Name of the Course: EIBX01

Biomedical Instrumentation

MODULE V

ULTRASOUND IMAGING

Dr. D.Najumnissa Jamal

Professor / EIE

ULTRASOUND

- Sound waves above 20 KHz are usually called as ultrasound waves.
- Sound waves propagate mechanical energy causing periodic vibration of particles in a continuous, elastic medium.
- Sound waves cannot propagate in a vacuum since there are no particles of matter in the vacuum.
- Sound is propagated through a mechanical movement of a particle through compression and rarefaction that is propagated through the neighbor particles depending on the density and elasticity of the material in the medium.

ULTRASOUND

- The velocity of the sound in
  - Air: 331 m/sec; Water: 1430 m/sec
  - Soft tissue: 1540 m/sec; Fat: 1450 m/sec
- Ultrasound medical imaging: 2MHz to 10 MHz
  - 2 MHz to 5 MHz frequencies are more common.
  - 5 MHz ultrasound beam has a wavelength of 0.308 mm in soft tissue with a velocity of 1540 m/sec.

SOUND PROPAGATION

Tissue	Average Attenuation Coefficient in dB/cm at 1 MHz	Propagation Velocity of Sound in m/sec
Fat	0.6	1450
Liver	0.8	1549
Kidney	0.95	1561
Brain	0.85	1541
Blood	0.18	1570

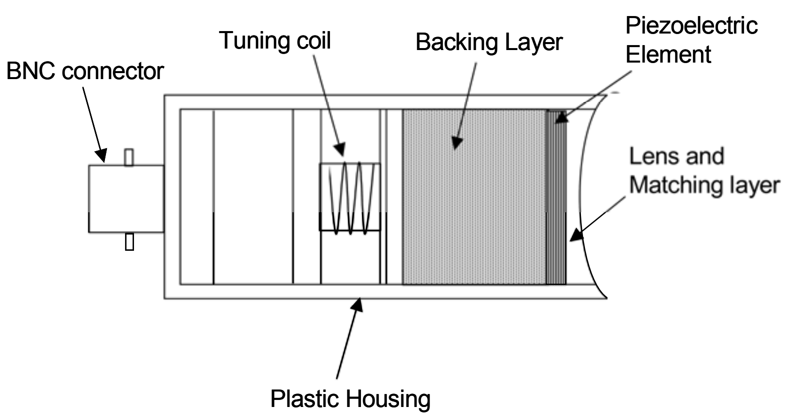
The attenuation coefficients and propagation speeds of sound waves.

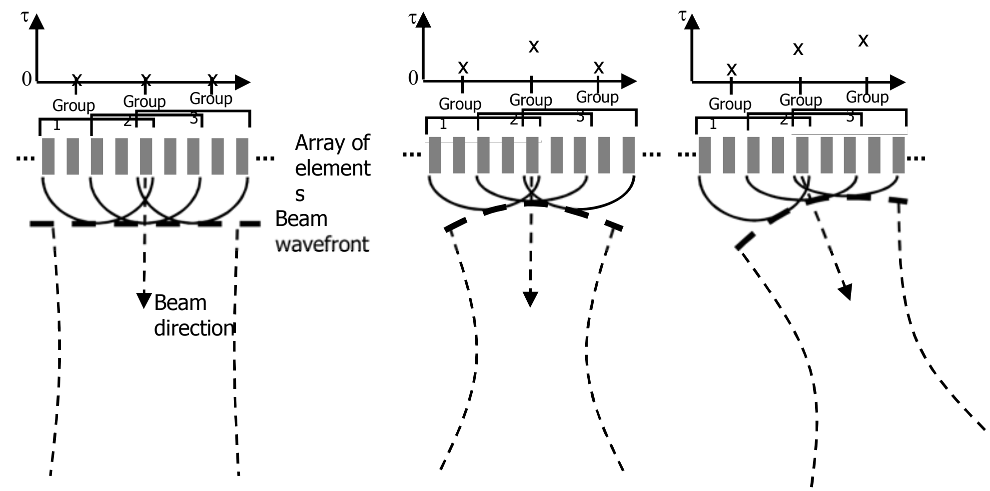
SOUND VELOCITY

- **The velocity of a sound wave in a medium, c, is related to its wavelength λ and**
- **frequency ν by $c=\lambda\nu$**

