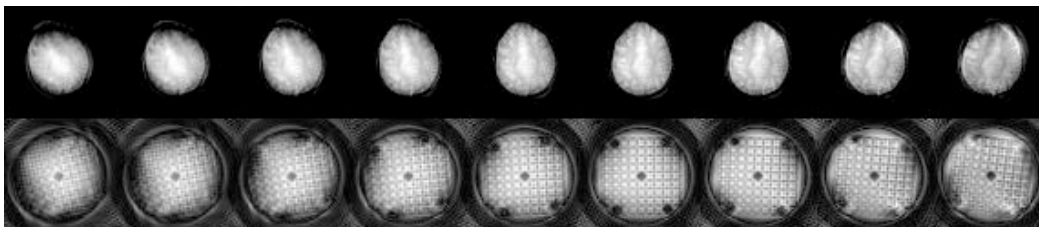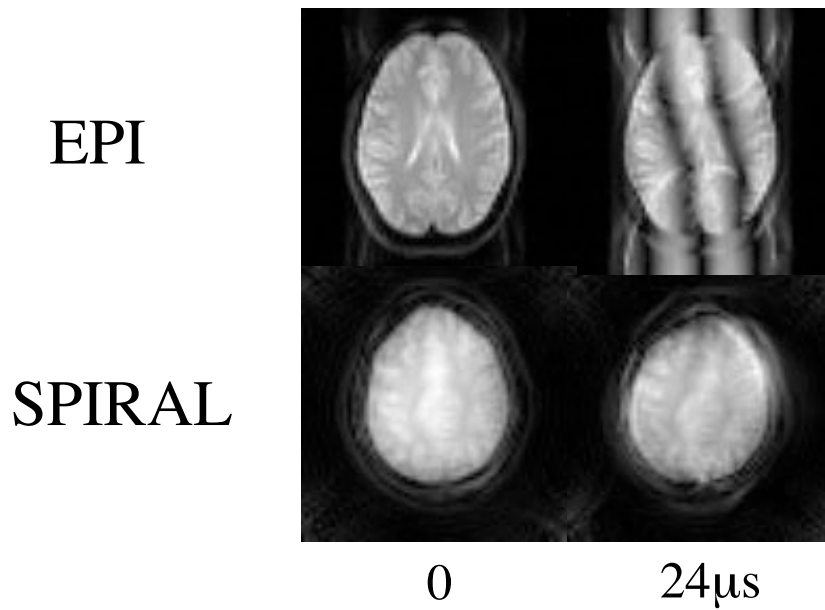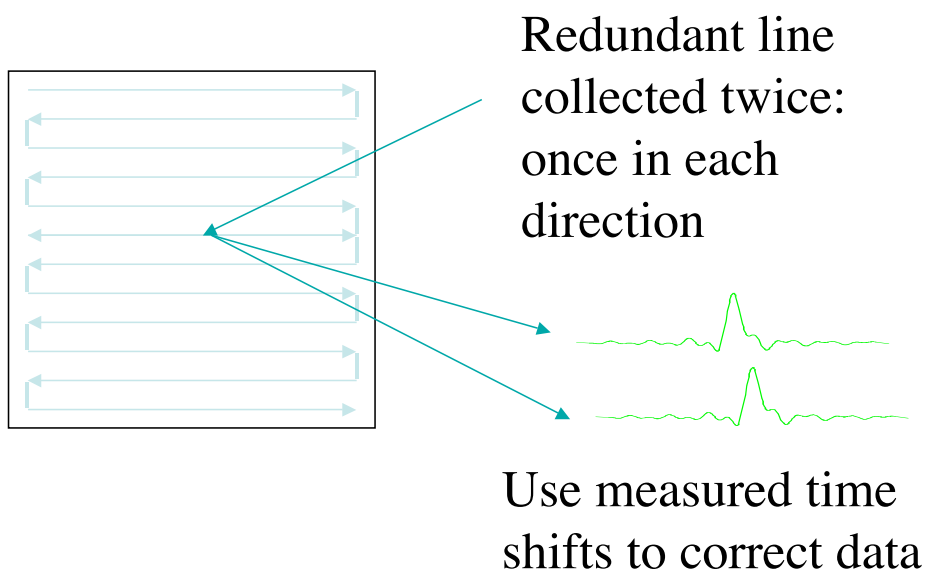
