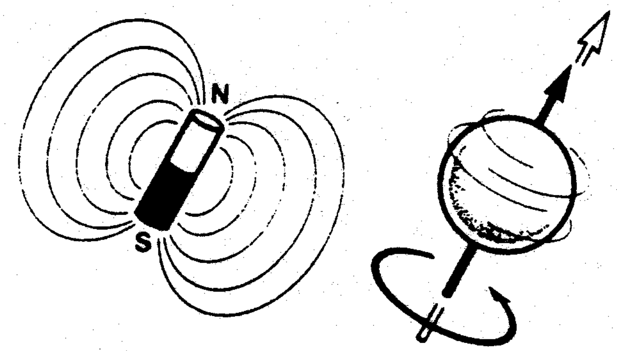
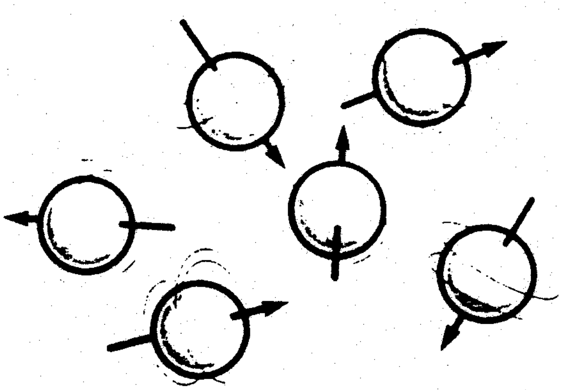
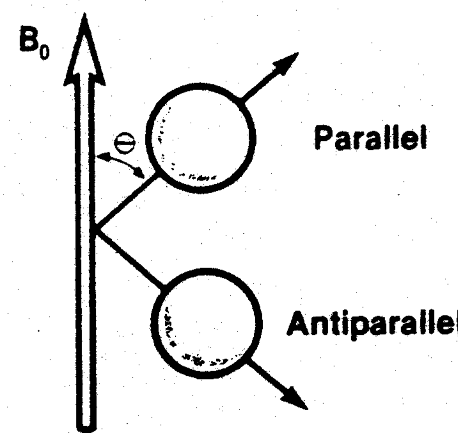
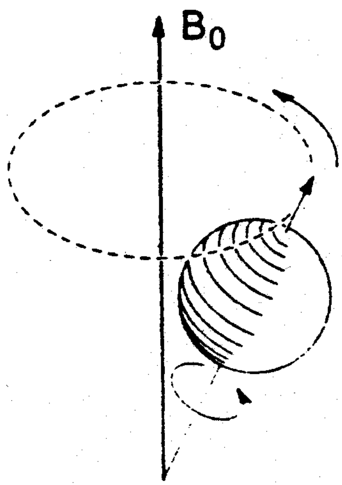
Larmor

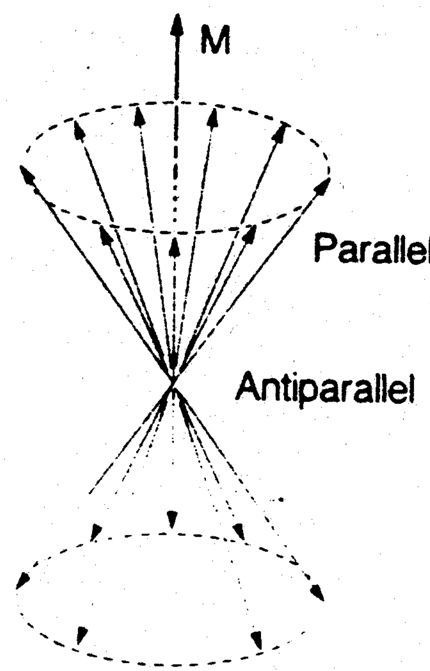
$\omega = \gamma B$











Illustrations from Hendrick, et al.

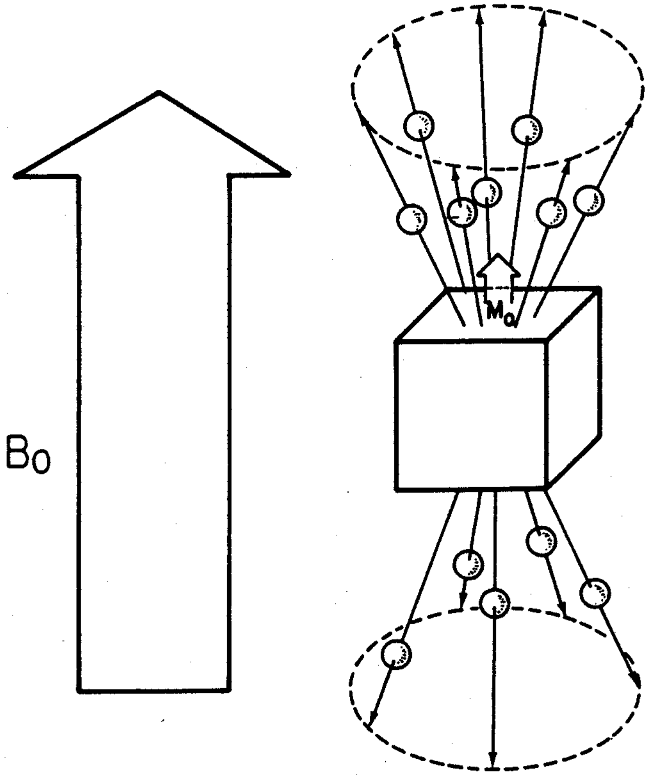


Figure 5. The net magnetization (M_0) resulting from the imbalance of hydrogen nuclear dipoles points along B_0 but is small compared with B_0.

