



## Professional Ultrasound Services

244 20th Avenue

San Francisco, CA 94121-2203

[www.jimbaun.com](http://www.jimbaun.com)

(415) 751-4090

### Ultrasound Interaction with Human Soft Tissue

---

#### 1. Attenuation – Physical Principles

- a. Reduction in intensity of an ultrasound beam as it travels through tissue
  - i. Examples: Davies Symphony Hall acoustic retrofit
- b. Consists of several predictable processes:
  - i. Absorption
    1. Conversion into heat
    2. Accounts for almost 80% of energy loss in US used in imaging intensities
    3. Actually removes energy from sound beam
    4. Amount of absorption related to tissue viscosity
      - a. Degree to which a fluid resist flow
      - b. Higher viscosity = higher absorption
    5. Absorption also related to particle relaxation time
      - a. Long relaxation time = higher absorption
  - ii. Scattering
    1. Generally dissipates energies
    2. Useful in Doppler applications
    3. Reflections occurring from small structure less than 1 wavelength in size.
  - iii. Reflection
    1. Useful in producing images
  - iv. Refraction
    1. Bending away of sound from incident
  - v. Divergence
    1. Uniform spreading out of a sound beam as it propagates away from the source.
    2. Related to beam focusing
  - vi. Diffraction
    1. Bending of a sound beam into a geometric shape by an aperture (or)
      - a. The change in the behavior of a wave front due to limitation of its lateral extent as by an aperture.
  - vii. Interference
    1. Constructive vs. destructive

**2. Attenuation Coefficient**

- a. Expresses total amount of energy loss in tissue
  - i. Coefficient: a mathematical relationship between factors that can be used to measure under specified conditions
- b. UNITS: in US = dB/cm/MHz
  - i. Decibels: a measure of sound, or echo, amplitude
- c. Total attenuation is DIRECTLY related to distance traveled and frequency of sound beam:
  - i. 1 dB/cm/MHz – round trip
- d. EXAMPLES:
  - i. Calculate attenuation of a 5.0MHz beam traveling to a reflector at a depth of 5 cm
    - 1.  $5 \times 0.5 = 2.5\text{dB}$  one way
  - ii. Same 5.0MHz beam returning as an echo.
    - 1.  $5 \times 0.5 = 2.5\text{dB} \times 2 = 5.0 \text{ dB}$  round trip

| Tissue | A.C (dB/cm) |
|--------|-------------|
| Water  | 0.0022      |
| Blood  | 0.18        |
| Fat    | 0.6         |
| Brain  | 0.6         |
| Liver  | 0.7         |
| Kidney | 0.9         |
| Muscle | 1.0         |
| Heart  | 1.1         |
| Bone   | 20.0        |
| Lung   | 41.0        |

**1. Reflection**

- a. Formula
- b. Angle of insonation
  - i. Normal incidence
  - ii. Oblique incidence
- c. Coefficients
  - i. Intensity reflection coefficient
  - ii. Intensity transmission coefficient
  - iii. Important points about reflectors found in the human body
    - 1. Strongest reflection from greatest changes in impedance
    - 2.  $\approx 1\%$  reflected form smooth connective tissue interfaces
    - 3. At normal incidence amount of reflection = degree of difference in impedance
    - 4. MUSCLE - BLOOD INTERFACES REFLECT <1%
    - FAT - MUSCLE INTERFACES REFLECT <1%
    - TISSUE - BONE INTERFACES REFLECT  $\approx 43\%$
- d. Specular reflection
- e. Non-specular reflection

$$R = \frac{(Z_2 - Z_1)^2}{(Z_1 + Z_2)^2}$$

## 2. Refraction

- a. Snell's law of optics: the ratio of the sine of the incident angle and the sine of the refracted angle are almost equal.
- b. Formula:
- c. **Refraction artifact:** the reduction in the number and amplitude of echoes returning to the transducer from areas adjacent to these oblique acoustic mismatches. These appear as "shadows" emanating from the rounded upper surface of structures. Refractory artifacts, or refractory shadows, are routinely seen arising from the lateral aspect the fetal head in axial section, from the edges of small cysts in the liver or other parenchymal organs, and from the edges of uterine fibroids to mention a few examples. (See p.168 *Red Book*)
- d. **Critical angle artifact:** If the speed of sound in the material on the second side of an interface ( $Z_2$ ) is significantly greater than that in the material on the first side of the interface ( $Z_1$ ) and there is a severe or "critical" angle of incidence, the sound beam may be refracted at  $90^\circ$  to incident. If all the energy is sent off at  $90^\circ$ , the transducer cannot detect echoes from the interface and "drop-off" or loss of imaging will occur in this area.