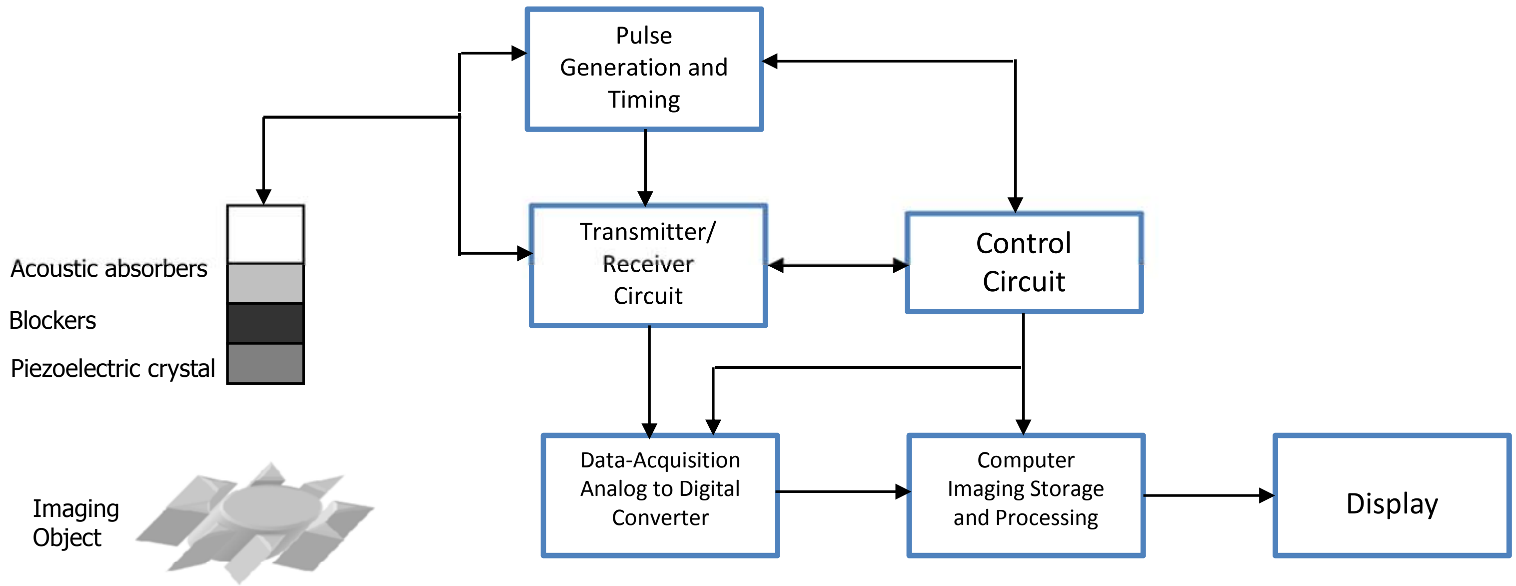
$$\text{relative intensity in } dB = 10\log_{10}\frac{I_1}{I_2}$$

TRANSDUCER AND ARRAYS





IMAGING SYSTEM



- **A schematic diagram of a conventional ultrasound imaging system**

ULTRASOUND IMAGING

- An ultrasound transducer provides brief pulses of ultrasound when stimulated by a train of voltage spikes of 1-2 msec duration applied to the electrodes of the piezoelectric crystal element.
- An ultrasound pulse
  - A few cycles long: 2-3 cycles.
- As the same crystal element is used as the receiver, the time between two pulses is used for detecting the reflected signal or echo from the tissue.