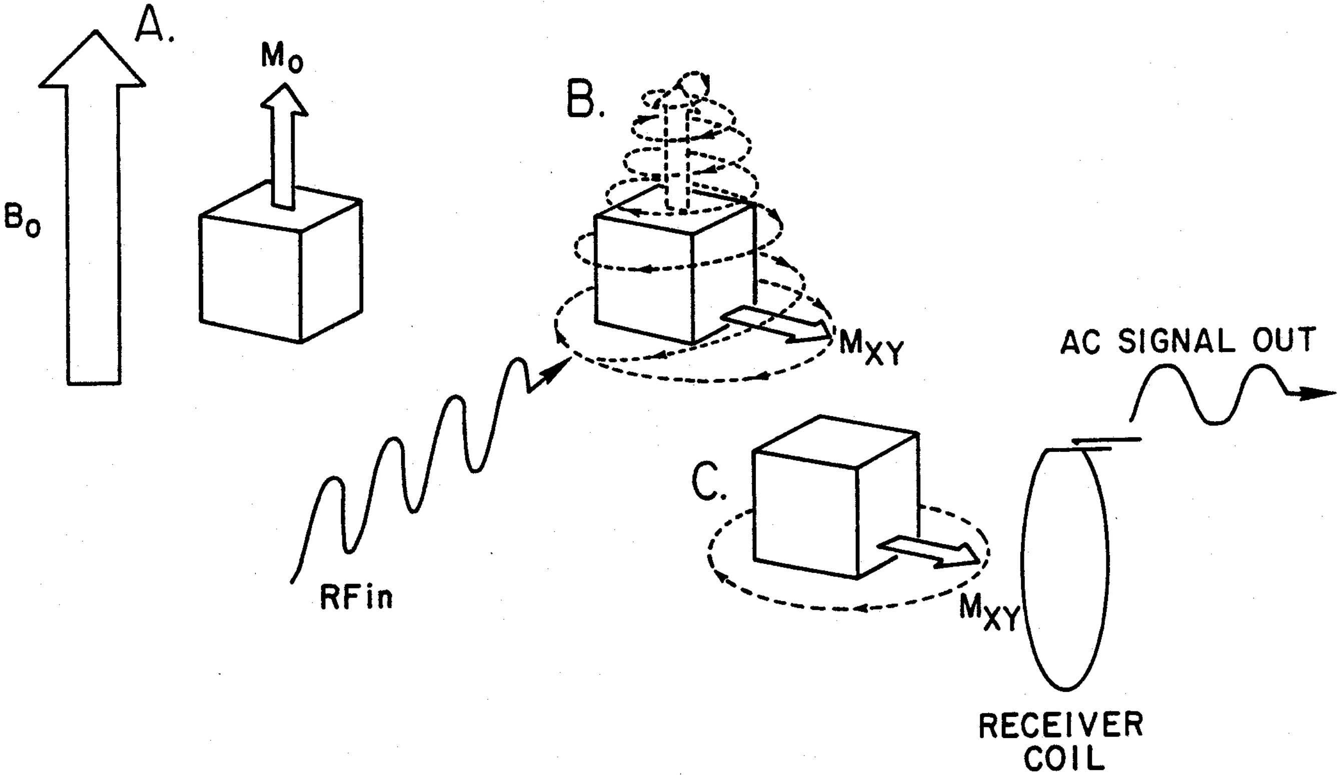
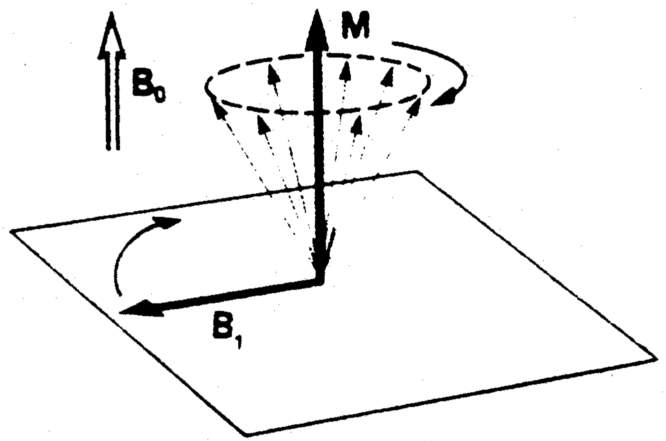
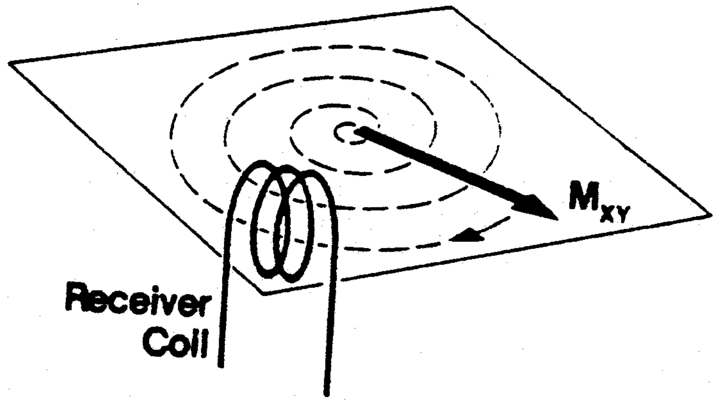
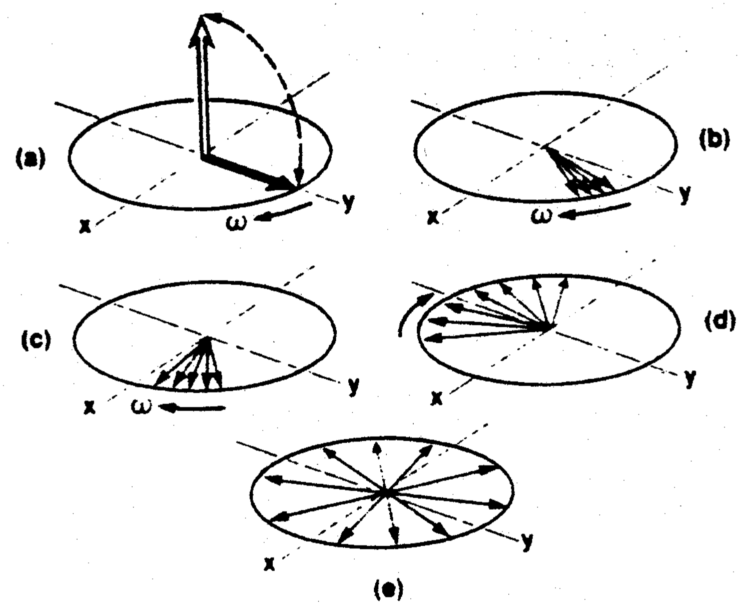
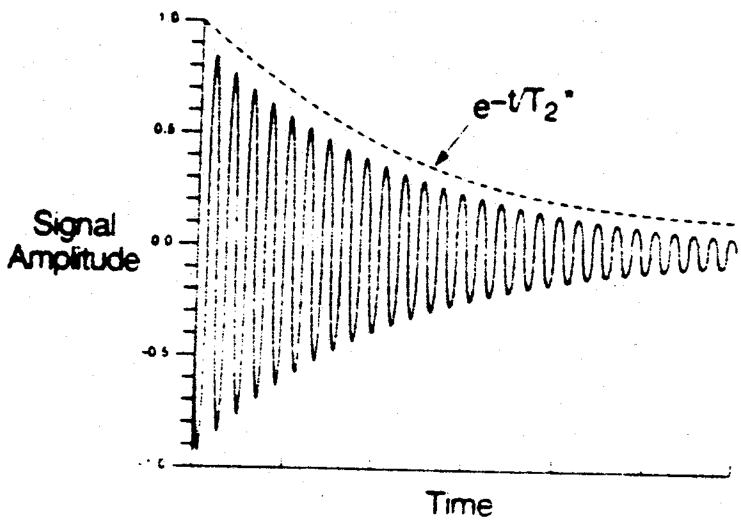


