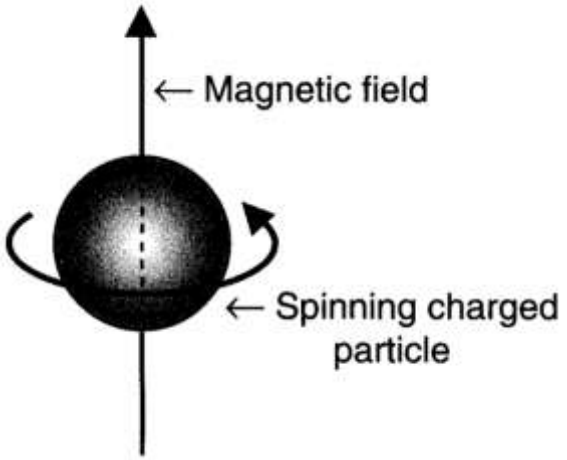
Medical Equipment II - 2010

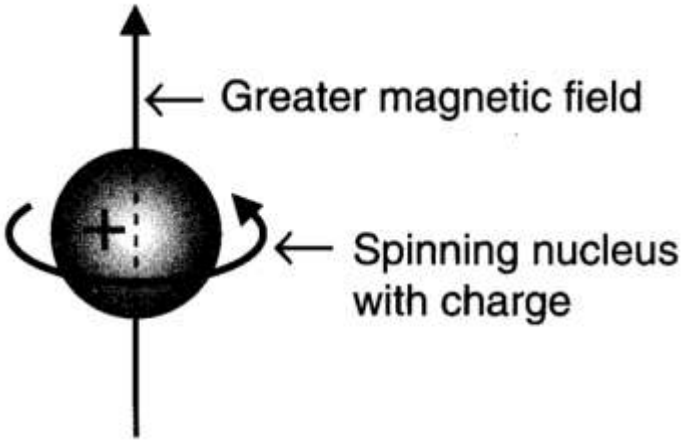
Magnetic Resonance Imaging(1)

