Ultrasound imaging and their application

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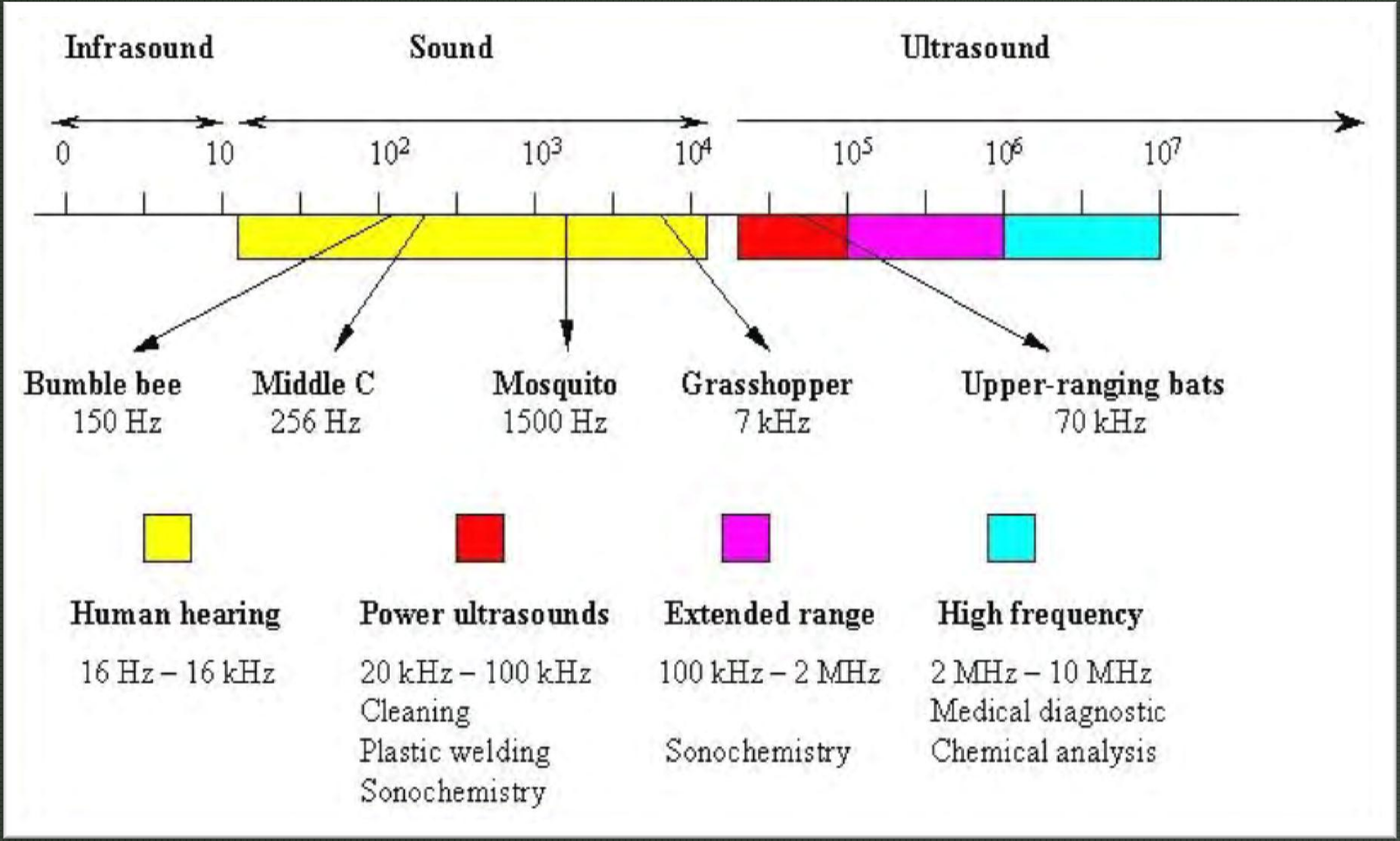
Outline

- History
- What is Ultrasound ?
- Uses of Ultrasound
- Physics of ultrasound &Ultrasonic echo imaging
- Ultrasound imaging system schematic
- Ultrasound imaging modes
- advantages and the Clinical Applications

History

- 1877: Discovery of piezoelectricity (Pierre and Jacques Curie)
- 1913: First sonar patent filed after Titanic disaster
- 1917: Sonar used for detecting range of u-boats during WWI
- 1930s: Ultrasound used for physical therapy for Europe’s football teams
- 1990s: Early 3D and 4D ultrasound imaging systems
- 2000s: Portable ultrasound systems,, MR-guided focused ultrasound
- Today : Diagnostic ultrasound is second most popular medical imaging
- modality after X-ray

What is Ultrasound ?