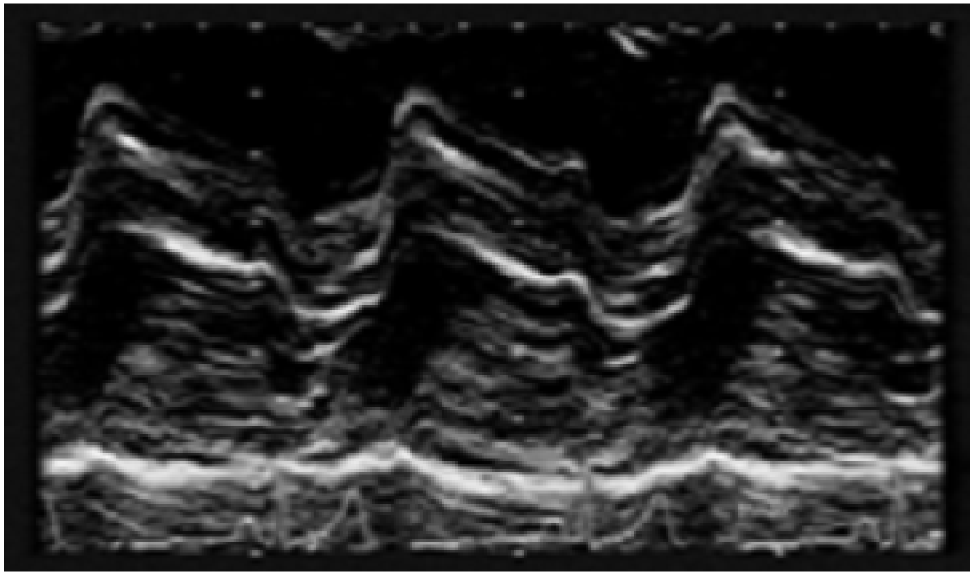
A-Mode Scan

- A-Mode scan:
  - Records the **amplitude of returning echoes from the tissue** boundaries with respect to time. In this mode of imaging the ultrasound pulses are sent in the imaging medium with a perpendicular incident angle.
  - Since the echo time represents the acoustic impedance of the medium and depth of the reflecting boundary of the tissue, distance measurements for the tissue structure and interfaces along the ultrasound beam can be computed.
  - The intensity and time measurements of echoes can provide useful three-dimensional tissue characterization.

M-Mode Scan

- Provides information about the **variations in signal amplitude due to object motion**.
- A fixed position of the transducer, in a sweep cycle, provides a line of data that is acquired through A-mode.
- The data is displayed as a series of dots or pixels with brightness level representing the intensity of the echoes.
- In a series of sweep cycles, each sequential A-line data is positioned horizontally.
- As the object moves, the changes in the brightness levels representing the deflection of corresponding pixels in the subsequent sequential lines indicate the movement of the tissue boundaries.
- The x-axis represents the time while the y-axis indicates the distance of the echo from the transducer.

M-Mode Image

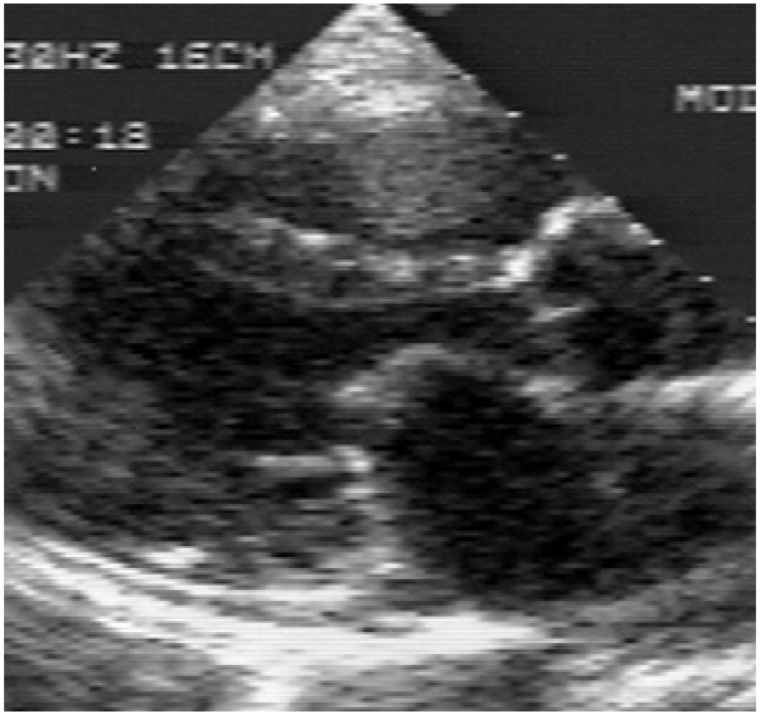


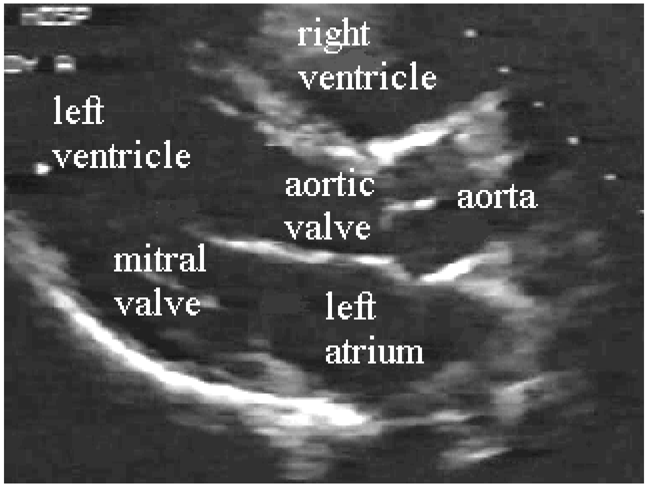
M-Mode display of mitral valve leaflet of a beating heart

B-Mode Scan

- Provides **two-dimensional images representing the changes in acoustic impedance of the tissue**.
- The brightness of the B-Mode image shows the strength of the echo from the tissue structure.
- To obtain a 2-D image of the tissue structure, the transducer is pivoted at a point about an axis and is used to obtain a V-shape imaging region. Alternately, the transducer can be moved to scan the imaging region.
- Several images of the acquired data based on the processing kernel filters can be displayed to show the acoustic characteristics of the tissue structure and its medium.