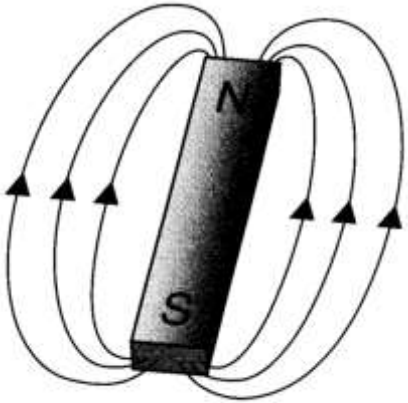
Professor Yasser M. Kadah

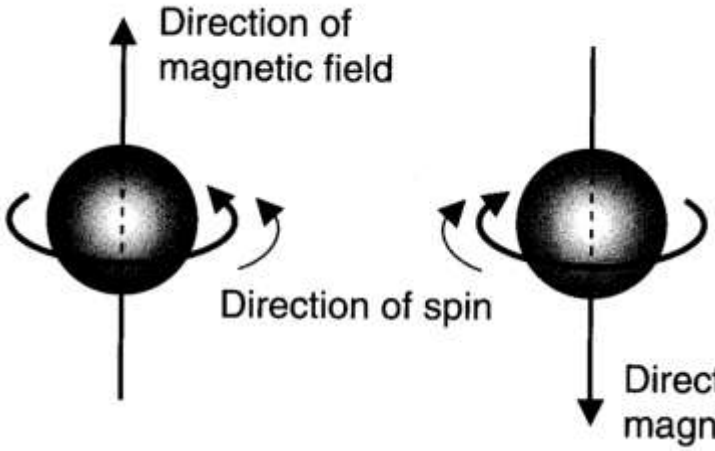
Web: http://ymk.k-space.org/courses.htm

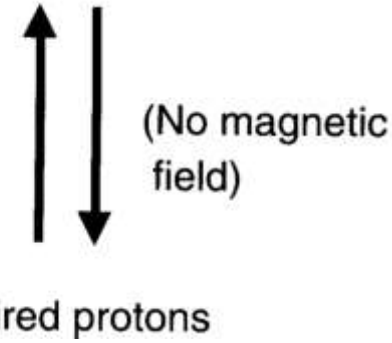
Spins

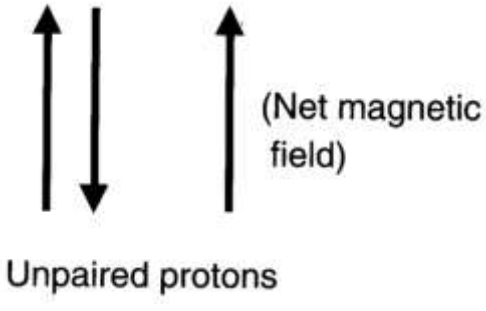

← Magnetic field
← Spinning charged particle


← Greater magnetic field
← Spinning nucleus with charge


N
S
Bar Magnet

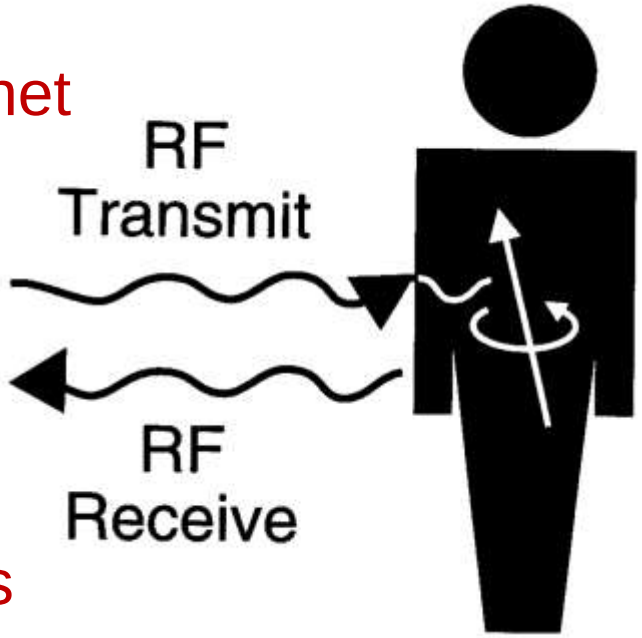

Direction of magnetic field
Direction of spin
Direction of magnetic field


(No magnetic field)
Paired protons

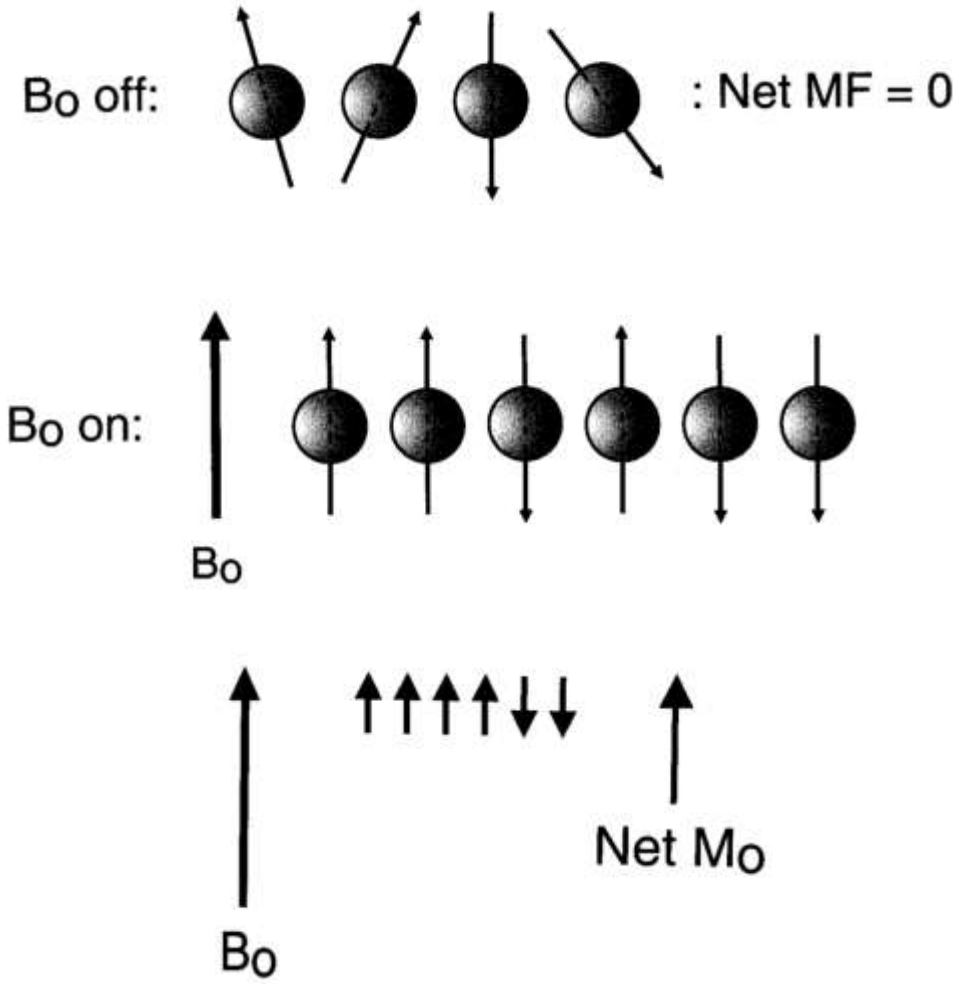

(Net magnetic field)
Unpaired protons

How to Perform MR Imaging

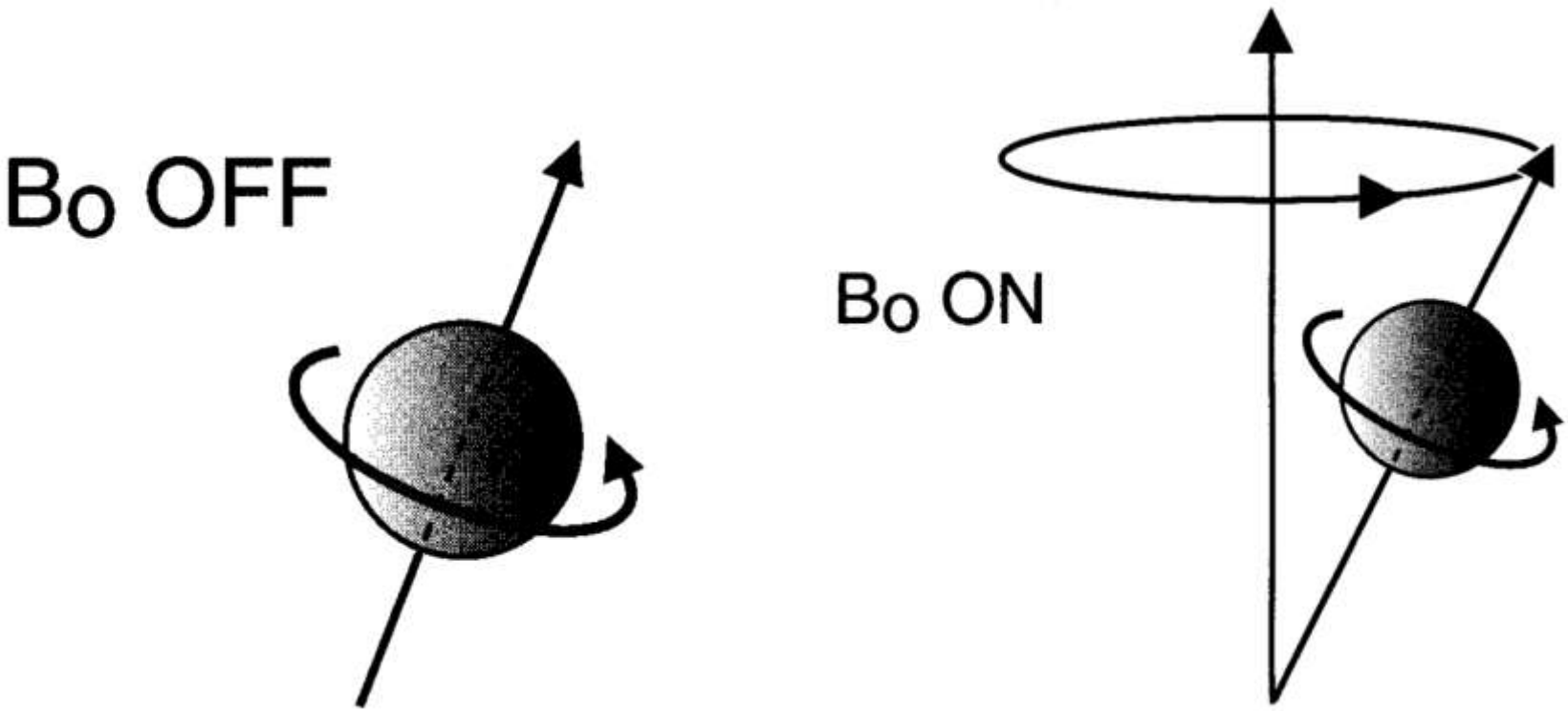
- **M**: Magnetic Field
  - Patient is placed inside magnet
- **R**: Radio-Frequency (RF) Pulse
  - RF pulse is applied
- **R**: Relaxation
  - After RF application, signal is collected from relaxation



