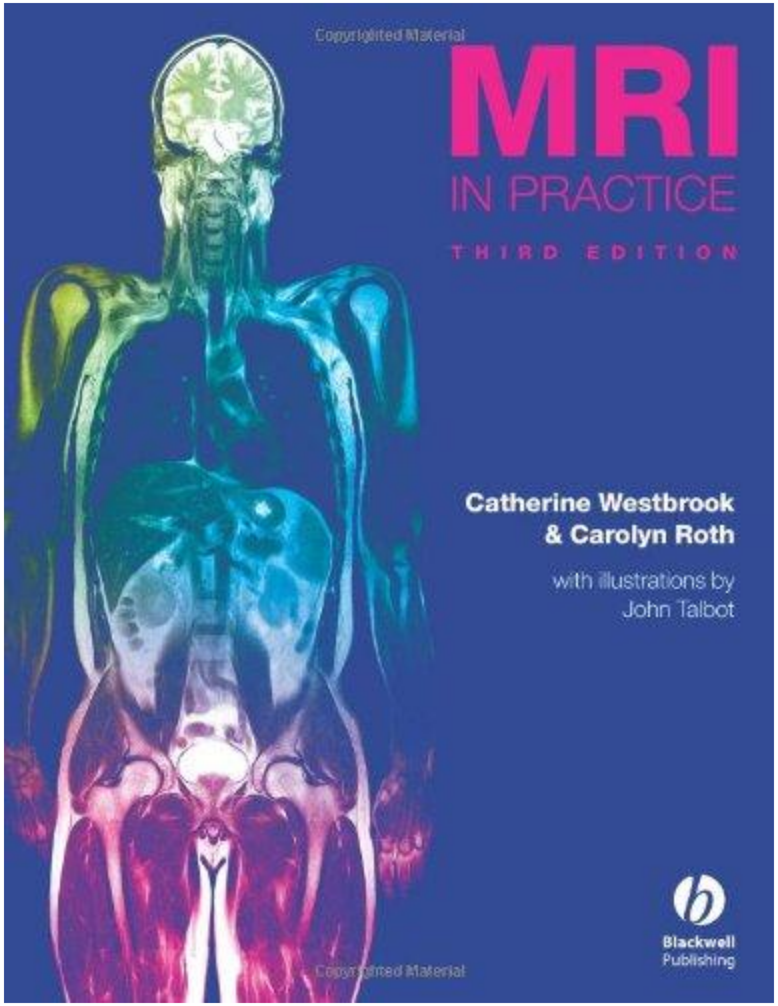
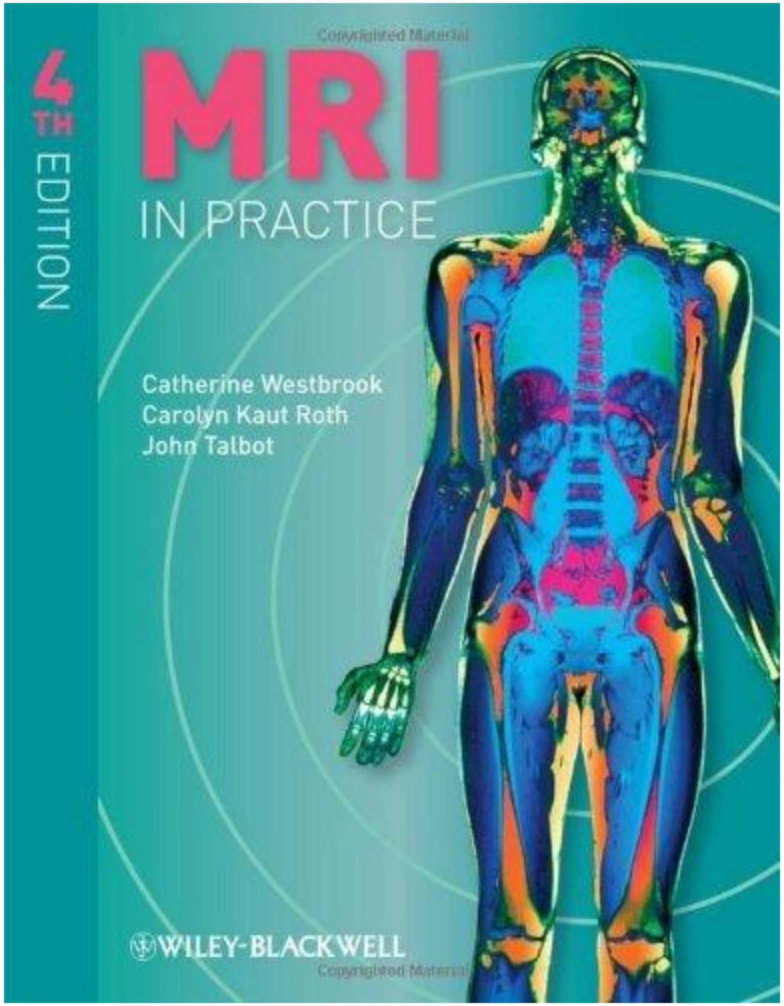
Pulse Sequences

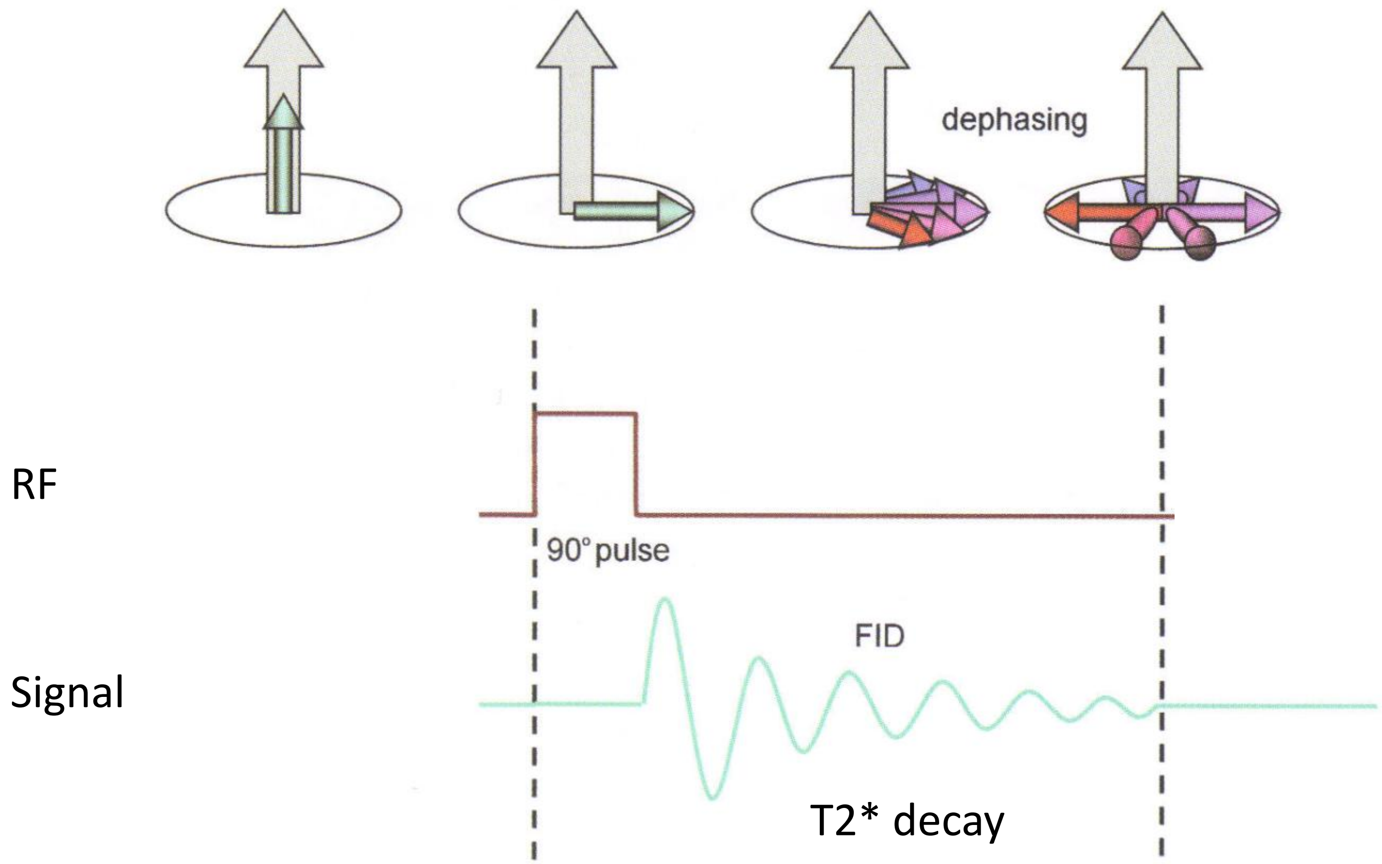
Lei Qin, PhD
Clinical MRI Physicist
Dana-Farber Cancer Institute

Reference Book



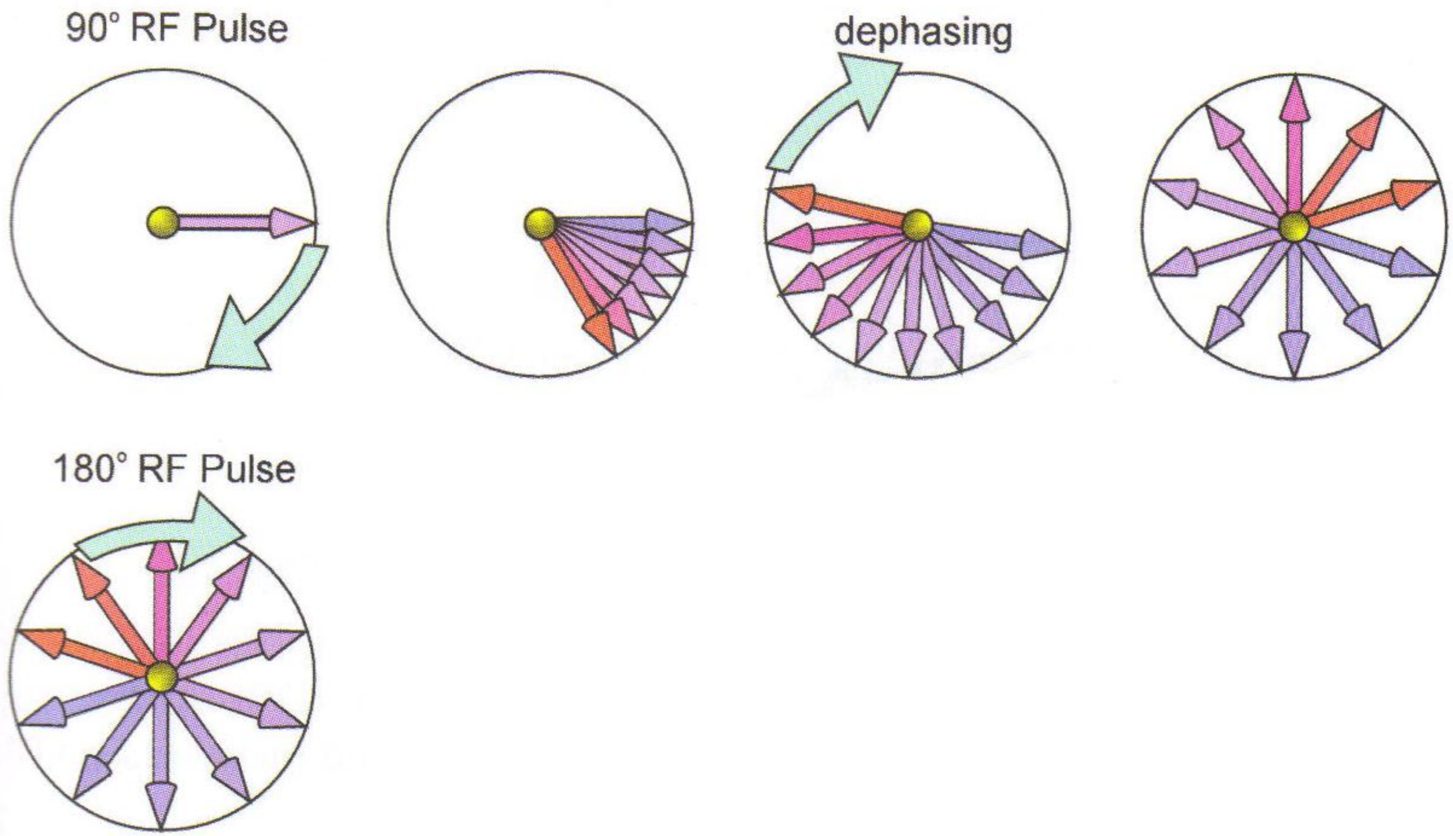


Pulse Sequence

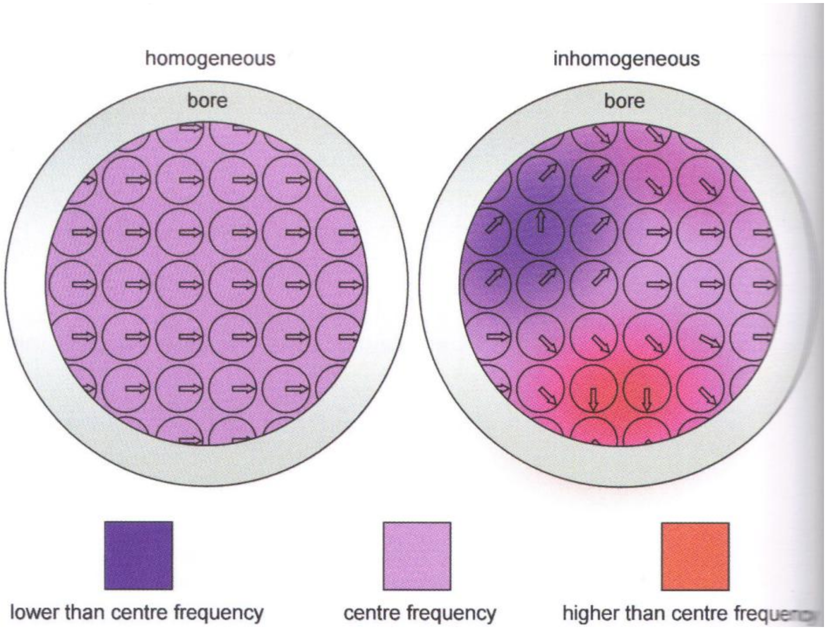


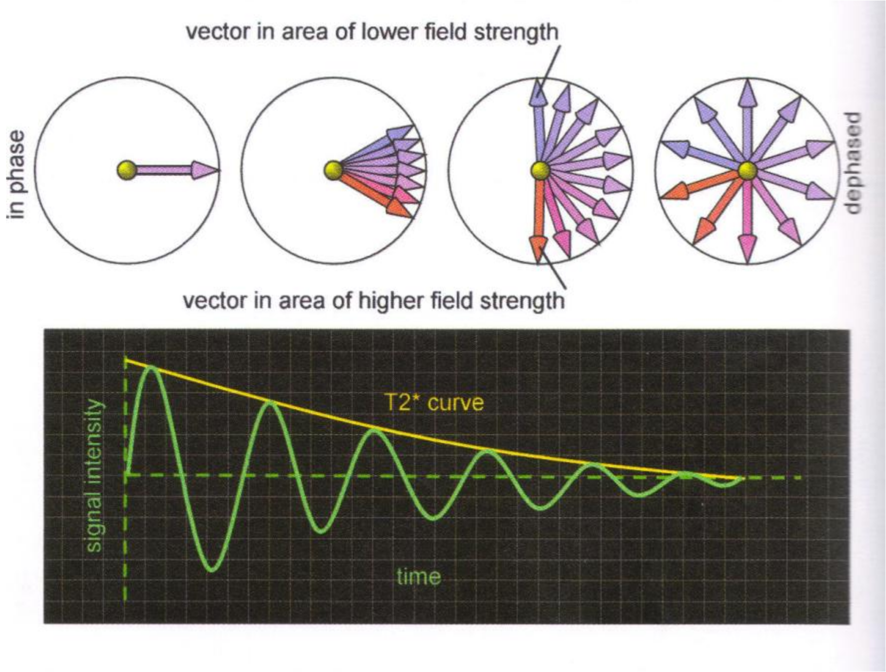
An MRI sequence is an ordered combination of RF and gradient pulses designed to acquire the data to form the image.

