ULTRASOUND EQUIPMENT TECHNIQUES

(Ultrasound waves)

LECTURE [3]

Phase Velocity–Group Velocity

There are two different fundamental sound velocities must distinguish between them: the group velocity and the phase velocity

2.3.2.1 Phase Velocity

The phase velocity of a wave is the speed at which a given phase of a wave travels through space. The **phase velocity** of a wave is the rate at which the phase of the wave propagates in space. This is the velocity at which the phase of any one frequency component of the wave will propagate. You could pick one particular phase of the wave (for example the crest) and it would appear to travel at the phase velocity. Phase velocity term generally comes into picture when there is a single wave, suppose in optical fiber when there is only one mode (i.e., single mode) then your phase velocity is defined and same as group velocity. Phase velocity corresponds to the propagation velocity of a given phase that is of a single frequency (i.e., single mode) component of a periodic wave. A propagating medium is said to be dispersive if the phase velocity is a function of frequency or wavelength, which is the case for example in all attenuating media. This means that the different frequencies contained in the signal do not propagate at constant velocities.

2.3.2.2 Group Velocity

The group velocity is the speed of the overall shape of a modulated wave (called the envelope). The **group velocity** of a wave is the rate that changes in amplitude (known as the envelope of the wave) will propagate through space. (The existence of different modes each has a different velocity). Group velocity actually corresponds physically to the velocity with which energy or information is transferred along the direction of wave propagation. If the wave is travelling through a medium of absorptive, and this does not always hold. In the case of an absorptive medium, the group velocity may vary from the phase velocity. It is important to be aware of the speed of dispersion because it affects are likely to be accurate measurements of the speed of sound. Hence similar to the average speed, the term has been defined so-called speed of the group, which gives a sort of average velocity of different modes.

2.3.3 Wavelength and Speed of Propagation

The **speed of sound** is the distance that a point on a wave (such as a compression or a rarefaction) travelled during a unit of time by a sound wave propagating through an elastic medium.

The **speed of sound** (c) in a medium depends on the **density** and **compressibility** of the medium. For example, in pure water, it is 1492 m/s (20 °C). Note that the speed of sound in air depends only on the **temperatur**e.

As known from basic physics the characteristic variables describing the propagation of a monochromatic wave in time and space are ***frequency* (*f*)** or period (T) ***velocity*** (***v***) and ***wavelength*** (**λ**) are related to each other following:

$$\lambda = vf = vT \quad \ldots\ldots\ldots\ldots..(2.1)$$

Usually measured waves in the electromagnetic spectrum, such as radio waves and light waves, is in millimeters, or nm, instead of centimeters or meters. This is because it has much shorter wavelengths than the sound waves.

As it does in water, ultrasound propagates in biological soft tissues as longitudinal waves, the average speed of ultrasound propagation of soft tissue is approximately 1540 m/s (fatty tissue, 1470 m/s; muscle, 1570 m/s). The construction of ultrasound images depends very much on the measurement of distances, which depends on this almost constant propagation speed. The speed in bone (3600 m/s) and cartilage is, however, much higher and can create misleading effects in images.

The wavelengths of ultrasound are closely related to ultrasound frequency, both influence the resolution of the images. Better resolution is associated with a higher ultrasound frequency, the shorter wavelength but absorption of the sound energy by tissue also increases with frequency. The resolution can be determining the degree of image clarity. That meant the resolution is the ability of the ultrasound machine to distinguish two structures (reflectors or scatters) that are close together as separate.

- ❖ The kinetic energy of the sound waves is converted to heat (thermal energy) in the medium when sound waves are absorbed. The applications of ultrasound to bring heat or agitation into the body (thermotherapy) were the first use of ultrasound in medicine.