ULTRASOUND EQUIPMENT TECHNIQUES

(Ultrasound waves)

LECTURE [10]

Refraction

The refracted wave obeys Snell's Law and describes reflection where ultrasound beam crosses an interface between two tissues at an oblique angle. The angle of refraction is dependent on two things; the angle the sound wave strikes the boundary between the two tissues and the difference in their propagation velocities. In Figure 15, for example, If the propagation velocity of ultrasound is higher in the first medium ($v1> v2$), the beam that enters second medium refracted at a less oblique (steeper) angle towards the center (A). If the velocity of ultrasound is higher in the second medium ($v_1< v_2$), refraction occurs away from the originating beam (B). As the beam emerges from medium 2 and reenters medium 1, it resumes its original direction of motion. This behavior of ultrasound transmitted obliquely across an interface is termed **refraction**. The presence of medium 2 simply displaces the ultrasound beam laterally for a distance that depends upon the difference in ultrasound velocity and density in the two media and upon the thickness of medium 2. Suppose a small structure below medium 2 is visualized by reflected ultrasound. The position of the structure would appear to the viewer as an extension of the original direction of the ultrasound through medium 1. In this manner, the sound is not reflected directly back to the transducer, refraction adds spatial distortion and the image being depicted may not be clear, or potentially altered, "confusing" the ultrasound system since it assumes that sound travels in a straight line.

These phenomena can allow for improved image quality by the use of acoustic lenses that can focus the ultrasound beam and improve resolution.

Big surface: Ultrasound refraction only happens at big surface compared to its wavelength.

- Velocity mismatch: The acoustic medium at both sides of the surface must have different sound velocity.
- Dependence on angle: The refracted wave obeys Snell's Law. Laws of reflection and refraction hold

$$\theta_i = \theta_r, \; sin\theta_i / sin\theta_r = v_1 / v_2$$

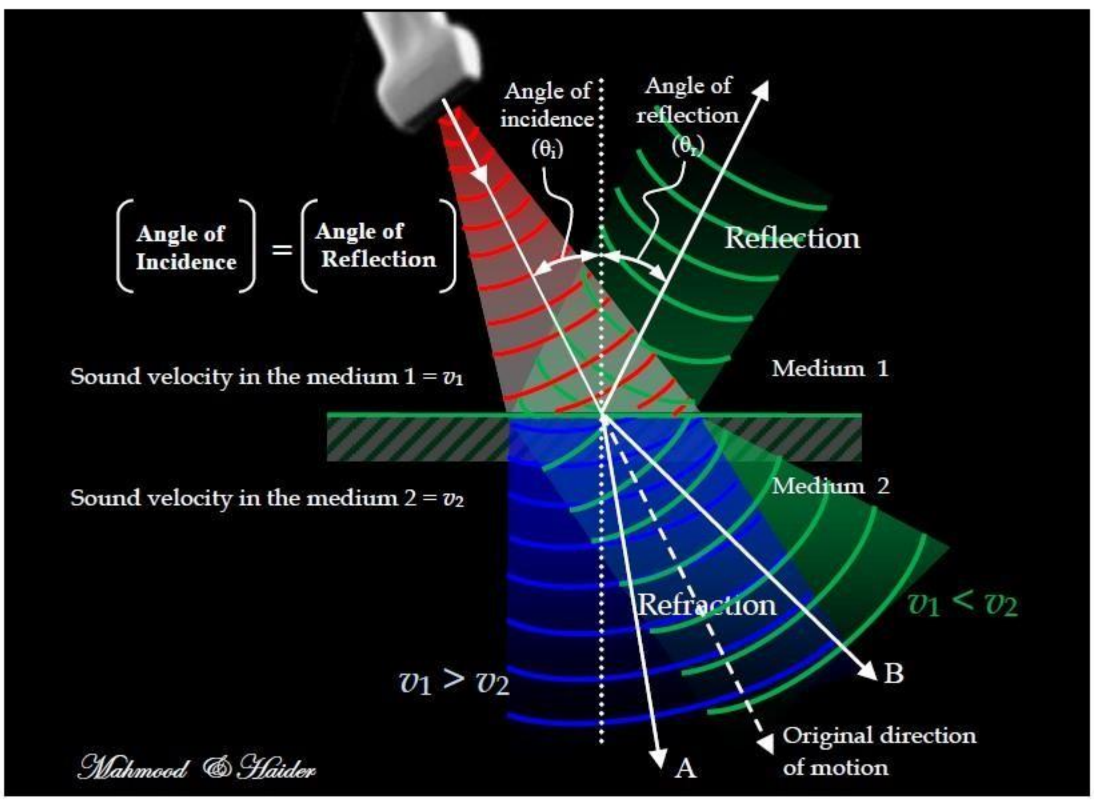

Figure 15: Lateral displacement of an ultrasound beam as it traverses a slab interposed in an

otherwise homogeneous medium.

