Magnetic Resonance and Medical Imaging lect 8

4th year /Medical Physics

Dr . Hanan Abd Ali

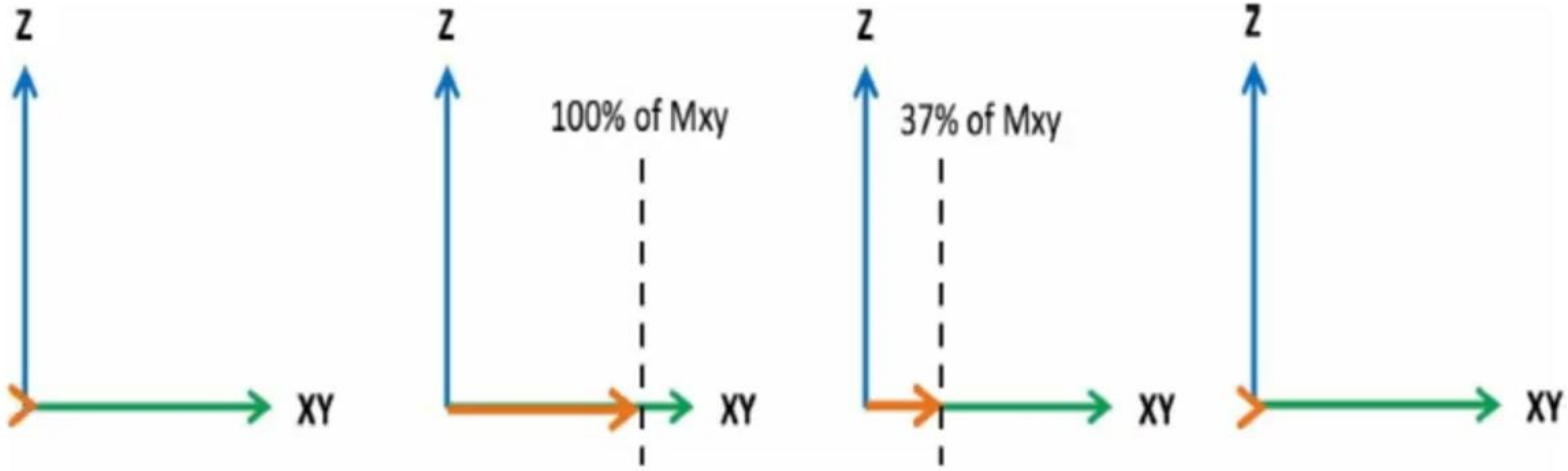
Dephasing of XY Magnetization

- Nuclear spins can be influenced by the magnetic fields of other nearby atoms. If these fields add to or subtract from the external B_0 magnetic field, then the Larmor frequency of the spins will change.
- If the nearby atoms are moving past the nuclear spins, like a comet having a close encounter with a planet, the Larmor frequency will only change for a tiny amount of time, but after the magnetic atoms pass by, the nuclear spins will be left with a phase shift.
- A multitude of these types of interactions causes the net transverse magnetization to gradually dephase until there is no signal left at all (see Figure 4-7). We will discuss this process in more detail when we talk about T2 relaxation times in

- **Excitation**: The magnetization cannot be measured before it is rotated and has acquired a component perpendicular to the magnetic field (a transversal component). The rotation is caused by transmitted resonant radio waves, a process called excitation.

- Relaxation times T1 and T2 are time constants that describe how quickly the magnetization is approaching equilibrium.
- The magnetization is longitudinal in equilibrium, meaning that it is pointed along the magnetic field (Mxy = 0, Mz = M0). Away from equilibrium,
- the transversal magnetization Mxy decreases on a timescale T2, while the longitudinal magnetization Mz approaches M0 on a timescale T1

- Exponential function When “something” decreases exponentially (the transversal magnetization, for example), it means that a specific fraction is lost when we wait for a certain
- period of time: When we say that T2 is 100 ms it means that about 60% of the signal is lost in 100 ms. The same fraction of the remaining signal is lost again if we wait another100 ms.
- The T1 relaxation too involves exponential functions, since the longitudinal magnetization approaches equilibrium exponentially after excitation (the difference decreases exponentially).