Figure 6. *A*, Net magnetization of the sample M_0 initially is aligned with the main magnetic field B_0, but it is so small in comparison to B_0 that it is undetectable. *B*, A radio-frequency (RF) field applied at the Larmor frequency tips tissue magnetization into the transverse plane, rendering it measurable as transverse magnetization, M_{xy}. *C*, Measurement of M_{xy} is possible because of its precession, which produces a changing magnetic flux linking a properly oriented loop receiver coil. The changing magnetic flux linking the coil induces an alternating current (AC) (alternating at the Larmor frequency) in the receiver coil. This alternating current, when amplified and digitized, becomes the signal from which the MR image is reconstructed.


M
B_0
B_1


M_{XY}
Receiver
Coil


(a)
(b)
(c)
(d)
(e)
x
y
ω


1.0
0.5
0.0
-0.5
e^{-t/T_2^*}
Signal
Amplitude
Time

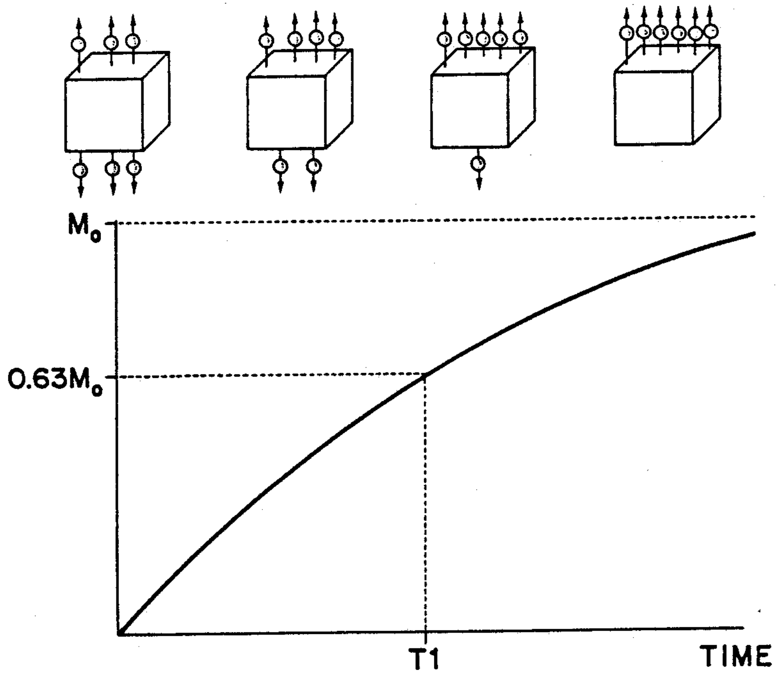


Figure 7. T1 recovery as a function of TR after a 90° pulse. Immediately after the 90° pulse, the population of higher-energy dipoles (antiparallel to B_0, pointing downward) and lower-energy dipoles (parallel to B_0, pointing upward) is equal. As energy is transferred from excited, higher-energy dipoles to the surrounding macromolecules, the longitudinal magnetization approaches its equilibrium value, M_0, which is a maximum imbalance of dipoles. T1 for a given tissue is defined as the time delay required after a 90° pulse for 63% of the tissue magnetization to recover along the direction of B_0.