B0 Field



Precession



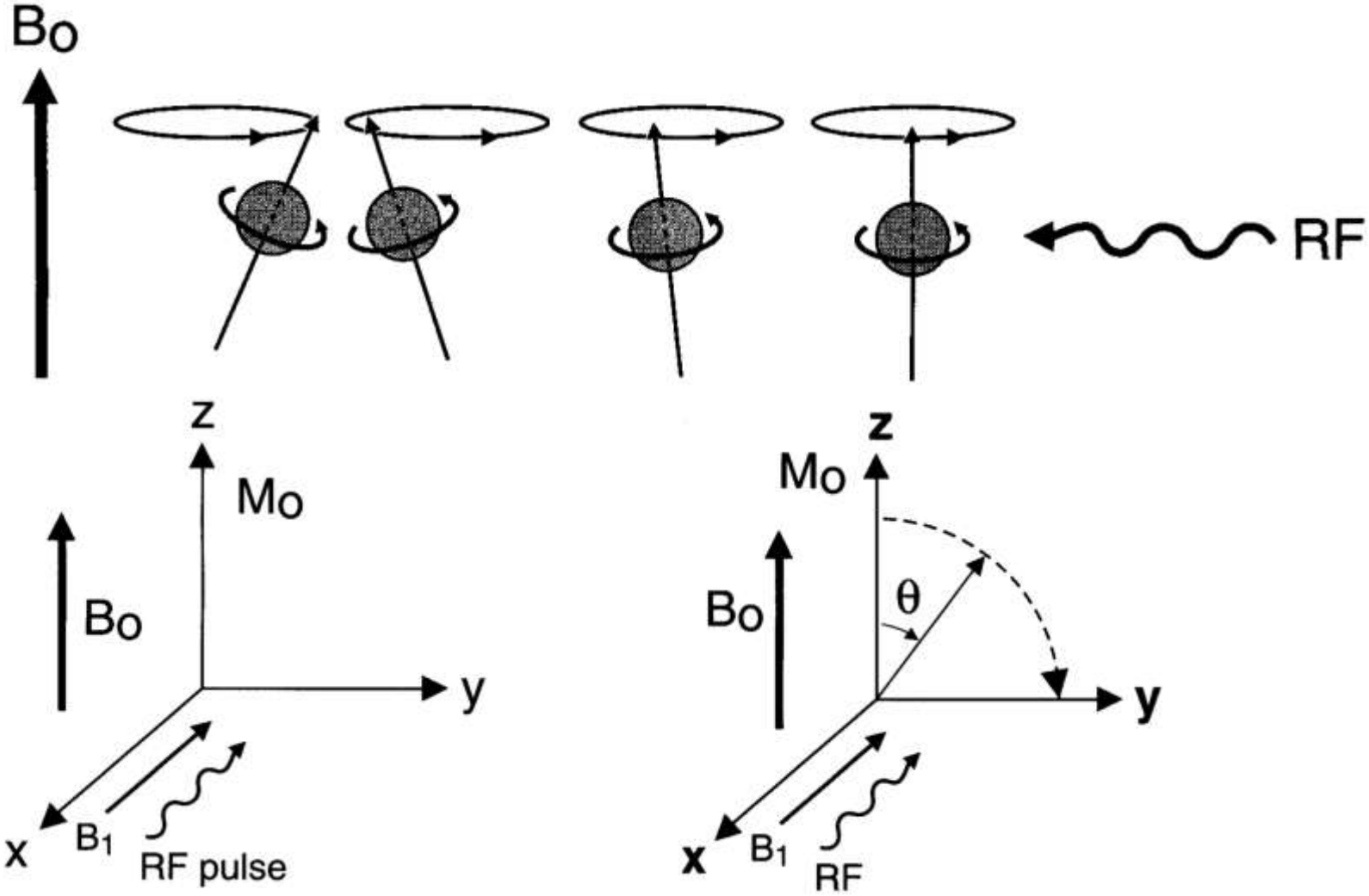
Larmor Equation

- The rate at which proton precesses around external magnetic field is given by:

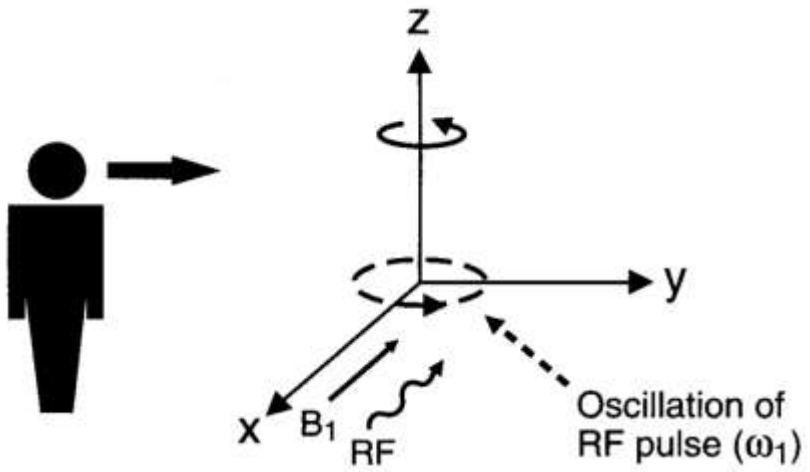
$$\omega = \gamma B_0$$

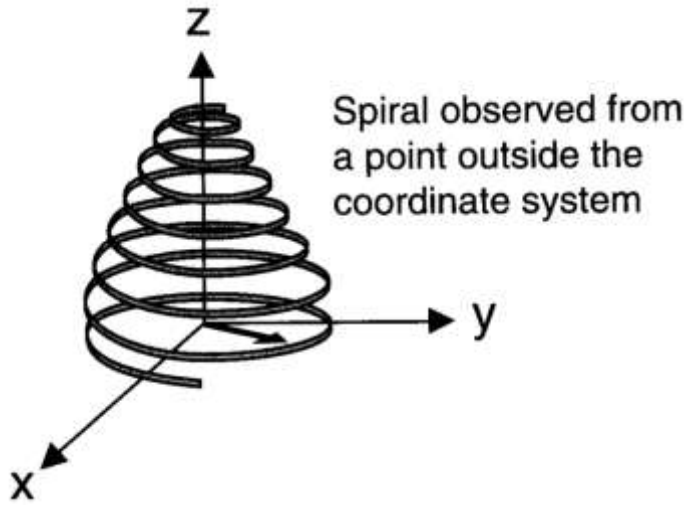
Nucleus	Spin Quantum Number (S)	Gyromagnetic Ratio* (MHz/T)
^{1}H	1/2	42.6
^{19}F	1/2	40.0
^{23}Na	3/2	11.3
^{13}C	1/2	10.7
^{17}O	5/2	5.8