Spin Echo Sequence



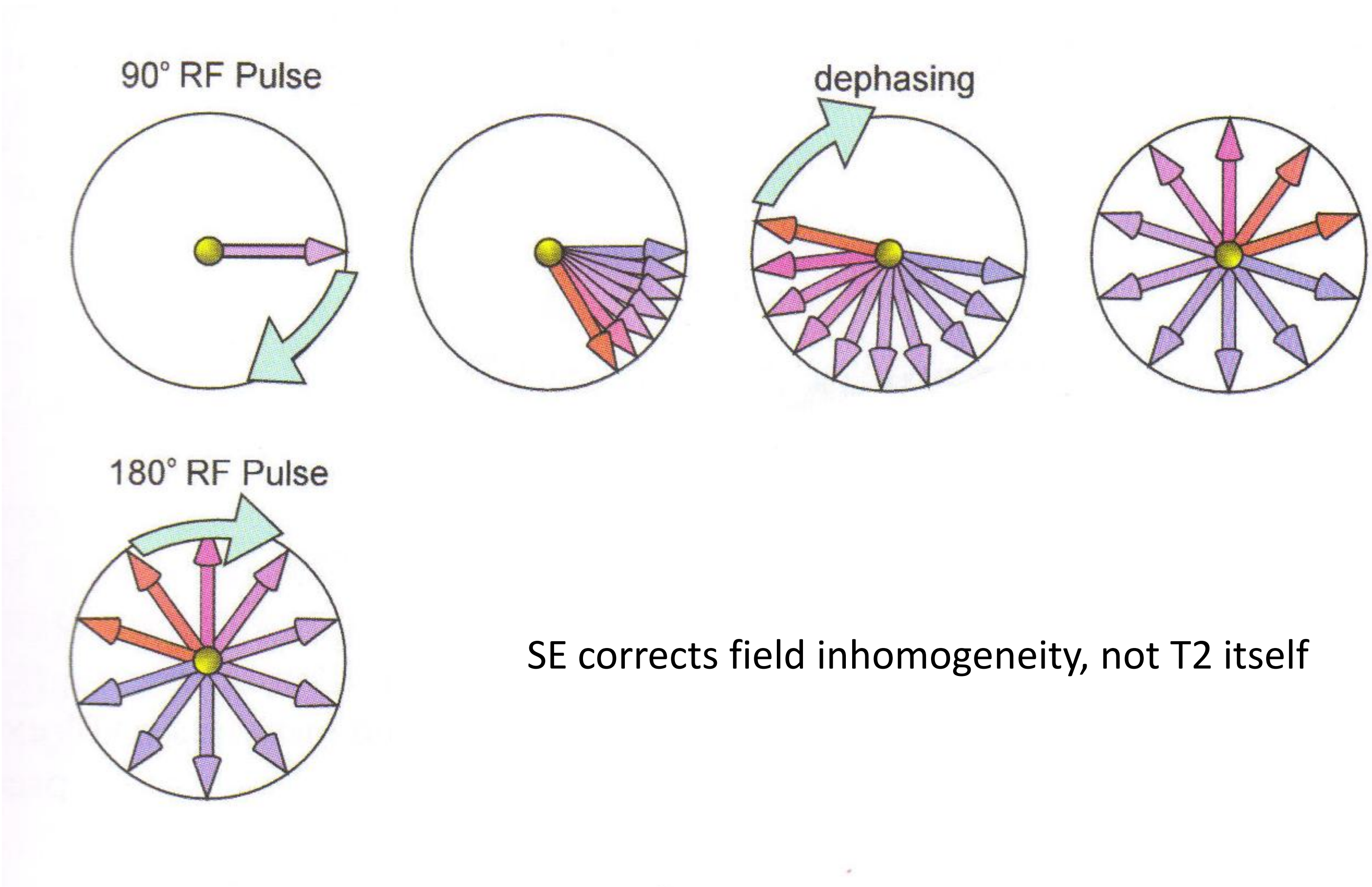
T2* Decay



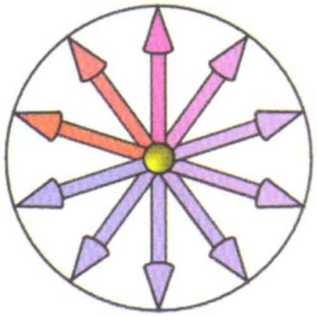


- T2* decay is faster than T2 decay since it is a combination of two effects
  - T2 decay itself
  - Dephasing due to magnetic field inhomogeneities

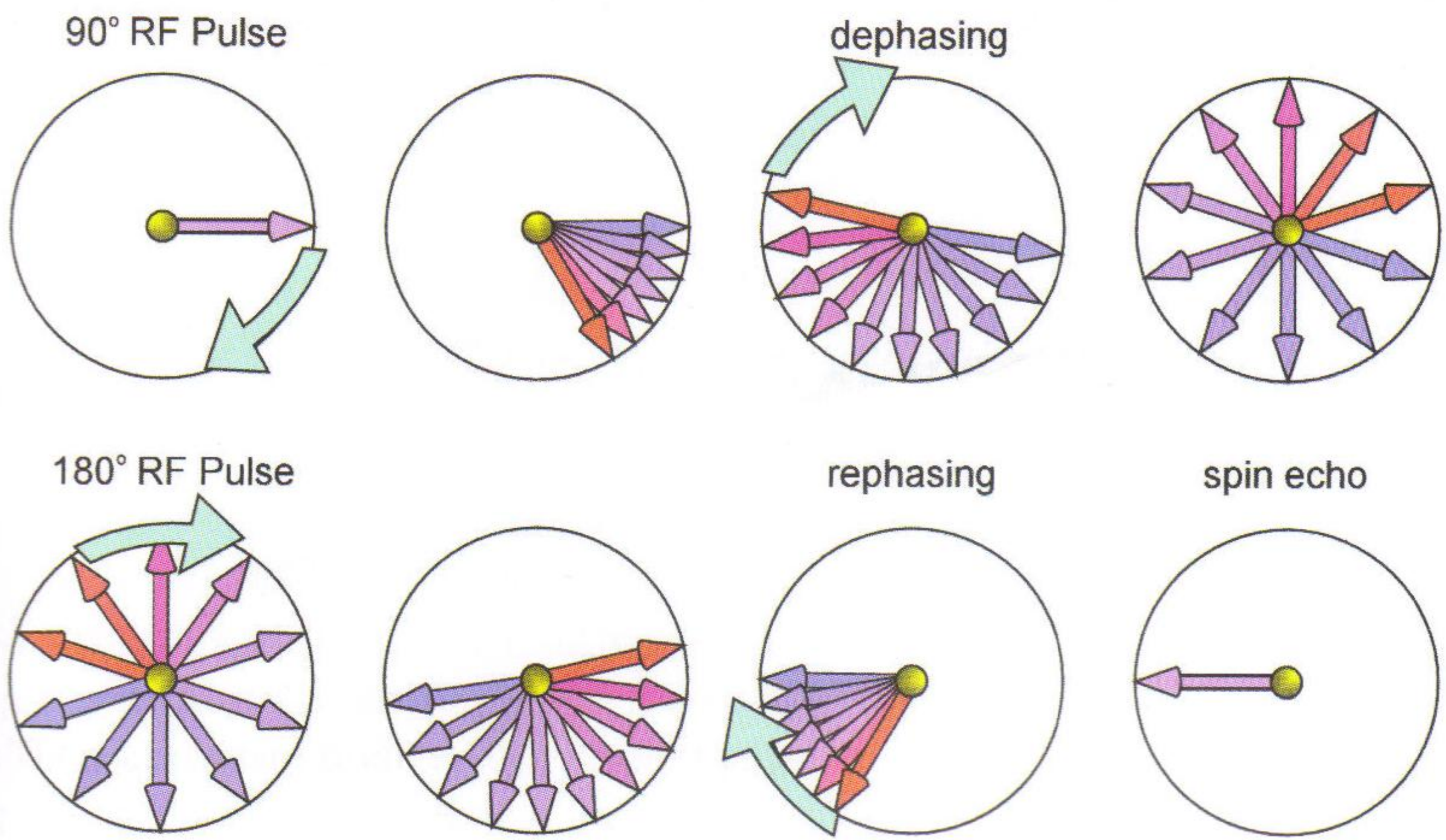
Spin Echo Sequence



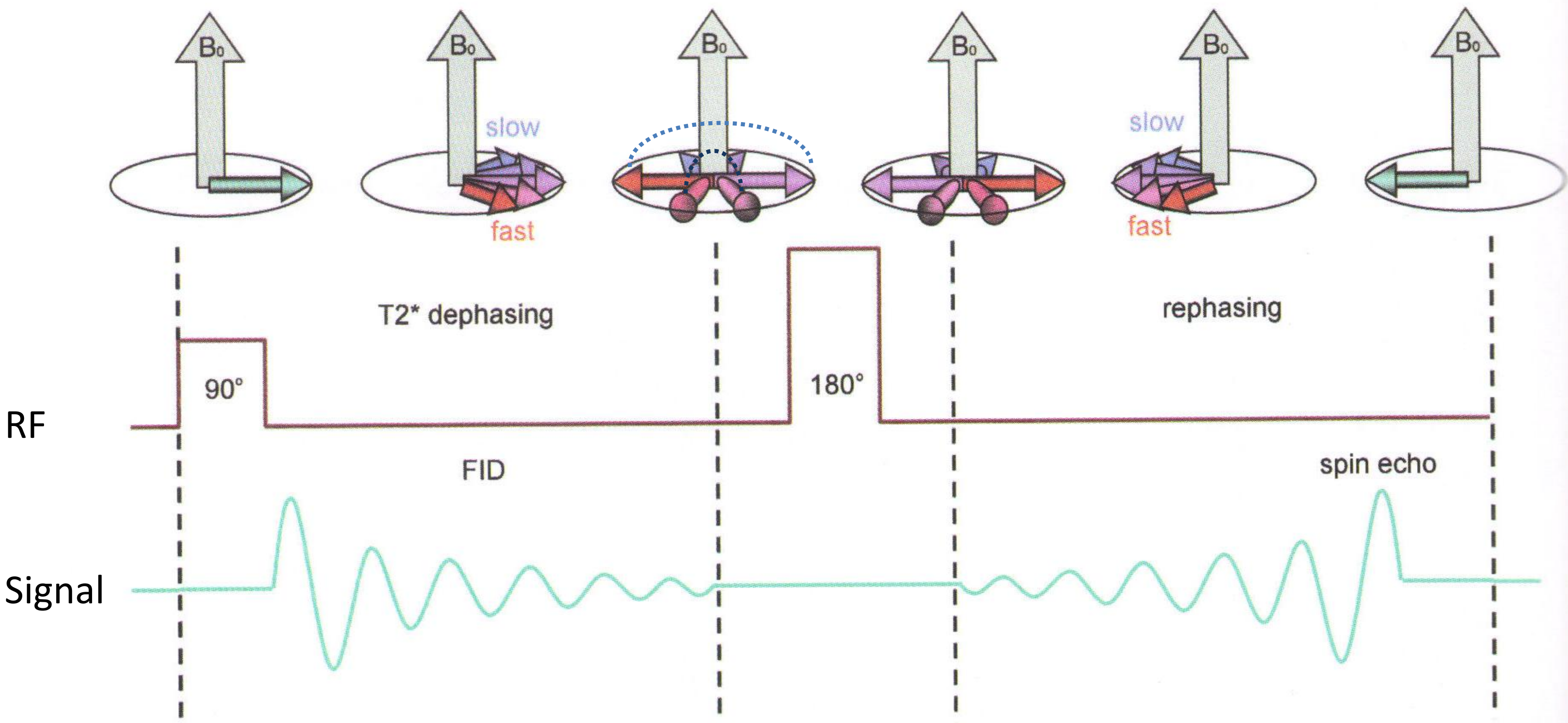
SE corrects field inhomogeneity, not T2 itself



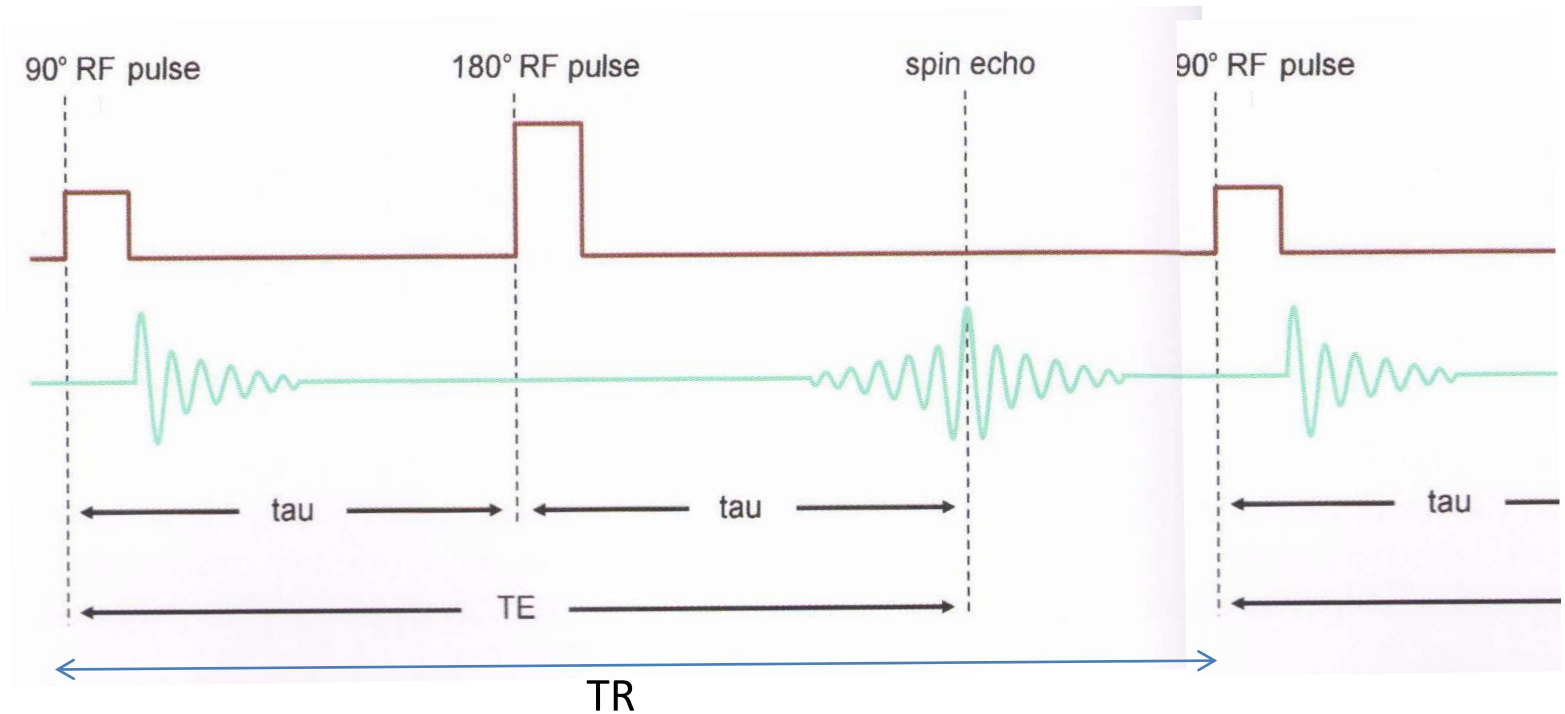
Spin Echo Sequence



Spin Echo Sequence

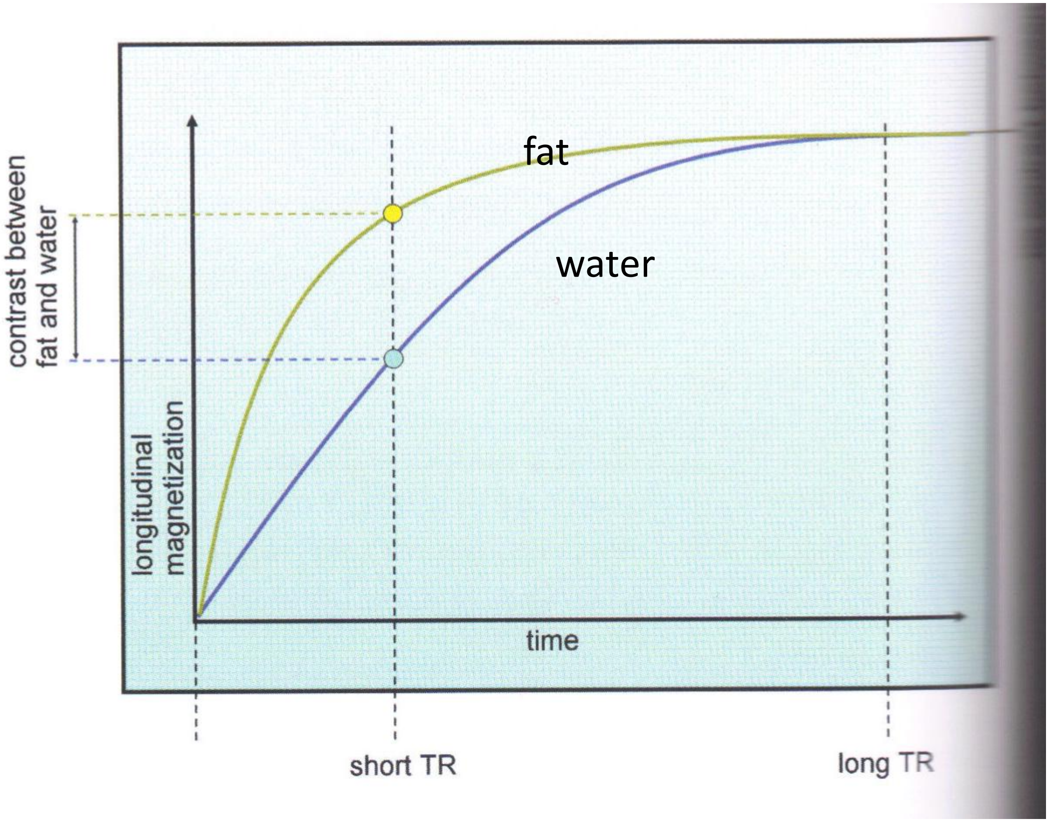


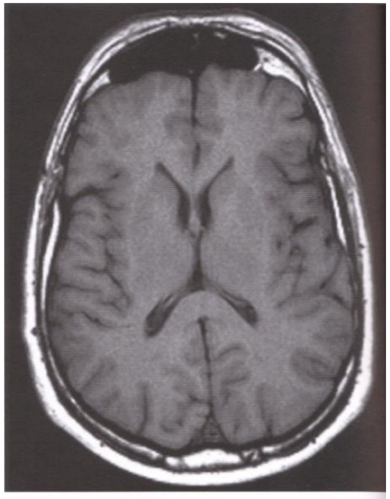
Timing parameters in spin echo



- TR is the time between each 90° excitation pulse
- TE is the time between the 90° excitation pulse and the peak of the spin echo