What is Ultrasound ?

- Acoustic waves are mechanical pressure waves
- Ultrasound waves are pressure waves that travel through a medium at a frequency greater than 20 kHz

Humans

- Can typically hear frequencies between 20 Hz to 20 kHz
- Children can detect higher frequencies than adults

Uses of Ultrasound

- **Ultrasound Imaging / Detection**

  Medical Sonography

  3-20 MHz

- **Sonar**

  Hz–kHz range

- **Non-destructive testing (NDT)**

  kHz–low MHz range

  Detection of cracks in materials

Uses of Ultrasound

- **Monitoring**

  Structural Health Monitoring

  Long term damage detection

  Infrastructure, aircraft

  Embedded sensor networks

  kHz-low MHz range

- **Fetal Heart Monitoring**

  Continuous detection and monitoring of fetal heart beat

  Low MHz range

Uses of Ultrasound

- **Ablation/Destruction of Tissues**

  ablation of kidney stones

  Tumor ablation

  MRI or Ultrasound guided

- **Other Uses**

Drug activation (Focused heating of drugs)

Vibration (Wire bonding)

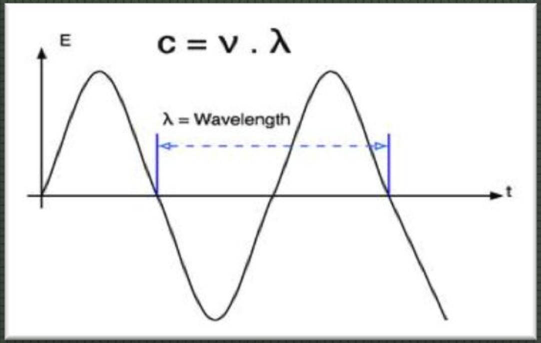
Tissue cutting

Water treatment

Physics of ultrasound &Ultrasonic echo imaging

- Wave length

  One complete wave cycle



- Frequency

  Number of vibrations that a molecule makes/second,

  Unit of cycles/s (Hz)