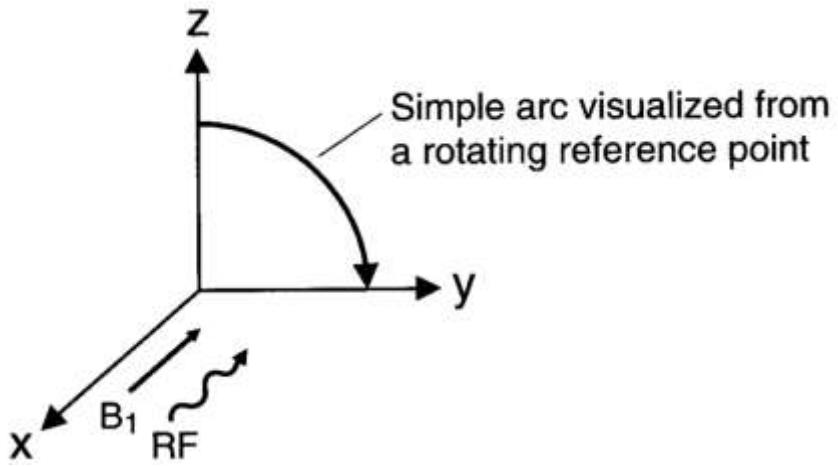
RF Pulse



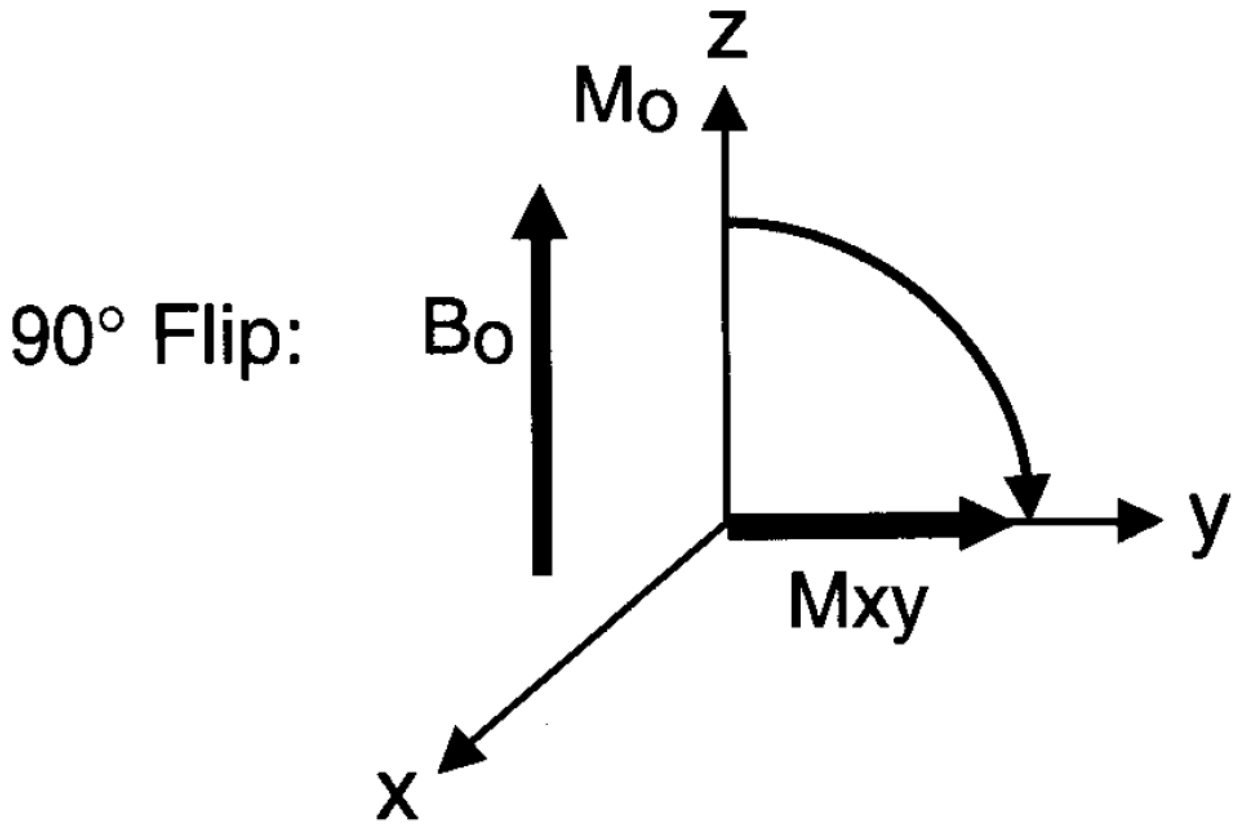
Rotating Frame of Reference



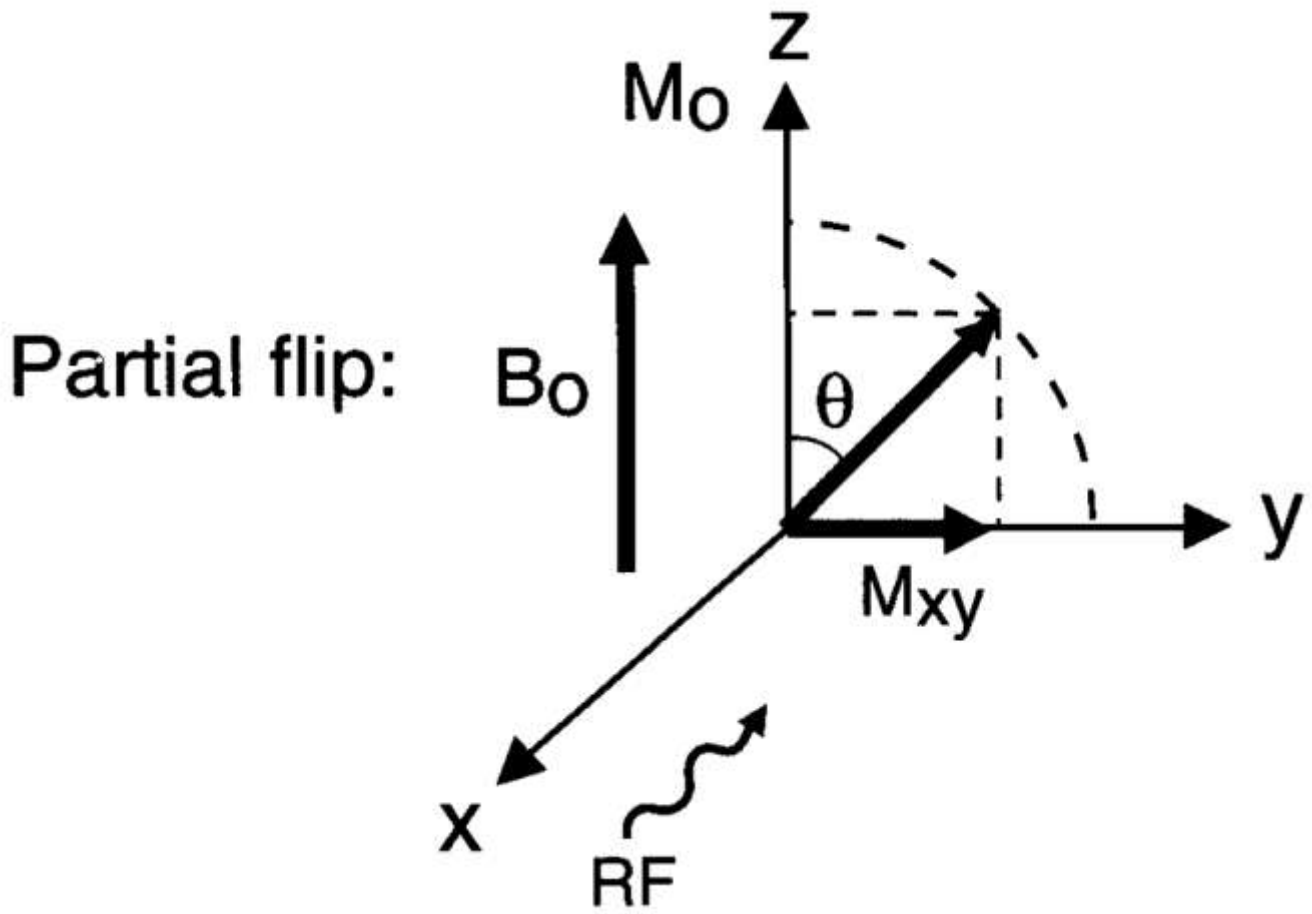




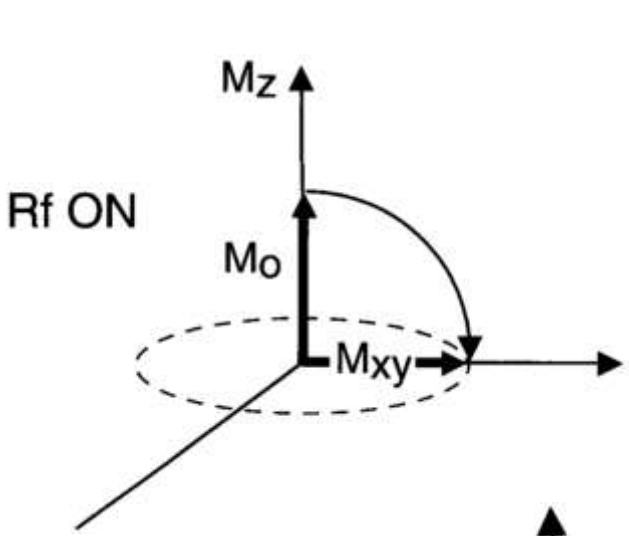
90° RF Pulse



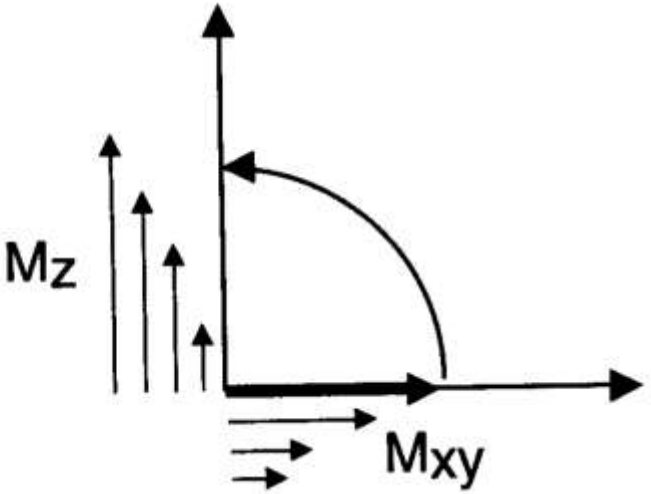
Partial Flip

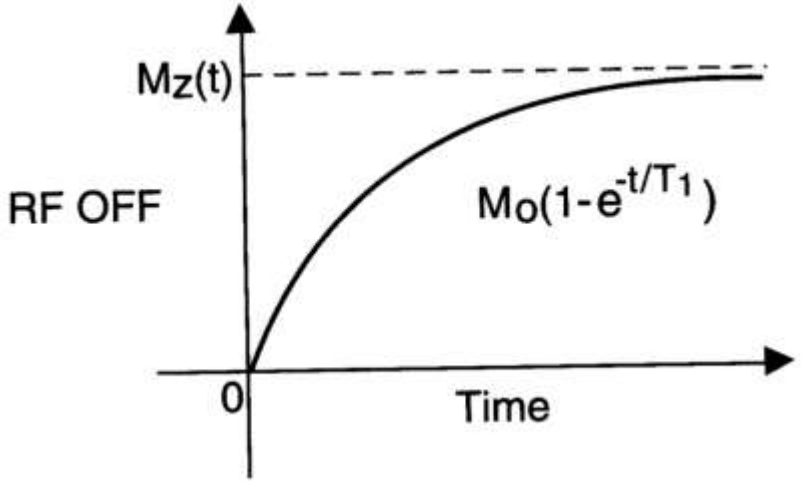


T1 Relaxation Time

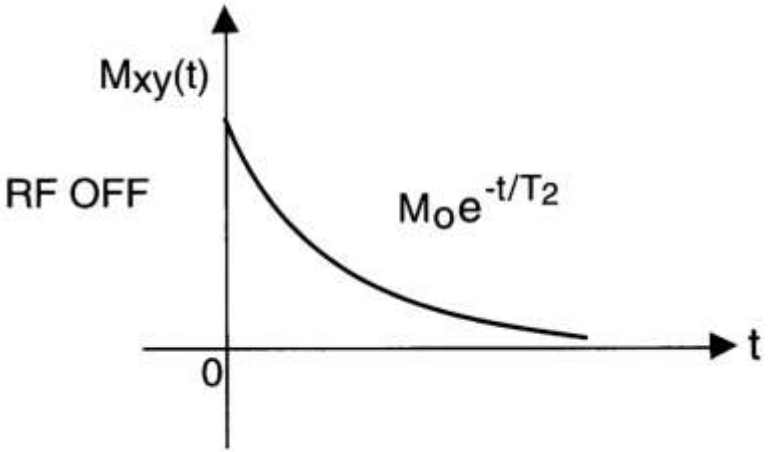


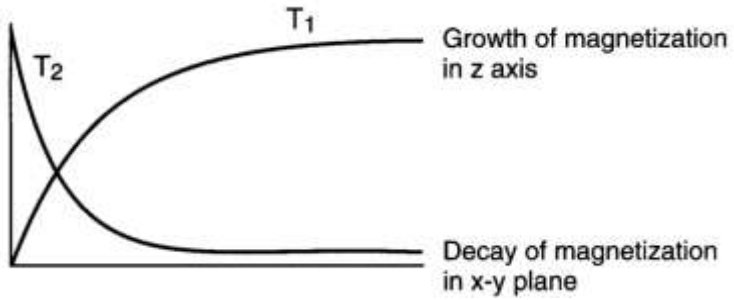
RF OFF

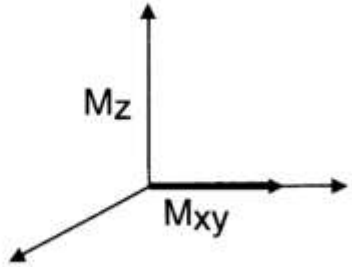




