1st
Semester

كلية المأمون الجامعة

قســـــم تقنيات الأشـــعة

المرحلة الثالثة

Physics of Magnetic Resonance

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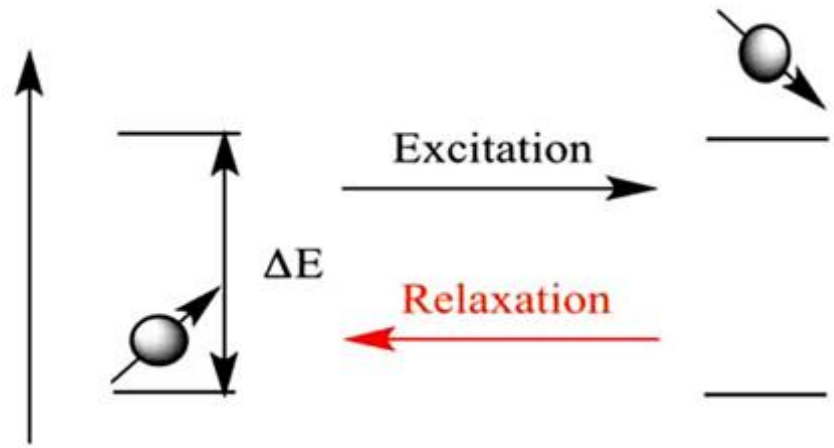
MSc Medical Imaging / MRI Applications

Introduction

- *Excitation of Protons: When radiofrequency (RF) waves at a specific frequency (Larmor Frequency) are applied to the body, energy is transferred to the protons. This energy causes the protons in the low-energy state to absorb the energy and transition to the high-energy state.*

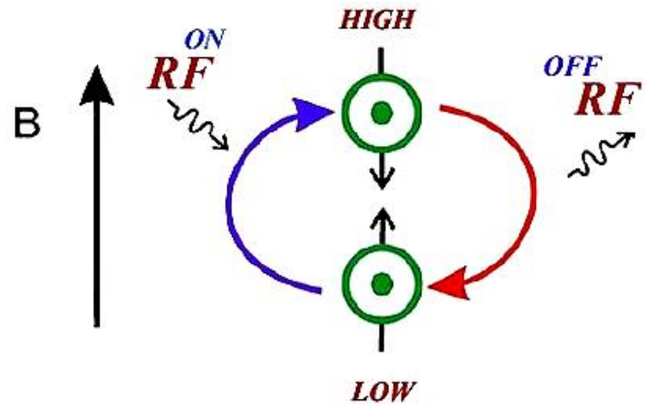


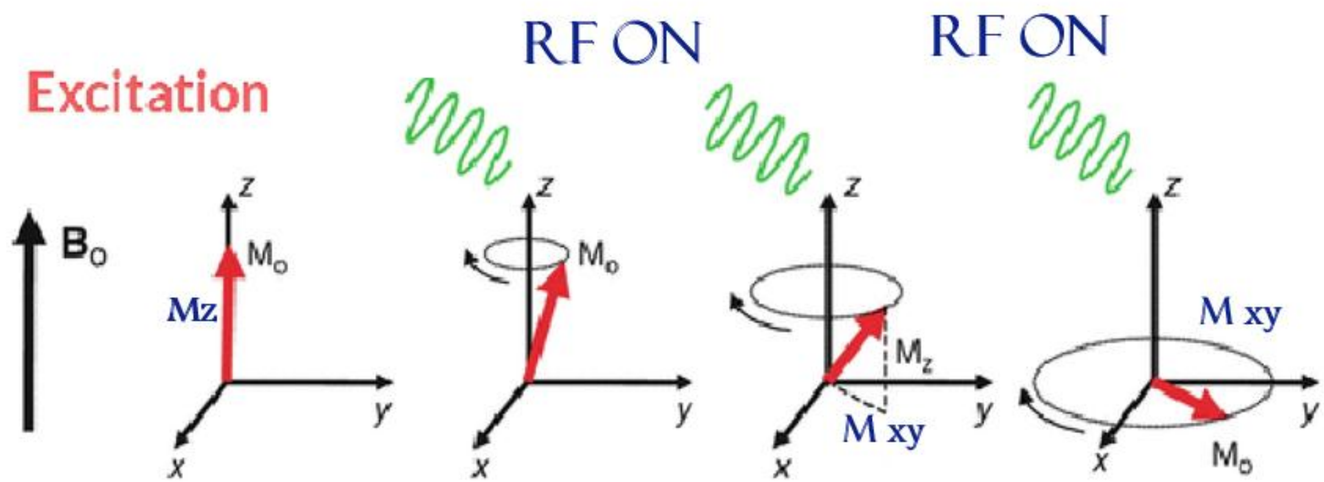
- *Relaxation (Return to Equilibrium): After the RF waves are turned off, the protons return to the low-energy state, releasing the excess energy they absorbed. This collective return, or* ***relaxation, occurs at different rates depending on the type of tissue that contains the protons****. These varying relaxation rates create the distinct gradient of shades in the gray-scale MRI image, giving it its characteristic contrast.*