  Higher frequency has smaller wavelength $c = f\lambda$

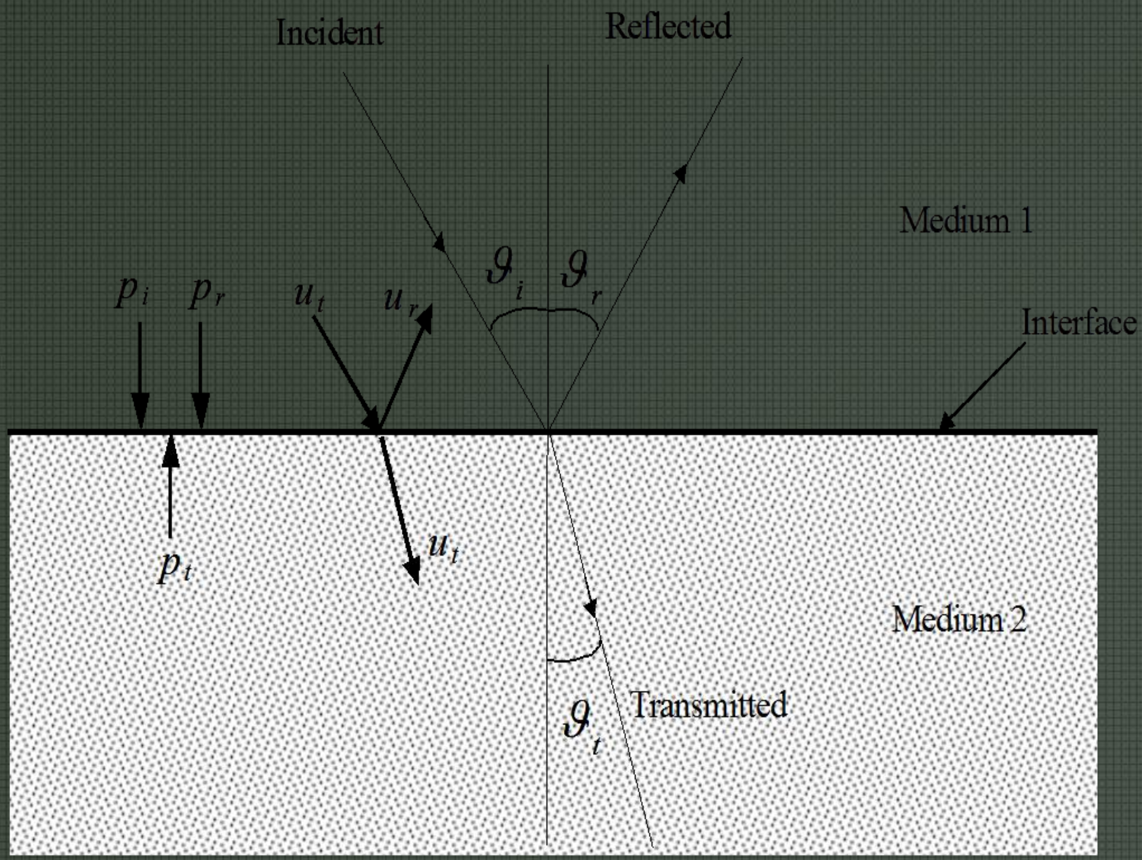
  Better spatial resolution

  Higher frequency waves degrade faster with distance

- Attenuation

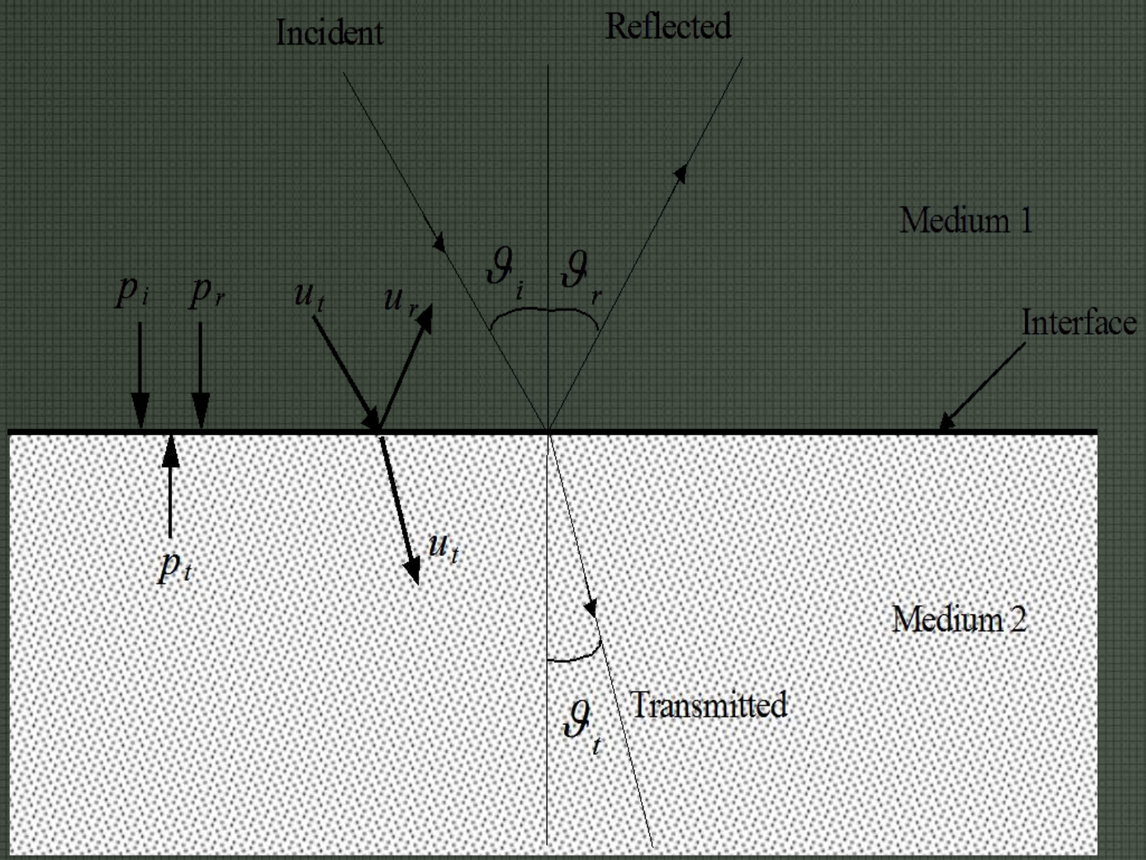
Physics of ultrasound &Ultrasonic echo imaging

