SNS COLLEGE OF ALLIED HEALTH SCIENCE

Affiliated to The Tamil Nadu Dr. M.G.R Medical University, Chennai

DEPARTMENT OF RADIOGRAPHY AND IMAGING TECHNOLOGY

COURSE NAME : EQUIPMENTS OF ADVANCED MODALITIES

UNIT : ULTRASONOGRAPHY/DOPPLER SYSTEM

TOPIC : BASICS AND PROPERTIES

FACULTY NAME: MRS.G.HELANA JOY

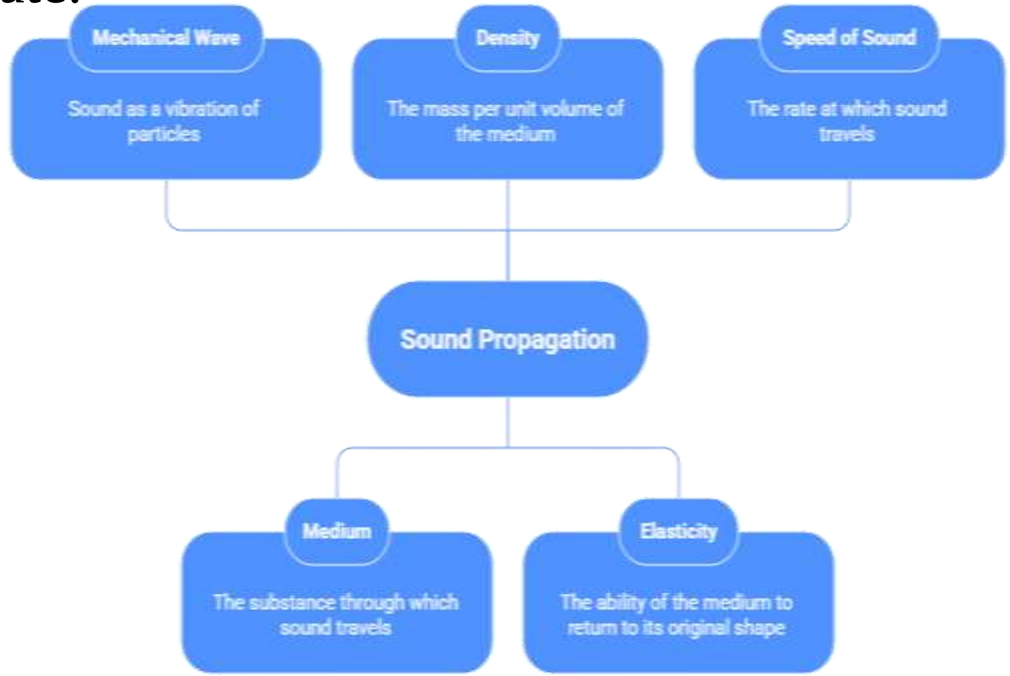
INTRODUCTION (Define)

Ultrasound

- Sound waves with frequency > 20 kHz (above human hearing range)
- Medical ultrasound: typically 2–18 MHz
- High frequency → Better resolution, Lower penetration
- Low frequency → Deeper penetration, Poorer resolution

PHYSICS OF ULTRASOUND & SOUND PROPAGATION

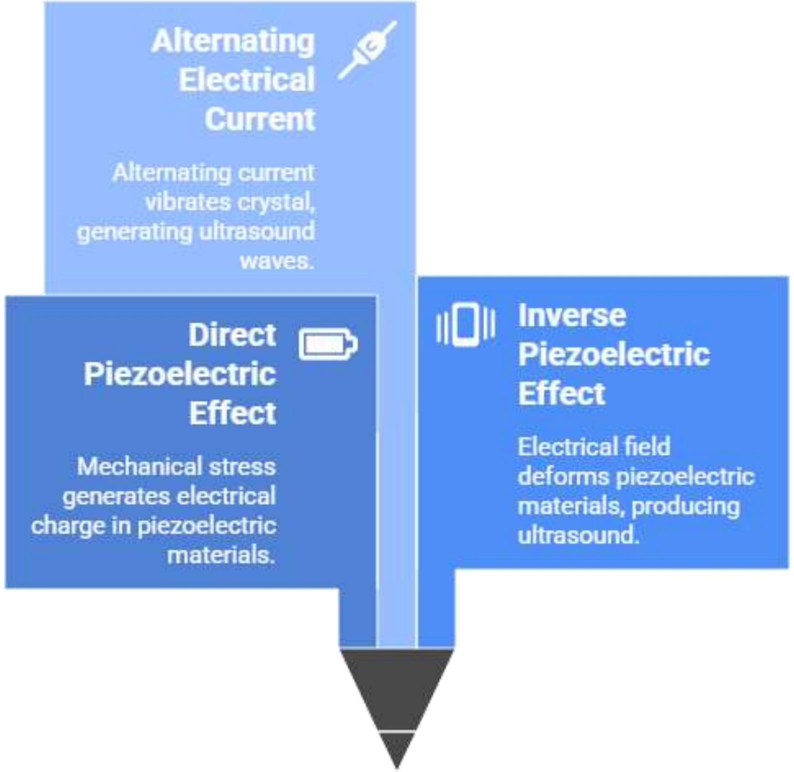
- Sound is a mechanical wave that propagates through a medium by causing the particles of that medium to vibrate.
- The speed of sound varies depending on the medium's properties, such as density and elasticity.



