MR Pulse Sequences

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Disclosure

- No conflicts of interest

Outline

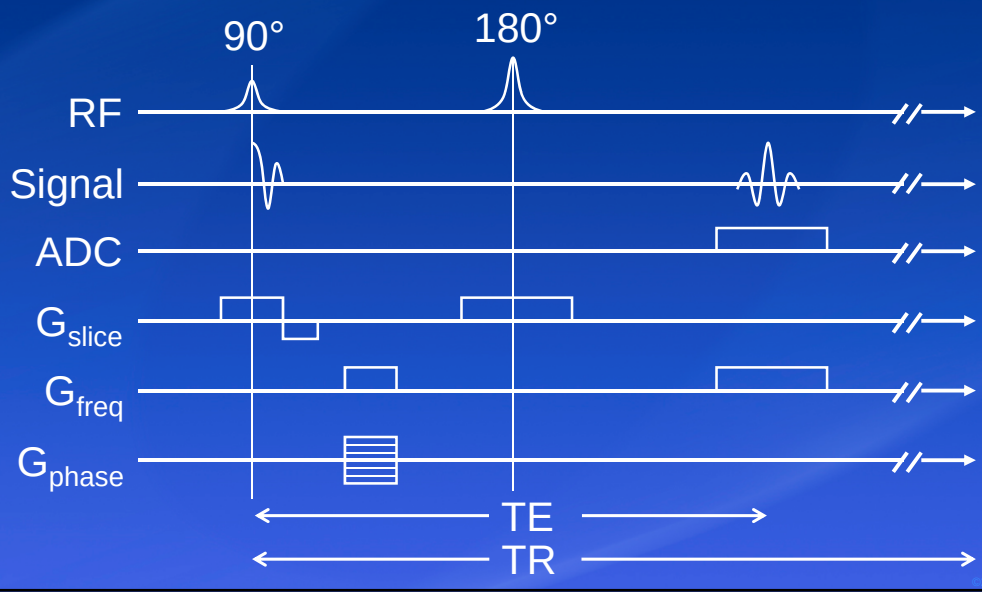
- Spin echo
- Inversion recovery
- Gradient echo
- Echo planar
- K-space trajectories

Spin Echo

- Uses 90° and 180° flip angles
- Spin density contrast: short TE, long TR
- T1 contrast: short TE, short TR
- T2 contrast: long TE, long TR
- Rephases effects from B_0 inhomogeneity, chemical shift, and magnetic susceptibility
- Scan time = TR x N_P x NSA

TR: Repetition time
N_P: # phase encodes
NSA: # signal averages =
NEX: # excitations

Spin Echo



Filling K-space

- The signal from the echo is sampled; the values are placed in k-space.

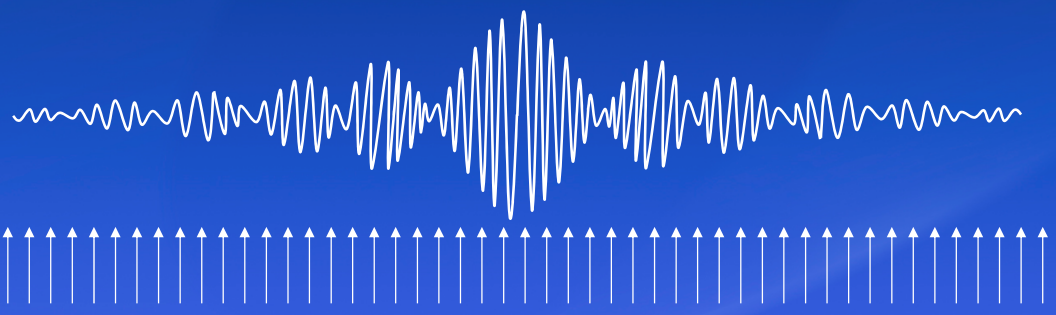
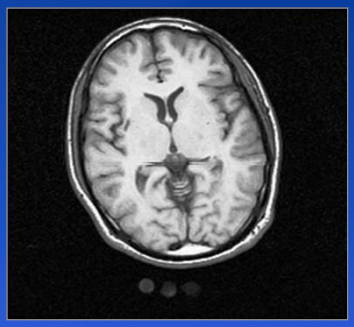
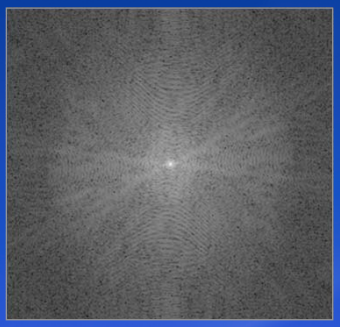