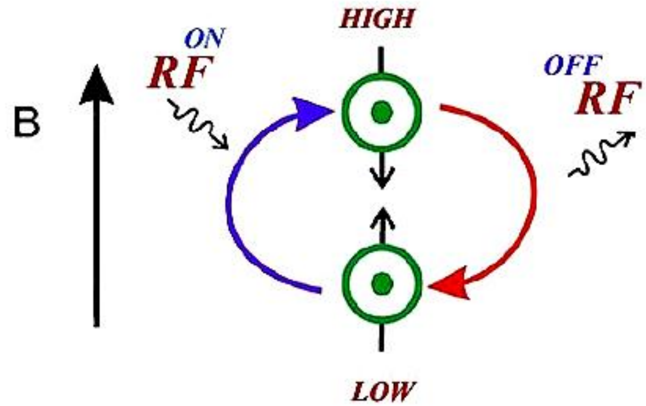
- *RF (radiofrequency) pulse: An impulse delivered by an RF transmitter. If the RF pulse is at or near the Larmor frequency, it will rotate the Mz magnetization vector into the (Mxy) referred to as the B1 field.*

- *The amount of rotation depends on the strength and duration of the pulse (B1=0.1 G in resonance / 10 to 100 MHz from RFt).*

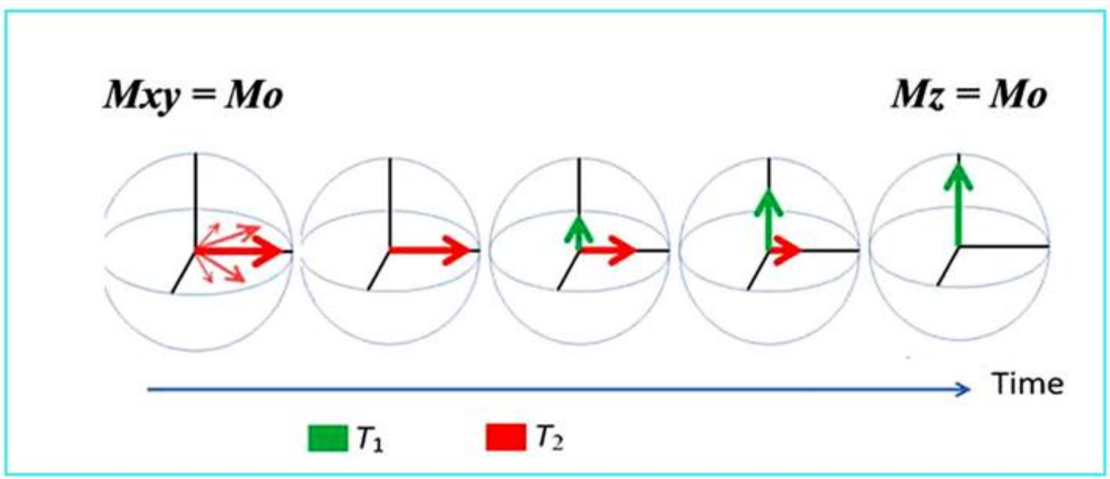
- *RF pulse between: 0° - 180° pulses are used to redefine flip angles. It is usually employed as an excitation pulse or a re-focusing pulse, important in contrast mechanism.*


B
ON
RF
HIGH
OFF
RF
LOW


RF ON
RF ON
Excitation
B0
z
M0
Mz
y
x
z
M0
y
x
z
Mz
M xy
y
x
z
M xy
y
x
M0



Relaxation Time
- Longitudinal M_z is : T_1 recovery time.
- Transverse M_{xy} is : T_2 decay time.



*A transverse magnetization Mxy is generated from the magnetization along the Z-axis. But **why specifically 90 degrees**? Let's explain the reasons:*

1- *Applying a 90-degree pulse ensures that the transverse magnetization is at its maximum level, leading to strong and clear signals that are used to form the images.*
2- *The 90-degree angle achieves an optimal balance between longitudinal and transverse magnetization.*
3- *After applying a 90-degree pulse, the transverse magnetization is at its peak strength, while the longitudinal magnetization has temporarily disappeared, allowing for precise data collection.*
4- *Reducing interference, the 90-degree phase angle helps minimize interference with other signals, improving the quality of the final image.*

Phase concept

- *Phase in wave physics is the angle or position of a specific point in the wave cycle at a given time.*

- *The concept of "phase" in the context of T2 relaxation is essential to understanding MRI signals(LESS IN T1) . When protons are exposed to magnetic field variations, their phase angles change, directly impacting the signals received during imaging.*

