ULTRASOUND EQUIPMENT TECHNIQUES

(Ultrasound waves)

LECTURE [7]

Ultrasound Modalities

Ultrasound is diagnostically useful in medicine two modalities, **continuous energy** and **pulsed energy**:

- Continuous sound energy uses a steady sound source, and has applications that include fetal heart beat detectors and monitors. This Doppler ultrasound can also be used to evaluate blood flow through different structures.

- Pulsed sound energy utilizes a quick blip of sound (like a hand clap), followed by a relatively long pause, during which time an echo has a chance to bounce off the target and return to the transducer. Through electronic processing of the returning sounds, a two-dimensional image can be created that provides information about the tissues and objects within the tissues.

2.9.1 Ultrasound Pulse Generator

The basic principles of ultrasound pulse production and transmission are illustrated in Figure 8. The pulse generator produces the electrical pulses that are applied to the transducer. For conventional ultrasound imaging the pulses are produced at a rate of approximately 1,000 pulses per second. A typical ultrasound pulse consists of cycles of oscillating amplitudes (see Figure 8), and contains a spectrum of frequencies (bandwidth) dominated by a center frequency.

Ultrasound relies on high-frequency sounds to image the body and diagnose patients. Therefore, ultrasound is longitudinal waves that cause particles to oscillate back and forth and produce a series of compressions and rarefactions. Sound source (piezoelectric transducer element) is vibrating object which is in contact with the tissue, causing it to vibrate. Vibrations are passed in the area of tissue next to the transducer to nearby tissues. This process continues vibrations or sound pass from one area of the tissue to another. The rate at which tissue structures vibrate back and forth is the frequency of the sound. The rate at which vibrations move through the tissue is the speed of sound. When the transducer is in contact with a patient (or some other medium) and a few hundred volts DC are suddenly applied to the disk, it instantly expands, thereby compressing layer of the material in contact with it. Due to the elasticity of the material the compressed layer expands and compresses an adjacent layer of material.

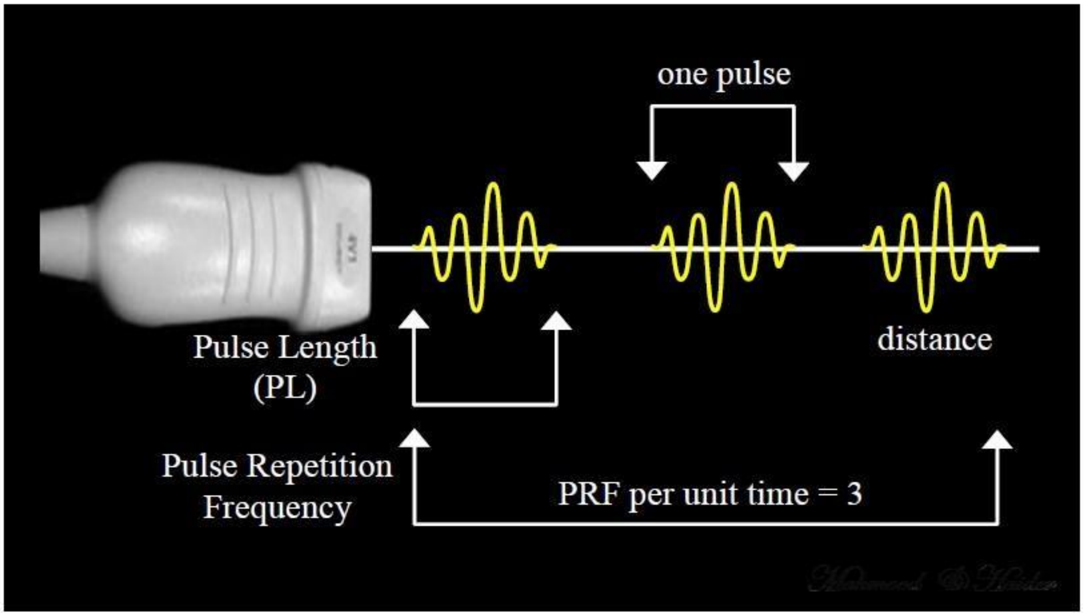

Figure 8: Schematic representation of ultrasound pulse generation.

In this way a layer or wave of compression travels with a *velocity v* through the material, followed by a corresponding wave of decompression of rarefaction. In imaging, such short regular pulses of ultrasound are used. This mechanical sound waves vibrating to create alternating zones of pressure and upset when spread through the body's tissues.

2.9.1.1 Short Pulse

For practical use, most modern ultrasound systems are designed based on the principle of pulse-echo technique, which means that transducer emits only a few cycles of pulses at a time into the human body. When encountering tissues interfaces, reflection and scattering will occur and produce pulse echoes, by detecting these echoes, tissue positioning and identification as well as diagnosis can be made. NOTE: This is the pulse rate (pulses per second) and not the frequency which is the number of cycles or vibrations per second within each pulse. The principal control associated with the pulse generator is the size of the electrical pulses that can be used to change the intensity and energy of the ultrasound beam.

2.9.1.2 Continuous Wave Mode

Frequency, period, wavelength and propagation speed are sufficient to describe continuous-wave (CW) ultrasound. Cycles repeat indefinitely. Sonography uses pulsed ultrasound, i.e., a few cycles of ultrasound separated in time with gaps of no signal.

If, instead of DC, an alternating current (AC) voltage is applied, the crystal face pulses forwards and backwards like a piston, producing successive compressions and rarefactions (Figure 9c). Each compression wave has moved forwards by a distance called the *wavelength* (λ) by the time the next one is produced.