SPATIAL DISTORTION
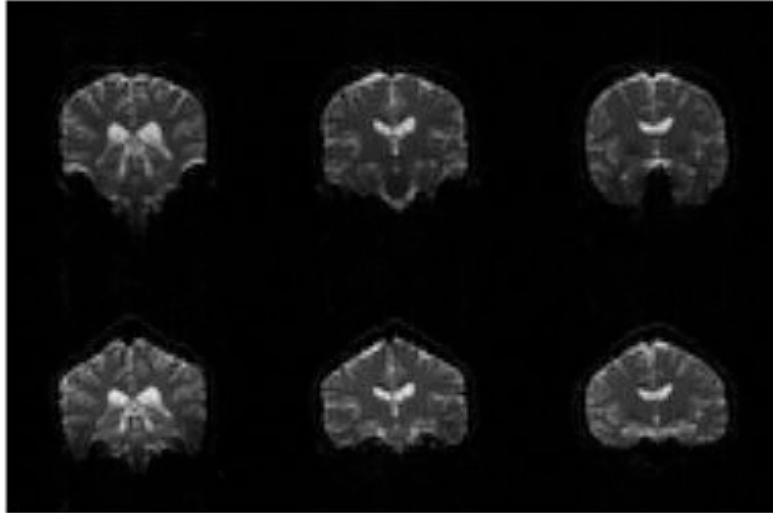
Off Resonance Behavior : EPI
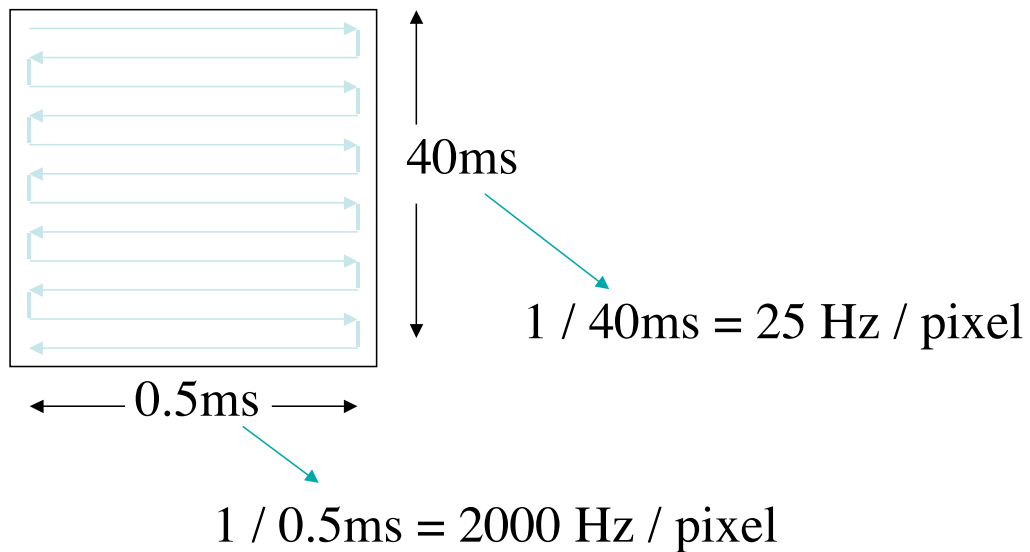
40ms

