1st Semester

كلية المأمون الجامعة

قســــم تقنيات الأشــــعة

المرحلة الثالثة

Physics of Magnetic Resonance

مدرس مساعد : عماد الربيعي

MSc Medical Imaging / MRI Applications

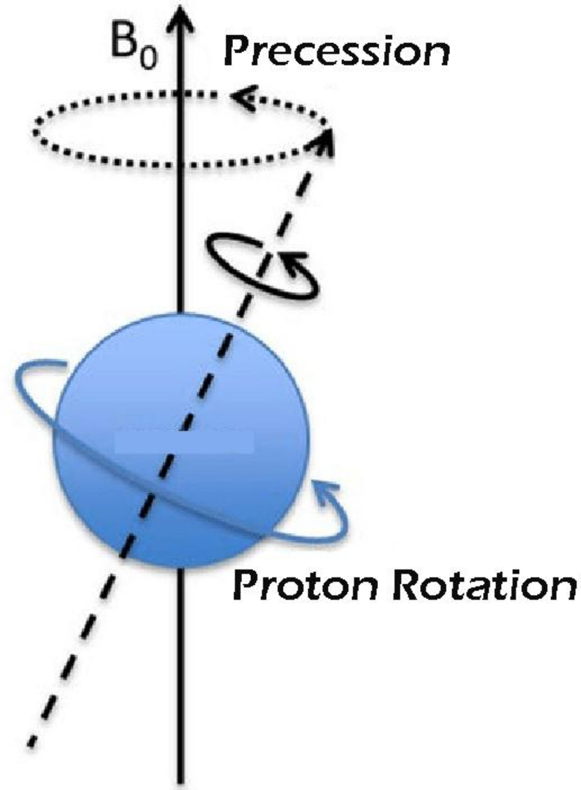
Lecture (2,3)

Magnetic Resonance Imaging

Precession

*precession refers to the **rotational movement of hydrogen nuclei (protons) when subjected to a strong magnetic field**. Each proton has a property known as spin, which gives it a magnetic moment. When placed in an external magnetic field (denoted as B_0), **these magnetic moments tend to align either parallel or anti-parallel to the field**.*

*Protons do not simply align with the field; they **wobble** or precess around the axis of the magnetic field, much like the motion of a spinning top. **This circular motion occurs at a specific frequency,** which depends on the strength of the external magnetic field and the type of nucleus.*



*The concept of precession is essential to MRI because it forms the foundation for generating and detecting signals. **As protons precess, they emit radiofrequency signals that can be captured and transformed into images**. In MRI, the magnetic moments of millions of protons combine to produce a measurable signal that forms the basis of the MRI image.*

The Larmor frequency

The Larmor frequency (also known as precessional frequency) is the frequency at which protons precess around the external magnetic field. This frequency is directly proportional to the strength of the magnetic field (B_0) and is described by the Larmor equation:

$$Wo\,(f) = \gamma\,.\,Bo$$

Wo : is the Larmor frequency

γ : is the gyromagnetic ratio (a constant specific to each Proton)

B_0 : is the strength of the external magnetic field.

For hydrogen nuclei (protons), the gyromagnetic ratio is approximately 42.58 MHz/Tesla. In a 1.5 Tesla MRI scanner, the Larmor frequency is around 63.87 MHz. The importance of the Larmor frequency lies in the fact that it defines the resonance condition in MRI—meaning the specific frequency at which protons will absorb RF energy efficiently, leading to excitation.

Out lines :

- *Hydrogen atom protons naturally spin.*
- *Their spin increases when exposed to an external magnetic field.*
- *This additional spin is called precession.*
- *The path of the proton's spin is called the precession path.*
- *The speed of the additional proton spin is called the Larmor frequency,*
- *which represents the number of rotations the proton makes around the magnetic flux line, measured in Hertz.*
- *The speed of the additional proton spin is directly proportional to the strength of the magnetic field.*

Depend on (y) :

Part one *: We can classify the MRI to two Types :*

1- H MRI (Standard MRI).

2- Multi-nuclei MR: Imaging of other nuclei besides hydrogen, such as sodium and phosphorus, which is useful in Metabolic Imaging and providing biochemical information of tumors.