2.12.3 Reflection

Ultrasound imaging is based on the "**pulse-echo**" principle in which performed by emitting a pulse from a transducer and directed into tissue. When a sound wave is incident on an interface between two tissues, part **reflected** from a boundary, and part **transmitted** (figure 16). According to the **law of reflection,** the angle of reflection of a reflected wave is equal to its angle of incidence.

Medical ultrasound imaging relies utterly on the fact that biological tissues **scatter** or **reflect** incident sound. **Scattering** refers to the interaction between sound waves and particles that are much smaller than the sound's wavelength λ, while **reflection** refers to such interaction with particles or objects larger than λ.

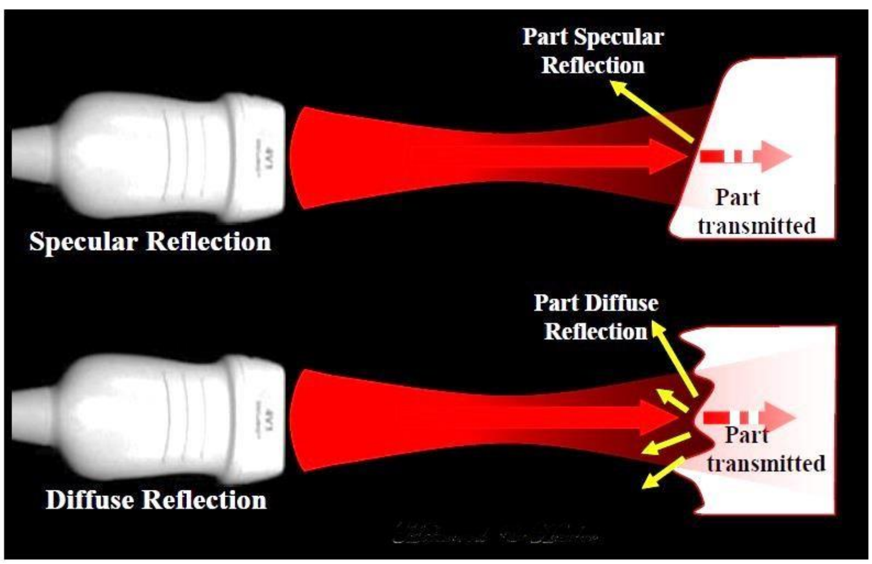

Figure 16: Reflection of ultrasound beam can be categorized as either specular or diffuse reflection.

Reflection can be categorized as either **specular** or **diffuse**. Specular reflectors are large, smooth surfaces, such as bone, where the sound wave is reflected back in a **singular direction**. The large smooth surface of the bone causes a uniform reflection because of the significant difference in the acoustic impedance between it and the adjoining soft tissue. The greater the acoustic impedance between the two tissue surfaces, the greater the reflection and the brighter the echo will appear on ultrasound.

2.12.4 Scattering

The scattering or reflections of acoustic waves arise from inhomogeneities in the medium's density and/or **compressibility**. Sound is primarily scattered or reflected by a discontinuity in the medium's mechanical properties, to a degree proportional to the discontinuity. (By contrast, continuous changes in a medium's material properties cause the direction of propagation to change gradually.) The elasticity and density of a material are related to its sound speed, and thus sound is scattered or reflected most strongly by significant discontinuities in the density and/or sound speed of the medium. The scattering or reflections of acoustic waves arise from inhomogeneities in the medium's density and/or **compressibility**. Rayleigh **scattering** occurs at interfaces involving structures of small dimensions as shown in figure 17. This is common with red blood cells (RBC), where the average diameter of an RBC is 7µm, and an ultrasound wavelength may be 300µm (5 MHz). When the sound wave is greater than the structure it comes in contact with, it creates uniform amplitude in all directions with little or no reflection returning to the transducer.