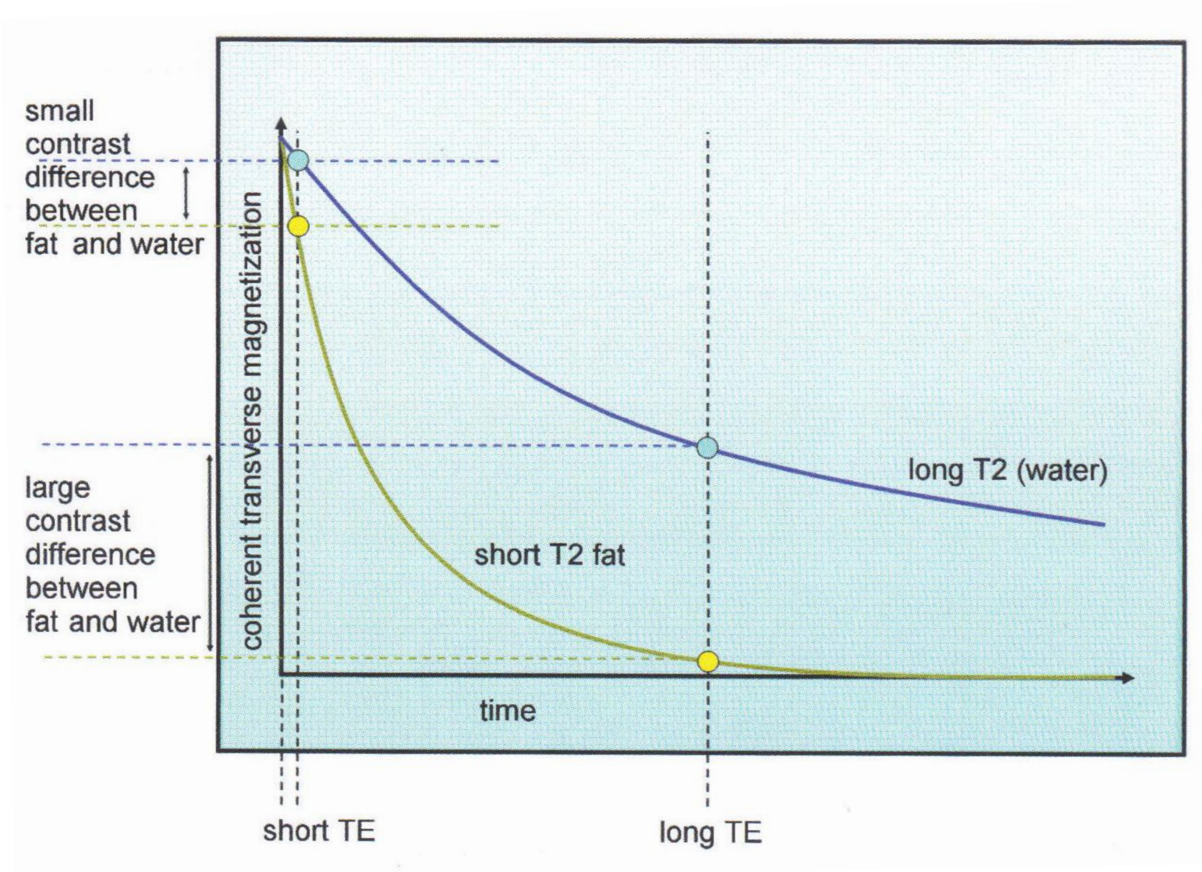
T1 Weighting

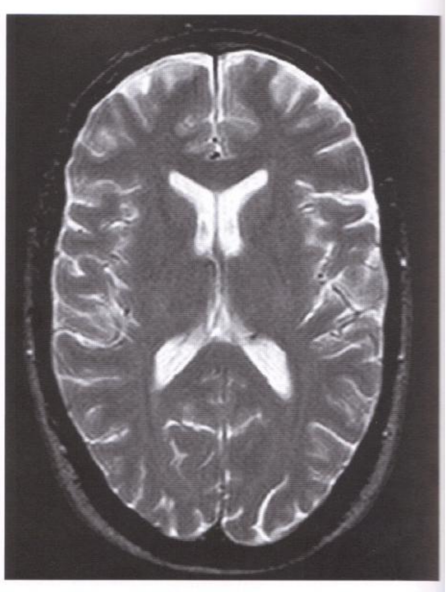




- TR controls the amount of T1 weighting
- For T1 weighting the TR must be short

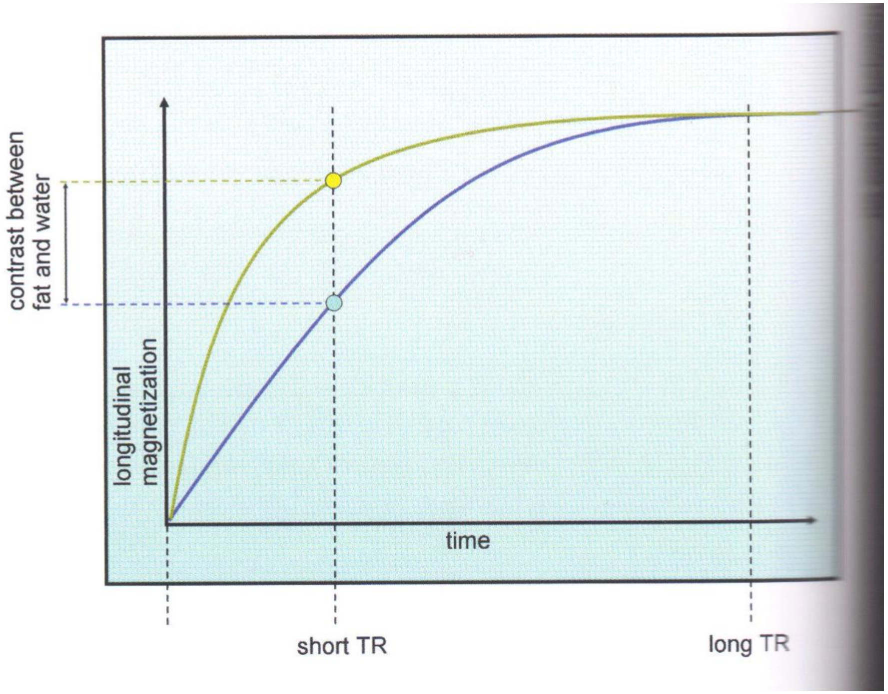
T2 weighting

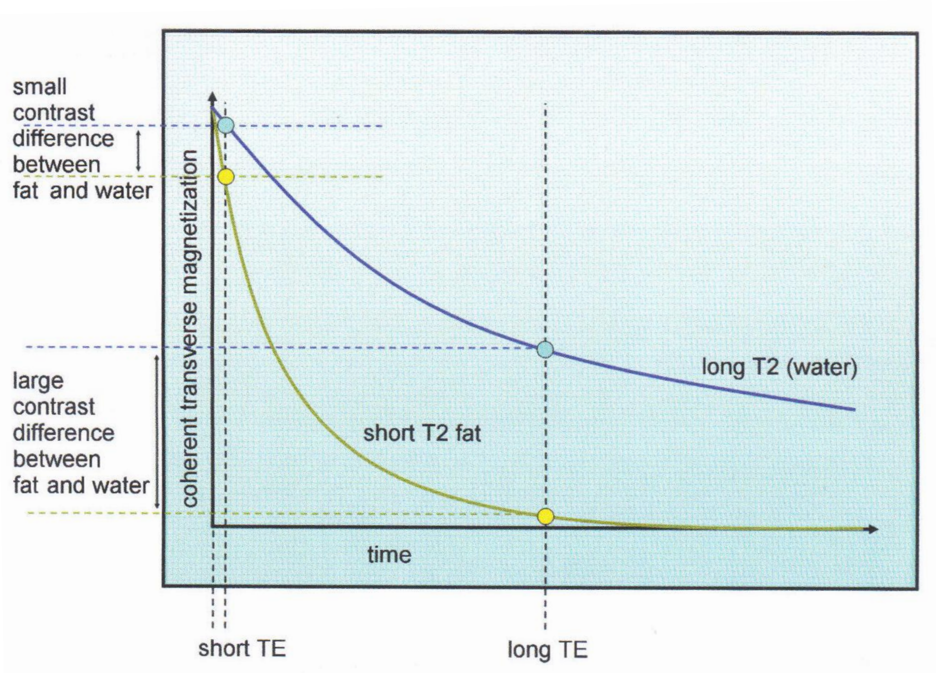


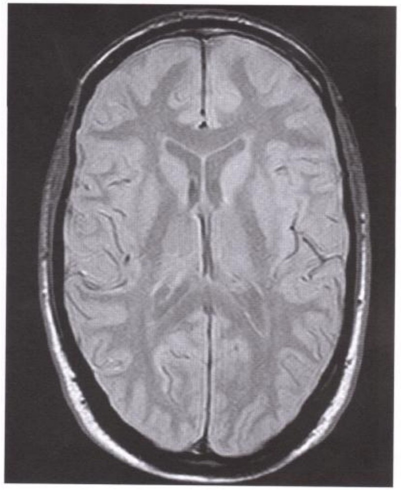


- TE controls the amount of T2 weighting
- For T2 weighting the TE must be long

Proton density weighting

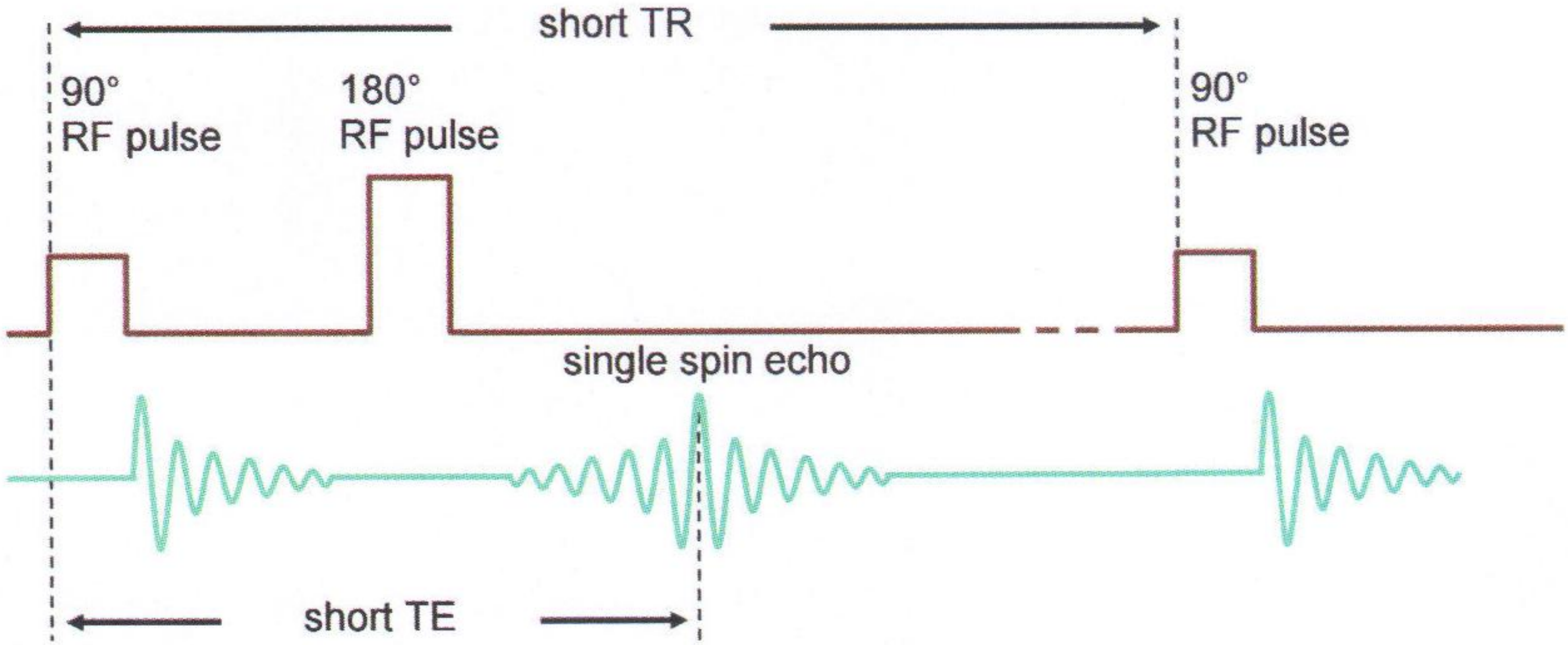


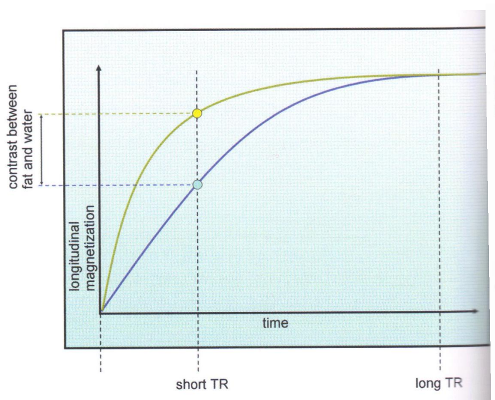


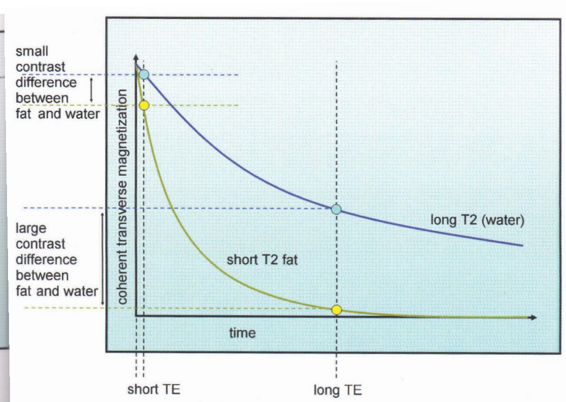


- For PD weighting the TR must be long and TE must be short

Spin echo using one echo



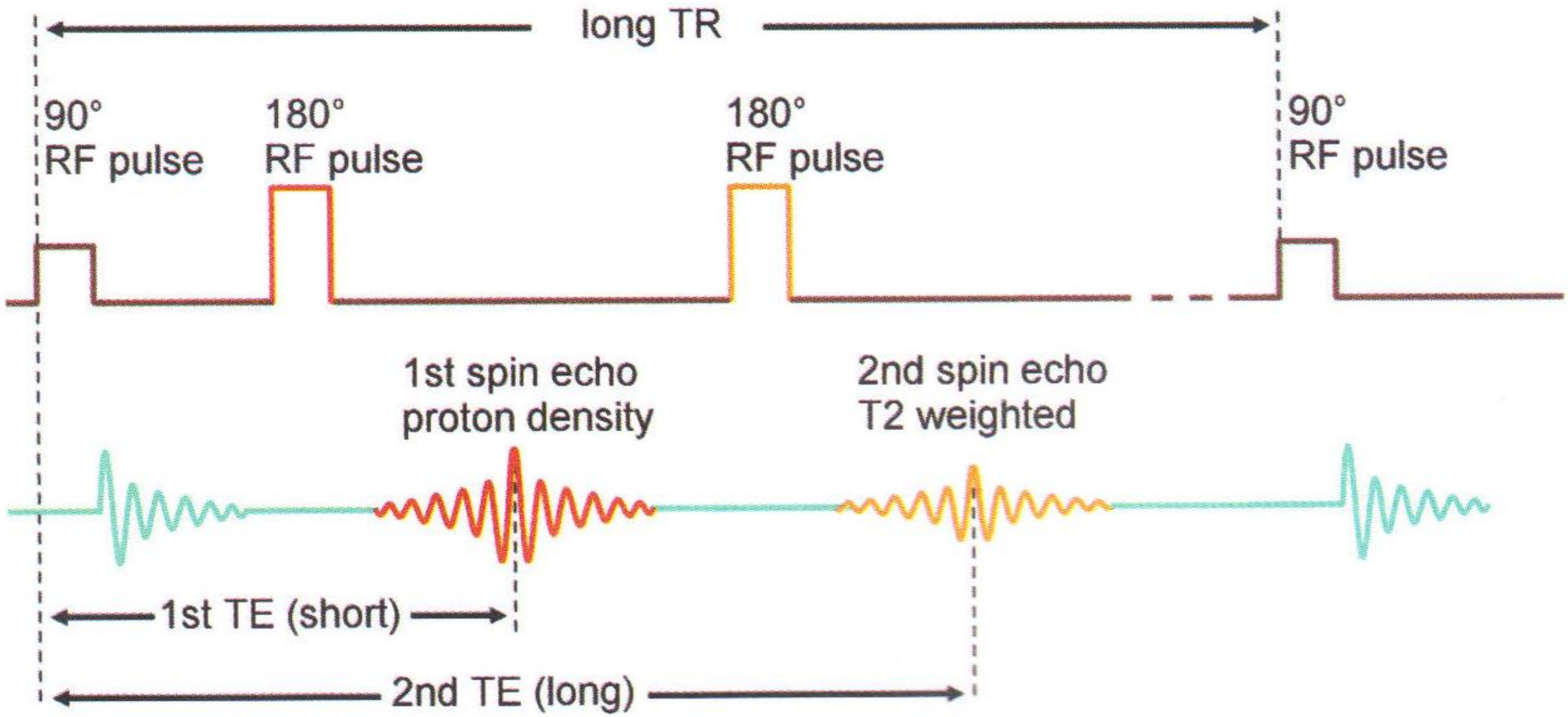




What contrast?

T1 weighting

Spin echo using two echoes



T2 weighting: long TR, long TE
PD weighting: long   TR, short TE

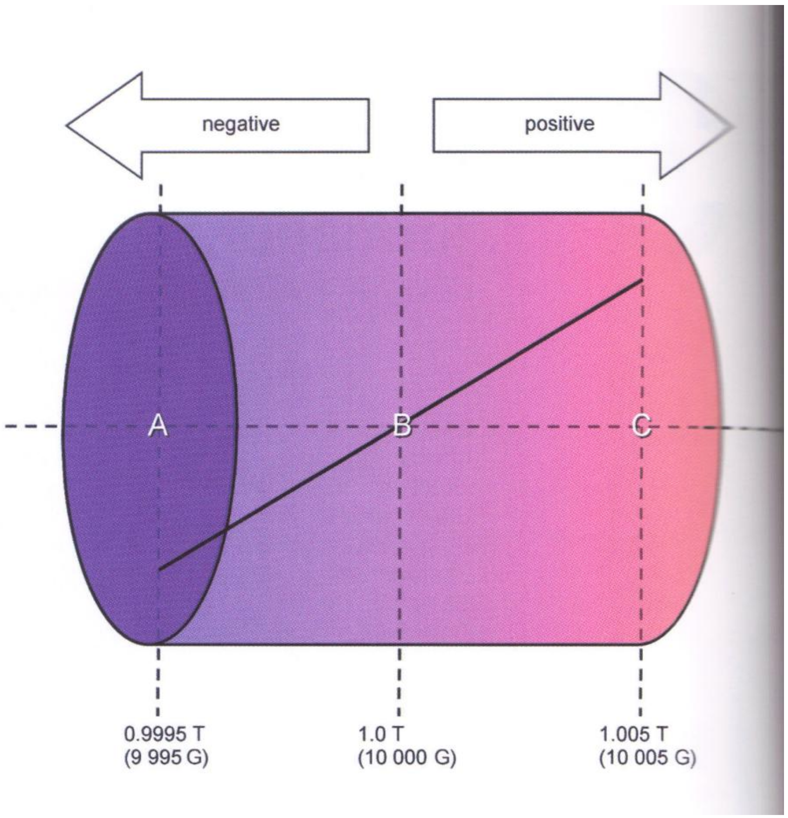
Typical values in spin echo

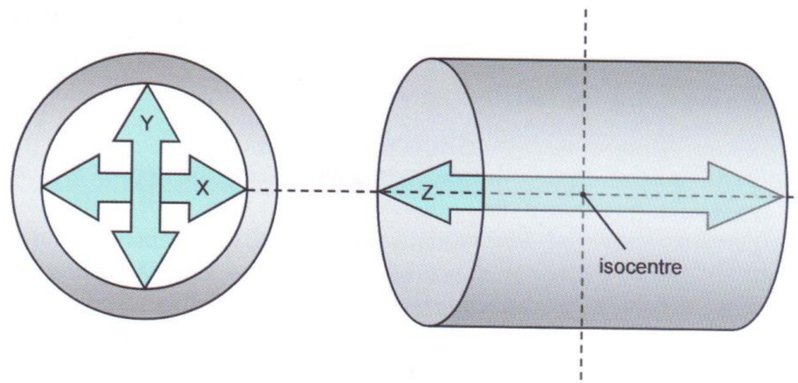
- T1 weighting
  - Short TE 10-20 ms
  - Short TR 300-700ms
  - Typical scan time 4-6 min