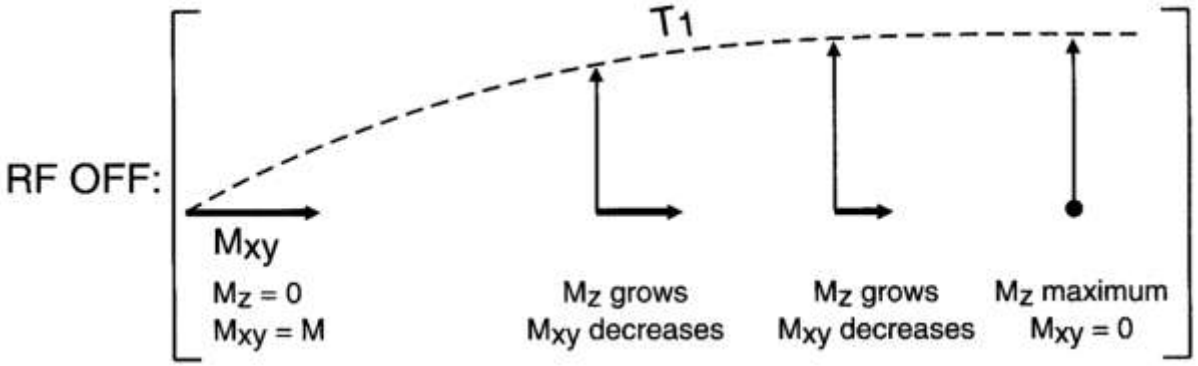
T2 Relaxation Time





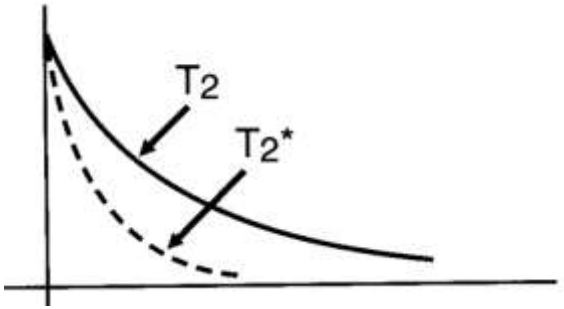


Loss of M_{xy}
Gain of M_z
} Independent processes



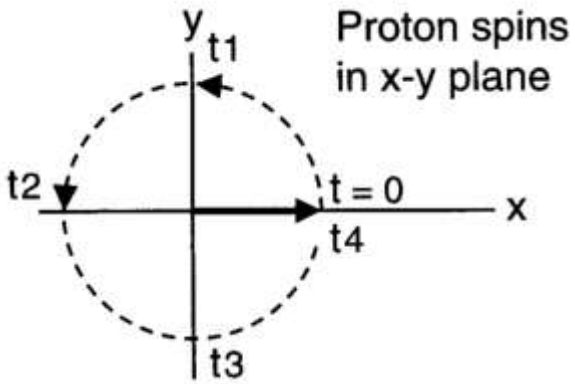
Causes of Signal Decay

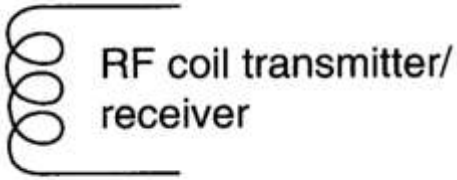
- Spin-Spin interactions
  - internal magnetic field inhomogeneity
- External magnetic field inhomogeneity
- T2 Relaxation
  - Only spin-spin interactions
- T2* Relaxation
  - Both spin-spin interactions and external field inhomogeneity present