1 / 40ms = 25 Hz / pixel

0.5ms

1 / 0.5ms = 2000 Hz / pixel

CONVENTIONAL IMAGING

0ms

$1 / 0ms = \infty$ Hz / pixel

8ms

$1 / 8ms = 125$ Hz / pixel
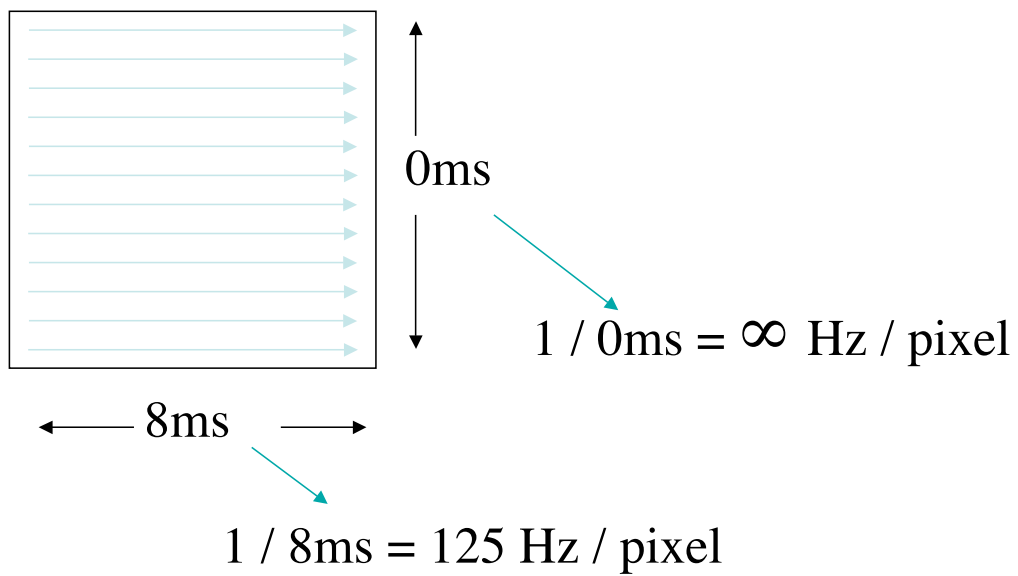
E. Wong, BE208, UCSD Winter 2007
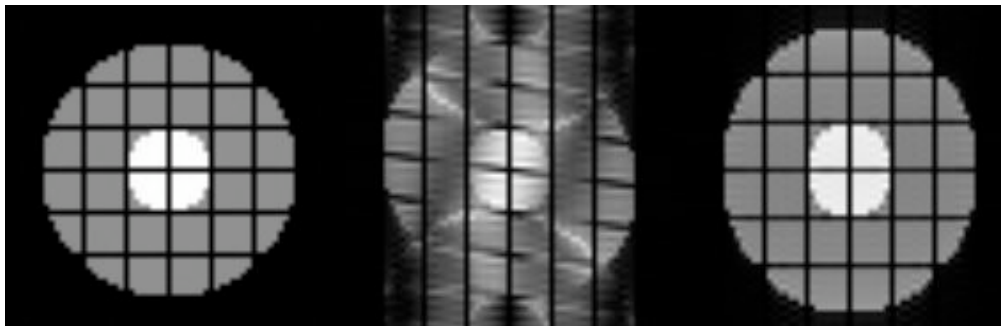
SHIM PATTERNS

PERFECT SHIM   X   Y

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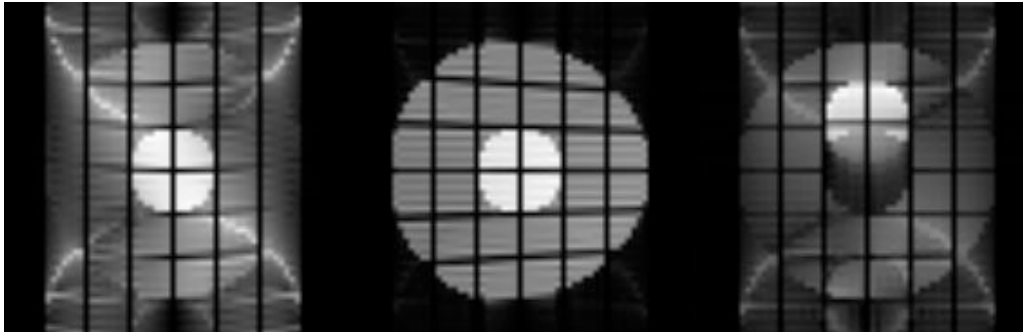
SHIM PATTERNS