1. Before 90° pulse Mxy is 0%

2. After the 90° pulse the Mxy is 100%

3. The Mxy slowly decays. The time it takes to decay to 37% is the time constant T2

4. The Mxy continues to decay until it reaches its starting value of 0%

T2 constant

Return to Equilibrium

- Immediately after RF excitation, the net magnetization vector seeks to realign itself with the external magnetic field. That is, the magnetization vector MZ slowly returns to its equilibrium position as the saturated nuclear spins individually give their energy back to surrounding nuclei in their local environment and return to their normal state of alignment with the external magnetic field.
- This is shown in (Figure 4-8) as the regrowth of M_Z along the Z-axis. The net result of these two motions, precession with dephasing and the return to equilibrium with B_0, are best thought of as two separate processes (Figure 4-9). The Z component gradually grows until it reaches its maximum value at equilibrium, M_0.
- However, in most tissues the XY component precesses and dephases until the net signal disappears at a rate that is at least ten times faster than the return of the Z component to equilibrium. Both of these changes in component magnitude, the shrinking of the XY component and MR signals, the spin echo and the gradient echo, are discussed later.

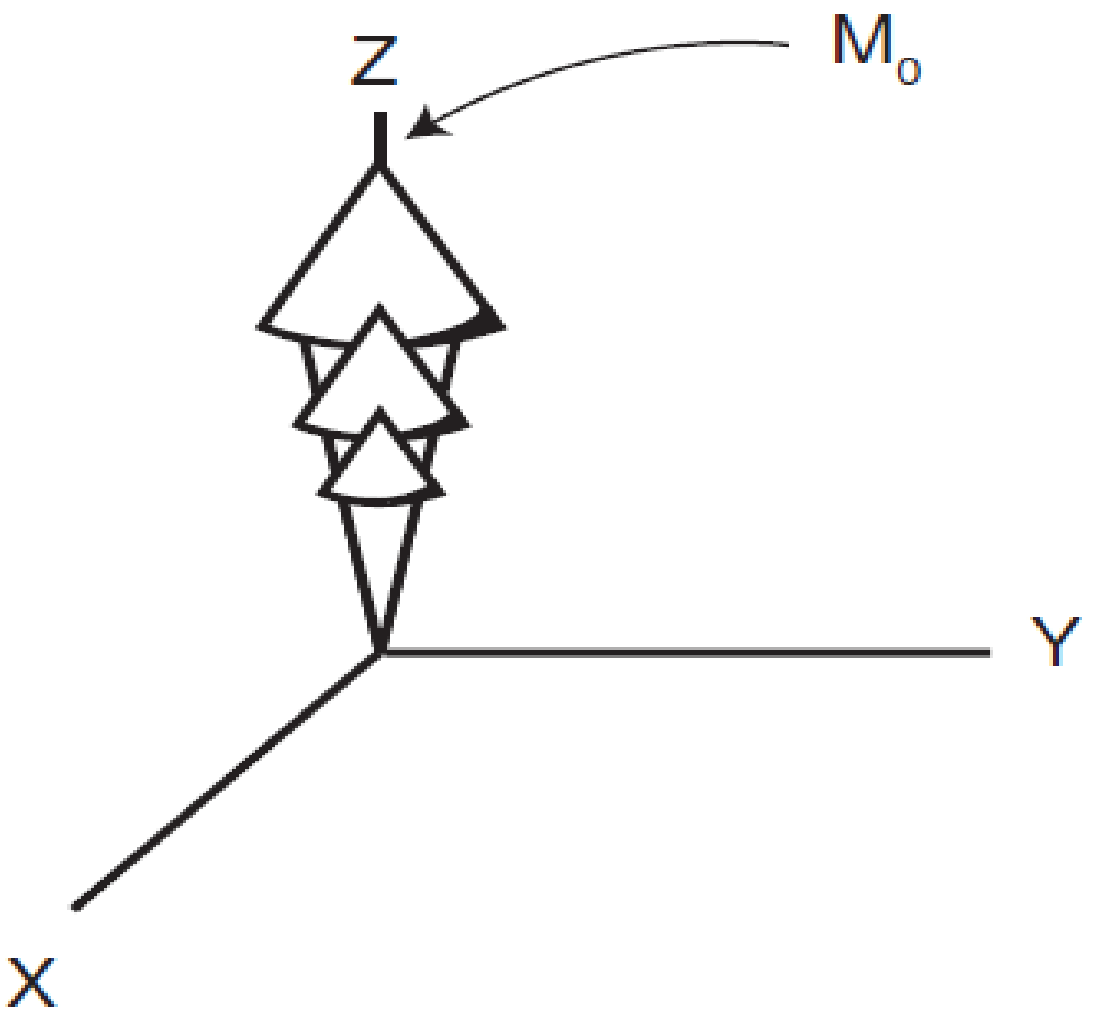
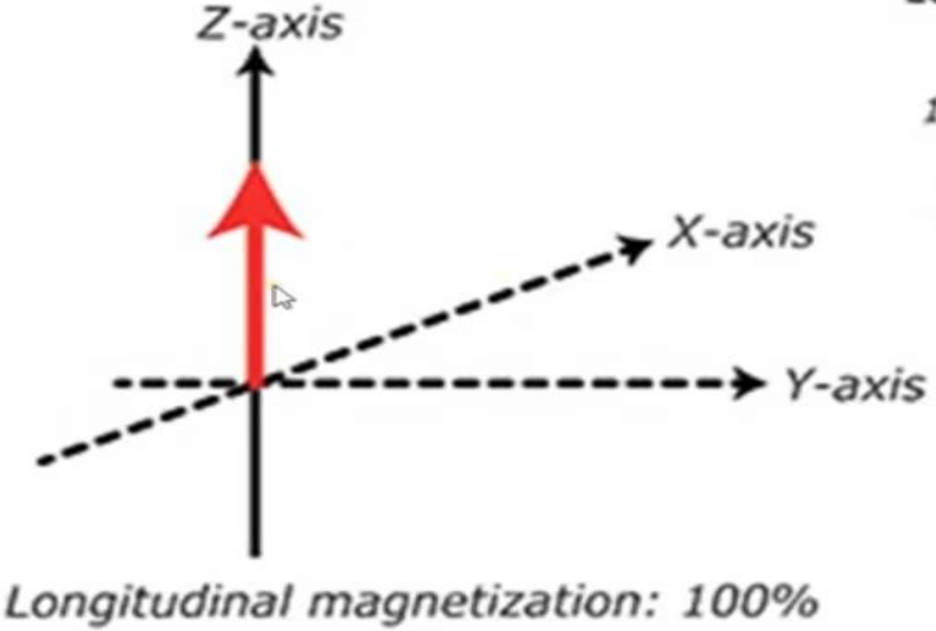
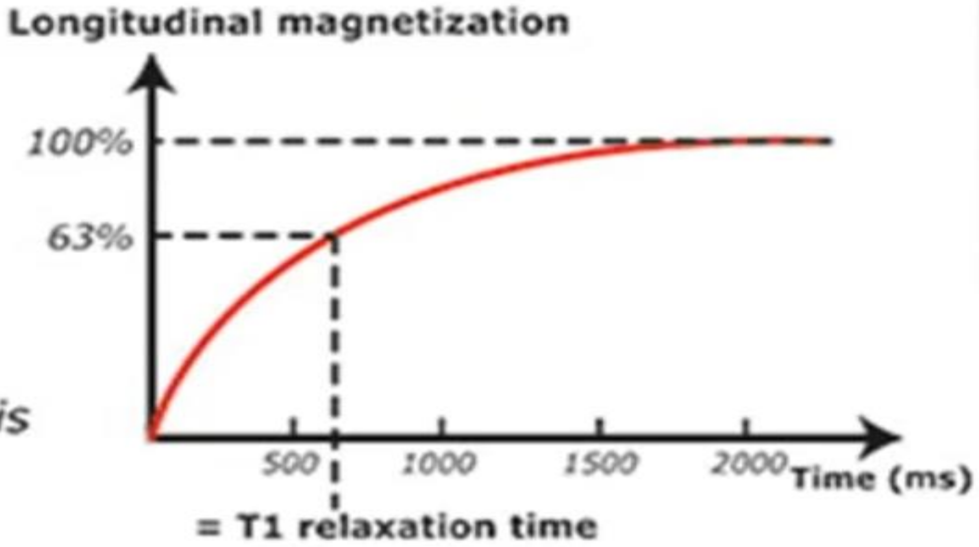