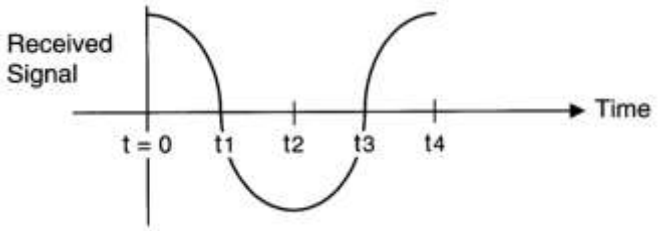


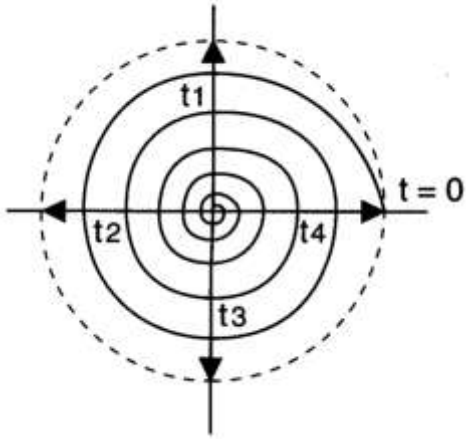
$$1/T_2^* = 1/T_2 + \gamma \Delta B$$

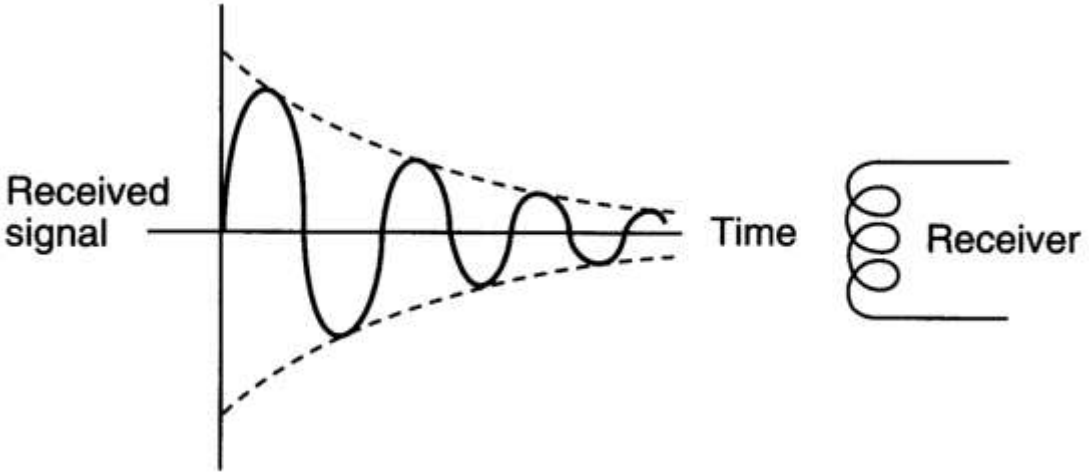
Received Signal: Free Induction Decay (FID)