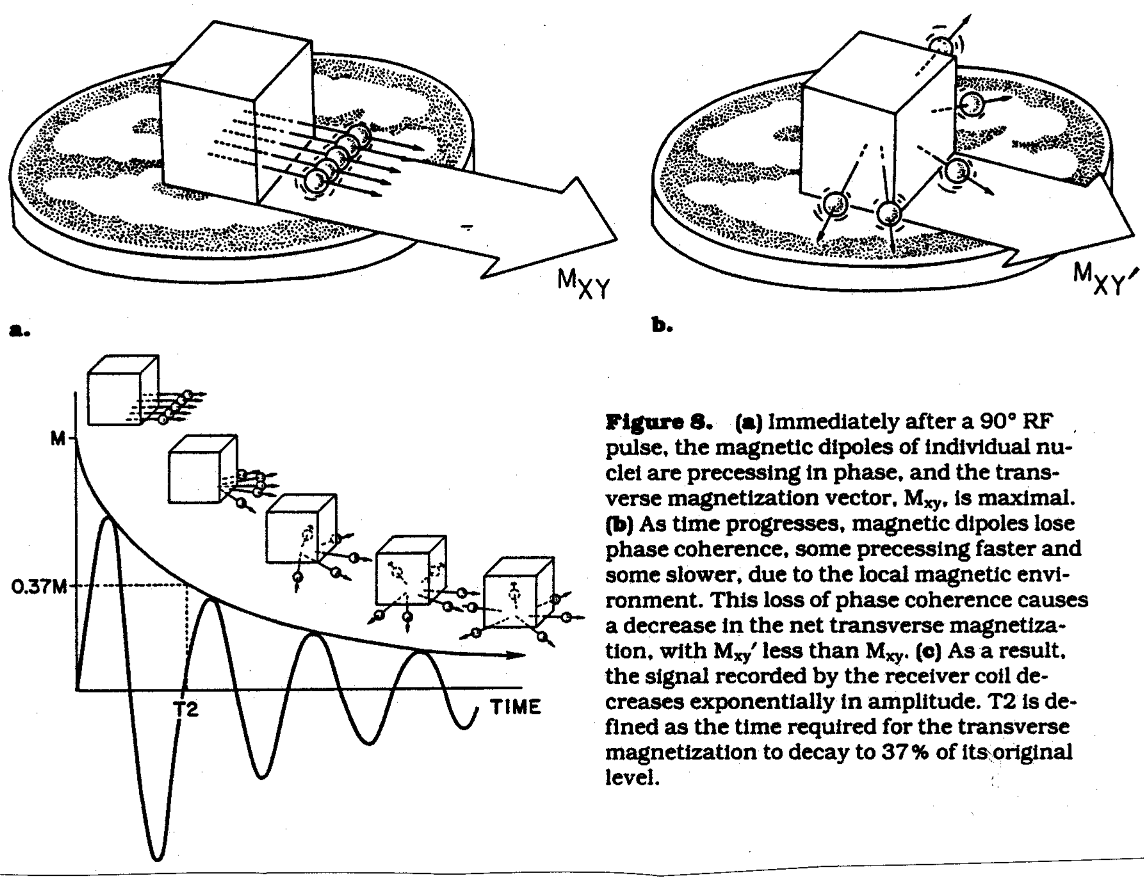
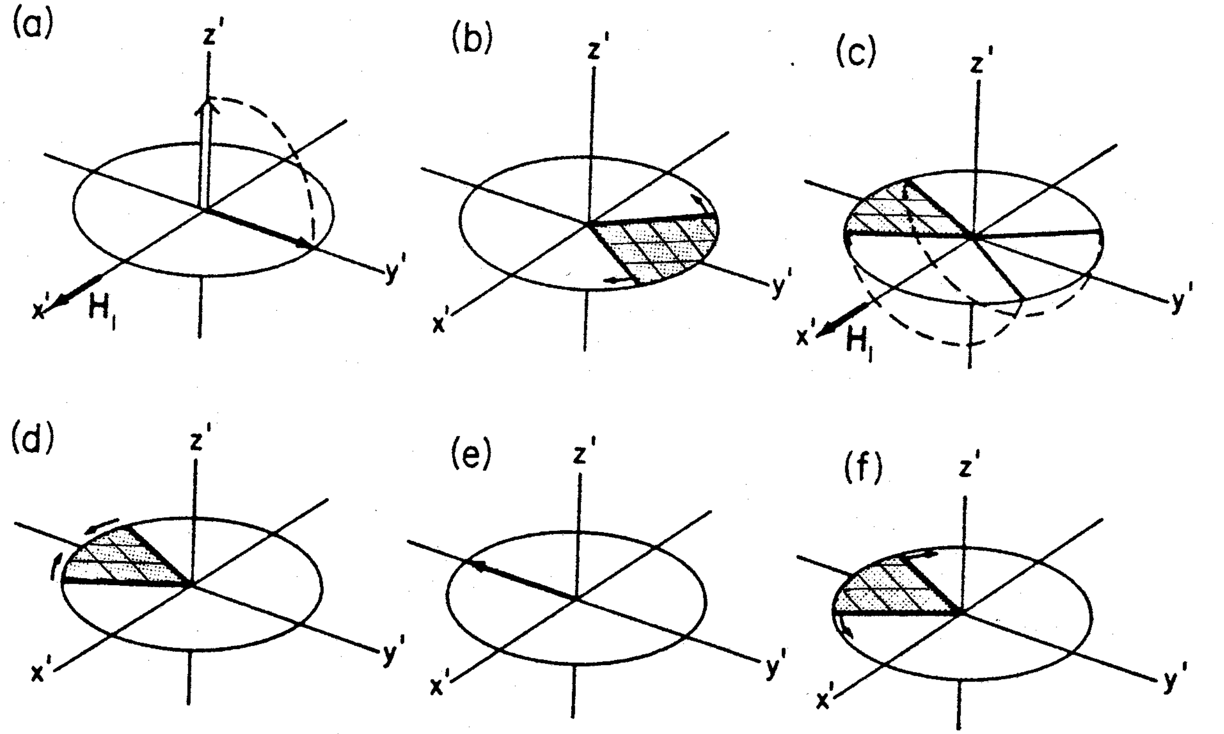