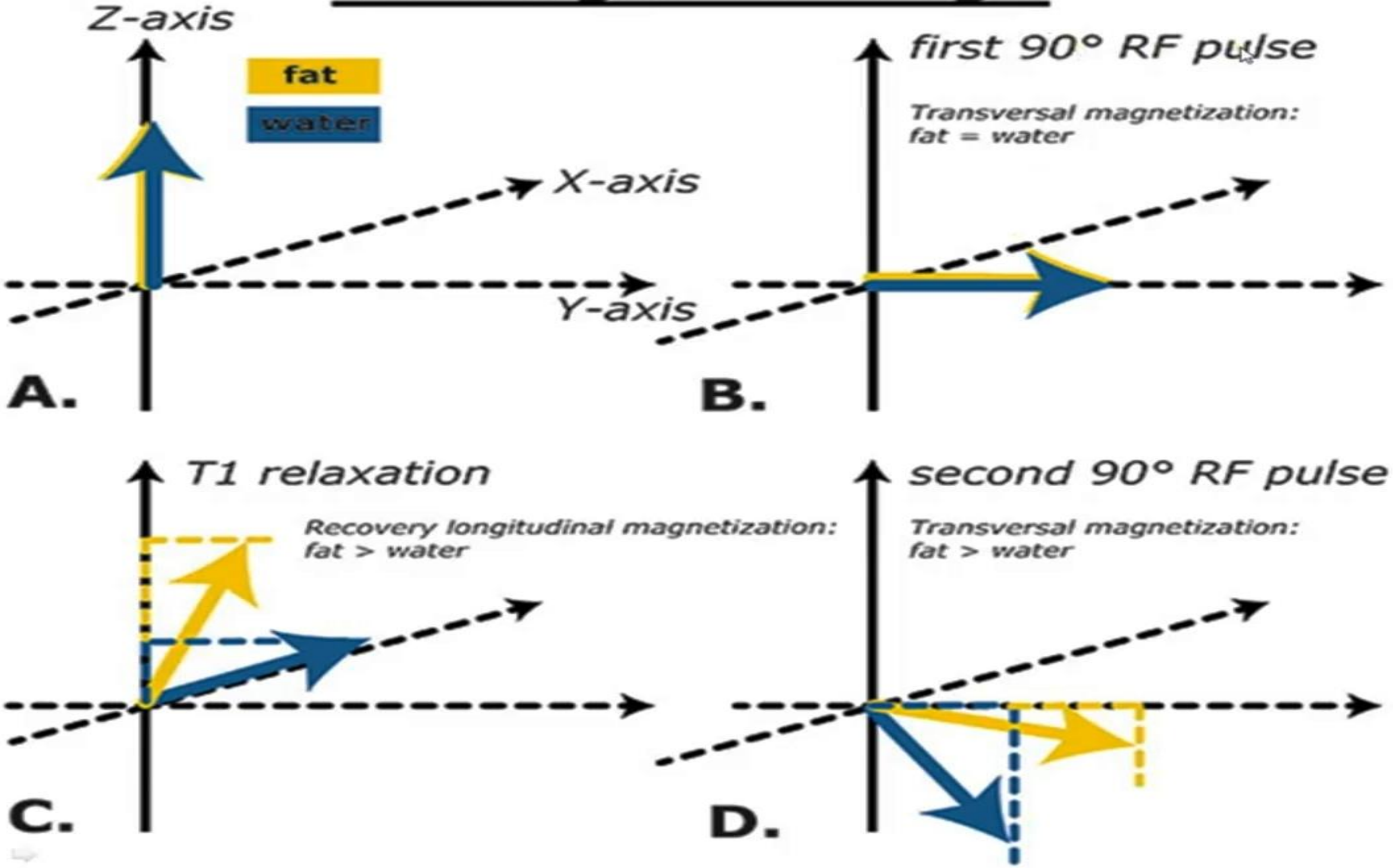
FIGURE 4-8 After a radiofrequency pulse, the Z component of net magnetization, M_Z, relaxes to equilibrium, M_0, along the Z-axis.