- Reflection:
- Refraction
- Diffusion



Physics of ultrasound &Ultrasonic echo imaging

- Reflection:
- Refraction



Physics of ultrasound &Ultrasonic echo imaging

- Diffuse Reflection

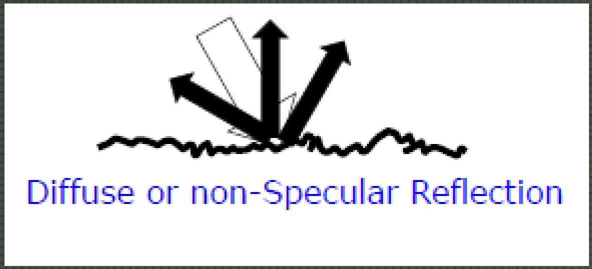
Most surfaces are rough

Parts of beam are redirected due to in multiple directions

Loss of coherence of beam

Decreased beam intensity

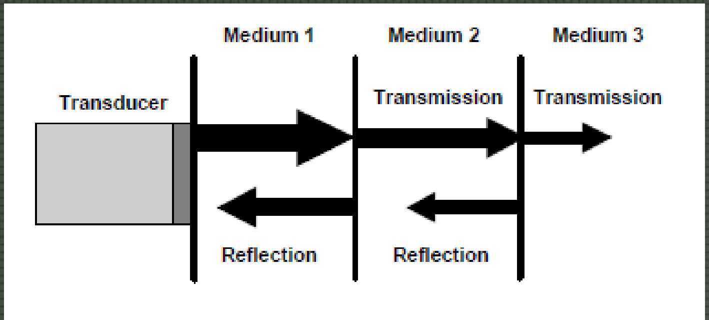
Increased acoustic clutter



Physics of ultrasound &Ultrasonic echo imaging

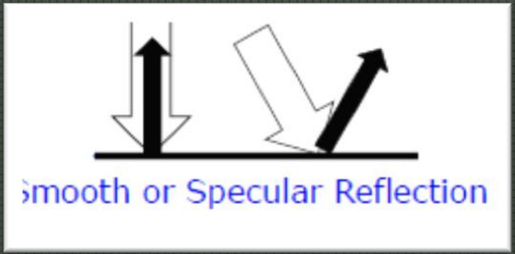
- Acoustic Impedance : Z=ρc

ρ: density, c : sound velocity



- Echo:

Reflected echo intensity depends on the acoustic impedances of the two adjoining media



Physics of ultrasound &Ultrasonic echo imaging

النسيج	رايل
الهواء	٤١٣
الدماغ	١،٥٨× ١٠٠٠٠٠٠٠
الرئة	٠,١٨ × ١٠٠٠٠٠٠٠
الدهن	١،٣٨ ×١٠٠٠٠٠٠٠
الماء	١,٤٨ × ١٠٠٠٠٠٠٠
الكبد	١,٦٥ × ١٠٠٠٠٠٠٠
الدم	١,٦٥ × ١٠٠٠٠٠٠٠
الكلية	١,٦٣ × ١٠٠٠٠٠٠٠
العضلات	١,٧١ × ١٠٠٠٠٠٠٠
الجمجمة والعظام	٧,٨ × ١٠٠٠٠٠٠٠٠

- Acoustic Impedance :