- Proton density/T2 weighting
  - Long TR 2000ms+
  - Short TE 20ms / long TE 80ms +
  - Typical scan time 7-15 min

Encoding and Image Formation

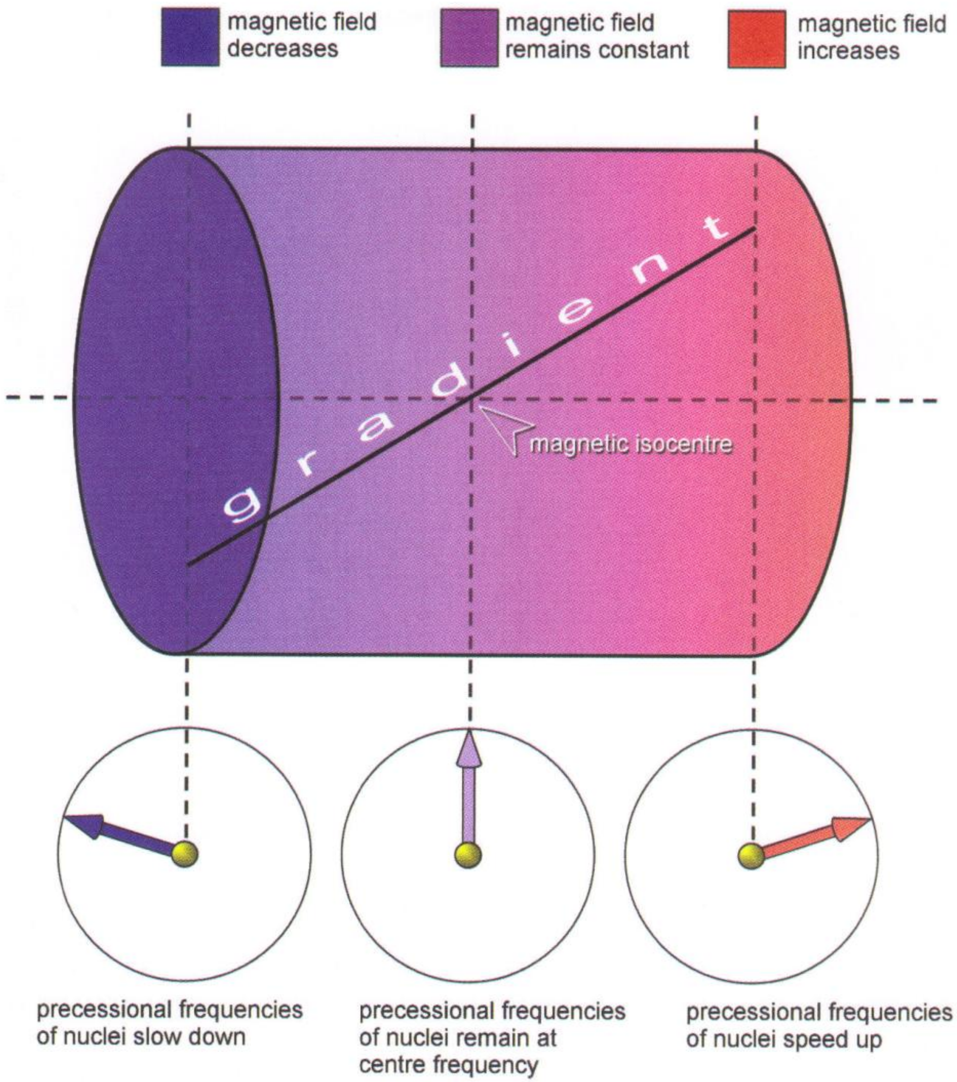
- Gradients





Z gradient – long axis of the magnet
Y gradient – vertical axis of the magnet
X gradient – horizontal axis of the magnet

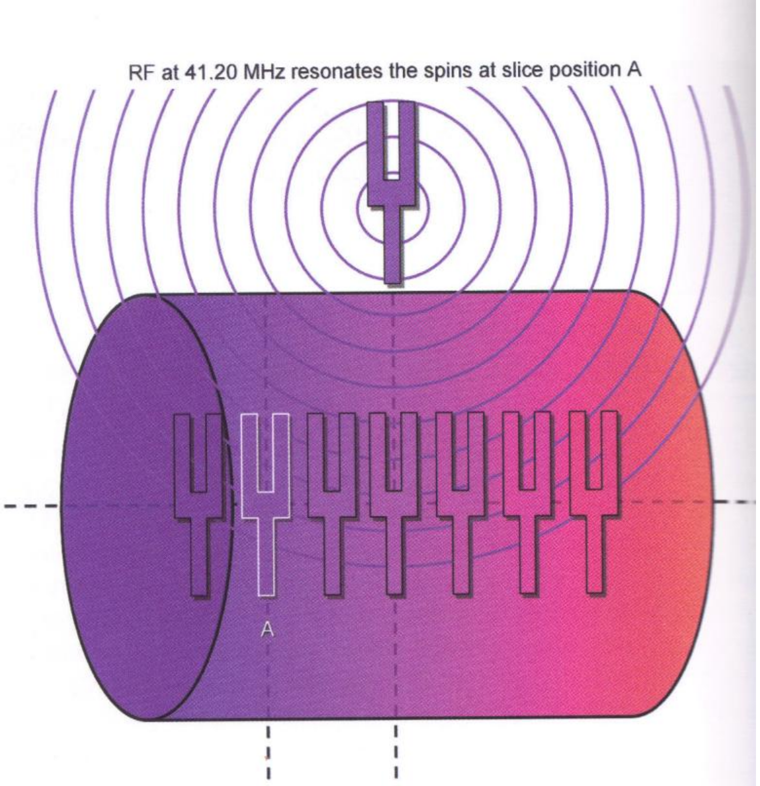
Gradients

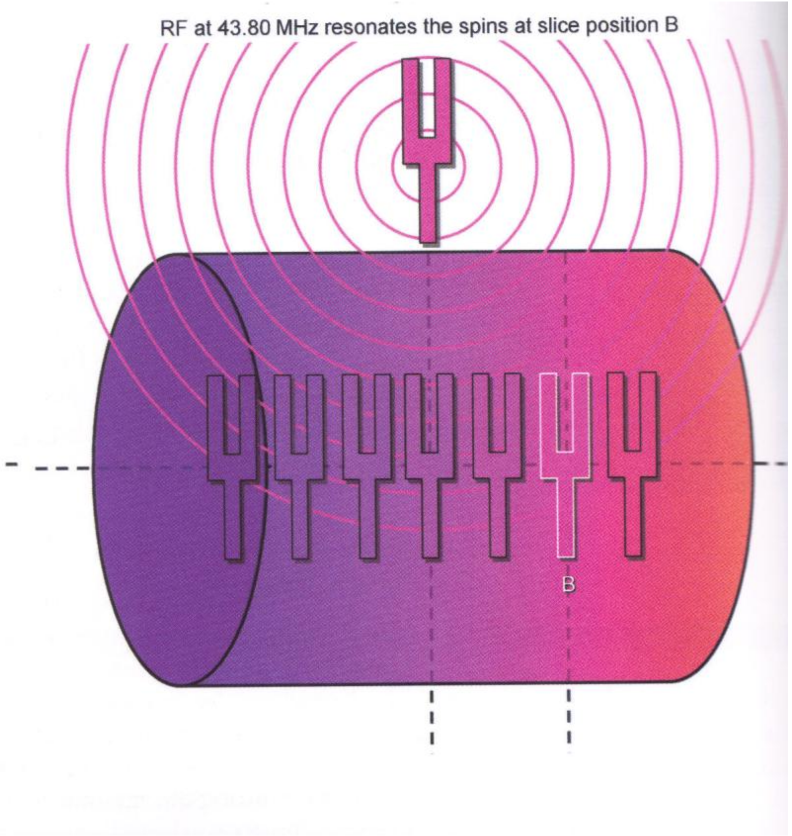


- Magnetic field gradients are generated by coils of wire situated within the bore of the magnet
- This gradient field interacts with B0, so the magnetic field strength along the axis of the gradient coil is altered in a linear way.
- Precessional frequencies vary according to the gradient field.

Slice selection

Tuning fork analogy

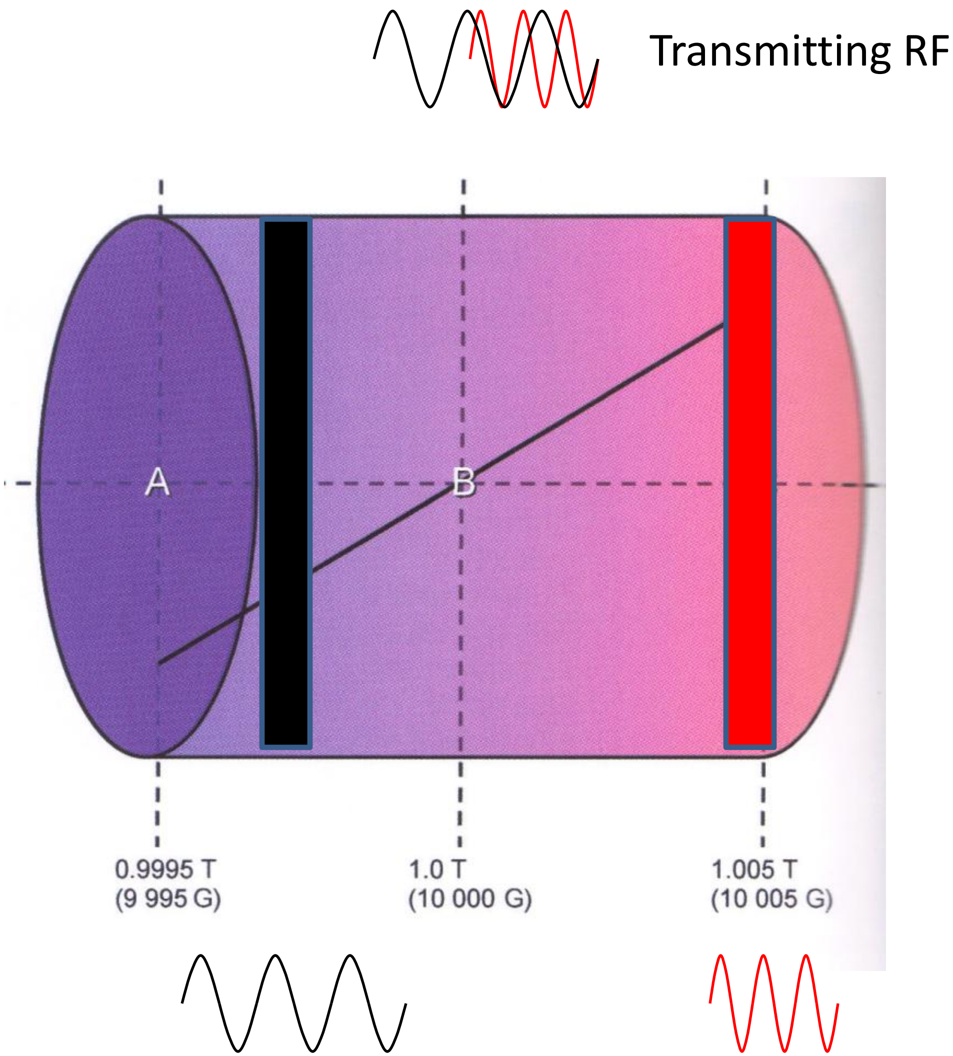




To produce resonance and excite spins in Slice A, a 41.2MHz RF must be applied

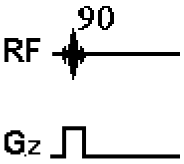
To produce resonance and excite spins in Slice B, a 43.8MHz RF must be applied