T1 relaxation





T1 weighted image



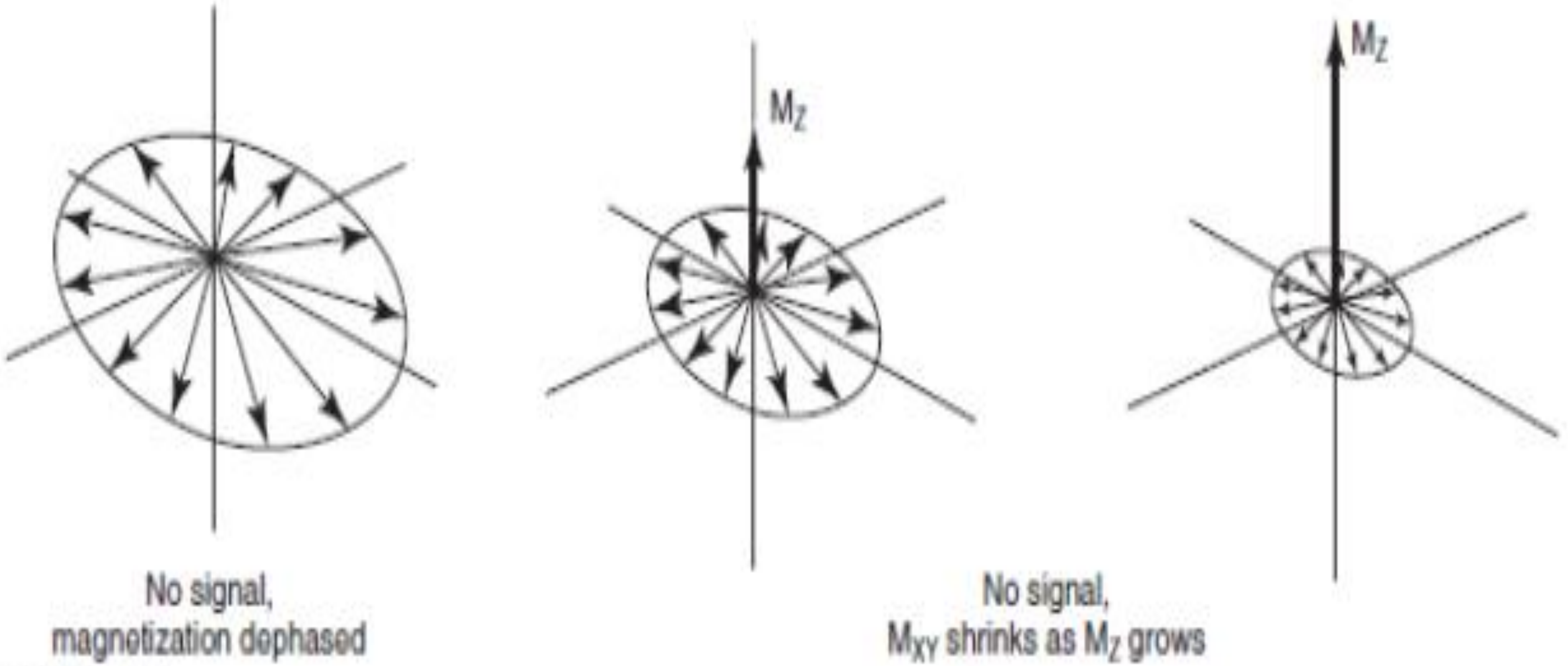


FIGURE 4-9 Relaxation of M_z occurs so slowly that the transverse magnetization is totally dephased and the signal is gone before noticeable recovery occurs. The rate of regrowth of M_z is controlled by the relaxation time, T1.

Free Induction Decay

- With all this complex motion of the net magnetization occurring, what can be observed? The only part of the net magnetization that can be observed is the XY component. As long as MXY precesses with spins in phase and is not zero, an oscillating signal is received.

- The strength of the signal received is proportional to the size of the XY component. As MXY dephases to a zero net value, the MR signal is reduced to zero. This decreasing MR signal, which is received after an RF pulse, is called a free induction decay (FID).

- The free induction decay is the primary MR signal. When the net magnetization vector is at equilibrium, there is no signal. The effect of the 90° RF pulse is to rotate the net magnetization vector onto the XY plane. At this point the signal decays exponentially. An oscillating MR signal is received from off-resonance spins, but the different frequencies in the XY component to the net magnetization vector begin to interfere with each other until there is no signal (see Figure 4-10).

- The oscillation of the signal is at the same frequency as the rotation of Mxy, namely, the Larmor frequency. As the net magnetization returns to equilibrium, the already dephased XY component shrinks concurrently, and the Z component increases.

- When MXY relaxes to zero, the MR signal is again zero. This sequence of events is shown in Figure 4-9 and, when repeated many times, constitutes the simplest MRI RF pulse sequence, which is called saturation recovery

Radiofrequency Pulse Diagrams

- In the macroscopic world, two events occur during an MRI sequence. First, an RF pulse, for example, a 90° RF pulse, is transmitted into the patient. The transmitted RF pulse is symbolized as RFt.
- Second, an RF signal symbolized as RFs is received from the patient. This signal is the FID, and these two events are diagrammed in Figure 4-11.
- There are two lines of information on the diagram. The horizontal axis in both cases is time. The top line, or RFt, is the RF signal transmitted into the patient. The bottom line, or RFs, is the FID, the MR signal received from the RF pulses transmitted into the patient are usually indicated on the RFt line by several ovals , as shown on the top line.