Image space k-space

FT





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Single Slice Spin Echo

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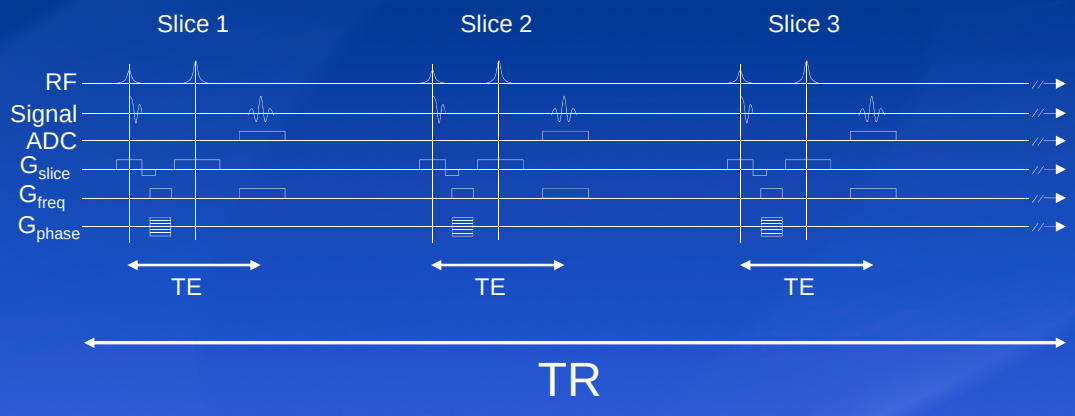
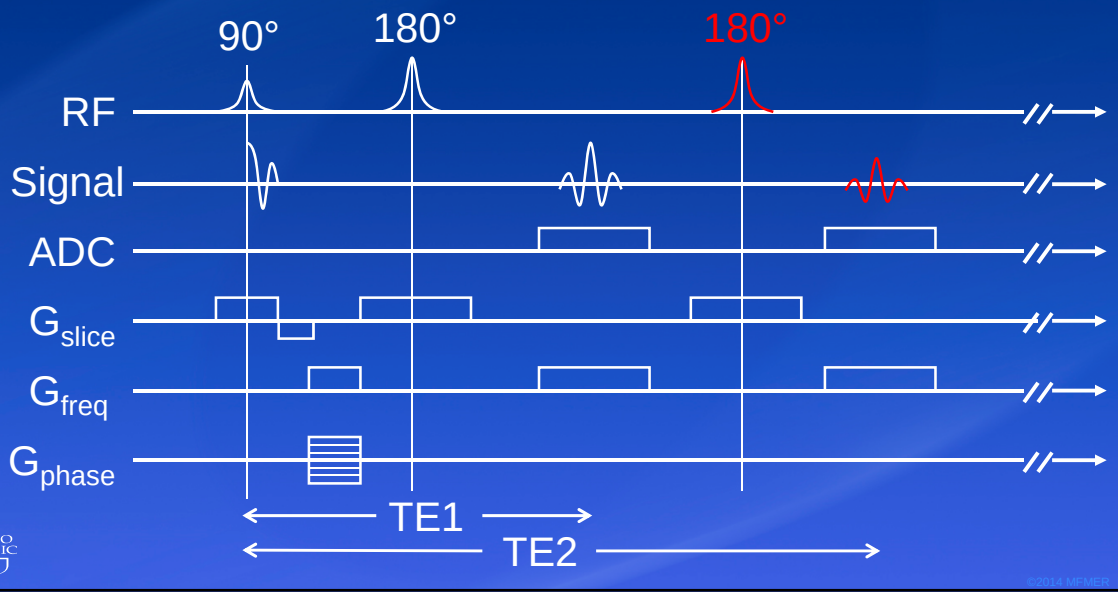
Multi-Slice Spin Echo



Multi-Echo Spin Echo

- Multiple images, each with different contrast
- Multiple 180° pulses, to create multiple echos
- Each echo is used to form a separate image
- Each image will have different contrast ranging from spin density to strong T2, depending on TE for that echo