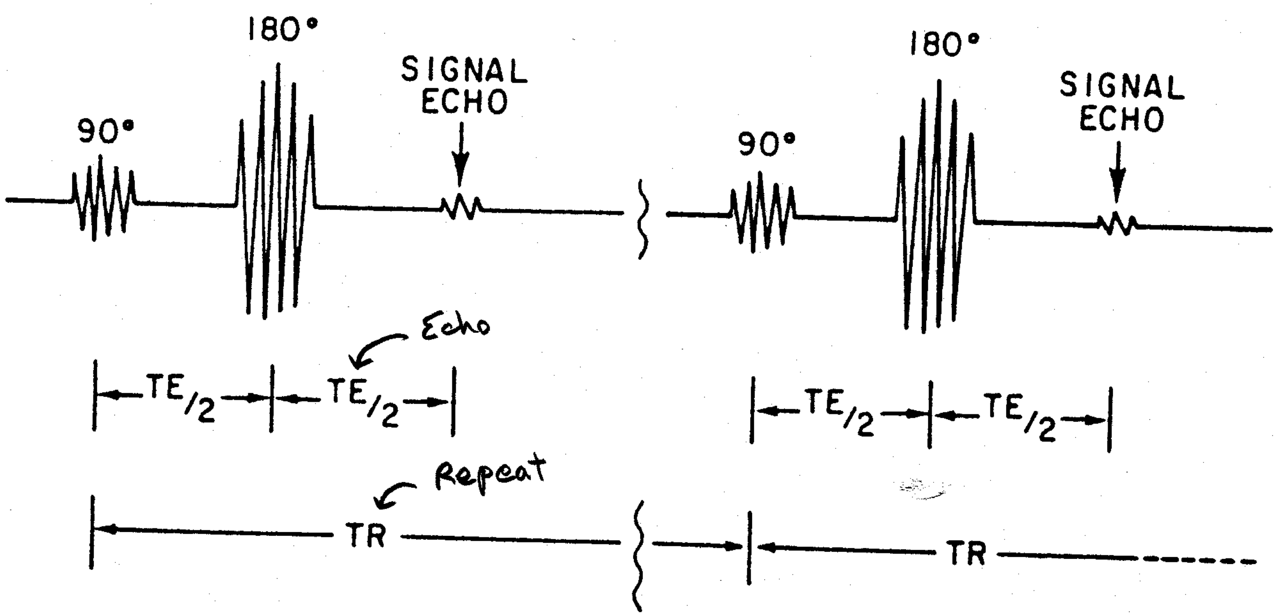
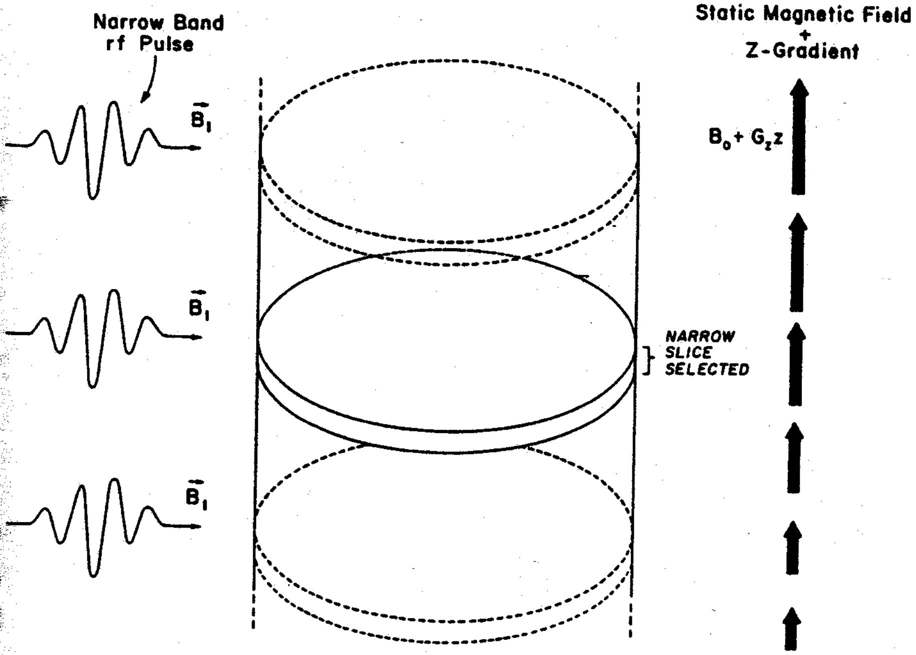


