

### Acoustic Variables

Pressure concentration of force in  
(Pascals (Pa)): an area

Density concentration of mass in  
( $\text{kg}/\text{cm}^3$ ): a volume

Distance (cm or mm): refers to the distance a particle moves.

Used to differentiate between the different types of waves (heat, light, sound etc). If one of the 3 variables have rhythmic oscillations then it is a sound waves.

### Basic Review

All waves carry what?

Energy

Sound must travel in a \_\_\_\_\_ line

Straight

ALL sound waves are \_\_\_\_\_ and \_\_\_\_\_

Longitudinal and mechanical

Sound (mechanical waves) need a \_\_\_\_\_ to travel through

Medium

Molecules in a sound wave are \_\_\_\_\_ and \_\_\_\_\_.

Compressed and rarefied

Acoustic Propagation Properties

The effect medium has on sound waves.

Bioeffects

The effects sound waves have on body tissue.

What are 2 types of mechanical waves?

Transverse and longitudinal.

What is the average speed of sound in soft tissue?

1540 m/s OR 1.54 mm

Another word for stiffness is?

Bulk modulus

### Basic Review (cont)

Stiffness and speed are \_\_\_\_\_ related.

Directly; increased speed = increased stiffness.

Speed and density are \_\_\_\_\_ related.

Inversely; increased speed = decreased density.

Sound travels the same speed no matter what \_\_\_\_\_.

Frequency; 5Mhz probe and 15 Mhz probe will travel at the same speed.

### Acoustic Parameters

Period Time it take to Source,  
(microsec- complete one NO  
onds): cycle.

Frequency # of cycles per Source,  
(MHz): second. NO

Power Rate of energy Source,  
(Watts): YES by  
adjusting  
output  
power.

Intensity Concentration of Source,  
( $\text{W}/\text{cm}^2$ ) energy. YES by  
adjusting  
output  
power.

Amplitude The difference Source,  
(Pa): between the YES by  
adjusting  
output  
power.  
peak of a wave  
(bigness).

Wavelength Distance to Source  
(mm): complete one AND  
medium,  
cycle. (1.54m- NO  
m/frequency)

### Acoustic Parameters (cont)

Propag- How fast a sound Medium,  
ation wave travels NO  
speed through a medium.  
(m/s)

**Used to define characteristics of a continuous wave (wave that is unable to produce an image).**

- Period and frequency are reciprocals.
- Frequency is inversely related to period and wavelength.
- Wavelength and period are directly related.
- Propagation speed is determined by stiffness and density.

### Intensity

Used to evaluate tissue exposure to sound energy

Determines the effects sound has on tissue.

Intensity is important when studying what?

Bioeffects

The strongest intensity is at they \_\_\_\_\_ of the beam.

Center/Focus (smallest area).

What intensity is the most important when studying bioeffects?

SPTA

SPTP is the \_\_\_\_\_ intensity

Highest

SATA is the \_\_\_\_\_ intensity.

Lowest

ALL intensities have units of?

$\text{W}/\text{cm}^2$  (power/area)



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### 5 Parameters of Pulsed Sound

|                                         |                                                                                                   |                                                     |
|-----------------------------------------|---------------------------------------------------------------------------------------------------|-----------------------------------------------------|
| Pulse duration (microseconds):          | Time it takes to complete one pulse.                                                              | Source, NO                                          |
| Spatial Pulse Length (mm):              | Distance it takes to complete one pulse.                                                          | Source, NO                                          |
| Pulse Repetition Period (PRP):          | Time from the start of one pulse to the start of the next (includes transmit and receiving time). | Source, YES by adjusting depth (Directly related).  |
| Pulse Repetition Frequency (PRF) (kHz): | # of pulses per second.                                                                           | Source, Yes by adjusting depth (inversely related). |
| Duty Factor (%):                        | Percentage of time that the pulse is on.                                                          | Source, YES by adjusting depth (inversely related). |

Characteristics used to define a pulse wave (wave that is able to produce an image).

- A pulse is made up of multiple cycles.
- 3 out of the 5 parameters can be adjusted using depth.

### How Sound Travels Through Media

#### Attenuation

Decrease in power, intensity, and amplitude due to sound waves decreasing as they propagate through media.

### How Sound Travels Through Media (cont)

Distance and attenuation are \_\_\_\_\_ related.

Directly; increased distance = increased attenuation.

Frequency and attenuation are \_\_\_\_\_ related.

Directly; increased frequency = increased attenuation.

3 processes that contribute to attenuation:

1. Reflection
2. Scattering
3. Absorption

2 types of reflection (energy reflected back):

1. **Specular:** smooth boundary, one direction
2. **Diffuse:** irregular border, multiple directions.

#### Scattering

Waves redirected in many directions due to small tissue interface; when tissue is < wavelength. Directly related to frequency.

#### Rayleigh scattering

When structures are MUCH smaller than the beam's wavelength. EX: RBC. Rayleigh scattering = frequency<sup>4</sup>. They are directly proportional; increased frequency = increased Rayleigh scattering.

#### Absorption

Ultrasonic energy is converted into heat. Directly related to frequency.

#### Attenuation Coefficient (dB/cm)

Used to compare the amount of attenuation in certain circumstances. Measured in decibels for when sound travels 1 cm.

Total attenuation = Attenuation coefficient x Distance (cm)

EX: depth = 5cm AC = 2 dB/cm then total attenuation = 10 dB.

Attenuation Coefficient in soft tissue = frequency/2

### How Sound Travels Through Media (cont)

Half layer thickness (penetration depth or half-boundary layer)

The distance sound travels in tissue that reduces intensity in half; Thin half layer = attenuates more

#### Impedance (rayls)

Resistance to sound traveling in a medium. Impedance = density x speed.

#### Normal incidence

Sound beam strikes boundary at 90 degrees (orthogonal, perpendicular, right). Reflection occurs if the boundaries have different impedances.

#### Oblique incidence

Sound beam strikes at any other angle other than 90 degrees; angle of incidence = angle of reflection.

#### Incident intensity (%)

Intensity before striking boundary; incident intensity = reflected intensity + transmitted intensity.

#### Reflected intensity

Intensity of sound wave after striking boundary and returning.

#### Transmitted intensity

Intensity of sound wave after striking boundary.

#### Refraction

Transmission with a bend. Can only occur IF 1. oblique incidence and 2. different propagation speeds of 2 media.



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