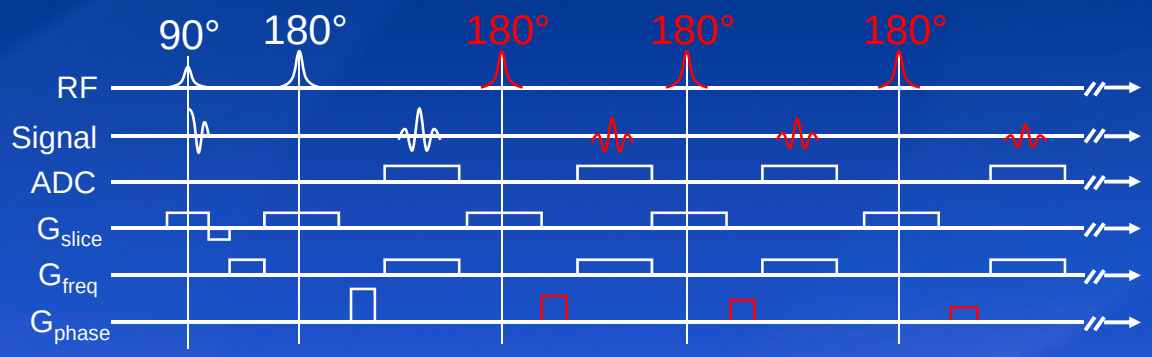
Multi-Echo Spin Echo



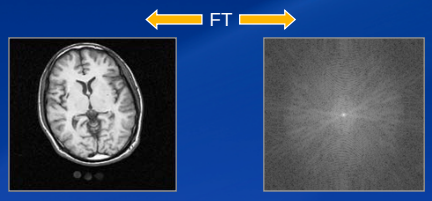
Turbo (Fast) Spin Echo

- Multiple 180° pulses to create multiple echos
- All echos used to create single image
- Scan time decreased by echo train length
- T1 and T2 weighting
- Scan Time = TR x N_P x NSA / ETL

Turbo Spin Echo

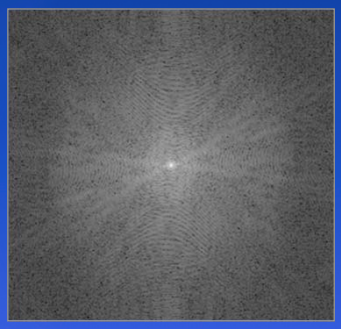


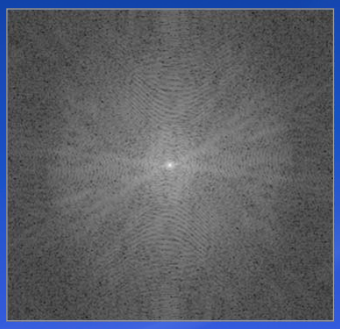
Echo Train Length (ETL) = 4



ETL = 4
is 4 Times
Faster!