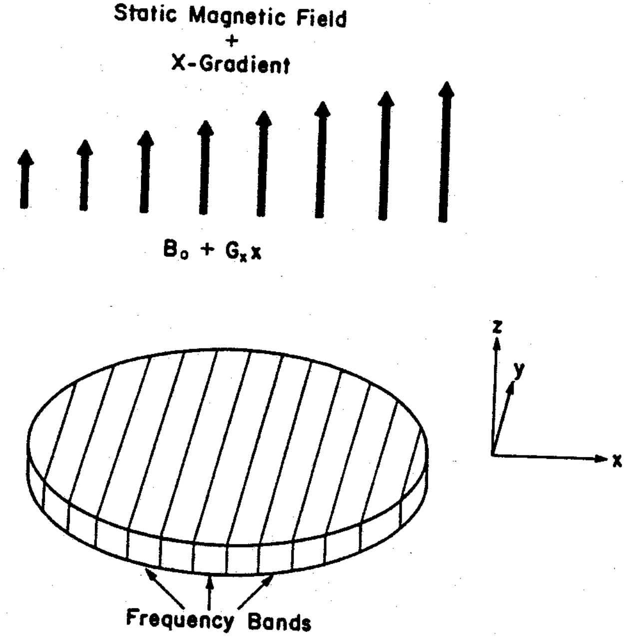
Figure 8. **(a)** Immediately after a 90° RF pulse, the magnetic dipoles of individual nuclei are precessing in phase, and the transverse magnetization vector, M_{xy}, is maximal. **(b)** As time progresses, magnetic dipoles lose phase coherence, some precessing faster and some slower, due to the local magnetic environment. This loss of phase coherence causes a decrease in the net transverse magnetization, with M_{xy}' less than M_{xy}. **(c)** As a result, the signal recorded by the receiver coil decreases exponentially in amplitude. T2 is defined as the time required for the transverse magnetization to decay to 37% of its original level.