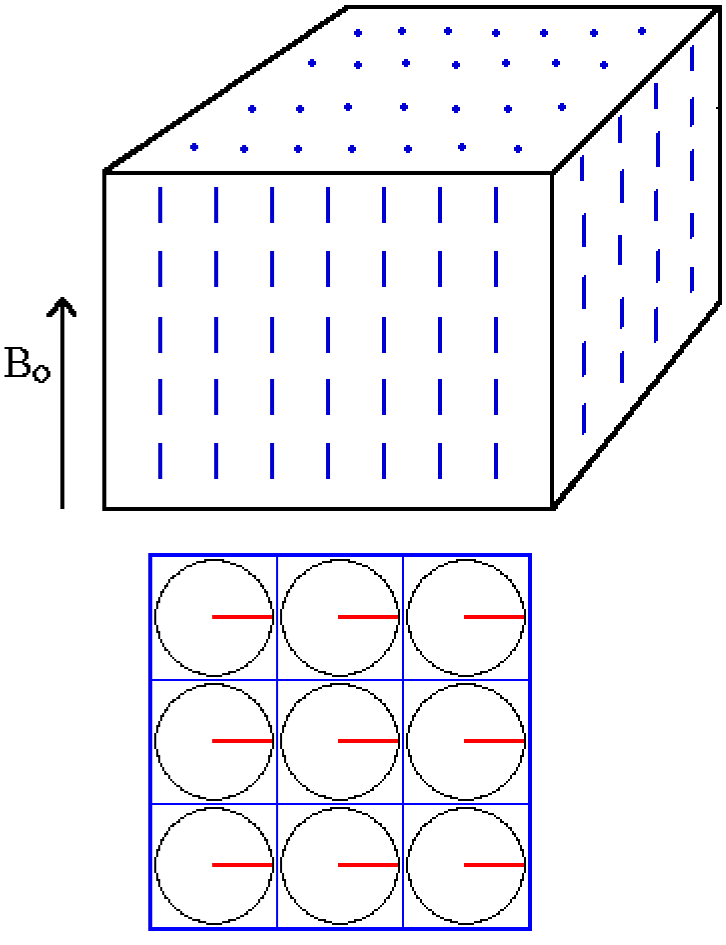
Slice selection



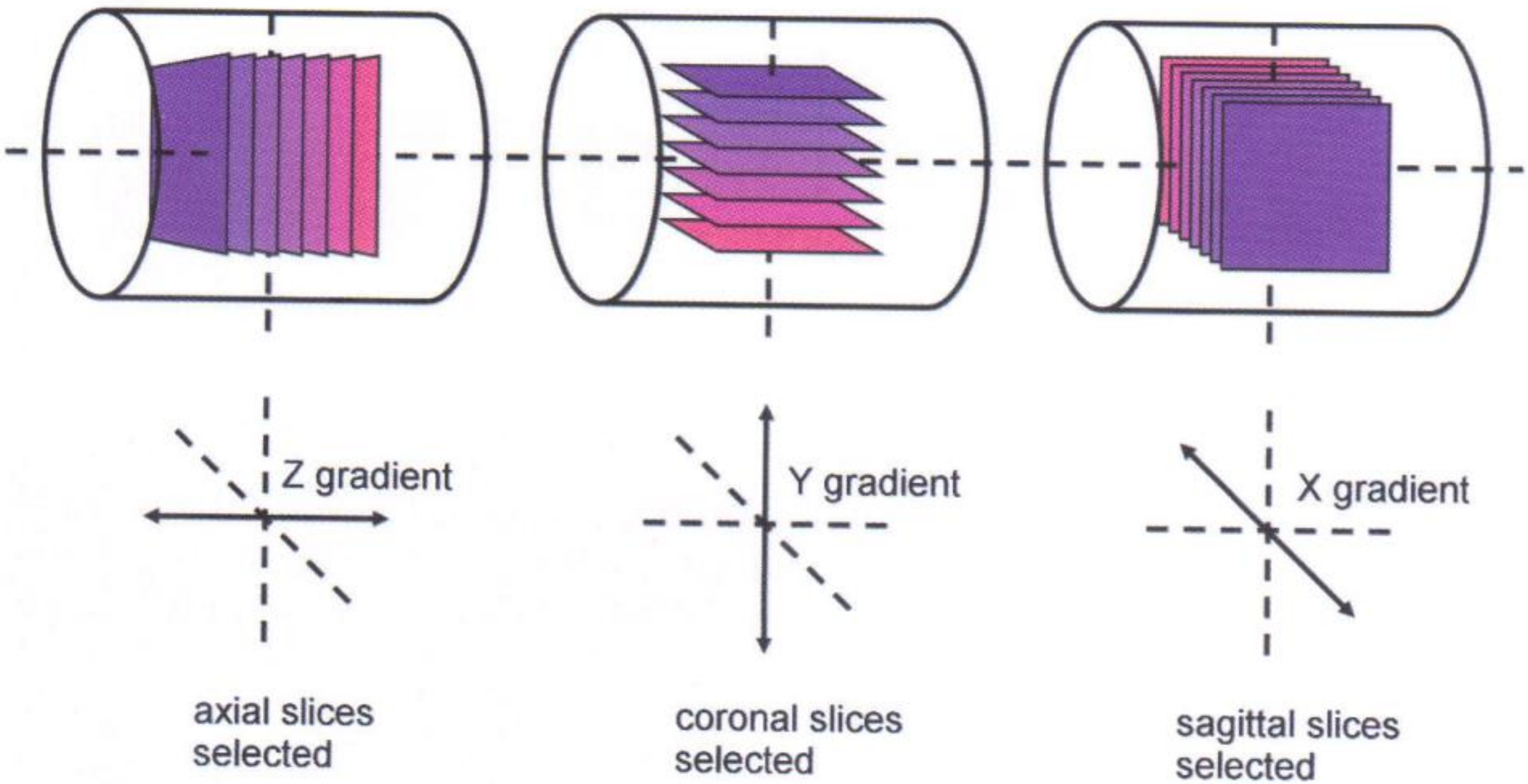
A slice can be selectively excited by transmitting RF with a band of frequencies coinciding with the Larmor frequencies of spins in a particular slice as defined by the slice select gradient.