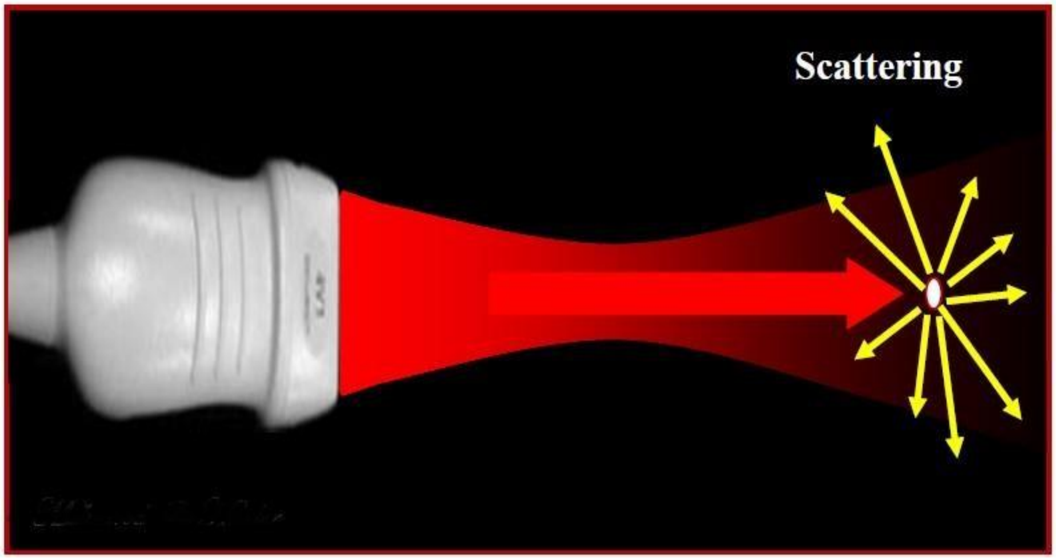

Figure 17: Rayleigh **scattering** occurs at interfaces involving structures of small dimensions.

- Scattering is dependent for four different factors:
  - ✓ the dimension of the scatterer,
  - ✓ the number of scatterers present,
  - ✓ the extent to which the scatterer differs from surrounding material,
  - and ✓ the ultrasound frequency.

In most diagnostic applications of ultrasound, use is made of ultrasound waves reflected from interfaces between different tissues in the patient. The reflected echoes return to the transducer and form the ultrasound imaging. The amount reflected depends on the difference in **acoustic impedance** of the two tissues.

2.12.5 Absorption

Absorption is the main form of attenuation. Absorption happens as sound travels through soft tissue, the particles that transmit the waves vibrate and cause friction and a loss of sound energy occurs and heat is produced. Sound intensity in the soft tissue decreases exponentially with depth (see figure 18).

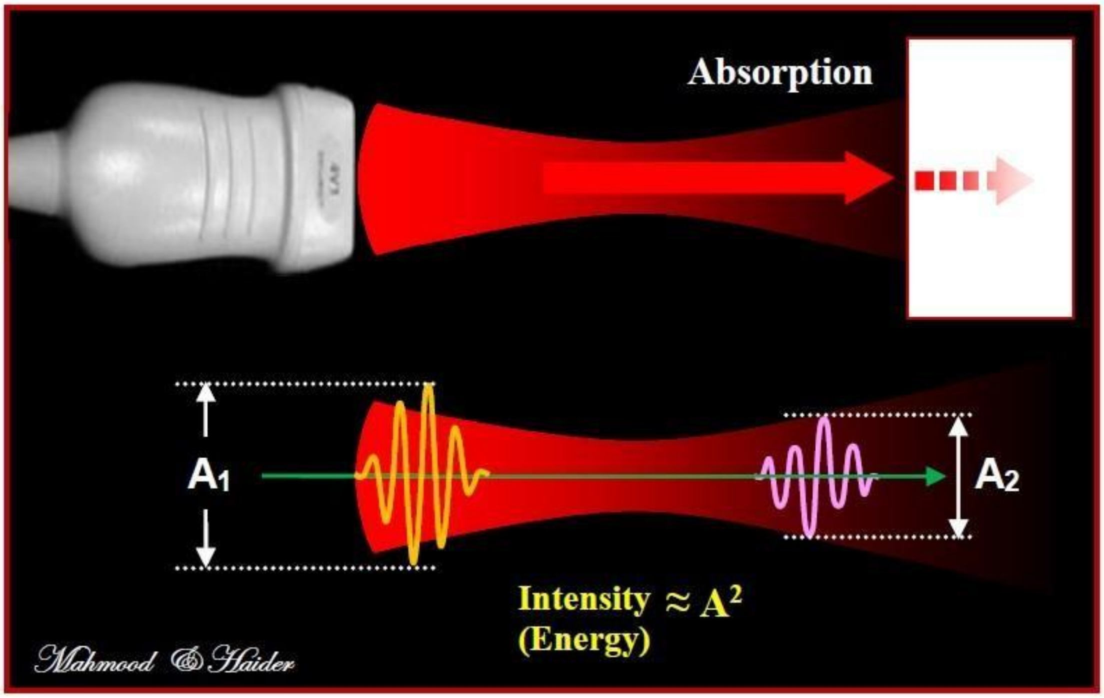

Figure 18: The Reduction of Pulse Amplitude by Absorption of Its Energy