(a)
z'
y'
x'
H_1
(b)
z'
y'
x'
(c)
z'
y'
x'
H_1
(d)
z'
y'
x'
(e)
z'
y'
x'
(f)
z'
y'
x'

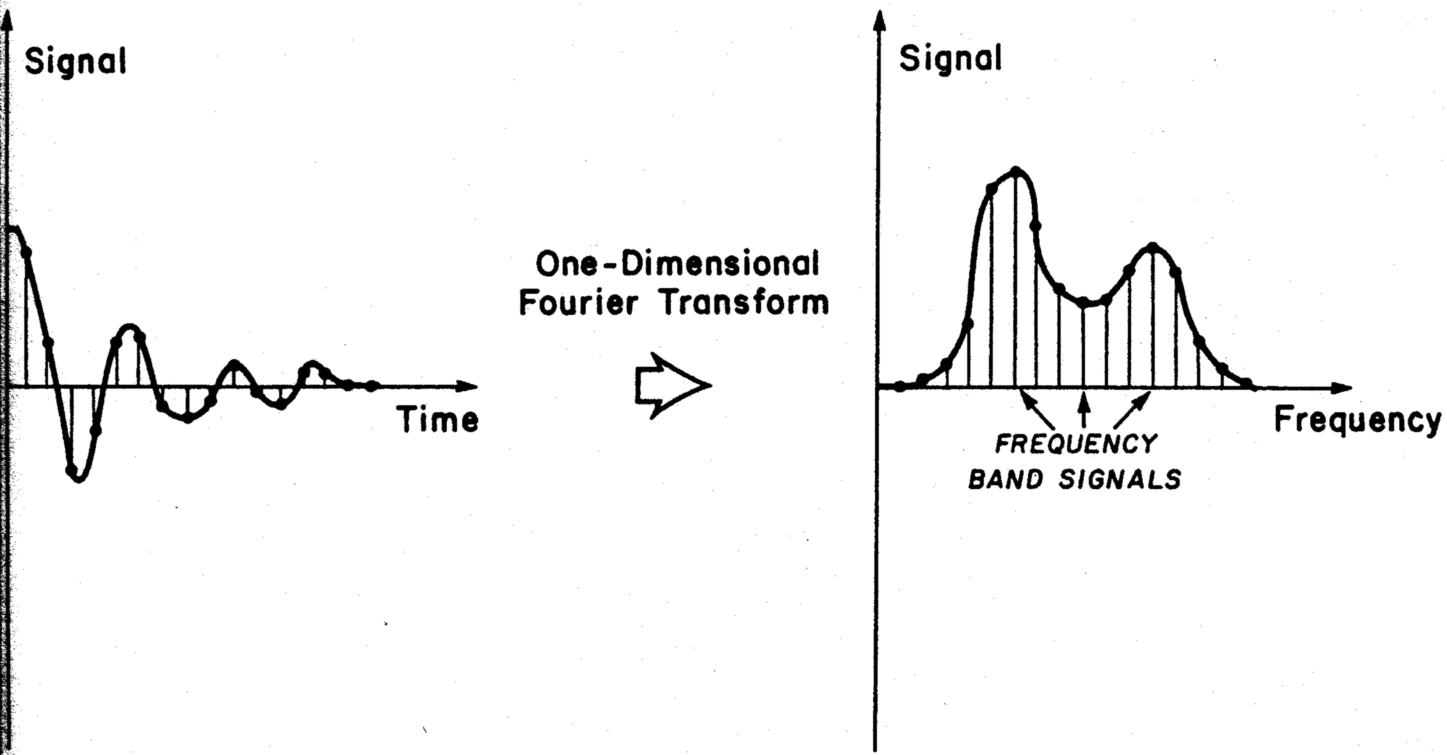

90°
180°
SIGNAL
ECHO
90°
180°
SIGNAL
ECHO
Echo
TE/2
TE/2
TE/2
TE/2
Repeat
TR
TR

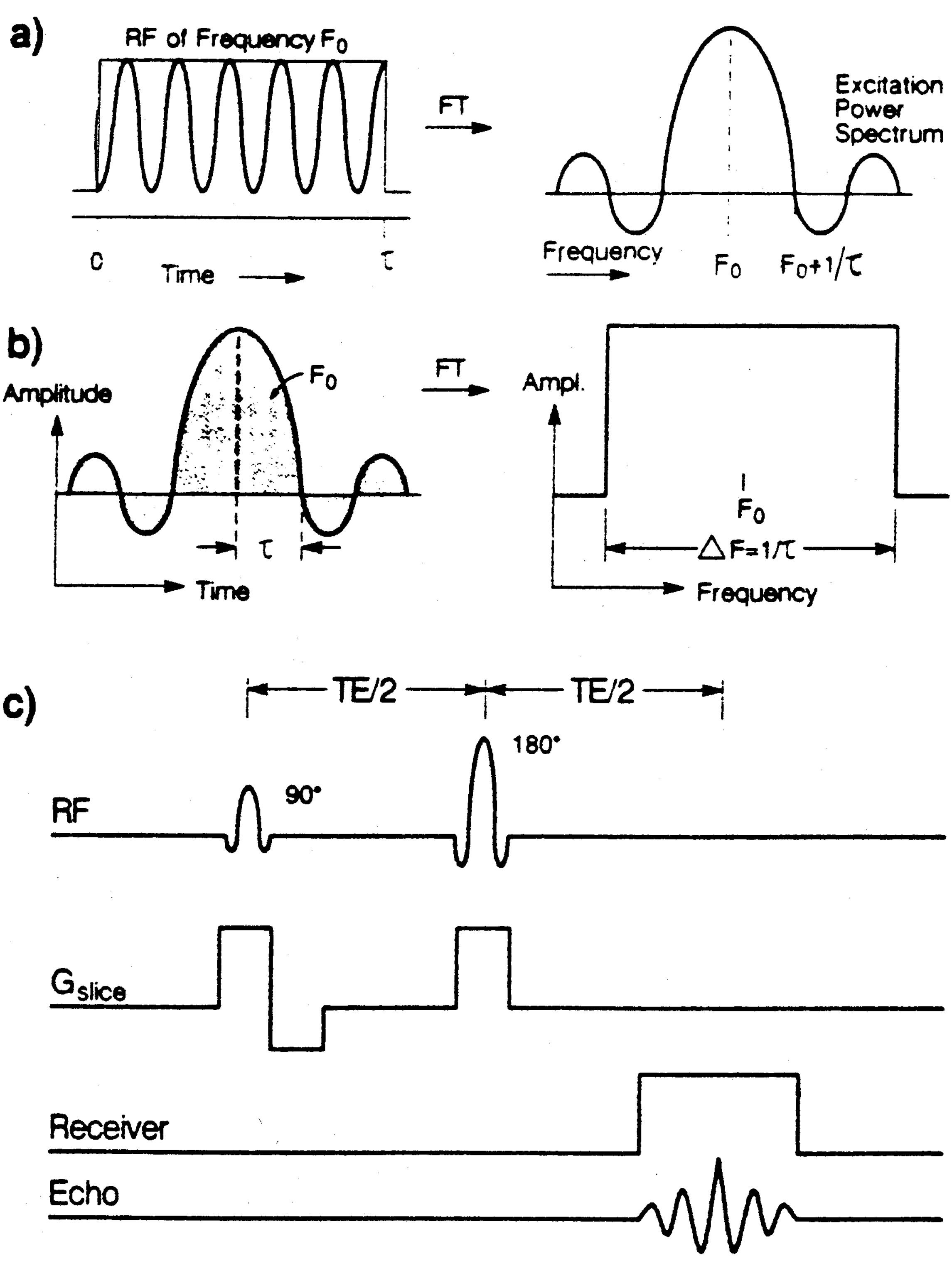

Narrow Band
rf Pulse
$\vec{B}_1$
$\vec{B}_1$
$\vec{B}_1$
NARROW
SLICE
SELECTED
Static Magnetic Field
+
Z-Gradient
$B_0 + G_z z$

a.


Static Magnetic Field
+
X-Gradient
$B_0 + G_x x$
z
y
x
Frequency Bands

b.


Signal
Time
One-Dimensional
Fourier Transform
Signal
Frequency
FREQUENCY
BAND SIGNALS



a)
RF of Frequency F0
0
Time
τ
FT
Excitation Power Spectrum
Frequency
F0
F0+1/τ
b)
Amplitude
F0
τ
Time
FT
Ampl.
F0
ΔF=1/τ
Frequency
c)
TE/2
TE/2
180°
90°
RF
Gslice
Receiver
Echo