Slice selection



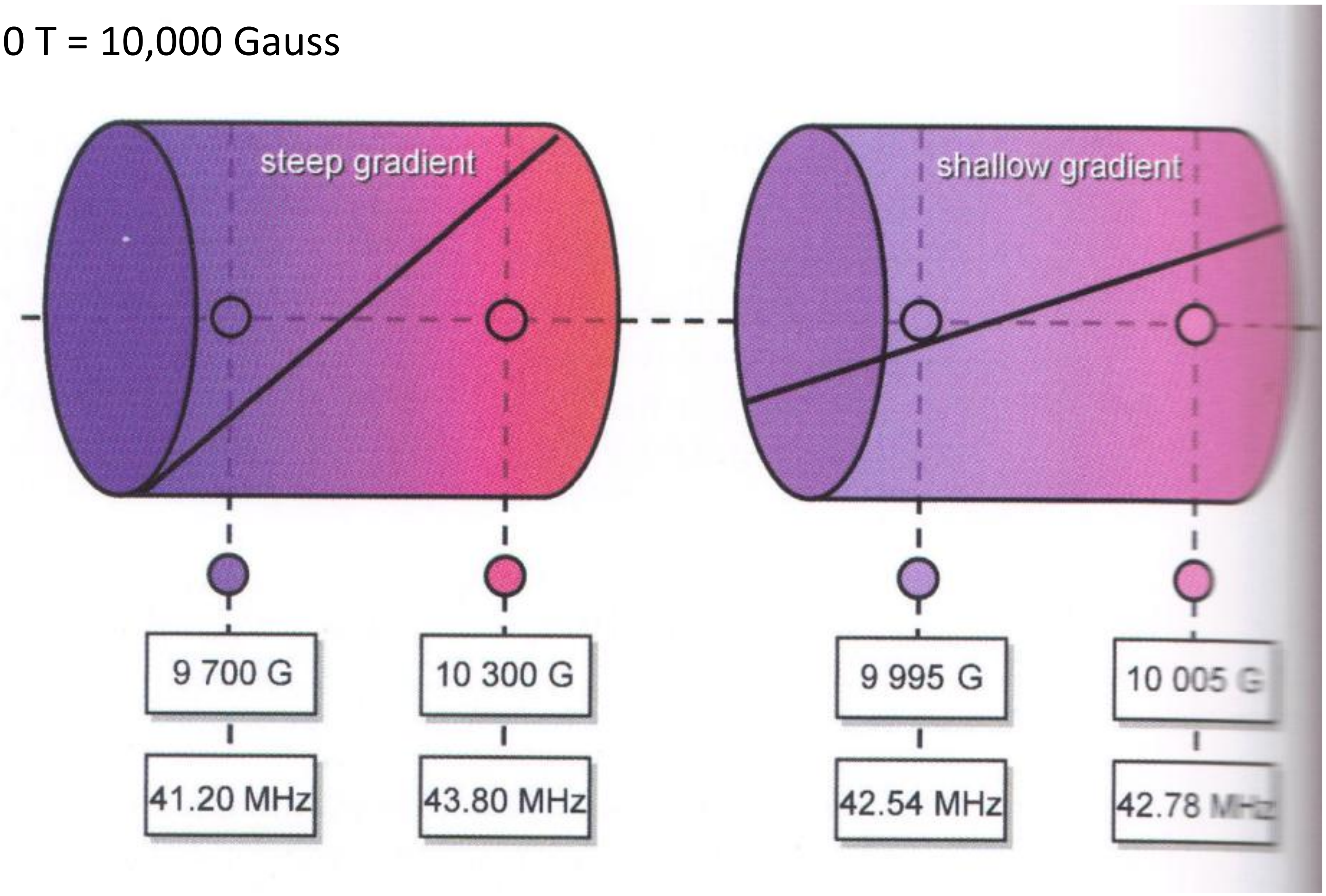


Slice selection

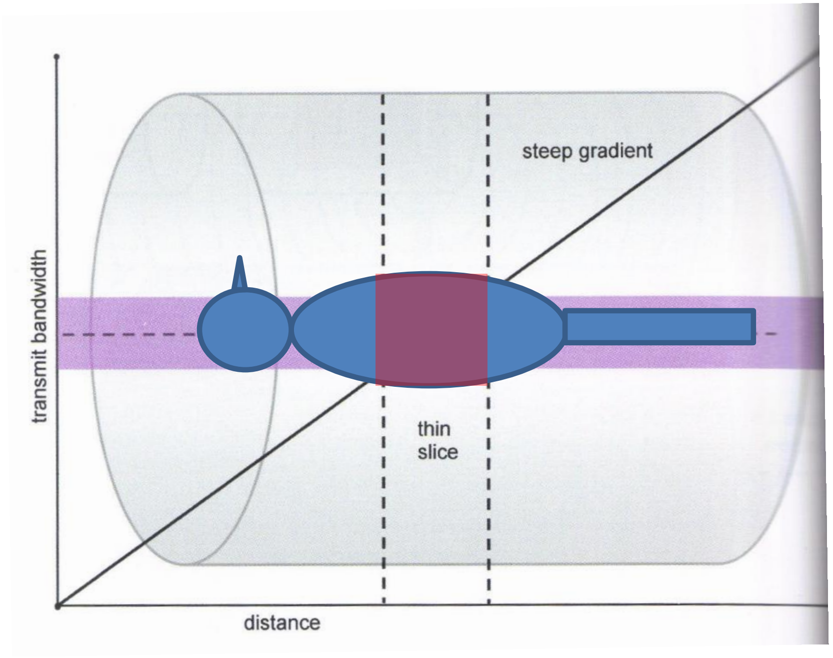


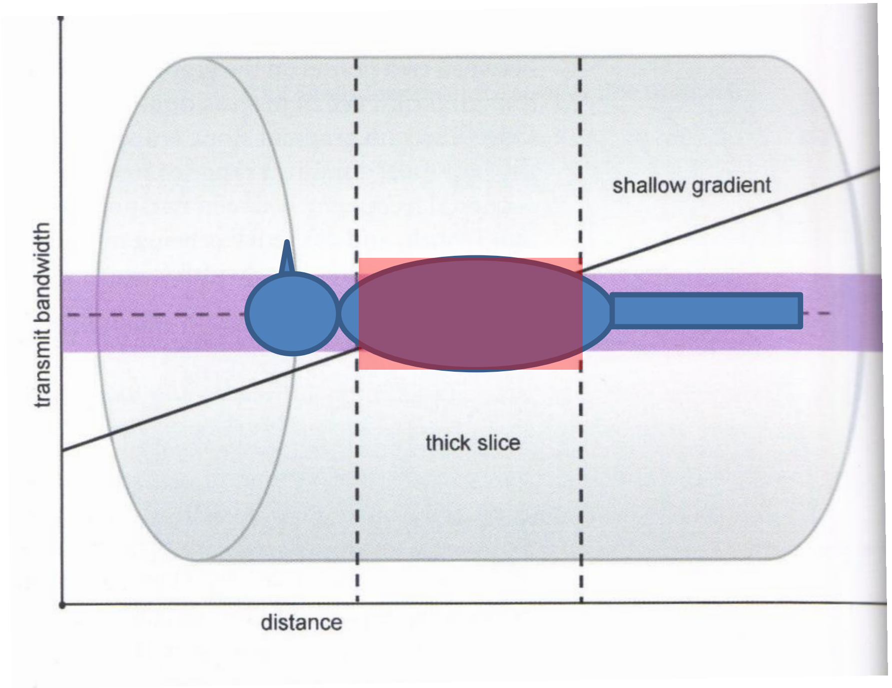
Gradient slopes

B0 = 1.0 T = 10,000 Gauss



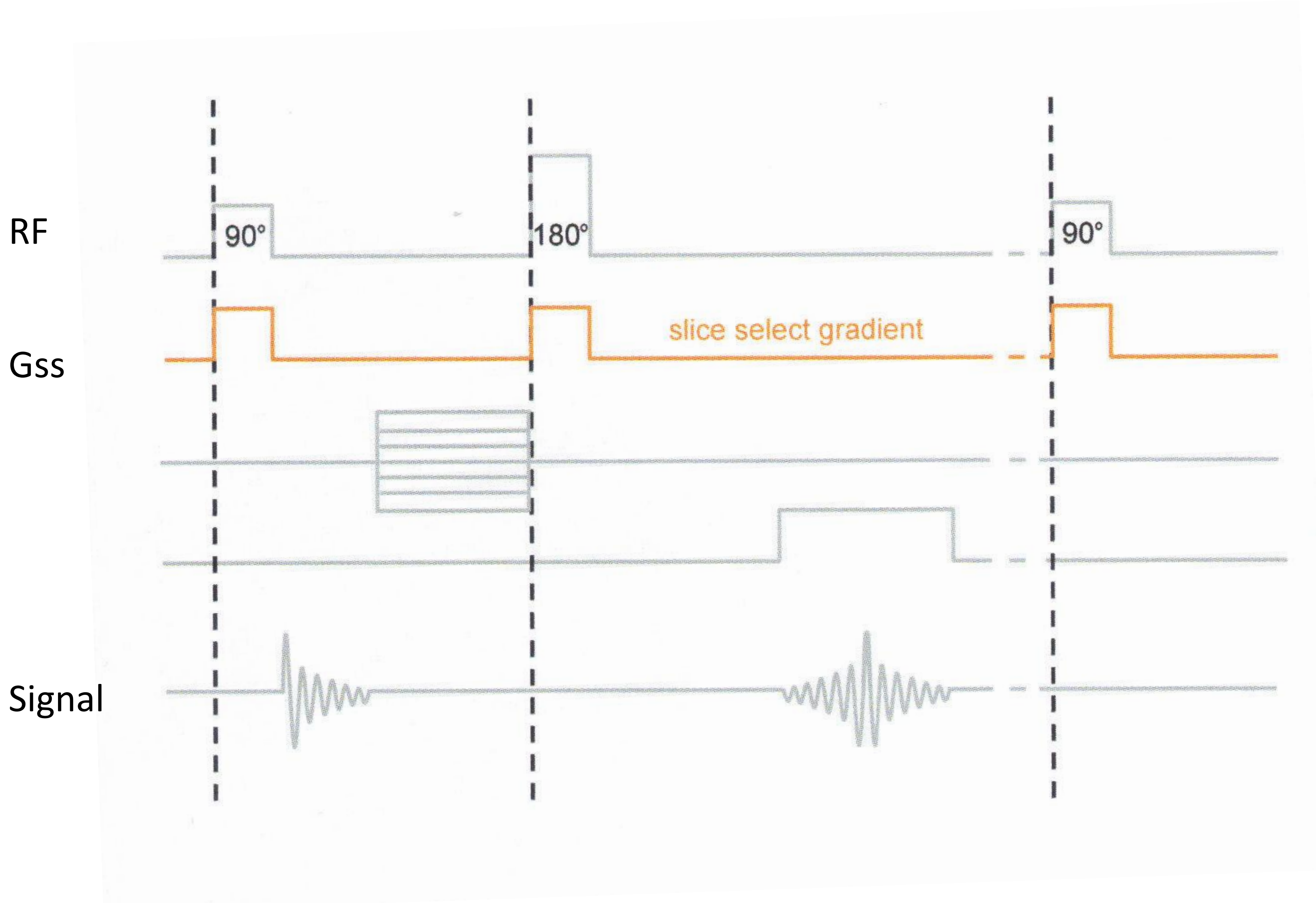
Slice thickness



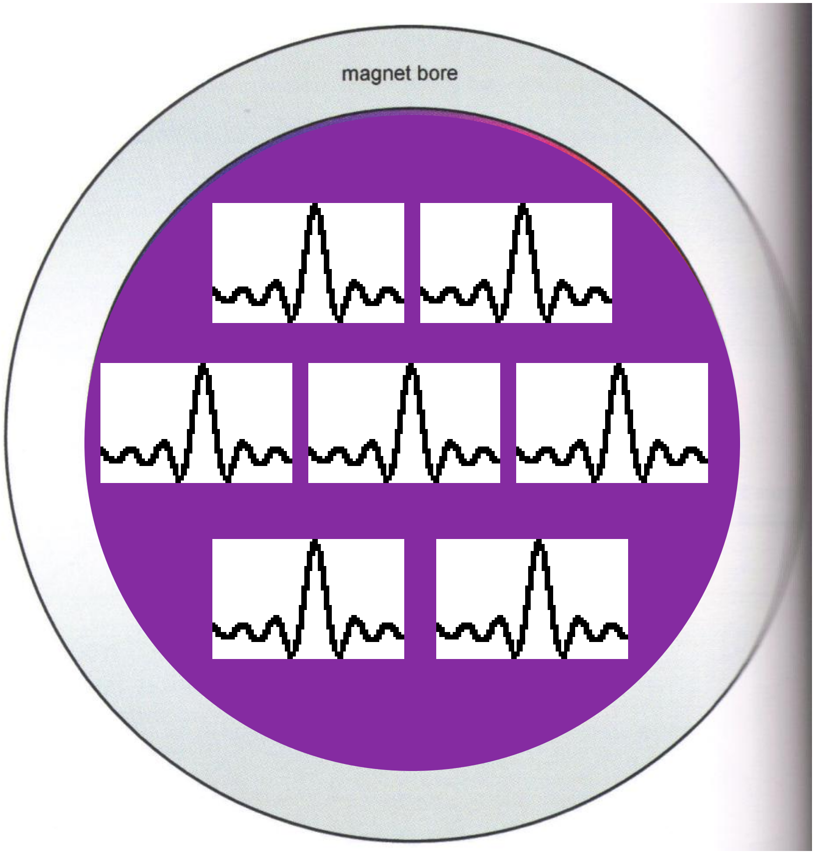


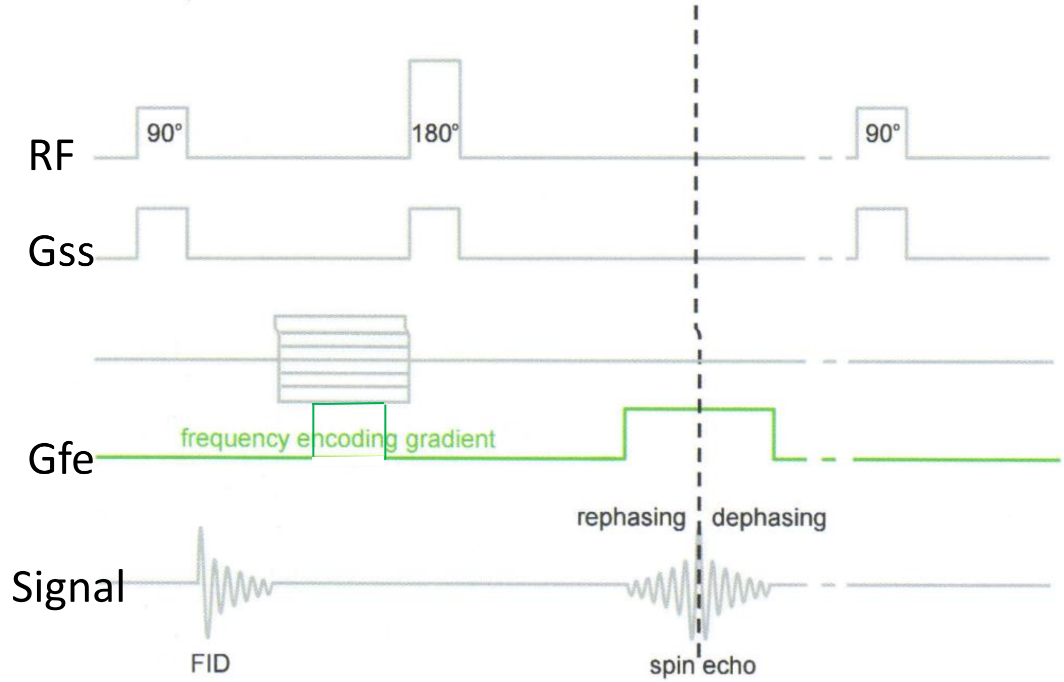
Thin slices – a steep slice select slop and/or narrow transmit bandwidth
Thick slices – a shallow slice select slop and/or broad transmit bandwidth