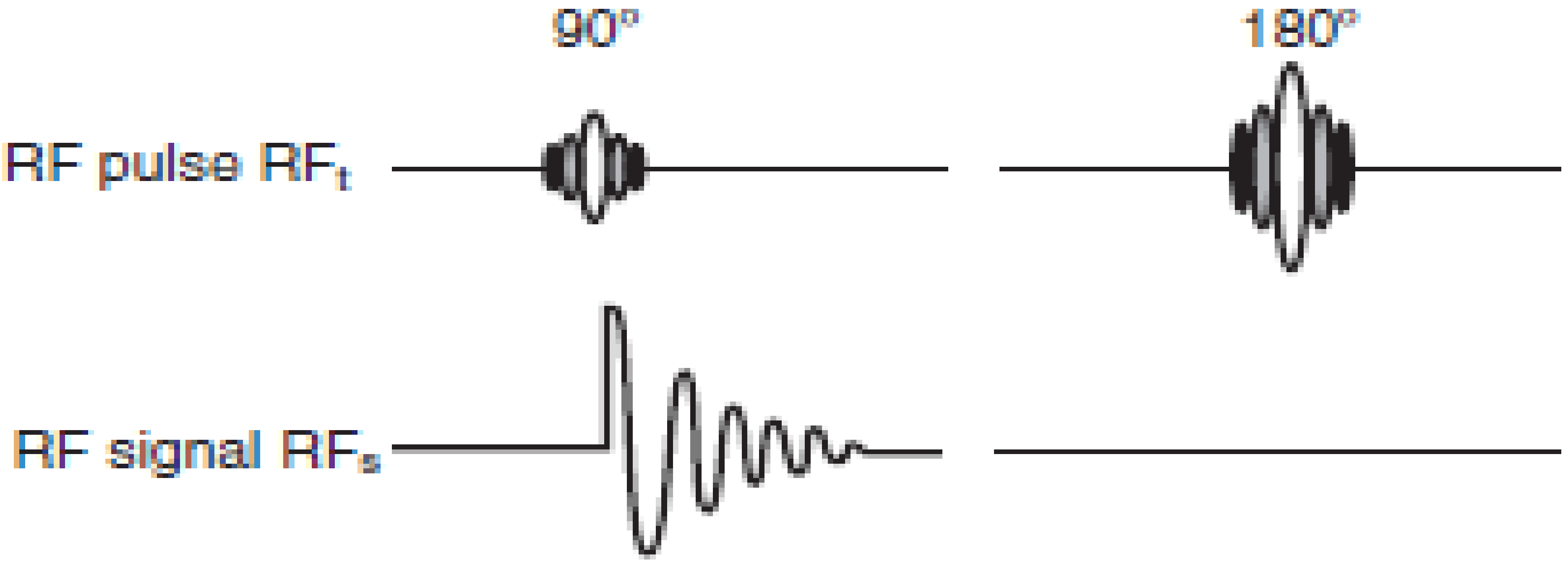


FIGURE 4-11 Simple radiofrequency (RF) pulse diagrams for a 90° and a 180° RF pulse. The top line represents the transmitted RF pulse (RF_t), and the bottom line represents the RF signal received (RF_s).

- The label above the smaller pulse indicates that it is a 90° RF pulse, and the label above the larger pulse indicates that it is a 180° RF pulse. After a 180° RF pulse, There is no FID because there is no XY component to the net magnetization.
- The signal from the patient is indicated by a plot of the intensity of the signal versus time. For the simple case given here, the diagram is correspondingly simple. In more complicated situations involving many pulses and signals, such diagrams are complicated but can be extremely descriptive.
- Additional lines are added to indicate excitation of the gradient magnetic fields necessary for spatial localization of the RFs. For now, it is sufficient to become familiar with this simple two line form of an RF pulse diagram. What about the amplitude and shape of the FID? The amplitude of the FID is equal to the amplitude of M_Z at the start of the RF pulse sequence.
- This amplitude is often equal to and always dependent on M_0, the equilibrium value. Therefore the amplitude of the FID is determined by the same parameters that influence M0, namely, the number of spins involved (the proton density), B0, and γ.