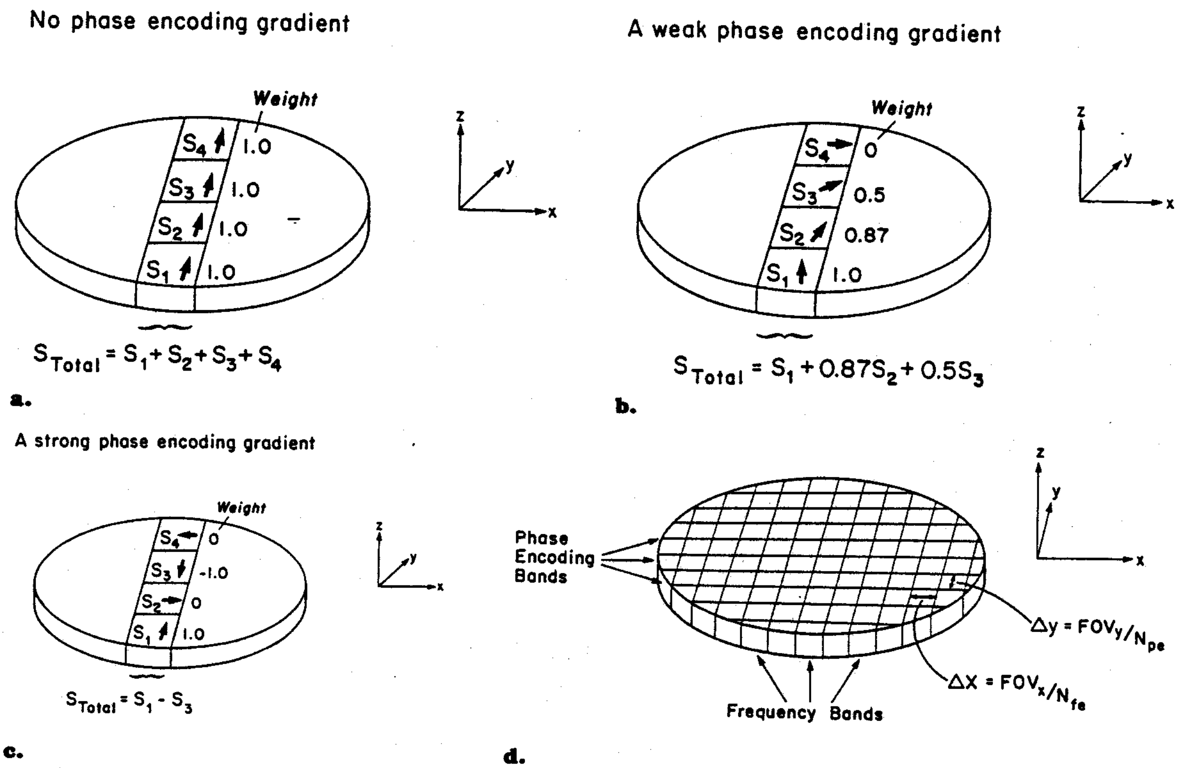
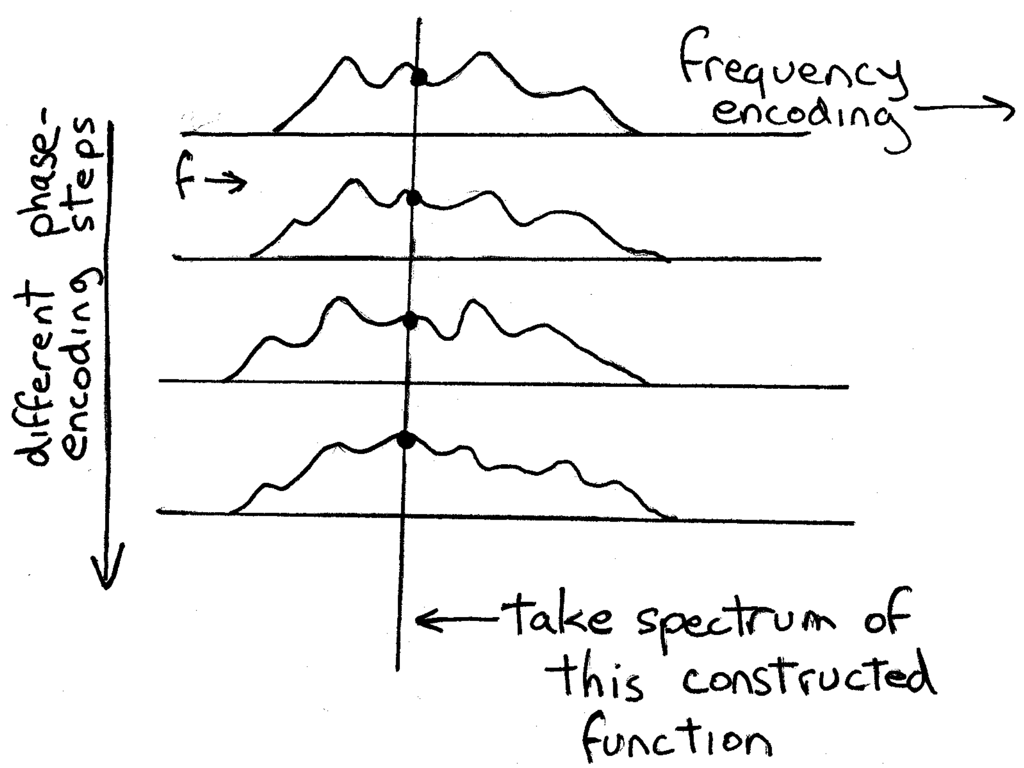
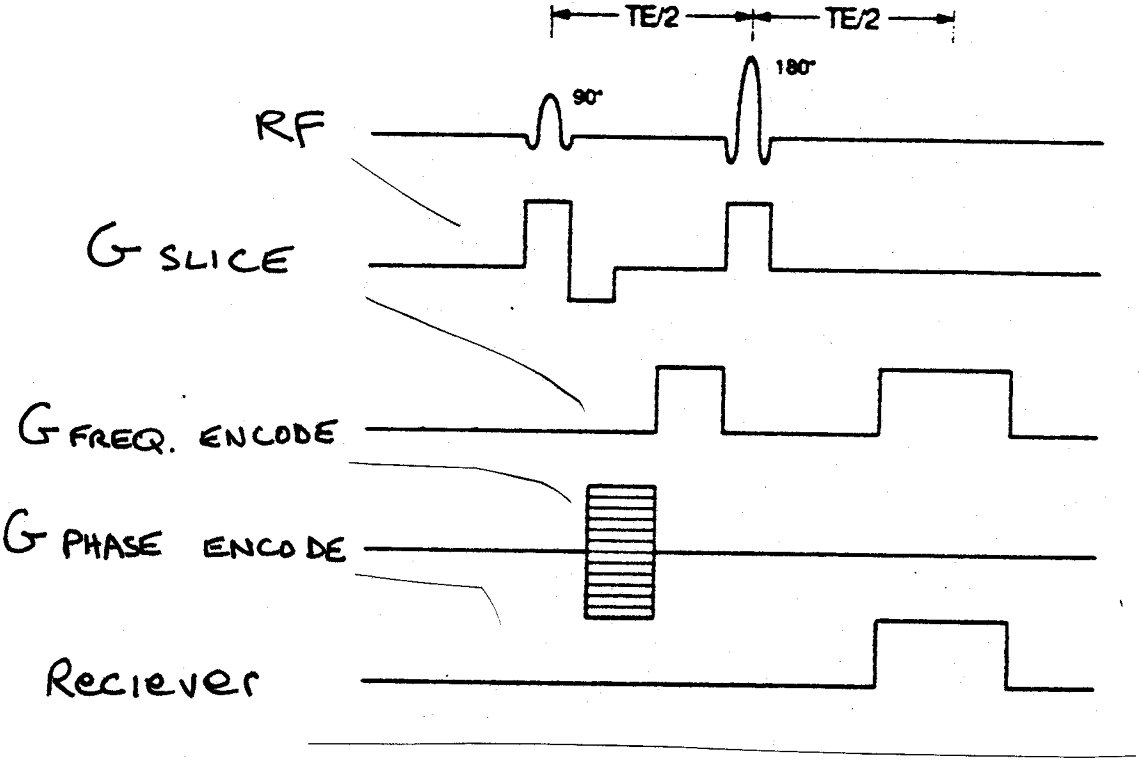


Figure 13. **(a)** Acquiring the signal (S) from the selected plane without phase encoding leaves the individual voxels in each frequency band in phase, so that the measured signal is just the sum of signals from each voxel. **(b)** The application of a weak phase-encoding y gradient prior to signal measurement produces a small amount of phase shift from voxel to voxel, weighting differently the signal from each pixel in a given frequency band. **(c)** Application of a stronger phase-encoding y gradient produces a greater phase shift from pixel to pixel, again weighting the signals from each voxel differently. **(d)** With a sufficient number of planar acquisitions, each with a different degree of phase encoding, and therefore a different relative weighting, the signals from individual pixels within each frequency band can be resolved. The pixel size in the x (frequency-encoding) direction (Δx) is determined by the field of view (FOV) in the x direction (FOV_x) and the number of pixels in the x direction (N_{fe}). Likewise, the pixel size in the y (phase-encoding) direction (Δy) is determined by the field of view in the y direction (FOV_y) and the number of pixels in the y direction, which in most cases is equal to the number of distinct phase-encoding steps (N_{pe}).



SPIN ECHO



TE/2
TE/2
90°
180°
RF
G SLICE
G FREQ. ENCODE
G PHASE ENCODE
Reciever