256 TR
Periods





64 TR
Periods

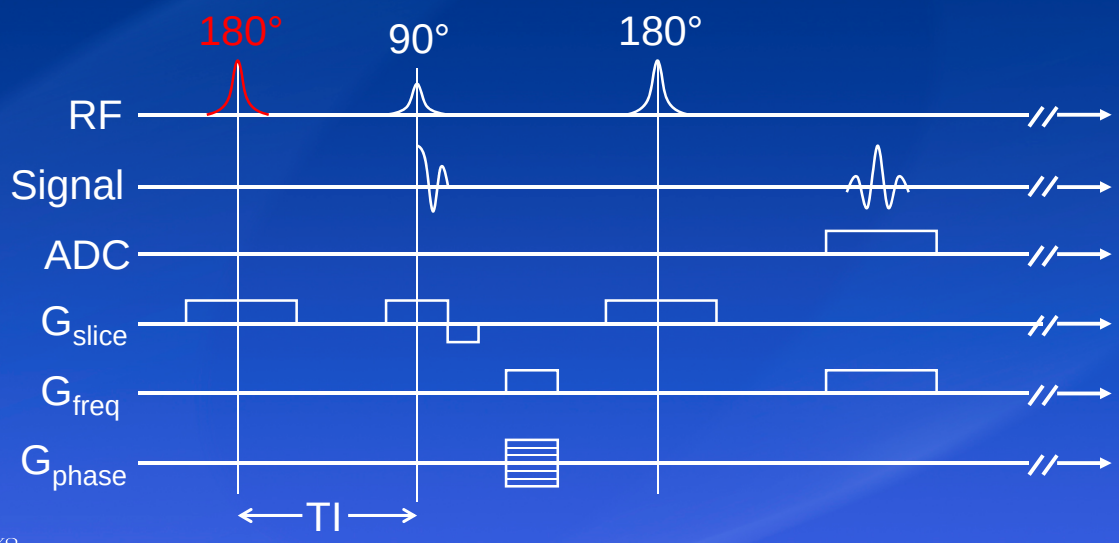
SE

FSE

Inversion Recovery

- Can be used to produce strong T1 weighted images
- Can be used to suppress fat, e.g. short TI inversion recovery (STIR)
  - Does not depend on B_0 inhomogeneity
- Can be used to suppress fluid, e.g. fluid-attenuated inversion recovery (FLAIR)

Inversion Recovery

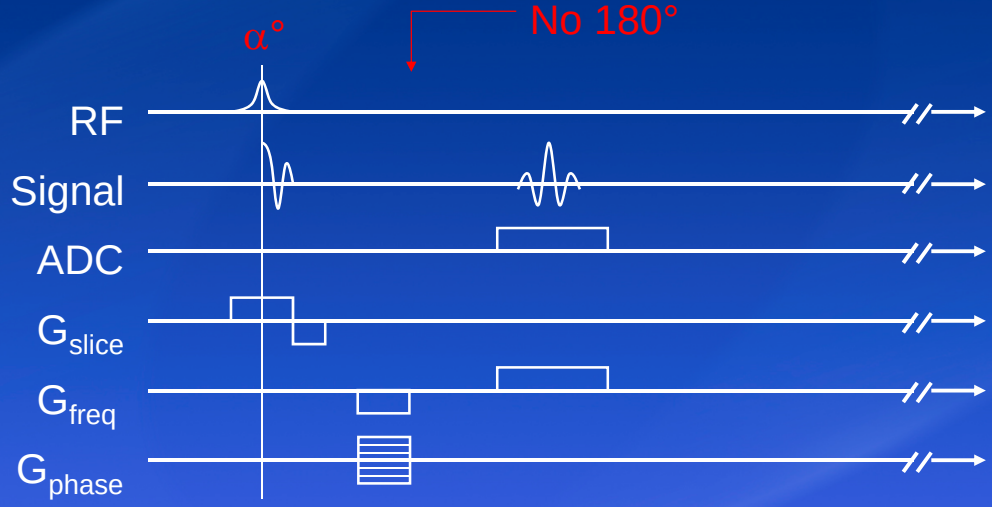


Inversion Recovery - STIR

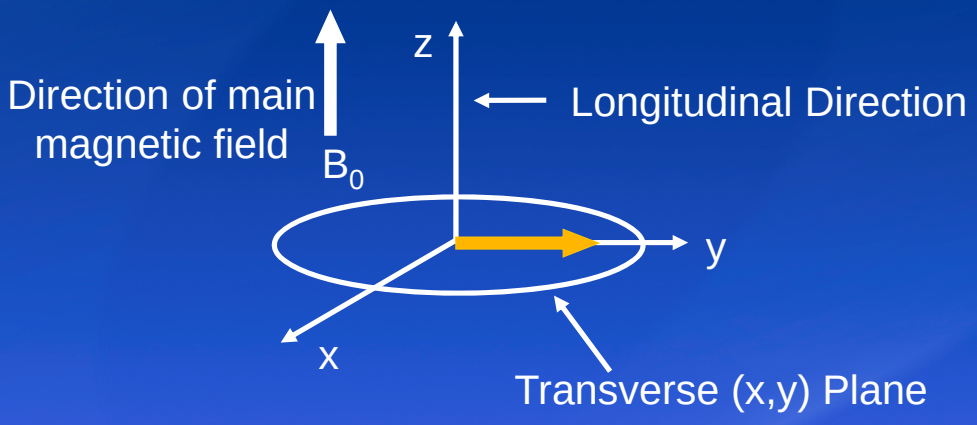
Gradient Echo

- Partial flip angle, no 180° refocusing pulse
- This allows very short TR
- Uses gradients to rephase echo
- Produces T1 or T2* contrast
- Scan time = TR x N_P x NSA
- Options include spoiled GE, steady-state GE
- Does not rephase effects of B_0 inhomogeneity, chemical shift, or magnetic susceptibility