As shown in Figure 9, the space through which the ultrasound pulse moves are the beam. In a diagnostic system, pulses are emitted at a rate of approximately 1,000 per second. The pulse rate (pulses per second) should not be confused with the frequency, which is the rate of vibration of the tissue within the pulse and is in the range of 2-20 MHz.

The *frequency* (f) with which compressions pass any given point is the same as the frequency at which the transducer vibrates and the frequency of the AC voltage applied to it. It is measured in megahertz (MHz). Using the 8.1 formula, it is possible to calculate the velocity, frequency or wavelength of a wave if the other two values are known. For comparison, Figure 8.9c shows the pressure wave-form of a pulsed wave, after periods in duration. Pulse duration is the amount of time from the beginning to the end of a single pulse of ultrasound.

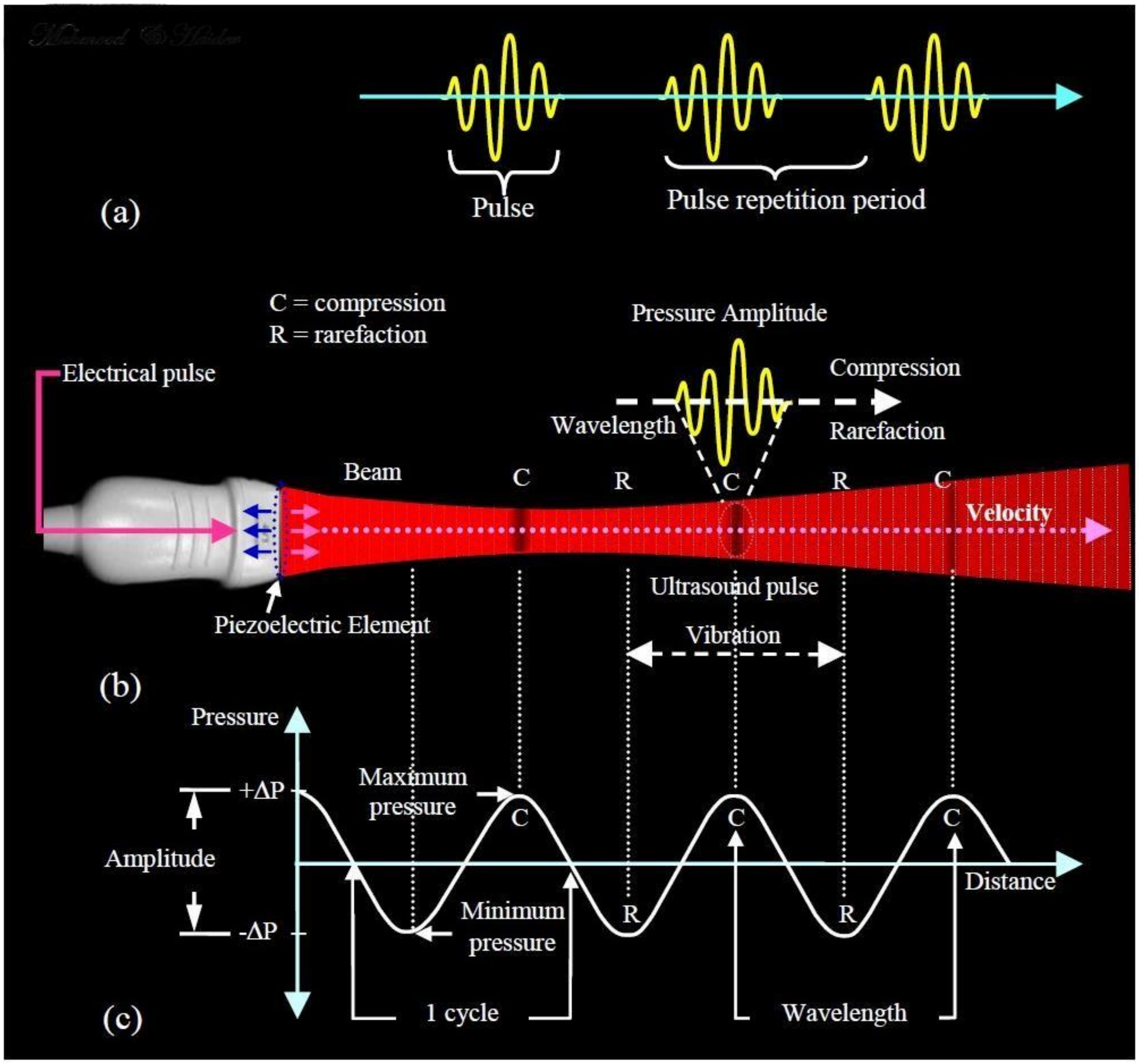

Figure 9: The Production of an Ultrasound Pulse.

The sound in most diagnostic ultrasound systems is emitted in pulses rather than a continuous stream of vibrations. At any instant, the vibrations are contained within a relatively small volume of the material. It is this volume of vibrating material that is referred to as the ultrasound pulse. As the vibrations are passed from one region of material to another, the ultrasound pulse, but not the material, moves away from the source.

In soft tissue and fluid materials the direction of vibration is the same as the direction of pulse movement away from the transducer. This is characterized as longitudinal vibration as opposed to the transverse vibrations that occur in solid materials. As the longitudinal vibrations pass through a region of tissue, alternating changes in pressure are produced.

During one half of the vibration cycle the tissue will be compressed with an increased pressure. During the other half of the cycle there is a reduction in pressure and a condition of rarefaction. Therefore, as an ultrasound pulse moves through tissue, each location is subjected to alternating compression and rarefaction pressures.