– Good MR nuclei are ^{1}H, ^{13}C, ^{19}F, ^{23}Na, ^{31}P

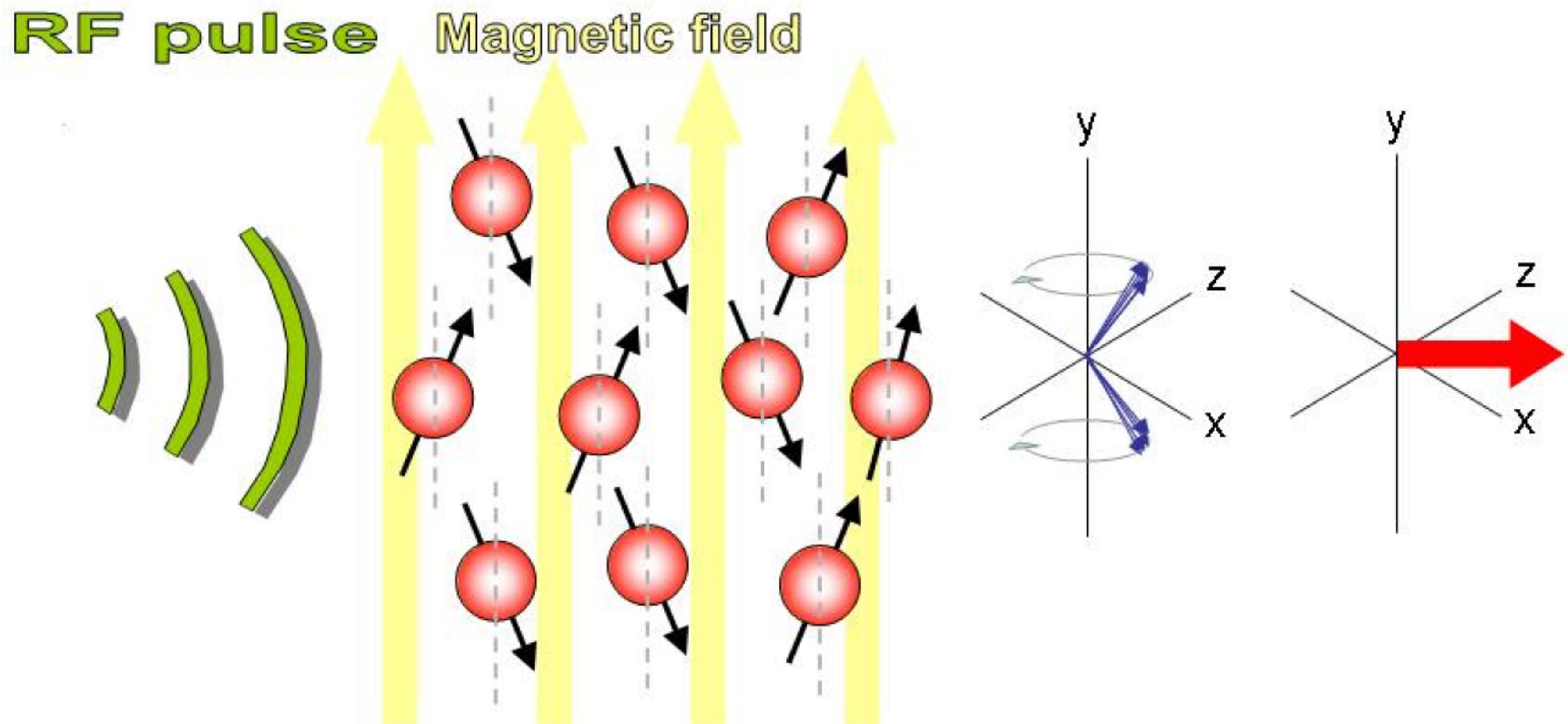
Part two *: hydrogen protons have different in larmor frequency in different tissues, like fat vs. water . this phenomena called* ***chemical shift****.*