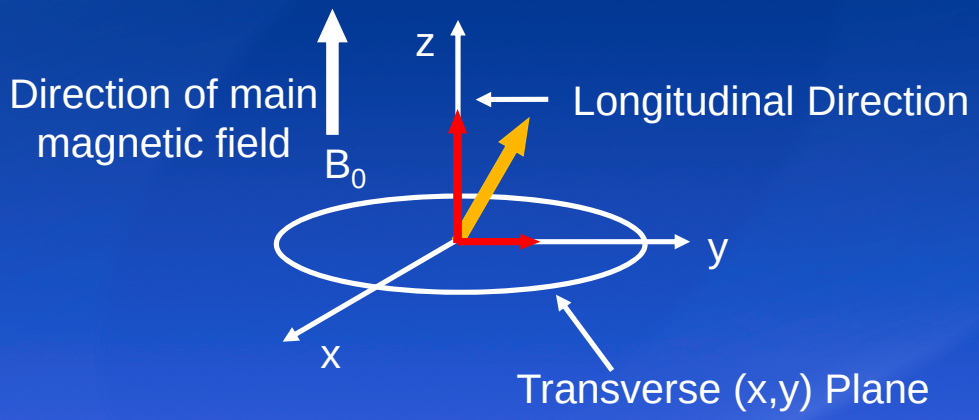
Gradient Echo



Flip Angle - 90°



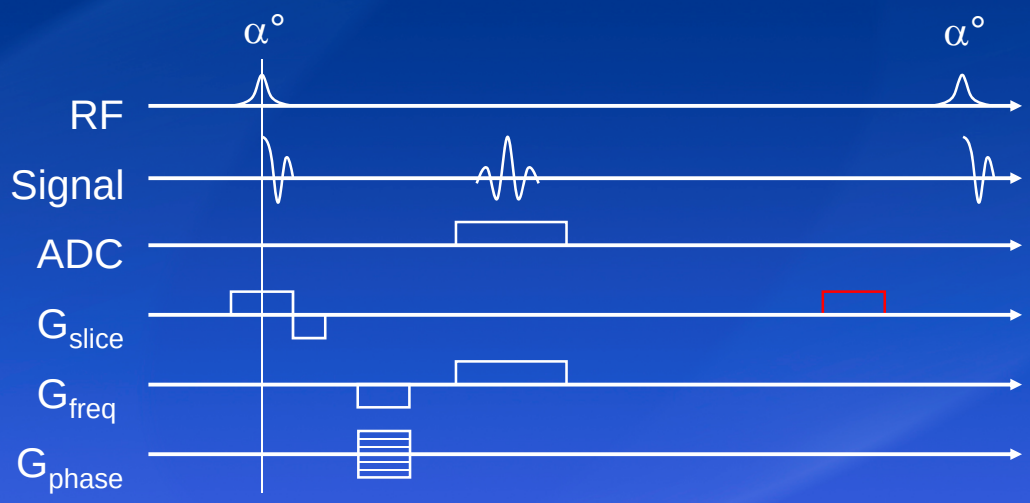
Flip Angle - α°



Gradient Echo (Spoiled / Incoherent)

- "Spoiling" is used to remove residual transverse magnetization at end of sequence, before next RF pulse
- Spoiling is accomplished by using extra gradient pulses, RF pulses, or both to completely dephase the spins
- E.g. Fast Low Angle Shot (FLASH); Spoiled Gradient Recalled Echo (SPGR); T1 Fast Field Echo (T1-FFE)

