



Professional Ultrasound Services

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Acoustic Wave Properties

1. Wave Variables

- a. Wavelength: review formula : $V = fw$
 - i. $W = v/f$
 - ii. Distance between adjacent areas of compression and rarefaction
 - iii. Wavelength and frequency are inversely related
 - iv. Clinical applications: trade-off
- b. Frequency
 - i. Number of wavelengths passing a given point in a second
 - ii. UNITS: Hertz
- c. Period
 - i. Reciprocal of frequency
 - ii. TIME it takes for one wave to pass a given point in space
 - iii. Same as wavelength, expressed in TIME units, not distance units
- d. Velocity: Propagation Sped
 - i. Inversely related **compressibility** of tissue (major determinant)
 1. Slower in MORE compressible: air, marshmallow
 2. Faster in LESS compressible: bones, metal
 - ii. All sound is transmitted through same type of tissue at same speed
 1. 1540 m/sec assumed in soft tissue in US applications
 - iii. Inversely related to **density**;
 1. More dense – less velocity: lead
 2. Less dense - higher velocity: air

2. Amplitude

- a. Definition: quantitative statement regarding strength of mechanical energy:
 - i. Reflected wave
 - ii. Received echo – voltage induced on receiver crystal
 - iii. Attenuated energy
 - iv. Scattered energy
- b. Maximum increase (or decrease) in the pressure of a wave
 - i. Stronger wave (compression) = higher amplitude
 - ii. EXAMPLES: loudness of audible sound
- c. May refer to:
 - i. Particle displacement
 - ii. Particle velocity
 - iii. Acoustic pressure: force/unit volume

3. Intensity

- a. Definition: energy/unit volume. In ultrasound application, the amount of energy flowing through a cross-section of an US beam per second.
- b. Spatial: the rate at which the wave transmits the energy over an area
- c. Temporal: the amount of energy present in a particular place at a particular time.
- d. Important when discussing bioeffects.
- e. Units: watt/cm^2

4. Phase

- a. Definition: the relationship of one wave to another. Cyclical occurrence
 - i. EXAMPLES: planets, menstruation, biological, chemical
 - ii. IN phase: US waves whose fronts are at the same position
 - iii. OUT of phase: US waves whose fronts are in different positions
- b. Interference: multiples wave fronts interact with each other depending on phase and frequency
 - i. CONSTRUCTIVE interference occurs when wave of the same frequency are in phase resulting in increased amplitude
 - ii. DESTRUCTIVE interference occurs when waves are out of phase resulting in decreased amplitude
 1. Contributes to attenuation
- c. HUYGEN'S principle: multiple wavelets interact to produce a single wave front.
 - i. Superimposition of wavelets form a complex wave front
 - ii.

5. Bioeffects

- a. **Thermal Mechanisms:** a major component of attenuation is absorption, or the conversion of ultrasound into heat as it passes through human soft tissue.
- b. **Non-thermal mechanisms:** mechanical bioeffects that appear to be caused by the motion of tissue as ultrasound passes though or near gas creating microbubbles. Cavitation
- c. **AIUM Statement on Safety:**
 - i. AIUM = American Institute of Ultrasound in Medicine
 - ii. Maximum output of a diagnostic ultrasound imaging system:
 1. 100 mWatts/cm^2 SPTA

6. Acoustic Variables: describe various parameters of sound waves.

- a. **Pressure:** a ratio of force acting on the surface of an object:
 - i. FORMULA: $P = \text{force/area}$
 - ii. EXAMPLE: pen vs. needle on the skin
- b. **Density:** mass per unit volume. Density of a medium is an important material property that affects certain ultrasound properties.
- c. **Particle Displacement:** the distance that a body has moved after being acted upn by a force
- d. **Temperature:** a measurement of the average kinetic energy of a substances molecules.