- Ultrasound is sound with frequencies above 20 kHz, commonly 1–15 MHz in medical imaging.
- Sound propagates as a mechanical wave of compression and rarefaction, needing a medium (solid, liquid, or gas).
- In tissue, propagation speed depends on the density and stiffness of the medium; faster in solids, slower in liquids/gases.

PRODUCTION OF ULTRASOUND: THE PIEZOELECTRIC EFFECT

- Ultrasound is produced in the transducer via crystals (often lead zirconate titanate) that generate sound waves when electrically stimulated (direct piezoelectric effect).
- The same crystals receive returning echoes, converting them back into electrical signals (reverse piezoelectric effect).
- The transducer shape and crystal arrangement determine the beam shape and resolution.



ULTRASOUND INTERACTION WITH MATTER

- Reflection: Occurs at tissue interfaces with different acoustic impedances; crucial for image formation.
- Scattering: Results in weak, diffuse echoes mainly at small or irregular interfaces, affecting image texture.
- Absorption: Conversion of ultrasound energy to heat, increasing with tissue viscosity and beam frequency; major in bone.
- Refraction: Bending of beam at boundaries due to changes in speed between tissues.

1

Reflection

Low-frequency reflection occurs strongly at impedance boundaries.

2

Absorption

High-frequency absorption converts ultrasound energy into heat effectively.

3

Refraction

Low-frequency refraction bends waves with minimal interaction.

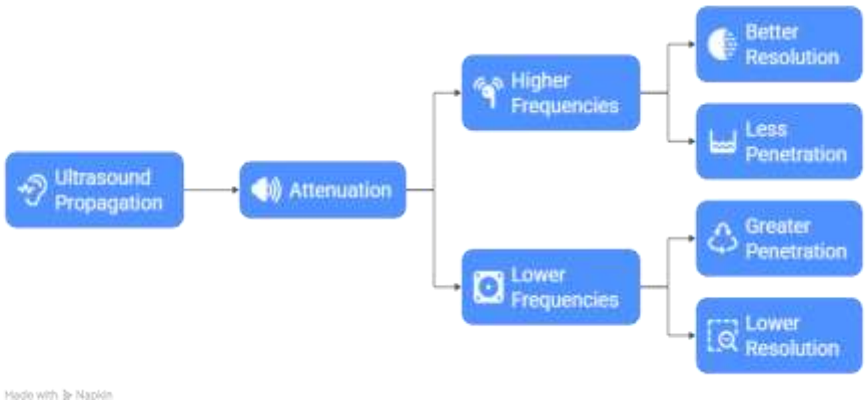
4

Scattering

High-frequency scattering disperses waves with less intensity.