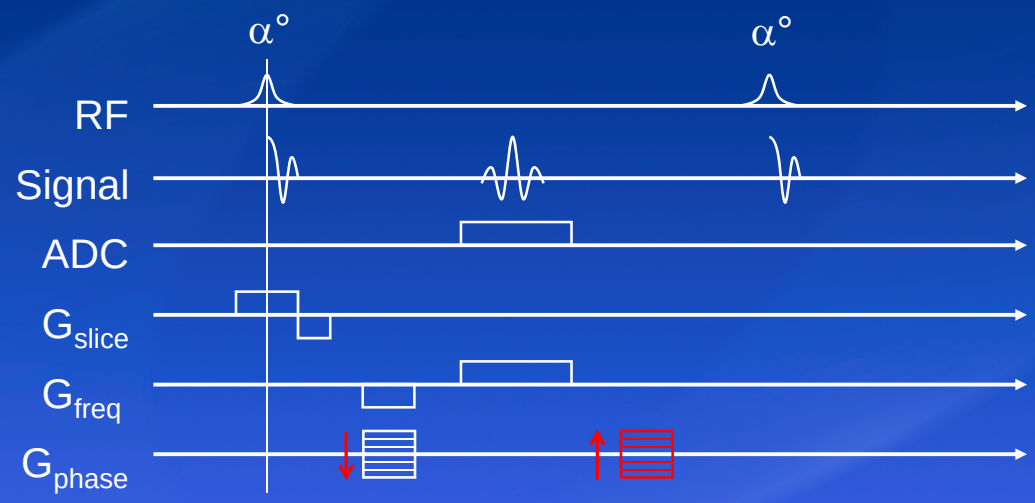
Gradient Echo – Spoiled / Incoherent



Gradient Echo (Steady-state / Coherent)

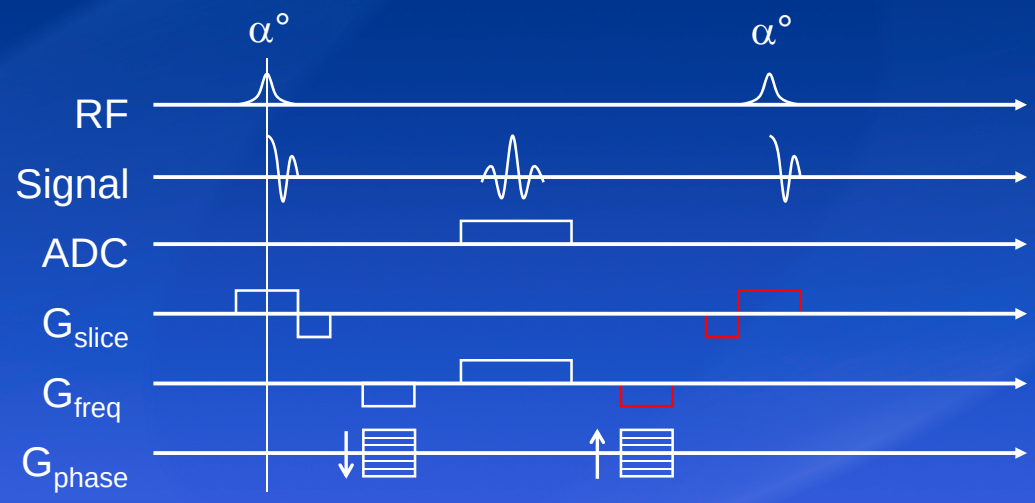
- Residual transverse magnetization at end of sequence is “rewound”
- This signal then combines coherently with new signal in the transverse plane, increasing overall signal
- E.g. Gradient Recalled Acquisition in the Steady State (GRASS); Gradient Recalled Echo (GRE); Fast Imaging with Steady-state Precession (FISP); Fast Field Echo (FFE)

