Spin-Lattice interaction

- A constant interaction growth rate from the proton interaction with the lattice (surrounding thermal reservoir) implies that the rate of change of the longitudinal magnetization is proportional to the difference (M0-Mz).the proportionality constant is empirically determined and represents the inverse of the time scale of the growth rate.

Tissue	T1 (ms)	T2 (ms)
Grey Matter (GM)	950	100
White Matter (WM)	600	80
Muscle	900	50
Cerebrospinal Fluid (CSF)	4500	2200
Fat	250	60
Blood	1200	100-200

T_1 relaxation leads to the

Solution for Longitudinal Magnetization:

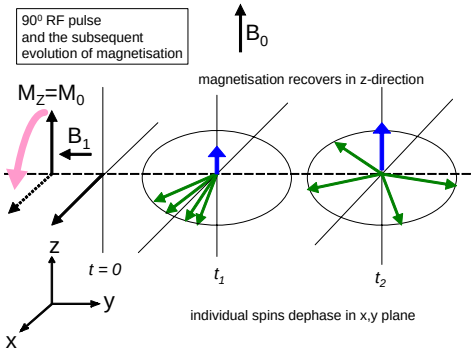
$$\frac{d\vec{M}_z}{dt} = \frac{(M_z - M_o)\hat{k}}{T_1}$$

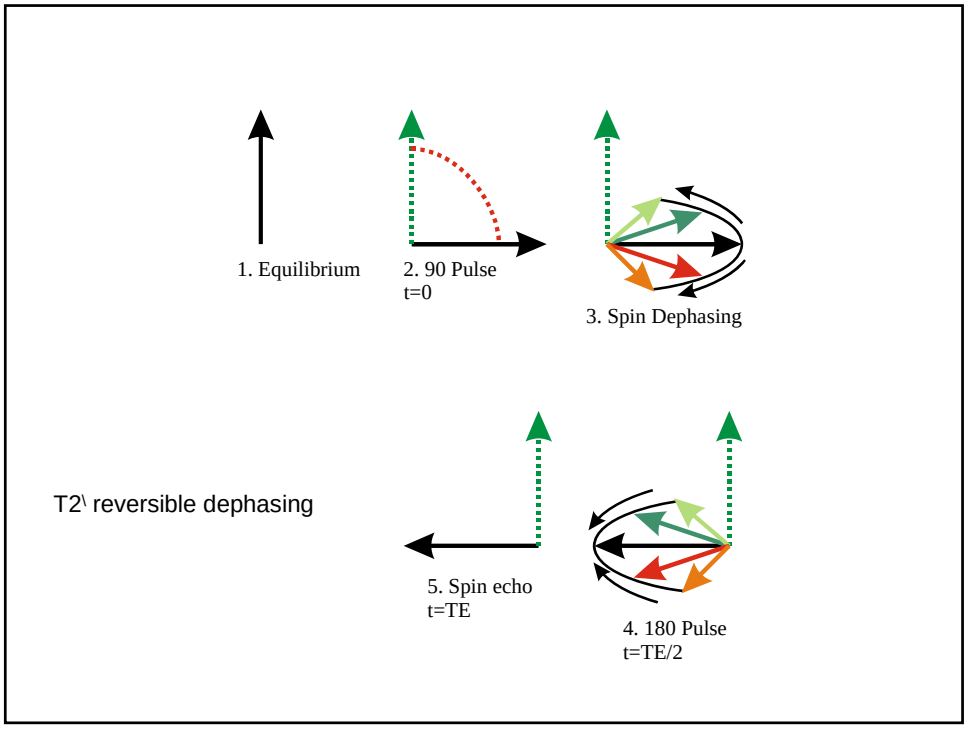
The greater the difference from equilibrium, the faster the change

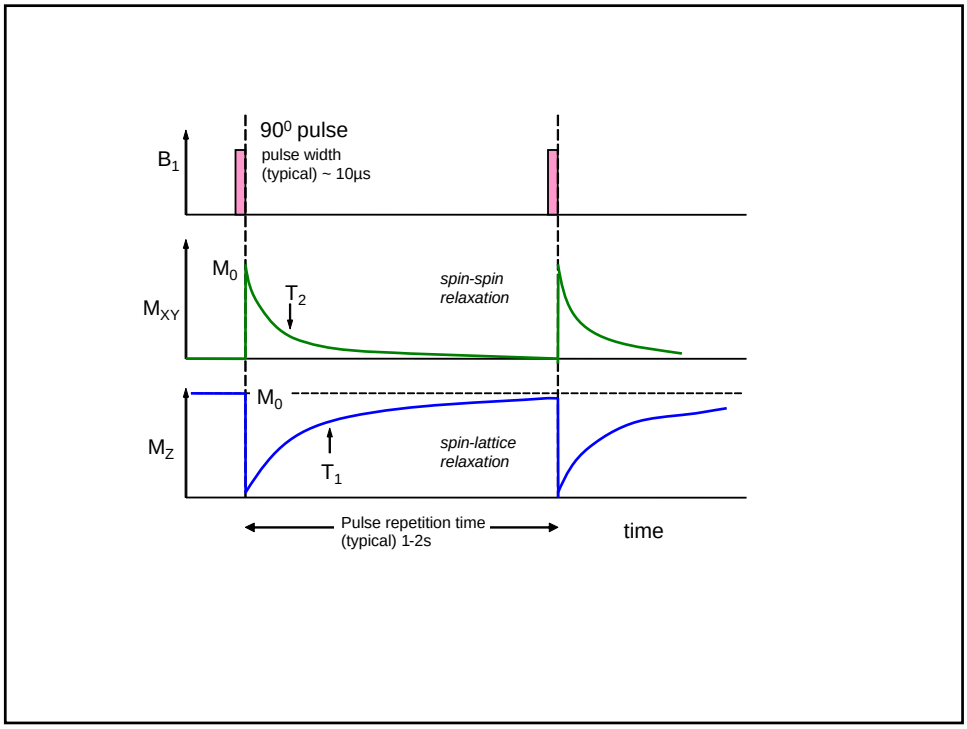
Solution:

$$M_z(t) = M_z(0)e^{-t/T_1} + M_0(1 - e^{-t/T_1})$$

Initial Magnetization — Return to Equilibrium


90º RF pulse
and the subsequent
evolution of magnetisation
B0
magnetisation recovers in z-direction
MZ=M0
B1
z
t = 0
t1
t2
y
x
individual spins dephase in x,y plane


1. Equilibrium
2. 90 Pulse
t=0
3. Spin Dephasing
T2\ reversible dephasing
5. Spin echo
t=TE
4. 180 Pulse
t=TE/2


90⁰ pulse
pulse width
(typical) ~ 10μs
B1
M0
T2
MXY
spin-spin
relaxation
M0
MZ
T1
spin-lattice
relaxation
Pulse repetition time
(typical) 1-2s
time

Bloch equation

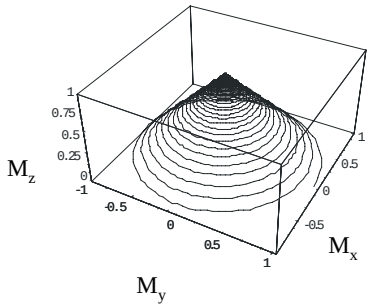
$$\frac{d\vec{M}}{dt} = \vec{M} \times \gamma \vec{B}_{ext} - \frac{M_x \hat{i} + M_y \hat{j}}{T_2} - \frac{(M_z + M_0)\hat{k}}{T_1}$$

For a constant field

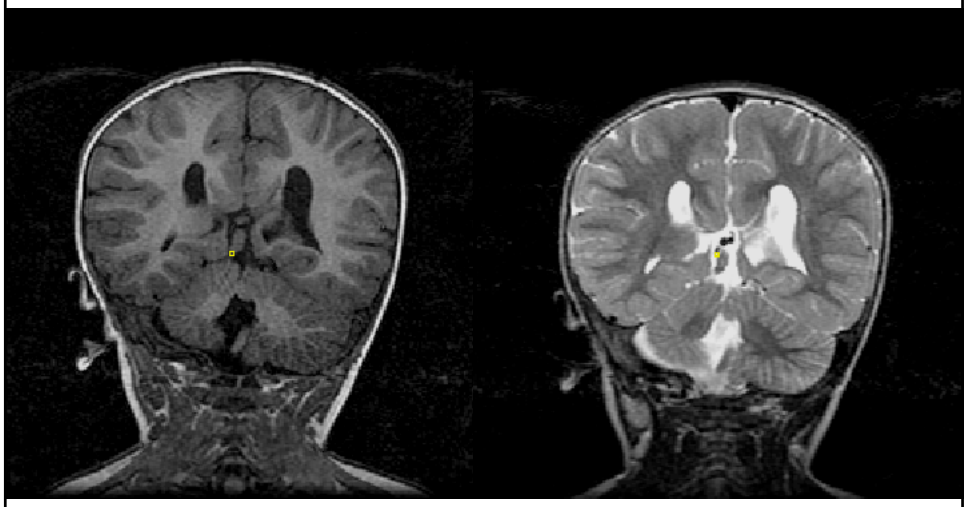
$$\frac{dM_x}{dt} = \omega_0 M_y - \frac{M_x}{T_2}$$

$$\frac{dM_y}{dt} = -\omega_0 M_x - \frac{M_y}{T_2}$$

$$\frac{dM_z}{dt} = \frac{M_0 - M_z}{T_1}$$


M_z
1
0.75
0.5
0.25
0
-1
-0.5
0
0.5
1
M_y
1
0.5
0
-0.5
M_x

T1 Weighted Image T2 Weighted Image



Chemical Shift

- Chemical shift is a small displacement of the resonance frequency due to shielding created by the orbital motions of the surrounding electrons (induced secondary field) in response to B_0.
- When a shielded and a deshielded proton are place within the same magnetic field , the shielded one experiences a lower local effective field and therefore has a lower resonance frequency than the deshielded proton.