Magnetic Resonance Imaging

Resonance

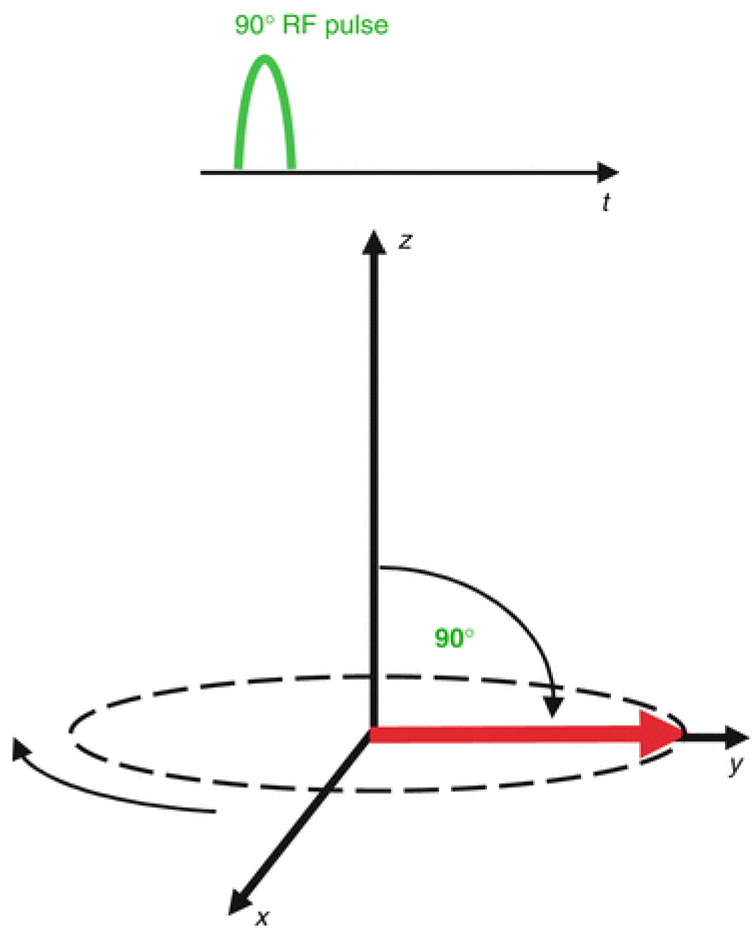
- is a physical phenomenon that occurs when a mechanical or electromagnetic system is exposed to an external frequency (energy), which is equal to or close to its natural frequency, resulting in what we describe as resonance. This results in vibrations, fluctuations, and oscillations—any system that has a natural frequency responds to external energy if it matches that frequency (this applies to electronics, audio waves, and even atoms!).

- RF energy is applied in the form of RF pulses, which are transmitted into the body by the MRI's ***RF coil.*** *These pulses briefly disturb the equilibrium alignment of the protons with the magnetic field (B_0),* ***flipping*** *their magnetic moments away from the field.*


RF pulse
Magnetic field
y
z
x
y
z
x

Radiofrequency (RF) Energy

The RF pulses used for excitation are designed to tip the net magnetization of protons away from its alignment with the external magnetic field. This process is called ***excitation*** *and is measured in terms of* ***flip angles****. For example, a 90-degree pulse tips the magnetization into the* ***transverse plane****, where it can be detected by the MRI system.*



The duration and strength of the RF pulse determine the flip angle*. Commonly used flip angles include 90 degrees for conventional spin-echo sequences and smaller angles (e.g., 30 to 60 degrees) for gradient-echo sequences. The RF pulse duration and frequency are chosen to match the Larmor frequency, ensuring efficient energy absorption by the protons.*

Once the RF pulse is applied, the magnetization vector is ***sloped*** *into the transverse plane, where it begins to precess around the external field. This precession induces an oscillating magnetic field in the RF coils, generating the MRI signal*
In an MRI device, this phenomenon occurs when protons are exposed to radiofrequency (RF) waves, and it goes through the following stages:

- Excitation*: When protons are exposed to RF waves, which match the Larmor frequency (the natural frequency of protons in the body), energy is transferred to the protons. This energy causes protons to transition* ***from a low-energy state to a high-energy state (moving from low energy to high energy).***

- Relaxation*: After the RF pulses are stopped, the protons return to their lower energy state, releasing the excess energy they absorbed. This collective return occurs at different rates depending on the type of tissue in which the protons reside.* ***These different rates of return and the energy emitted contribute to the contrast seen in the gray scale of an MRI image****.*


THANKS !