Gradient Echo – Steady State / Coherent



E.g. FISP

Gradient Echo – Steady State / Coherent

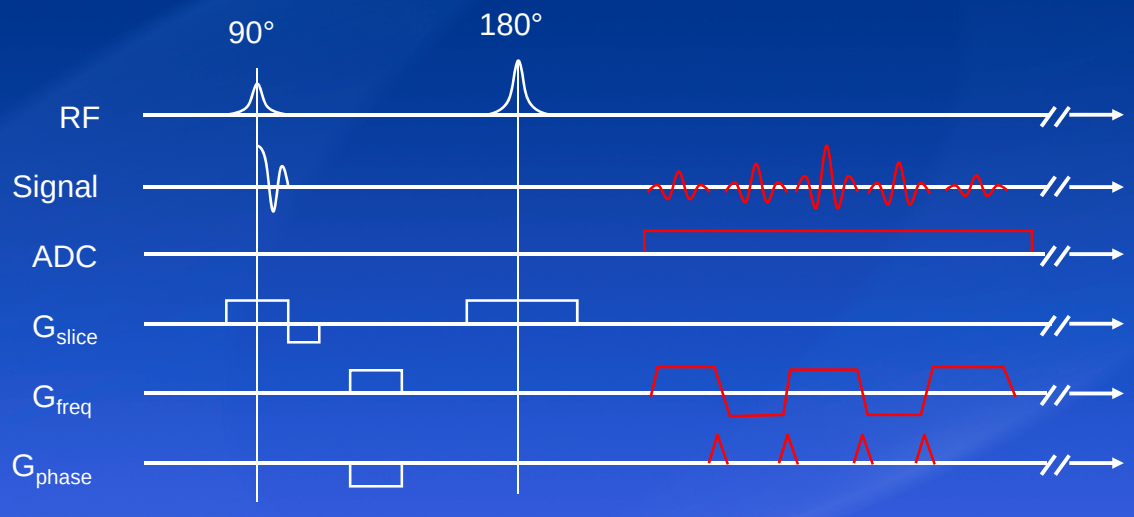


E.g. True FISP

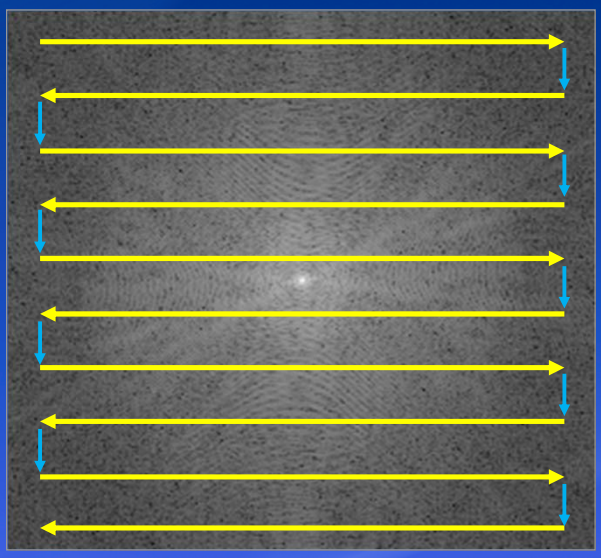
Echo Planar

- Method of ultrafast MR signal acquisition
- All of k-space can be acquired in a “single shot” by rapid gradient reversal and echo collection after a single set of RF pulses
- EPI is a fast readout mechanism; the excitation pulses produce the contrast, the signal is read with EPI

Echo Planar



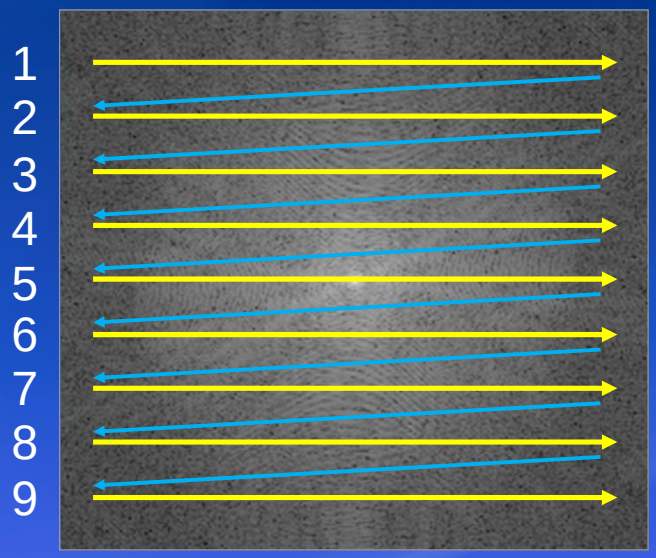
Echo Planar – Filling K-space



K-space Trajectories

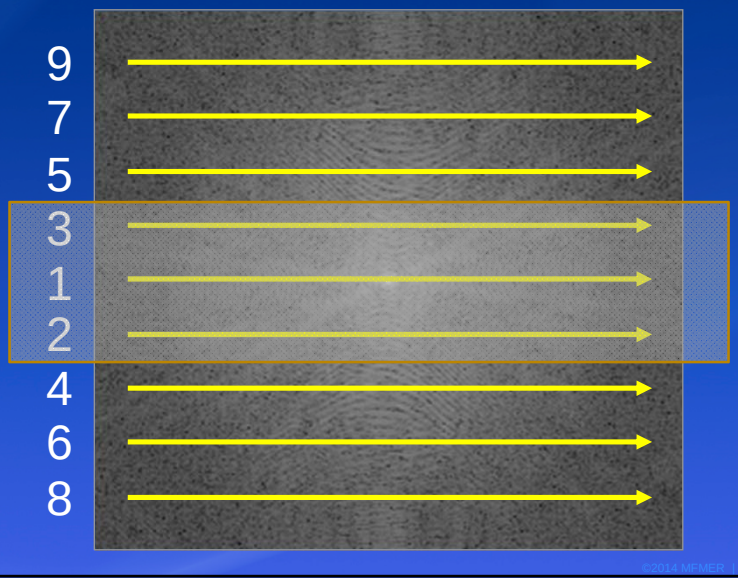
- Cartesian
  - Linear
  - Centric
- Non-cartesian
  - Radial
  - Propeller
  - Spiral