$$X^2 \qquad\qquad X\,Y \qquad\qquad FAT$$

EPI
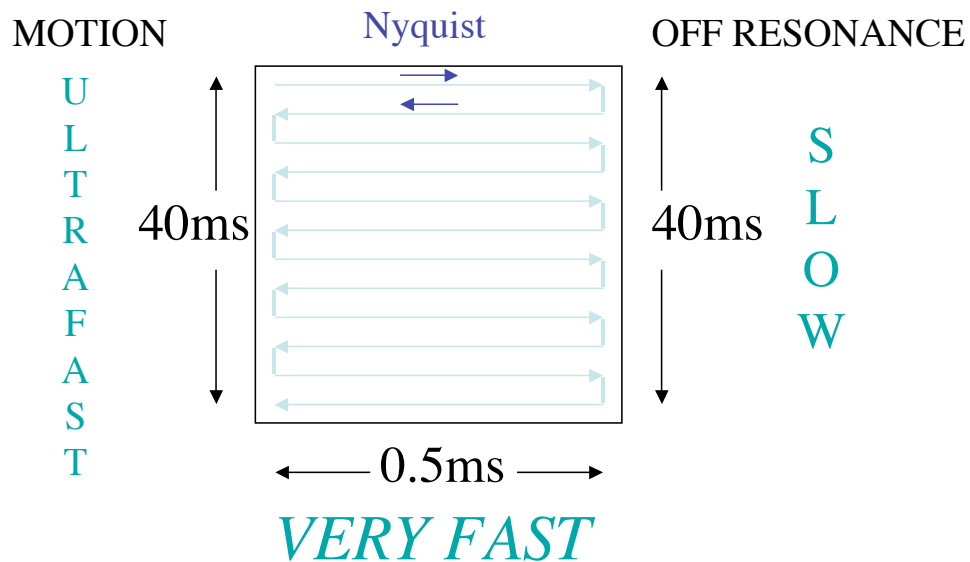
MOTION   Nyquist   OFF RESONANCE

U
L
T   40ms   40ms   S
R   L
A   O
F   W
A
S
T

0.5ms

VERY FAST

CONVENTIONAL IMAGING

MOTION   No relative time shifts   OFF RESONANCE

S L O W

60s   8ms   0ms   **I N S T A N T A N E O U S**

FAST

SPIRAL

MOTION   OFF RESONANCE

U L T R A F A S T

30ms   30ms   **S L O W**

1ms

VERY FAST

SPIRAL PSF (on resonance)

REAL

FT

IMAGINARY

POINT SPREAD FUNCTION
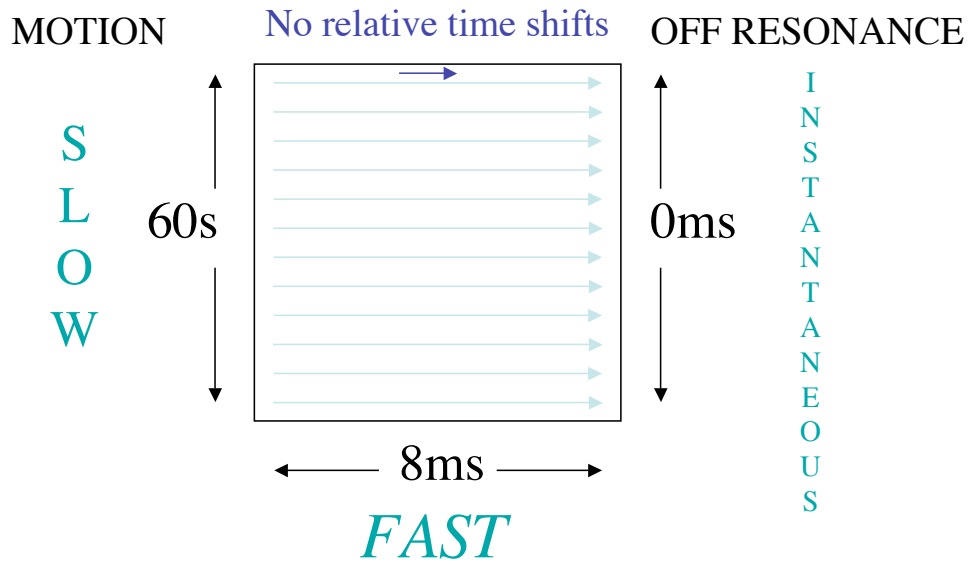
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SPIRAL PSF (off resonance)