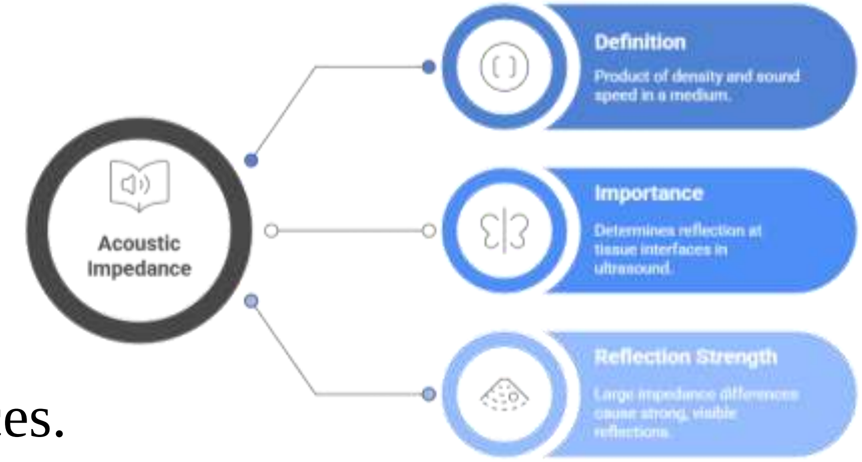
ULTRASOUND PROPERTIES IN TISSUE

- **Propagation:** Ultrasound travels through soft tissues at an average speed of 1540 m/s.
- **Attenuation:** Attenuation limits the depth of penetration of ultrasound. Higher frequencies are attenuated more rapidly, providing better resolution but less penetration. Lower frequencies provide greater penetration but lower resolution.



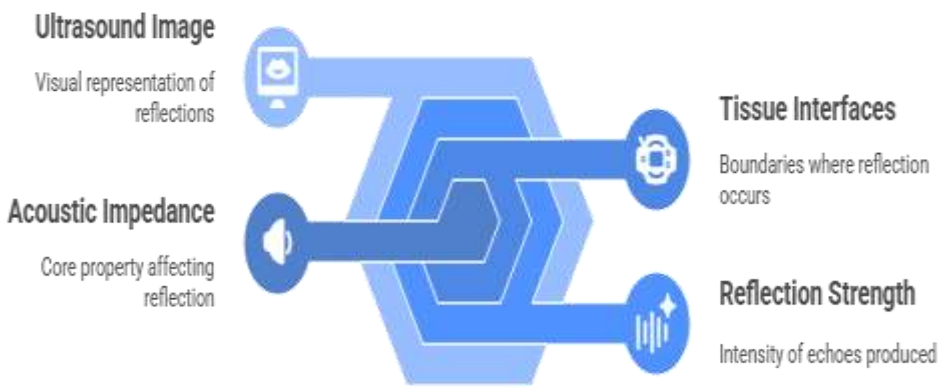
ACOUSTIC IMPEDANCE (Z)

- **Definition:** A measure of a material's resistance to the propagation of sound waves. It is the product of the medium's density (ρ) and the speed of sound (c) in that medium:
- $Z = \rho c$
- **Importance:** Differences in acoustic impedance between tissues determine the amount of reflection at tissue interfaces. Large differences in acoustic impedance result in strong reflections, which are visible as bright echoes on the ultrasound image.



ACOUSTIC IMPEDANCE & PROPERTIES IN TISSUE

- Differences in impedance govern the strength of reflected echoes and thus image contrast.
- Major impedance mismatch at soft tissue–air or soft tissue–bone interfaces produces strong reflections/shadows.

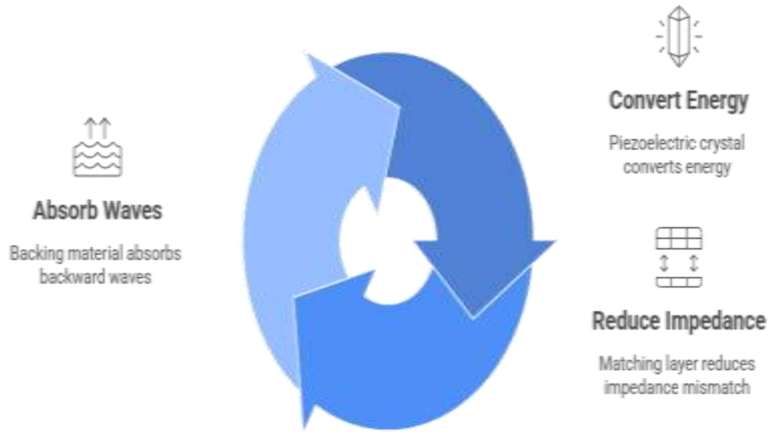


DOPPLER AND SYSTEM COMPONENTS

Doppler systems measure motion (blood flow) via frequency shifts in returning echoes.