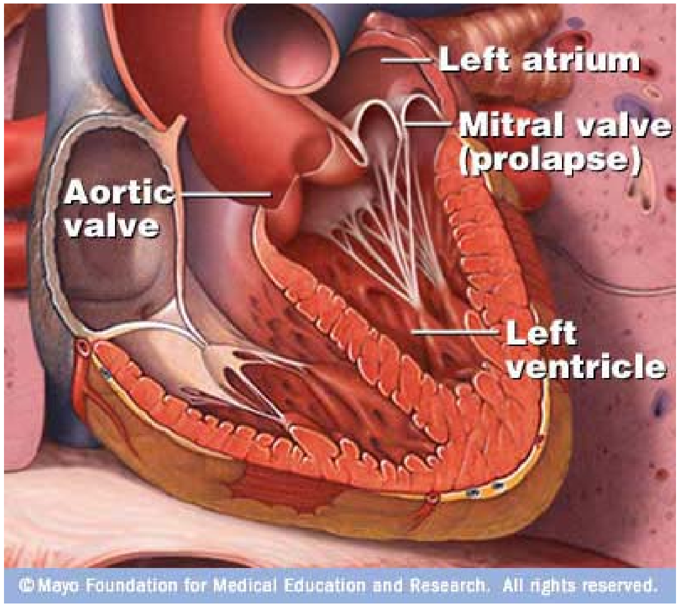
B-Mode Image

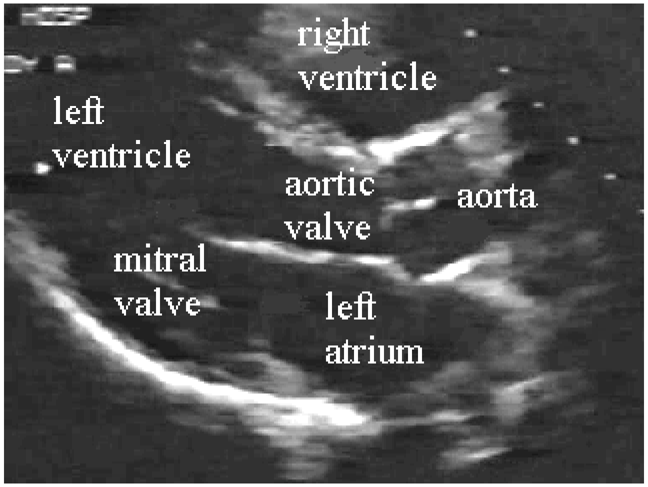




The "B-Mode" image of a beating heart with mitral st

Mitral Valve

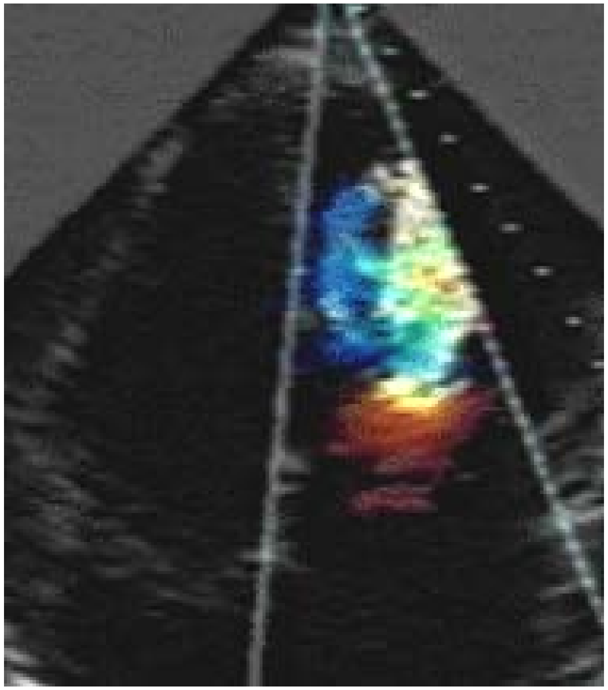




Doppler Image

$$f_{doppler} = \frac{2v\cos\theta \quad f}{c}$$

where v is the velocity of the moving source or object, f is the original frequency, c is the velocity of the sound in the medium, and is the incident angle of the moving object with respect to the propagation of the sound.



A Doppler image of the mitral valve area of a beating heart.