Timing of Slice selection gradient in SE

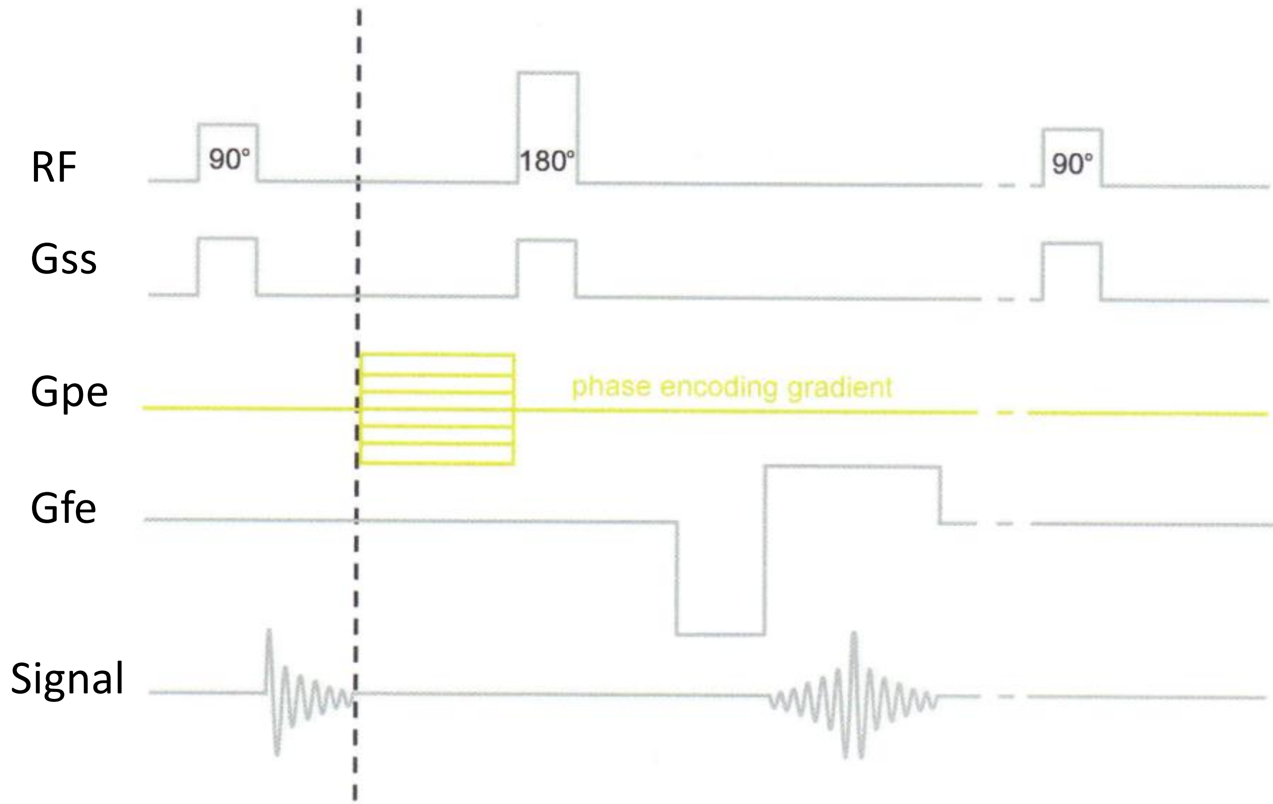


Frequency Encoding

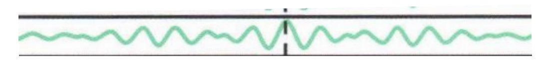


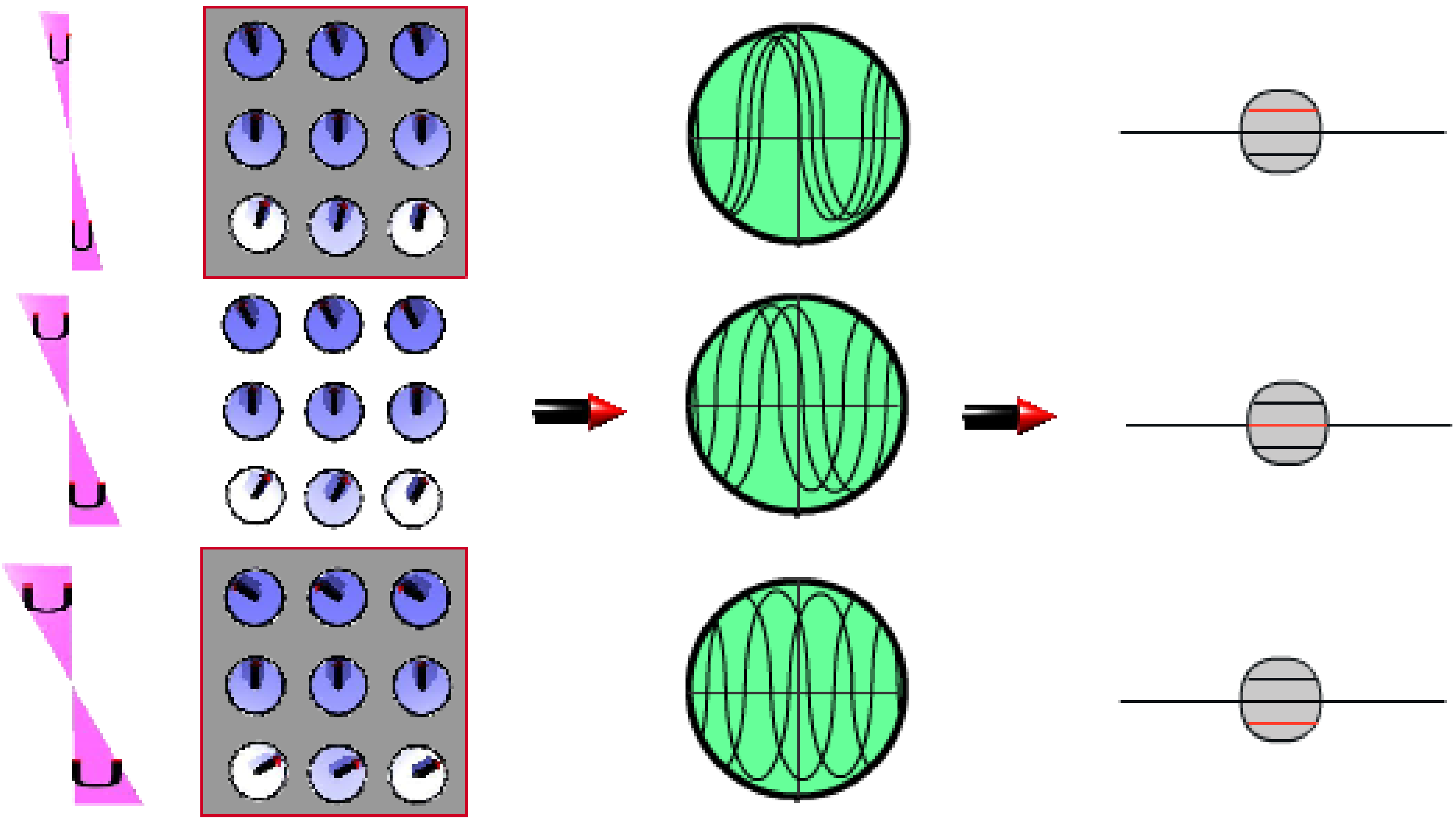


Phase Encoding

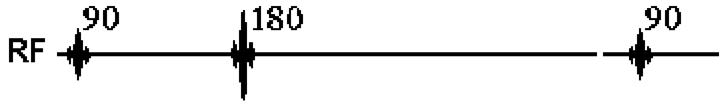


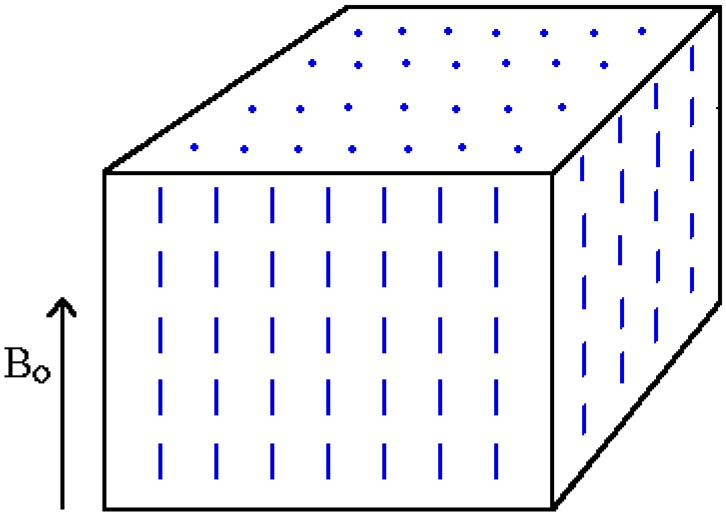
Phase Encoding

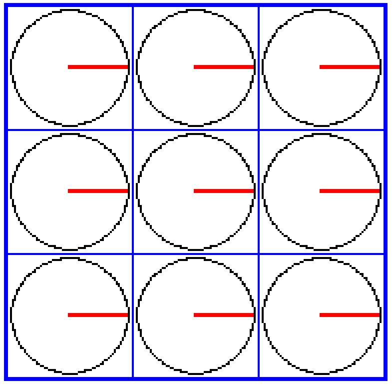




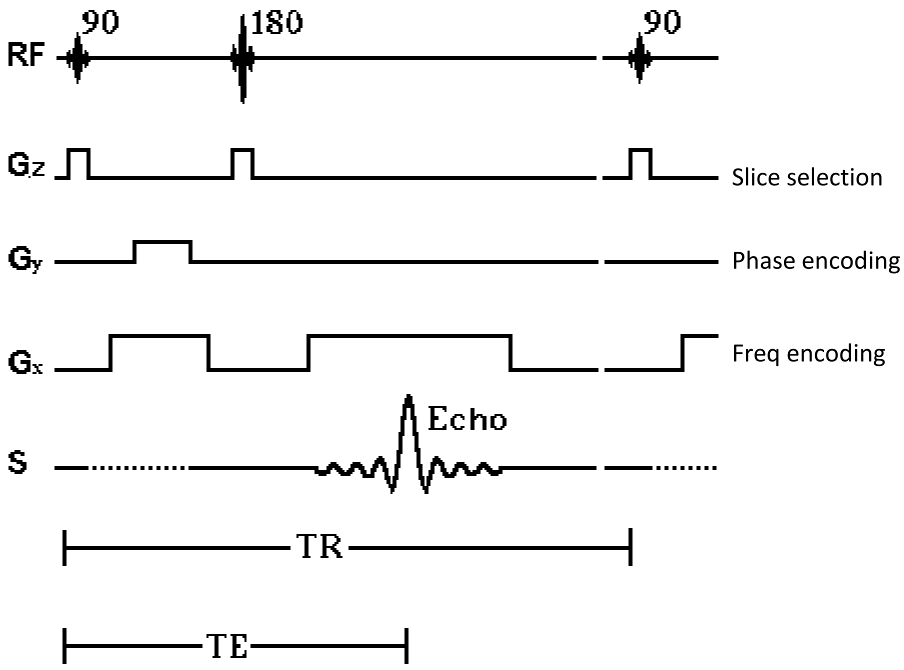
Slice selection

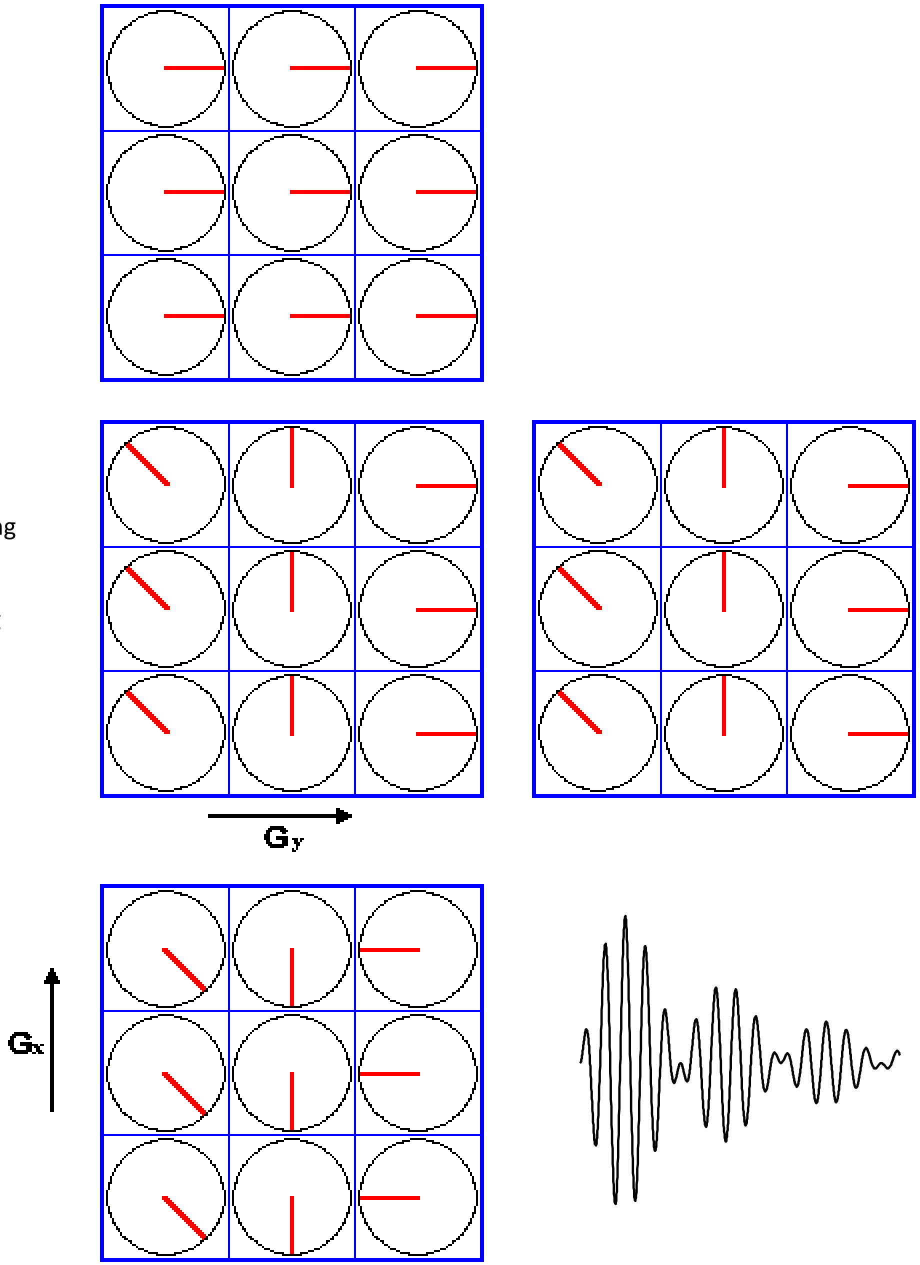




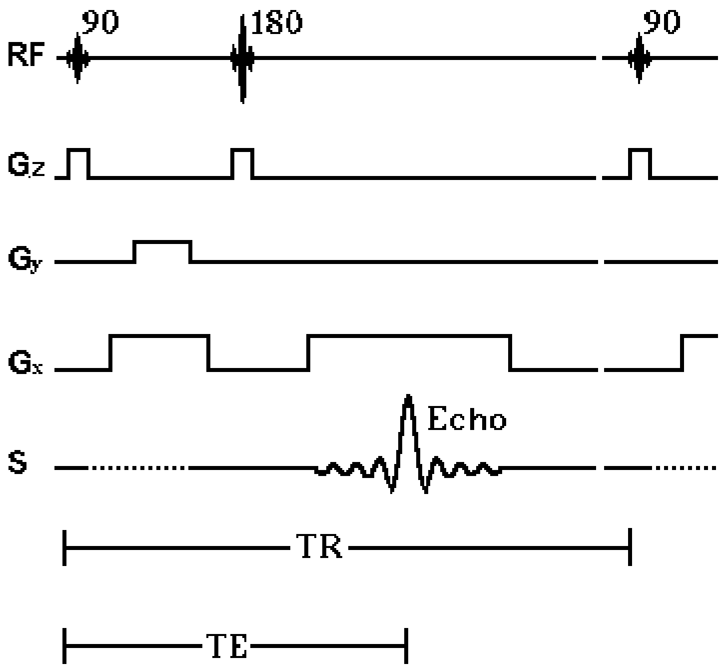


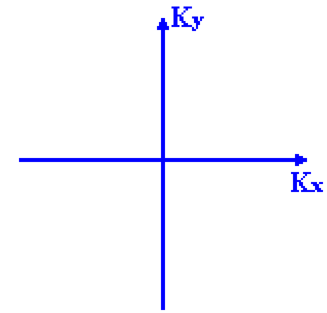
MRI Spatial Encoding

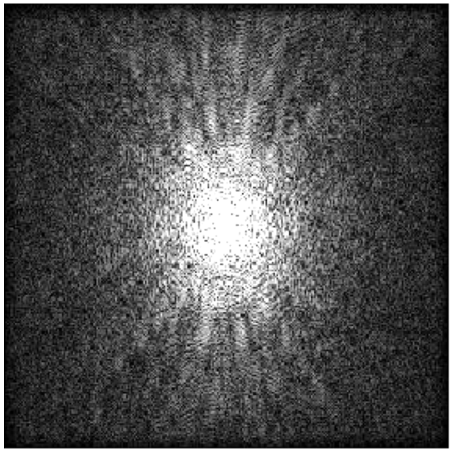




MRI Spatial Encoding



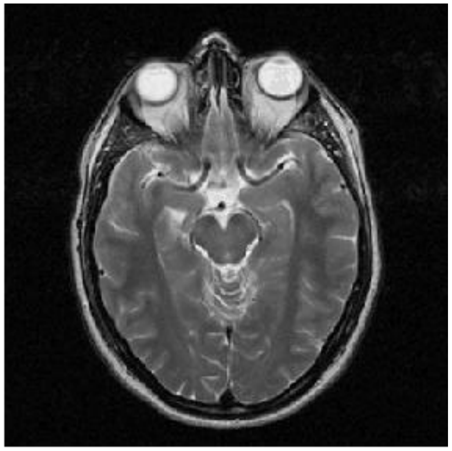




a

K Space

Fourier Transform



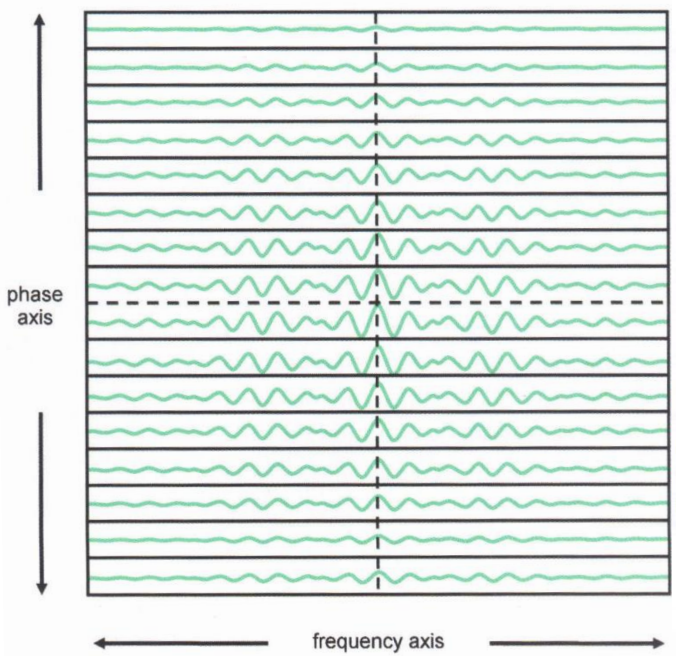
b

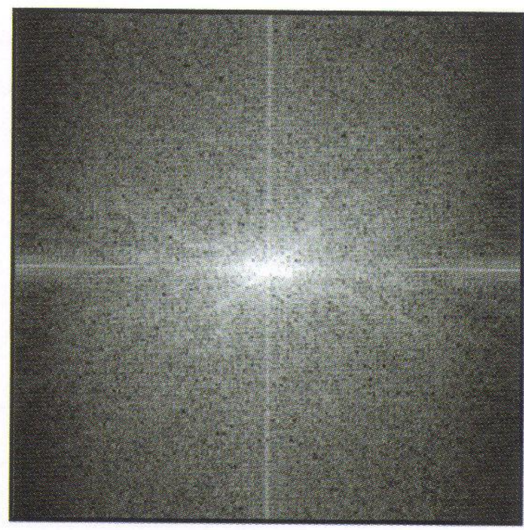
Image Space

Image Formation

- The same TR is repeated untill the K-space is filled.
- The phase gradient is altered every TR.
- Scan time = phase matrix * TR   and more…