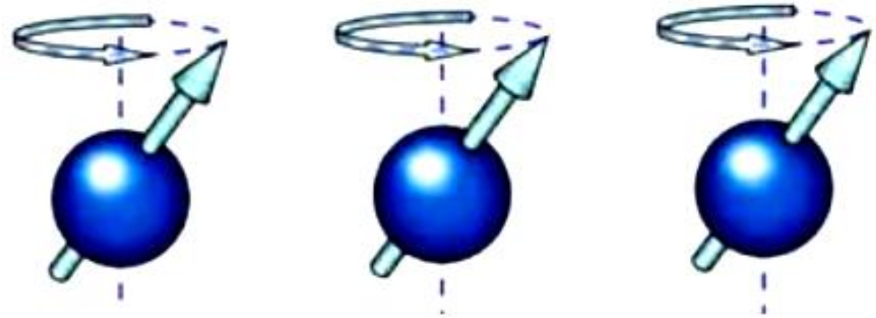
- *As protons experience changes in their surrounding magnetic fields, their phase angles shift. These shifts in phase angles cause variations in the received signal, which plays a role in creating the MRI image.*

- *Changes in phase angles result in a loss of coherence between the protons, known as phase coherence loss. This is an important factor in understanding how MRI signals diminish over time during T2 relaxation.*

- *Due to phase coherence loss, the transverse relaxation signal decreases, a process known as T2 relaxation. This decrease in signal strength is key to differentiating tissue types in MRI scans.*

In phase and Out of phase*: During excitation, protons are in an in phase state in both Mz and Mxy. However, once the RF energy is turned off, the protons enter an Out of phase state, meaning they return at different rates. This is because each tissue has its own unique magnetic properties. This variation is one of the key factors in understanding MRI images.*

IN PHASE

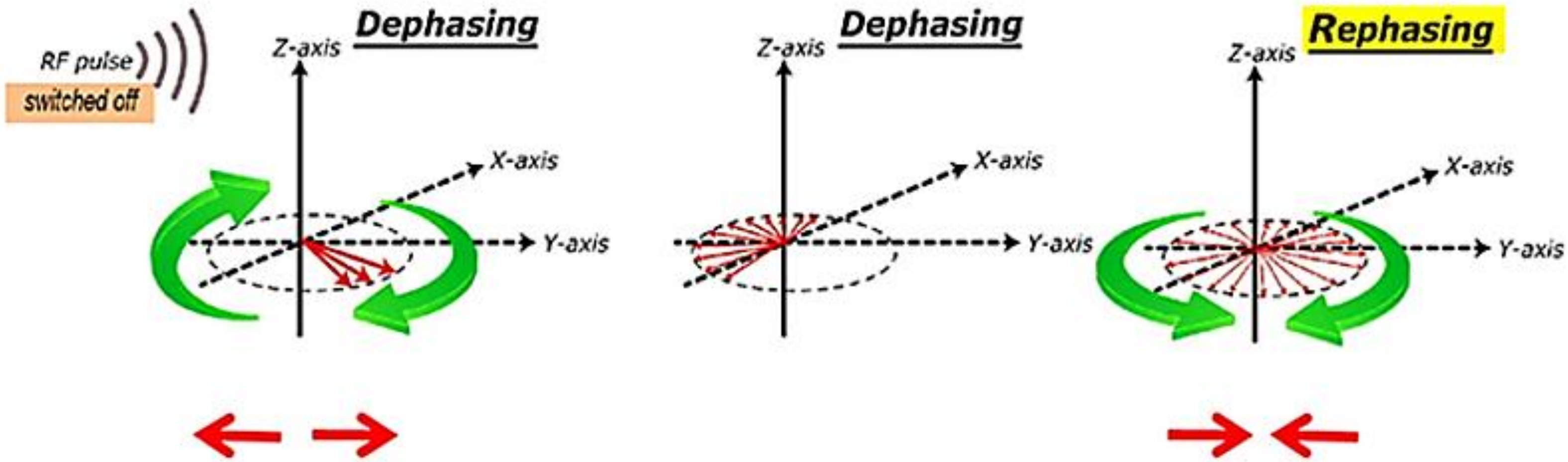


OUT PHASE

DEPHASE vs REPHASE

- ***Dephasing:*** *This refers to the Mxy plane, where protons begin to spread apart in their axes (like the opening of a flower) in the transverse magnetization. Here, the protons start to differ in their speeds and separate from each other, as each tissue has its own unique speed.*

- ***Rephasing:*** *This also refers to the Mxy plane, where protons begin to move back toward the center (like the closing of a flower). The speeds of the protons start to synchronize, and afterward, longitudinal magnetization occurs.*



RF pulse
switched off
Dephasing
Z-axis
X-axis
Y-axis
Dephasing
Z-axis
X-axis
Y-axis
Rephasing
Z-axis
X-axis
Y-axis

Property	T1 (Longitudinal Relaxation)	T2 (Transverse Relaxation)
Relaxation Mechanism	Energy transfer from protons to the surrounding lattice (environment)	Loss of phase coherence between protons within the same tissue
Influencing Factors	Material properties themselves	Interactions between protons and magnetic field inhomogeneity
Complexity	Less complex; more predictable effects	More complex; involves magnetic field interactions


THANKS !