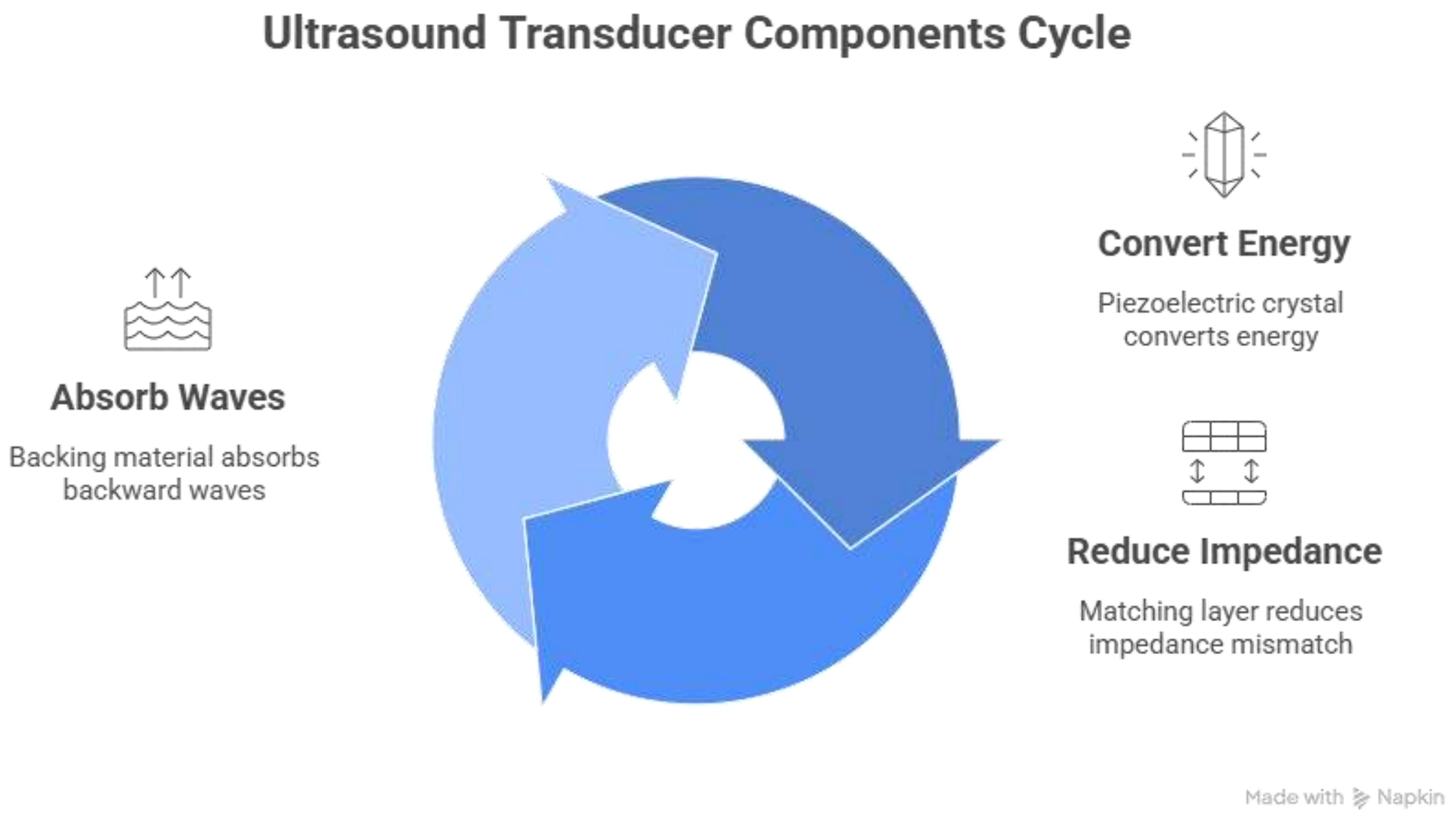
System blocks:

- Transducer: Generates and detects ultrasound waves via the piezoelectric effect.