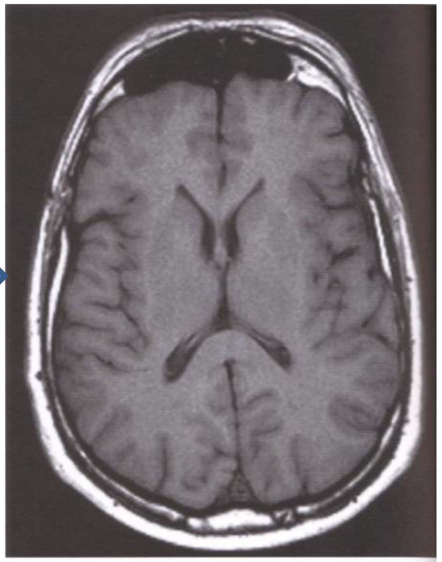
K-space



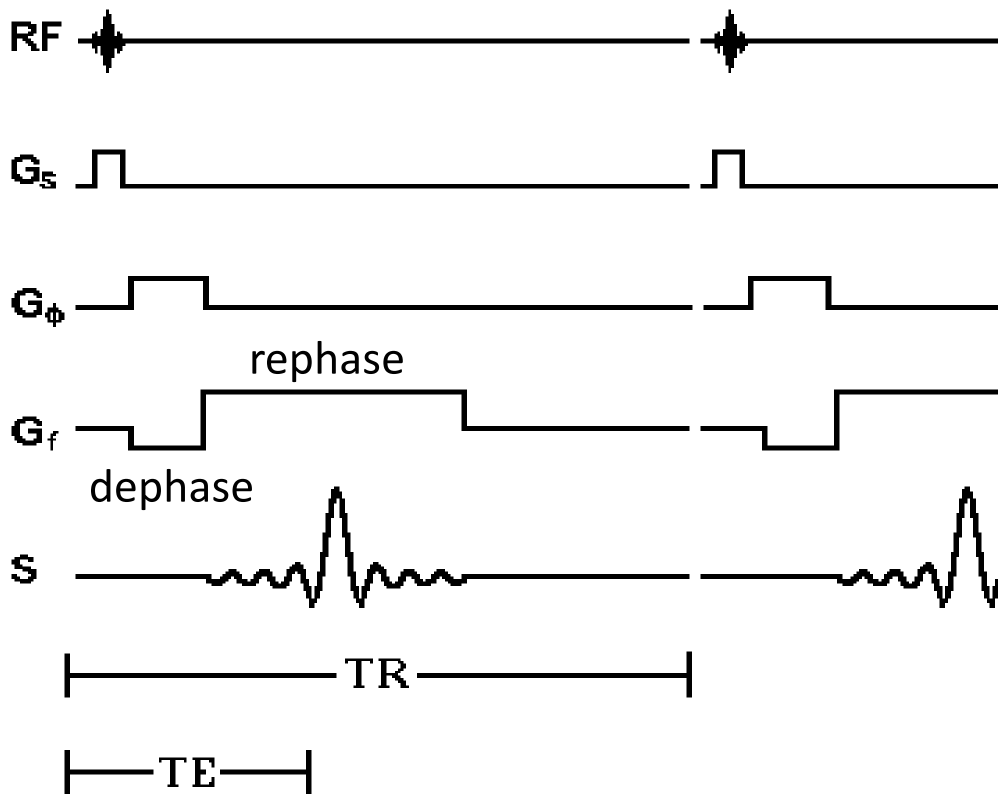


data

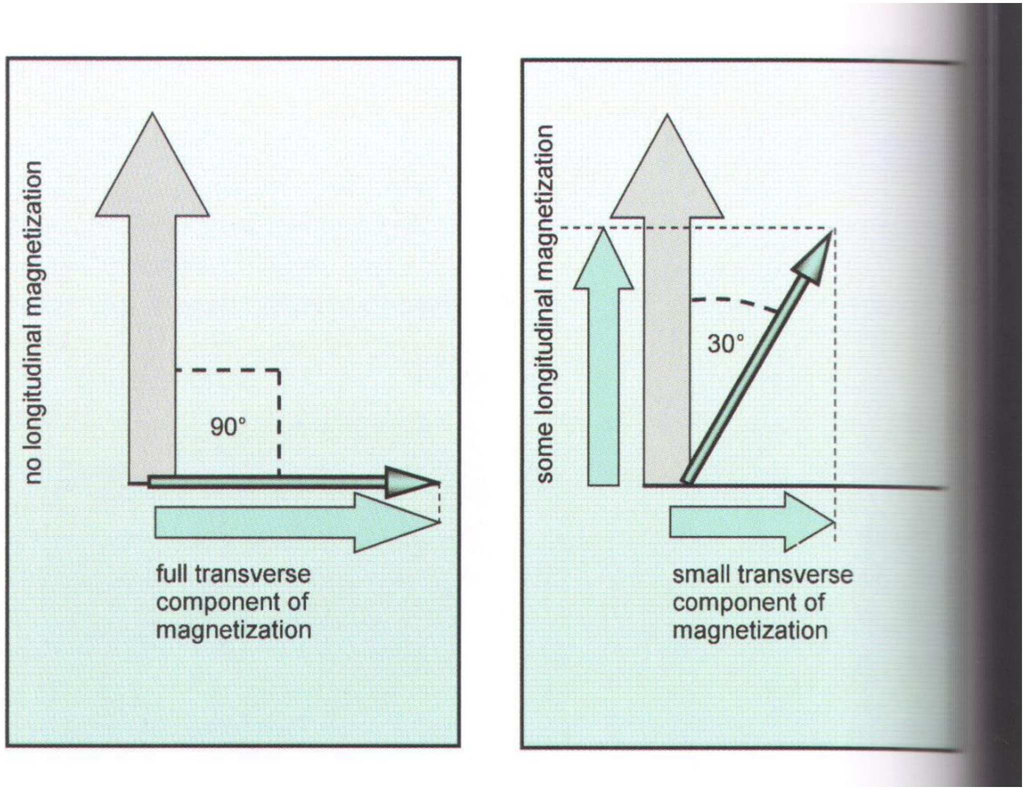
Fourier
Transform



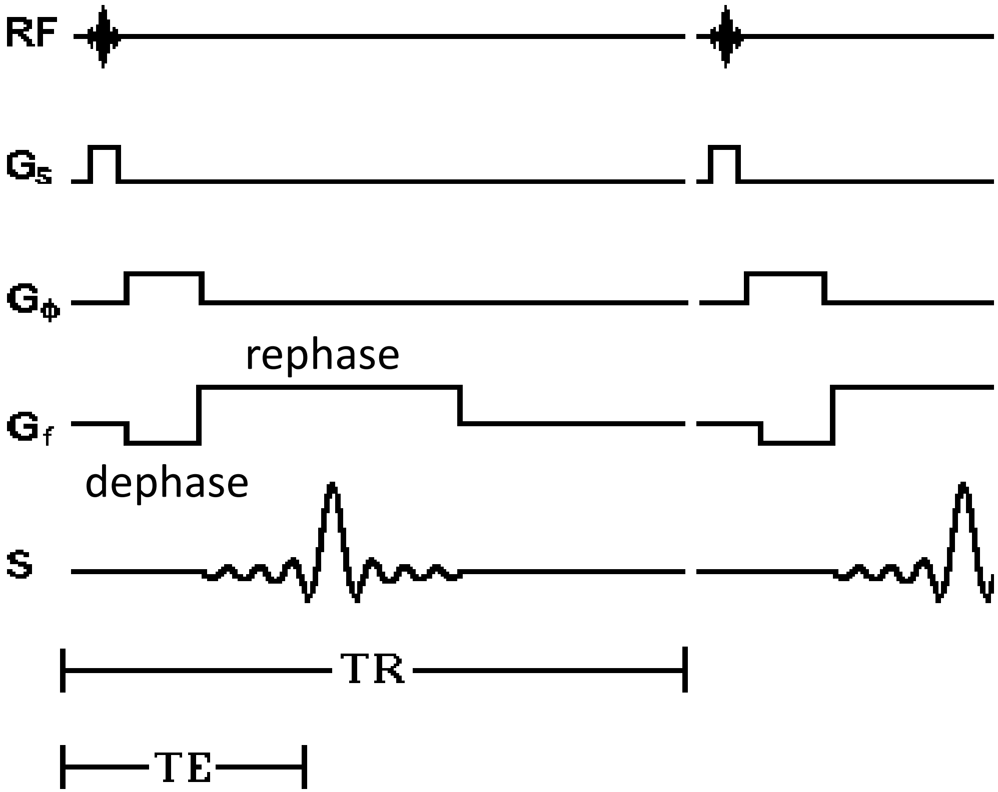
Conventional gradient echo



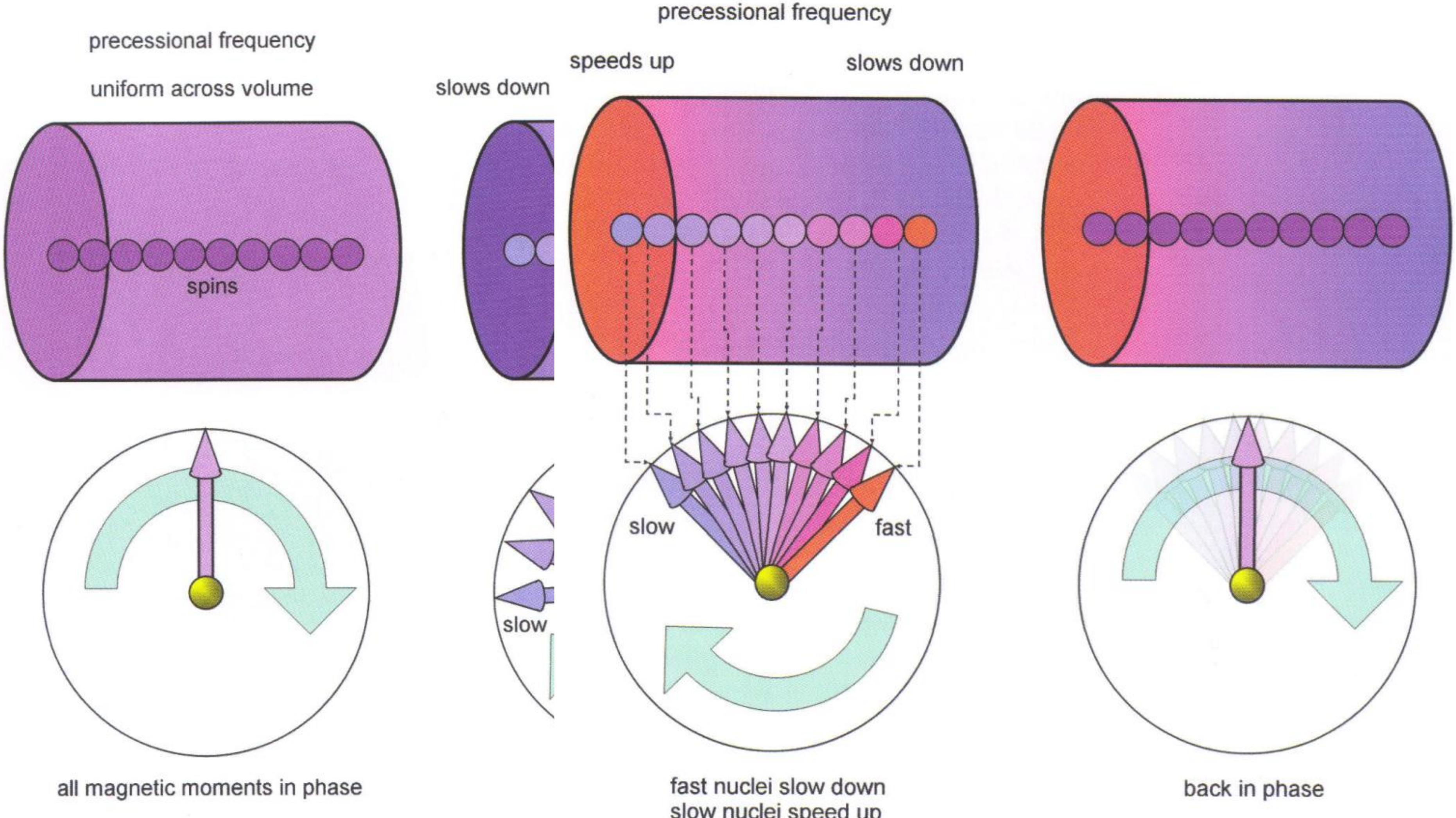
Conventional gradient echo



Conventional gradient echo



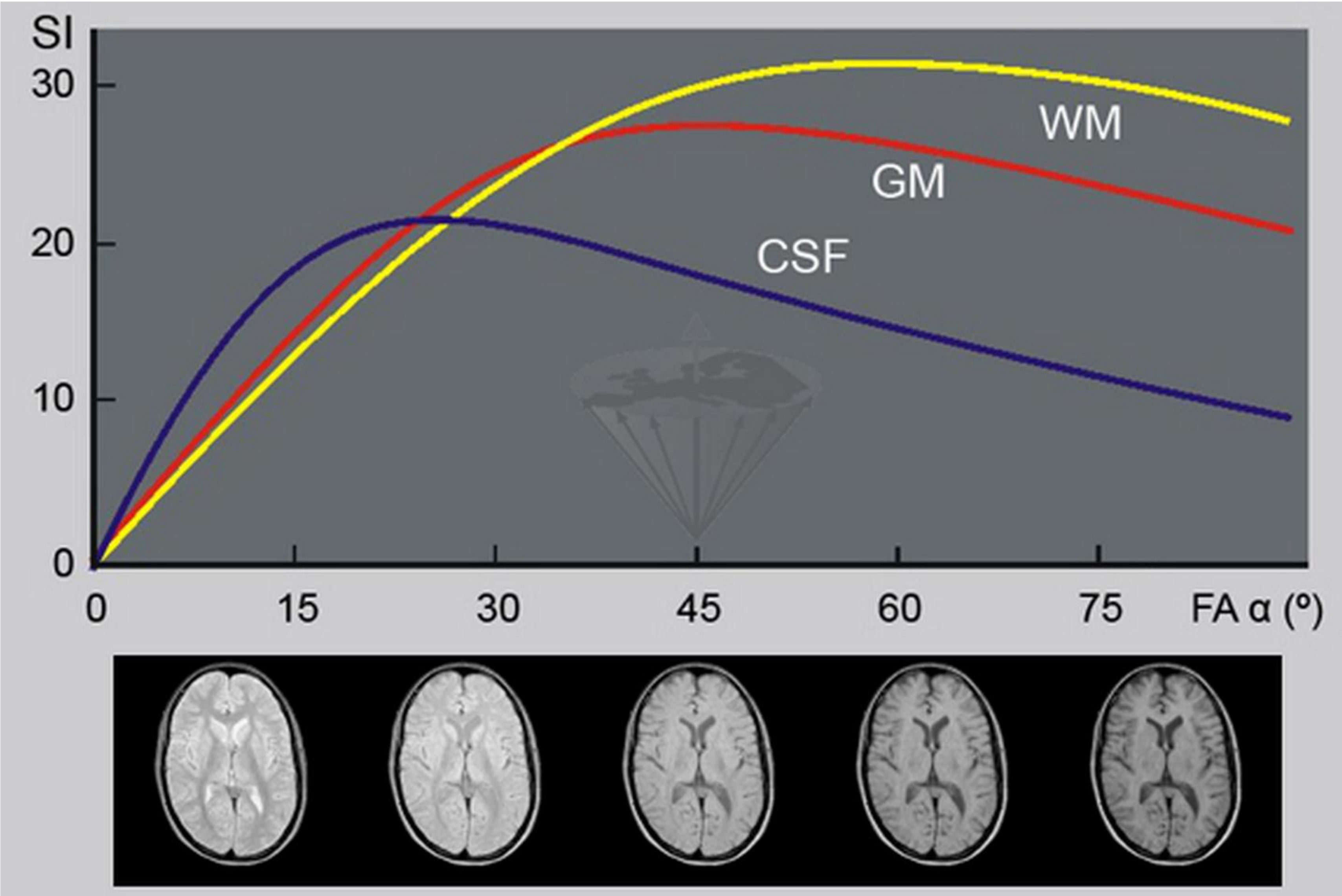
Gradients Dephase & Rephase



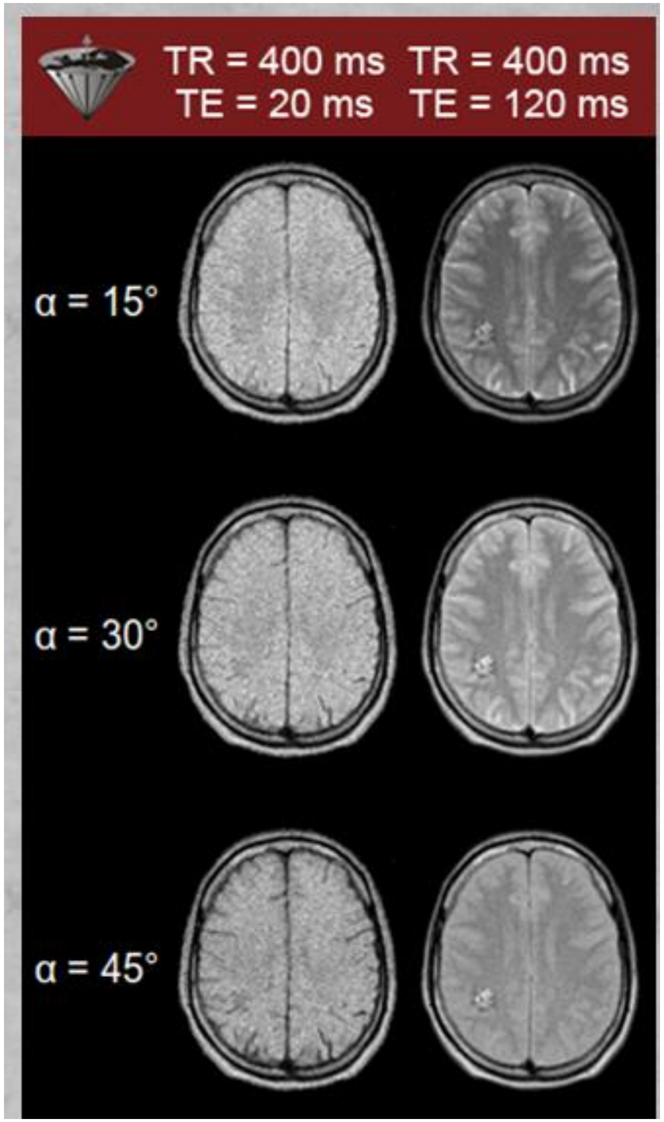
Gradient echo

Gradient echo pulse sequences

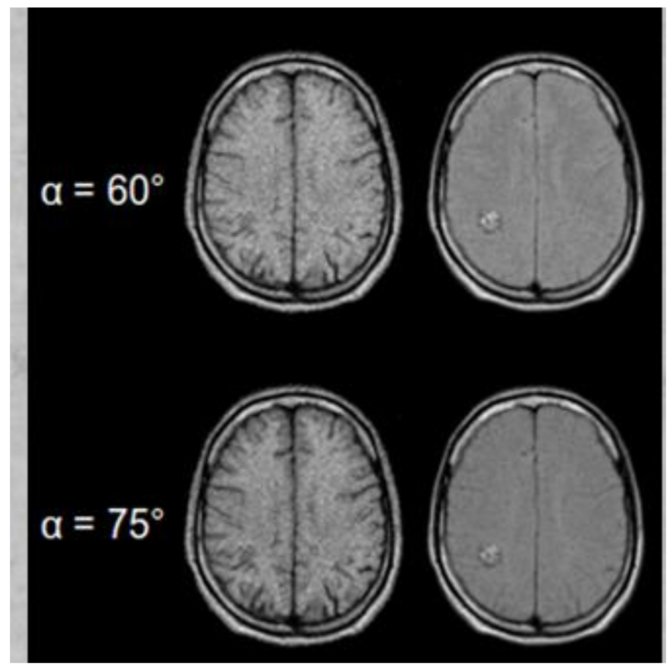
- Frequency encoding gradient is initially applied negatively to speed up the dephasing of the FID.
- Then its polarity is reversed producing rephasing of the gradient echo.
- Gradient does NOT compensate for magnetic field inhomogenities.
- Used to acquire T2*, T1, and proton density weighting
- A gradient is quicker to apply than a 180 pulse, therefore the minimum TE, TR and scan time can be reduced.



TR=400ms, TE=20ms, B0=1.5T

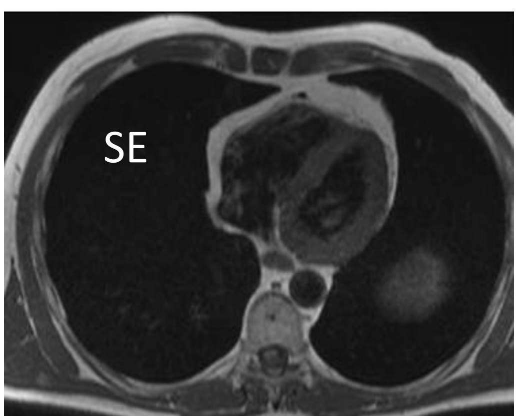


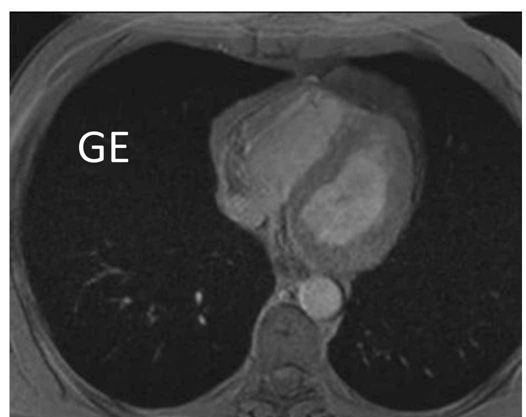
Vascular malformation not visible in the TE=20ms images, but well delineated in long TE images.



Uses of gradient echo

- Used for breath-hold acquisitions in the abdomen
- Used for dynamic contrast enhancement
- Used to produce angiographic type images, because the flowing nuclei which have been previously excited, always give a signal as gradient rephasing is not slice selective.





Summary

- An MRI sequence is an ordered combination of RF and gradient pulses designed to acquire the data to form the image.
- The slice select gradient is switched on during the 90 and 180 pulses in SE, and during the excitation pulse only in GE.
- The slope of the slice select gradient determines the slice thickness along with the transmit bandwidth.
- The phase encoding gradient is switched on between excitation and the signal collection.
- The frequency encoding gradient is switched on during the collection of the signal.