- Hypoechoic

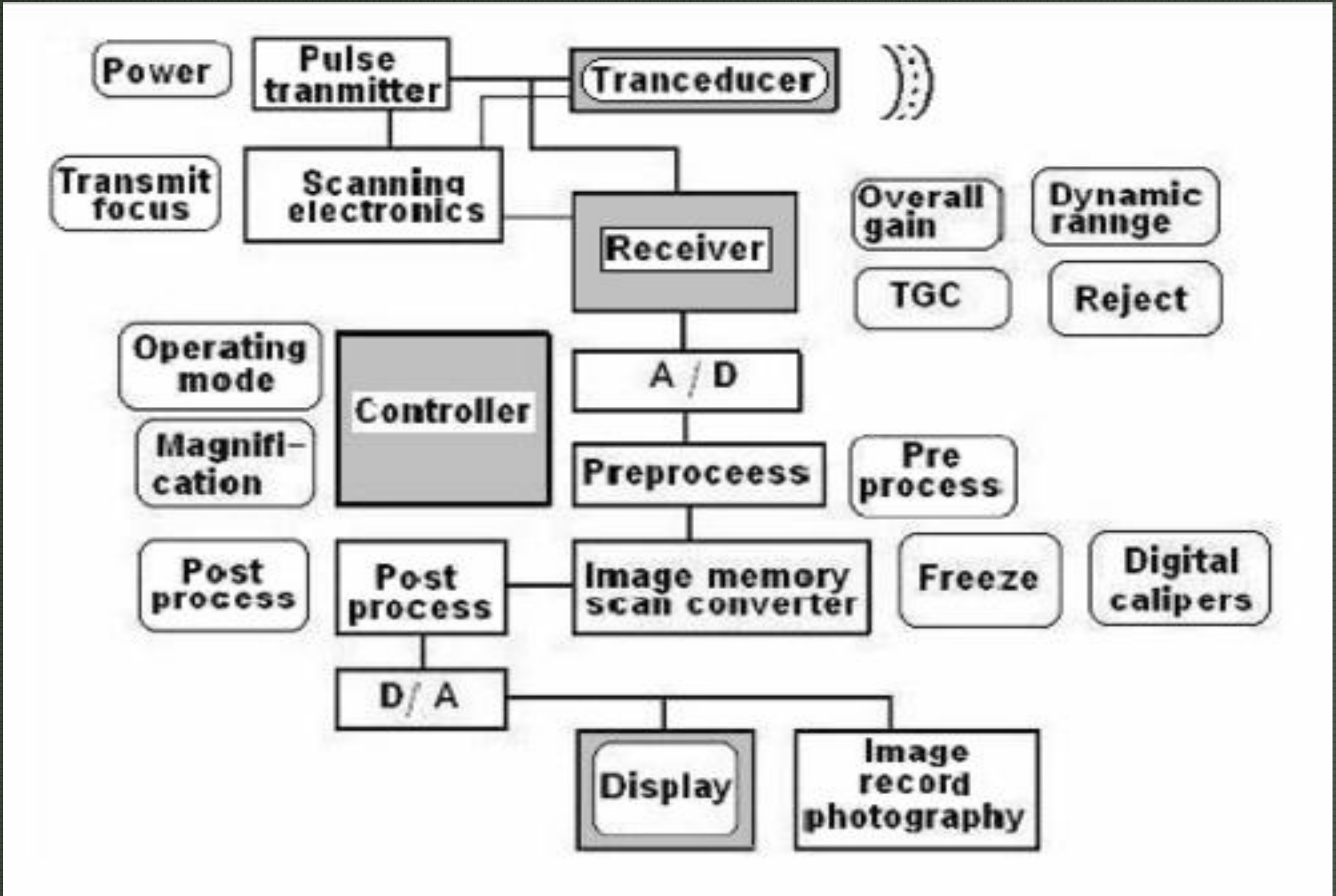
  Dark regions in ultrasound, images lack scatters,

  Fluids

- Hyperechoic

  Bright regions have many scatters

Ultrasound imaging system schematic



Ultrasound imaging system schematic

- Transducer (electrical signal to a acoustic signal)

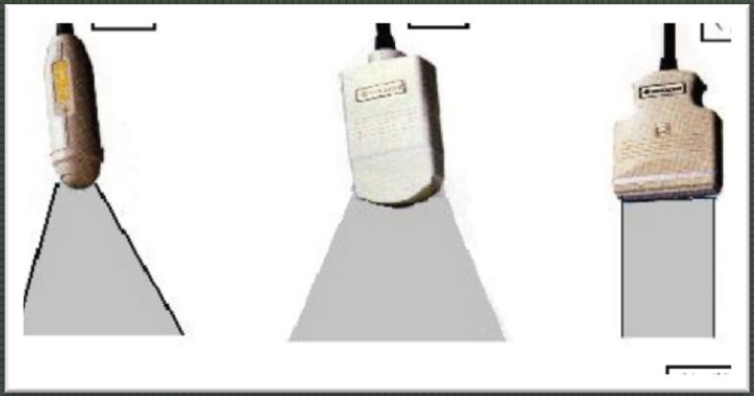
generates pulses of ultrasound and sends them into patient

Organ boundaries and complex tissues produces echoes

(reflection or scattering) which are detected by the   transducer

Echoes displayed on a grayscale anatomical image

Brightness corresponds to echo strength



Ultrasound imaging system schematic

- Pulse Transmitter:

  PRF(pulse repetition frequency)

- Receiving:
- A\D, D\A
- Gain of receiver:(TGC- time gain compensation)

Ultrasound imaging system schematic

- Transducer types:

  Auto-scan transducers

    Mechanical sector probes(annular array)