Cartesian - Linear

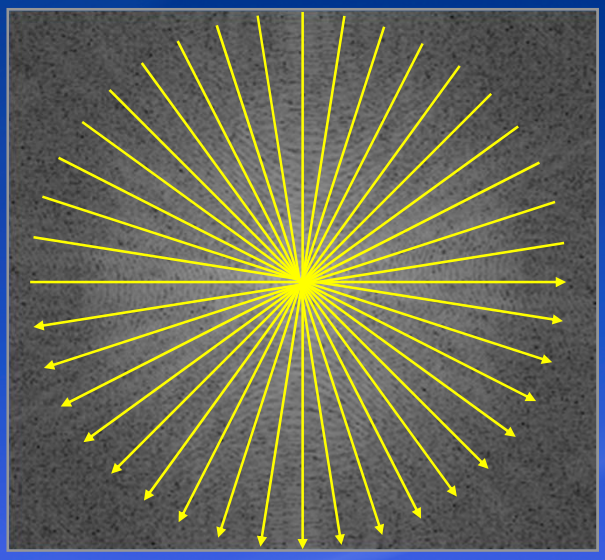


Cartesian - Centric

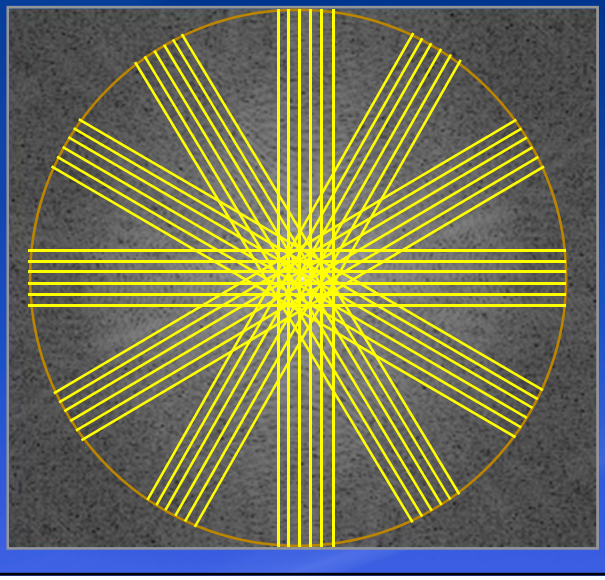
Image contrast at center of k-space



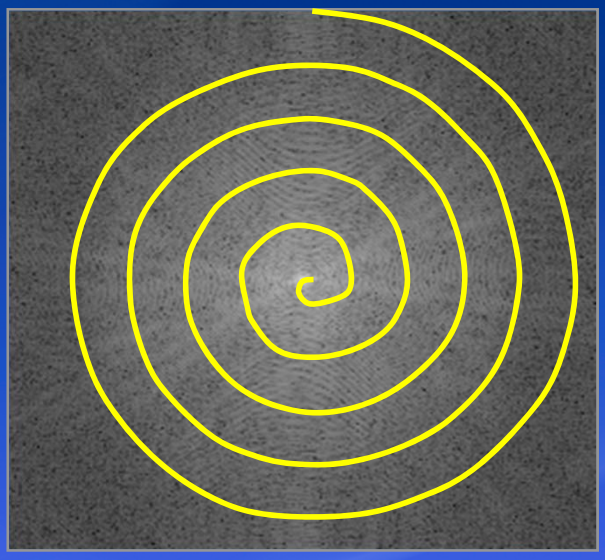
Non-Cartesian - Radial



Non-Cartesian - Propeller



Non-Cartesian – Spiral



Recommended Reading

- Handbook of MRI Pulse Sequences. Bernstein, King, Zhou. 2004
- Breast MRI – Fundamentals and Technical Aspects. R.Edward Hendrick. 2010
- AAPM/RSNA Physics Tutorial for Residents – Fundamental Physics of MR Imaging. RAPooley. 2005
- MRI From Picture to Proton. McRobbie, Moore, Graves, Prince. 2007

Thank You
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