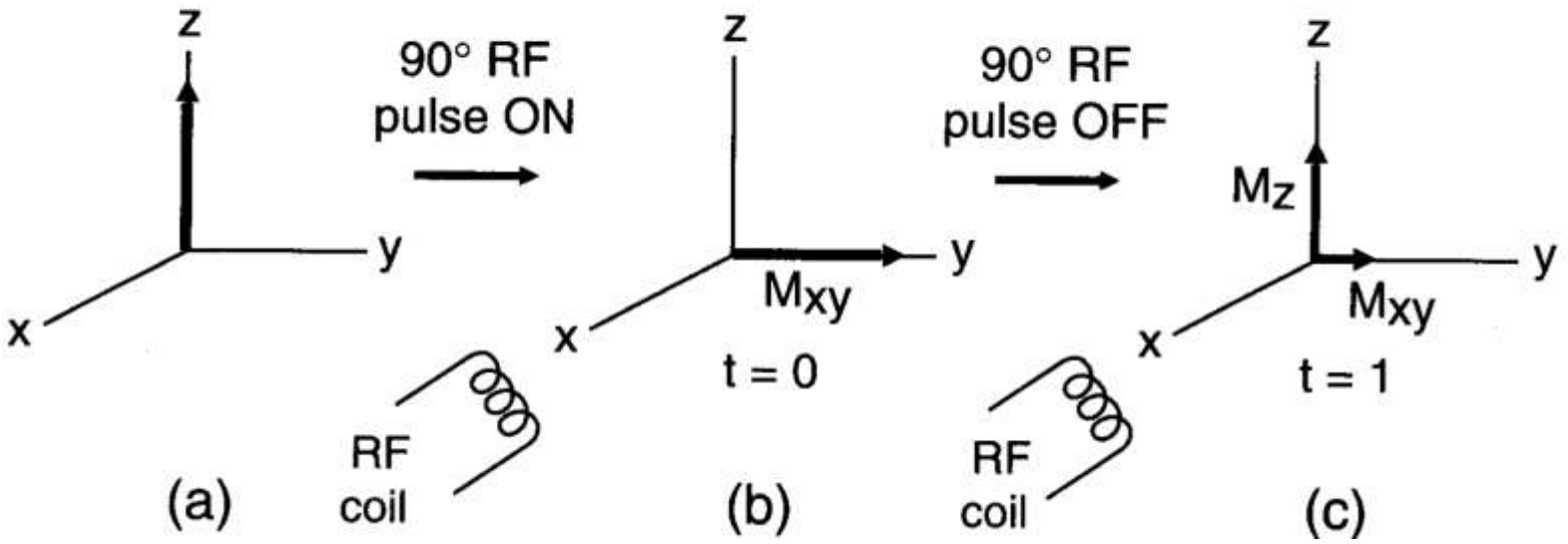


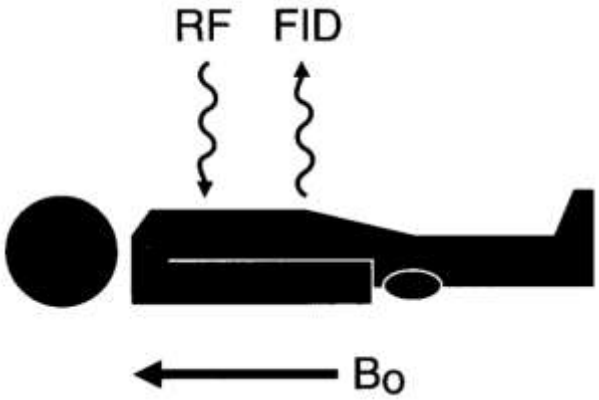


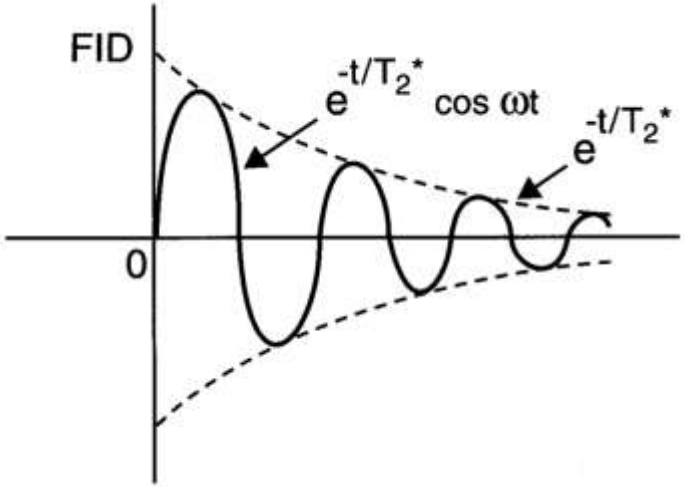




Sequence of Events

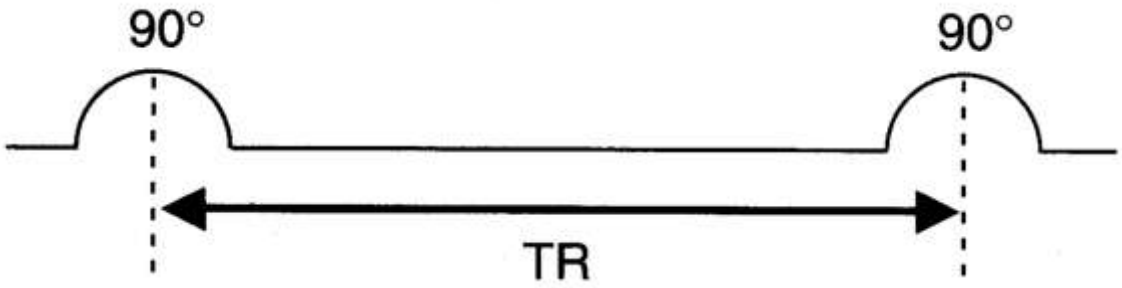






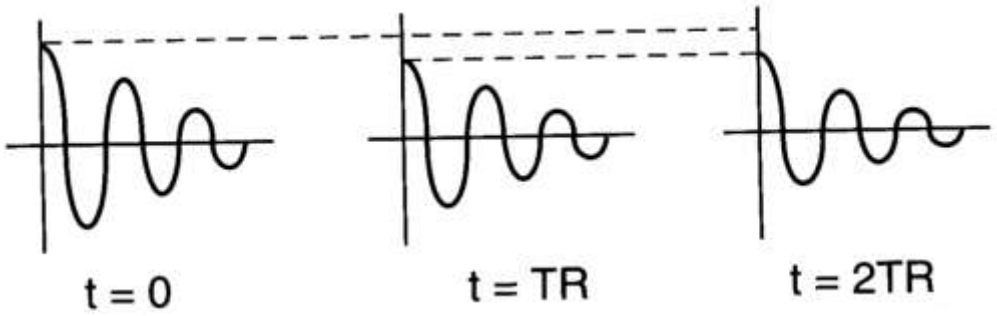
Pulse Repetition Time (TR)

- Distance between successive RF pulses



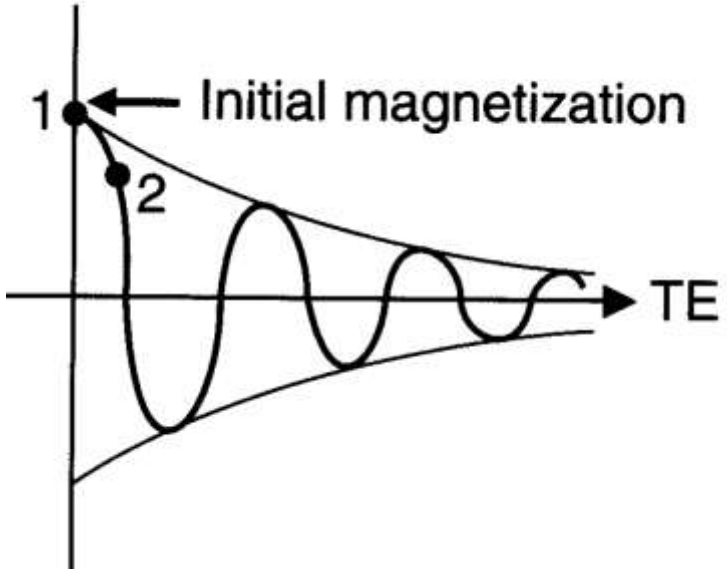
- At t=TR,

$$M_z(TR) = M_0 (1 - e^{-TR/T1})$$



Echo Time (TE)