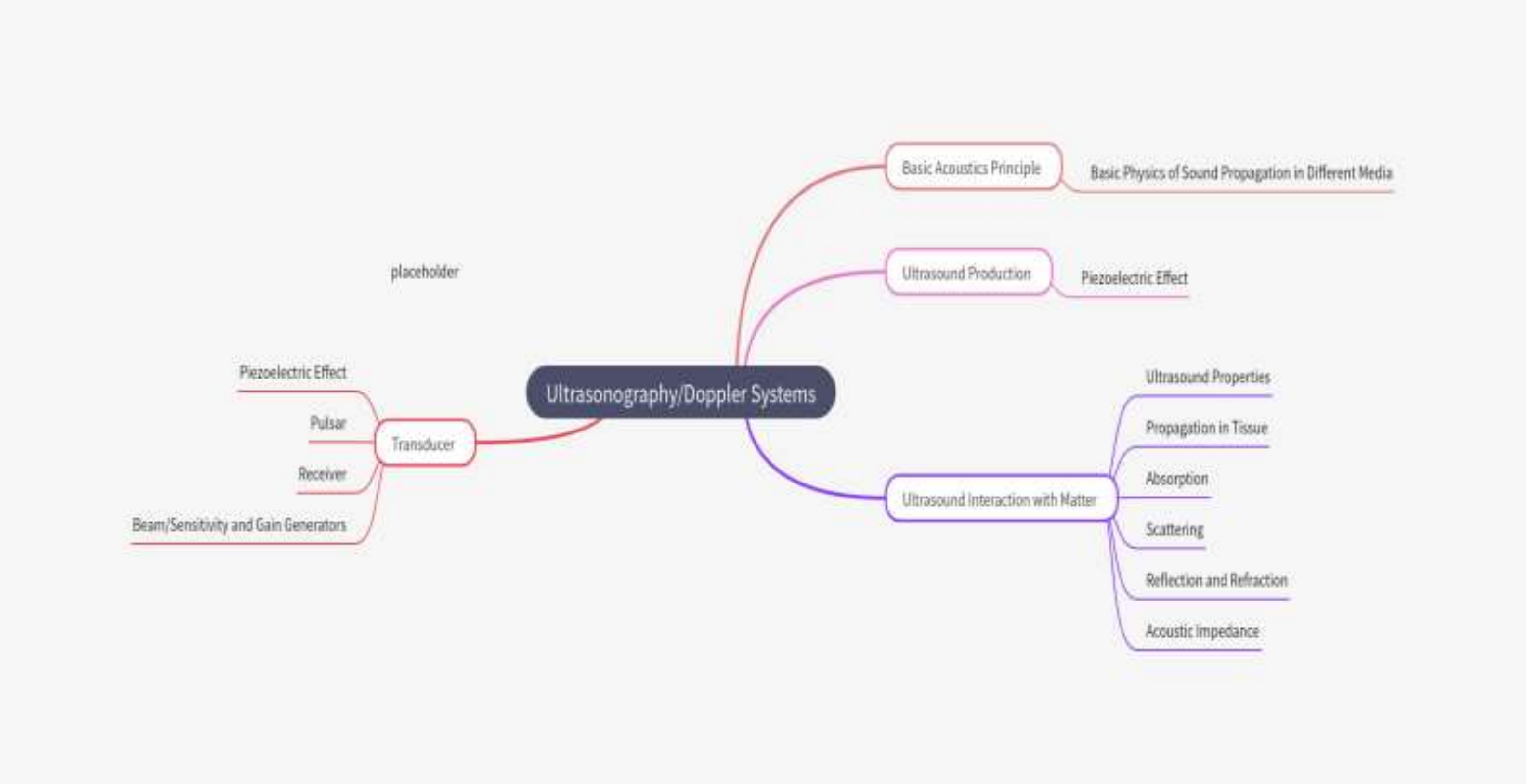


DOPPLER AND SYSTEM COMPONENTS

- Pulser: Sends electrical pulses to the transducer.
- Receiver: Processes detected echoes and transforms them for display.
- Beam Formation/Sensitivity/Gain Controls: Adjust imaging parameters for optimal visualization.


Ultrasound Transducer Components Cycle
Absorb Waves
Backing material absorbs backward waves
Convert Energy
Piezoelectric crystal converts energy
Reduce Impedance
Matching layer reduces impedance mismatch
Made with Napkin

SUMMARY


Ultrasonography/Doppler Systems
Basic Acoustics Principle
Basic Physics of Sound Propagation in Different Media
Ultrasound Production
Piezoelectric Effect
Ultrasound Interaction with Matter
Ultrasound Properties
Propagation in Tissue
Absorption
Scattering
Reflection and Refraction
Acoustic Impedance
placeholder
Transducer
Piezoelectric Effect
Pulsar
Receiver
Beam/Sensitivity and Gain Generators

References

- https://www.nysora.com/topics/equipment/physics-of-ultrasound/

- https://www.showmethepocus.com/physics