REAL

FT

IMAGINARY

POINT SPREAD FUNCTION
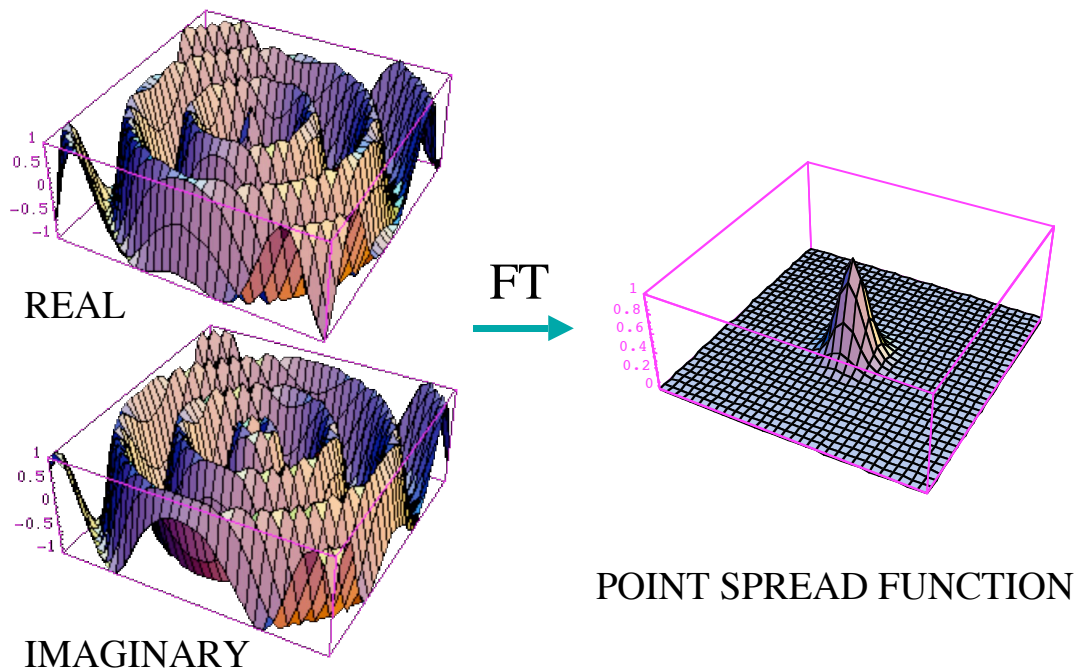
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SUMMARY

- Nyquist ghosts
  - Unique to EPI
  - Primarily caused by timing errors
  - Secondarily by off resonance effects
  - Pretty fixable
- Equivalent timing errors in Spiral cause rotation/blurring
  - Also fixable

SUMMARY

- Image distortion
  - Primarily caused by off resonance effects
  - Same as regular chemical shift artifact, but exaggerated
  - Pretty fixable
- Equivalent effects in Spiral cause blurring, and is harder to fix

SUMMARY

- Signal dropout is due to TE, slice thickness, SE vs GE as in conventional imaging
- EPI is unusually sensitive to scanner instability because of:
  - High sensitivity to off resonance effects
  - High SNR from low resolution