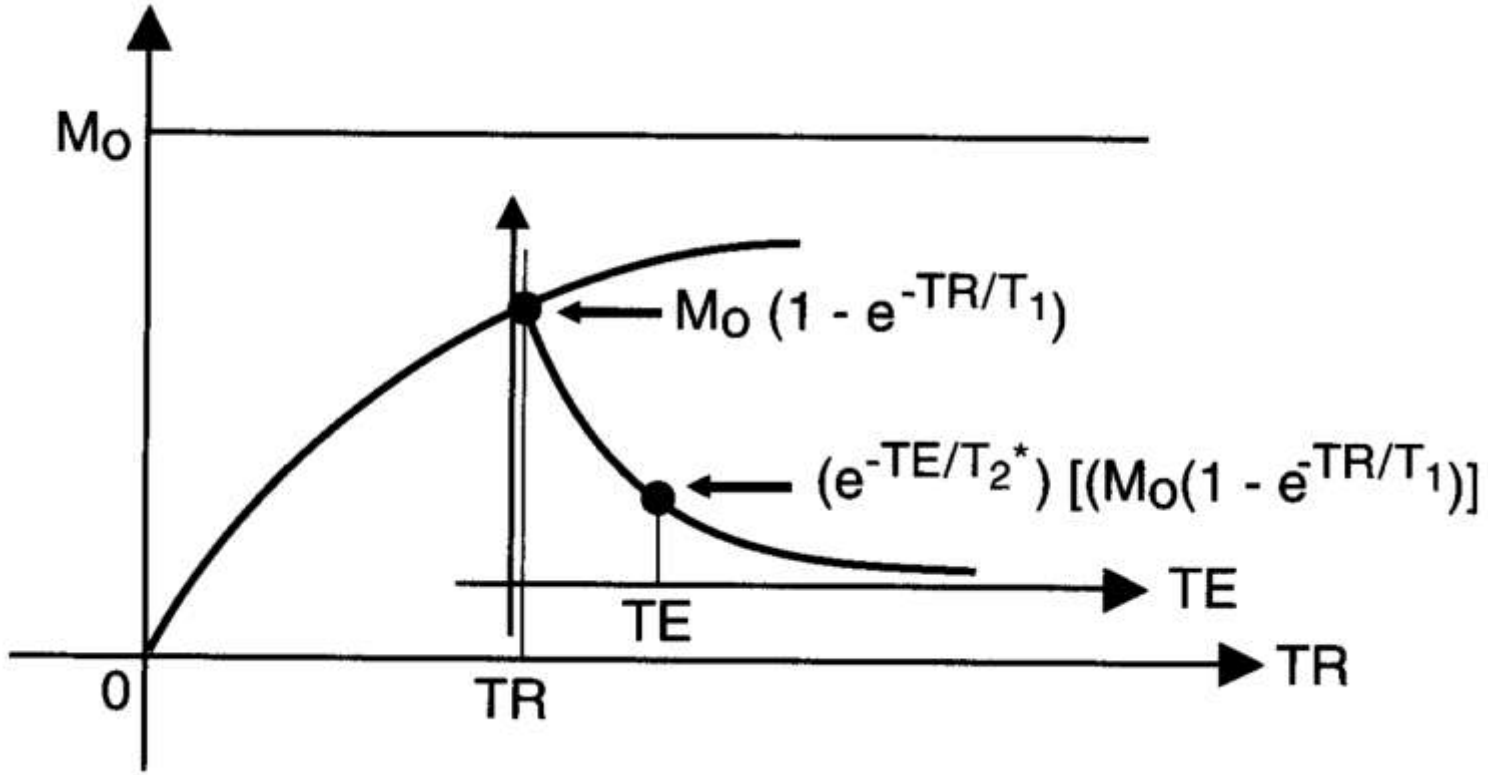
- Time sampling of FID starts



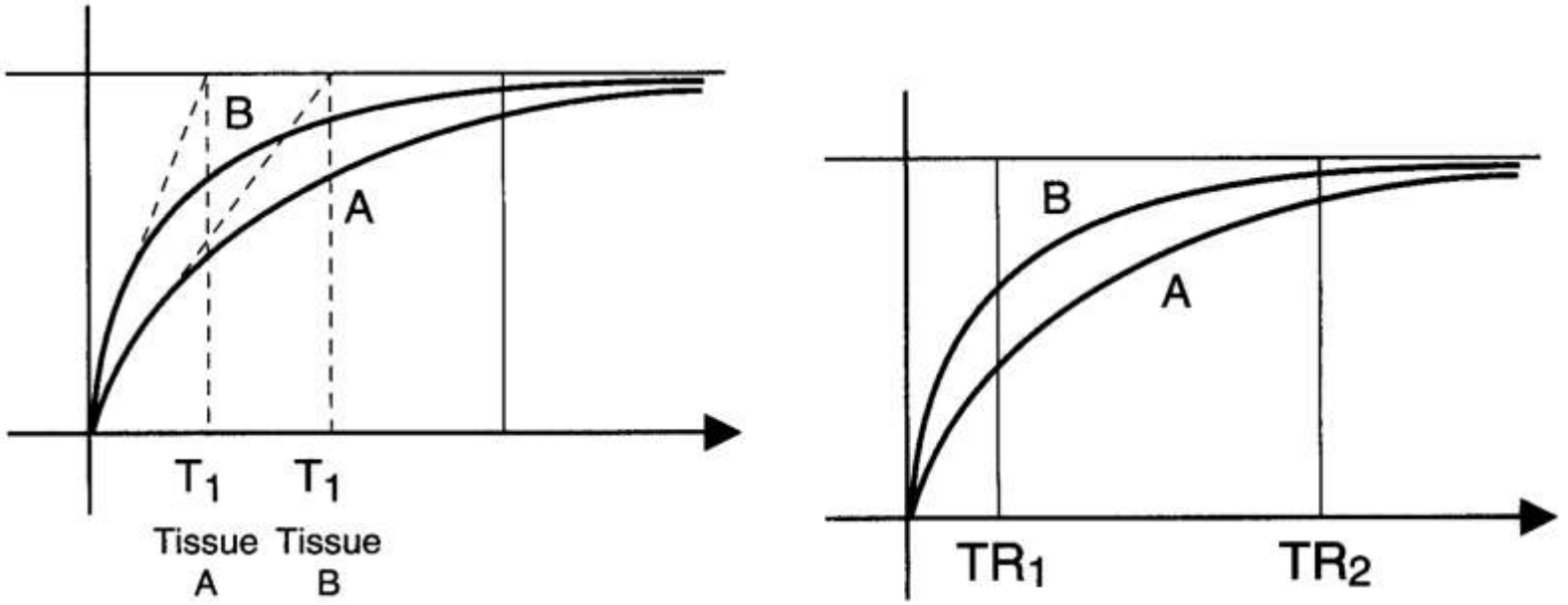
$$M_0 \cdot (e^{-TE/T2^*})$$

Tissue Contrast

$$\text{Signal Intensity} = SI \propto N(H)(e^{-TE/T2^*})(1 - e^{-TR/T1})$$

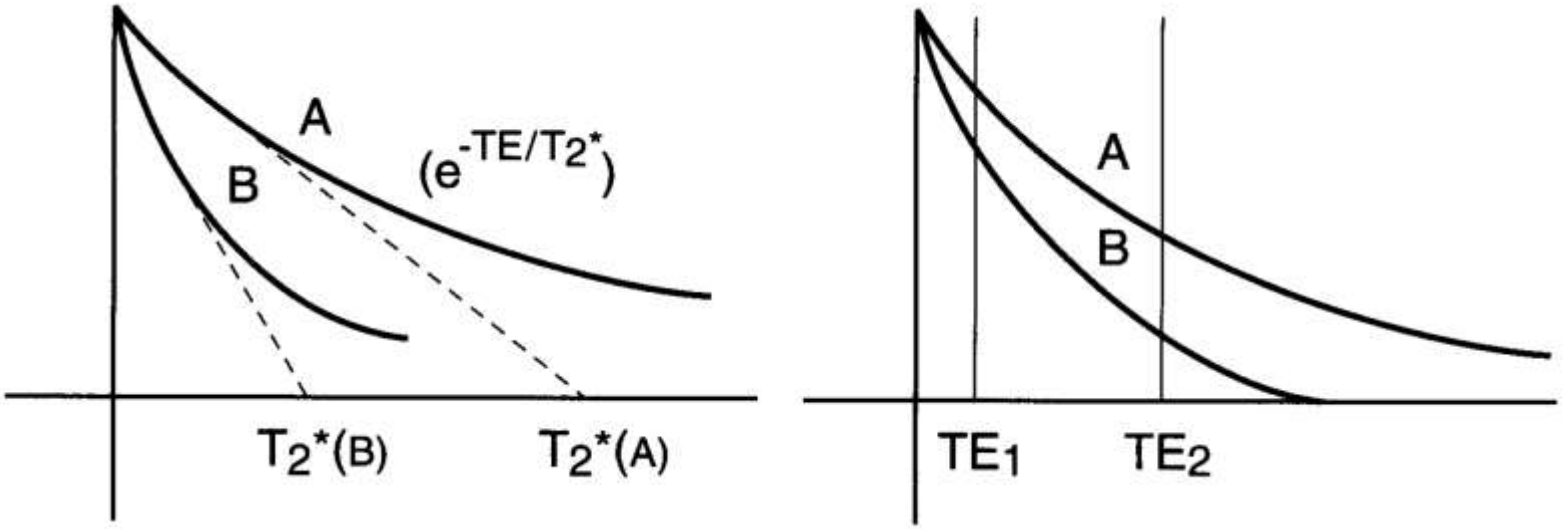


T1-Weighting



Long TR reduces the T_1 effect.

T2-Weighting



Short TE reduces the T_2 effect.*

Tissue Contrast

Tissue	T_1 (ms)	T_2 (ms)
H_2O	2500	2500
fat	200	100
CSF	2000	300
gray matter	500	100

Problem Assignments

- Solve the problems at the end of each chapter.