    Special transducer (trans rectal)

    Linear probe(linear probes, electronic convex probes, phased arrays)

Ultrasound transducers

Ultrasound imaging modes

- A-mode(Amplitude mode)
- M-mode(Motion mode)
- B-mode(Brightness mode)
- 3D imaging
- Doppler

Ultrasound imaging modes

- A-mode(Amplitude mode)

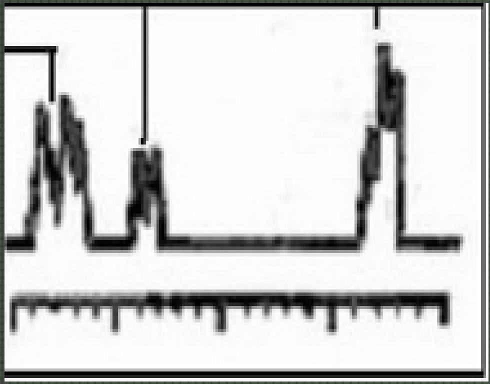
Oldest, simplest type

Display of the envelope of pulse-echoes vs. time, depth d = ct/2

Measure the reflectivity at different depth below the transducer position

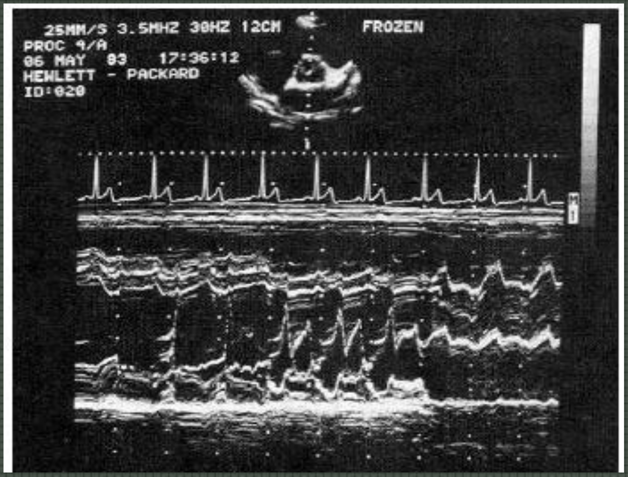
Applications: ophthalmology (eye length, tumors), localization of brain midline, liver cirrhosis, myocardium infarction

• Frequencies: 2-5 MHz for abdominal, cardiac, brain; 5-15 MHz for ophthalmology, pediatrics, peripheral blood vessels



Ultrasound imaging modes

- M-mode(Motion mode)
- Display the A-mode signal corresponding to repeated input pulses in separate column of a 2D image, for a fixed transducer position
- – Motion of an object point along the transducer axis (z) is revealed by a bright
- trace moving up and down across the image
- – Often used to image motion of the heart valves, in conjunction with the ECG



Ultrasound imaging modes

- B-mode(Brightness mode)
- Move the transducer in x-direction while its beam is aimed down the z-axis, firing a
- new pulse after each movement
- Received signal in each x is displayed in a column
- Unlike M-mode, different columns corresponding to different lateral position (x)
- Directly obtain reflectivity distribution of a slice! (blurred though!)

Ultrasound imaging modes

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Ultrasound imaging modes

- 3D imaging
- By mechanically or manually scanning a phased array transducer in a
- direction perpendicular to the place of each B-mode scan
- • Can also electronically steering the beams to image different slices

Ultrasound imaging modes

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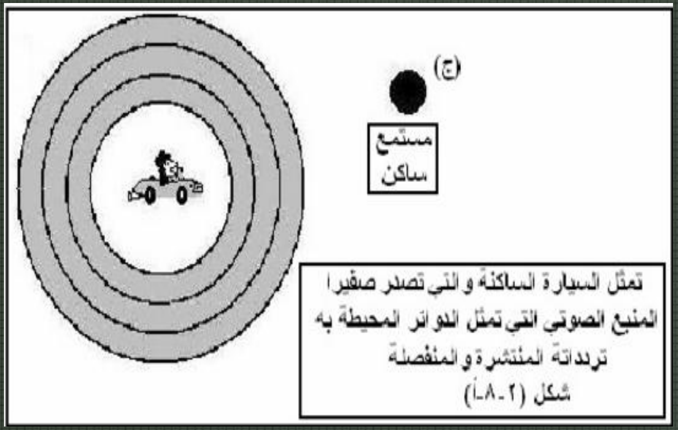
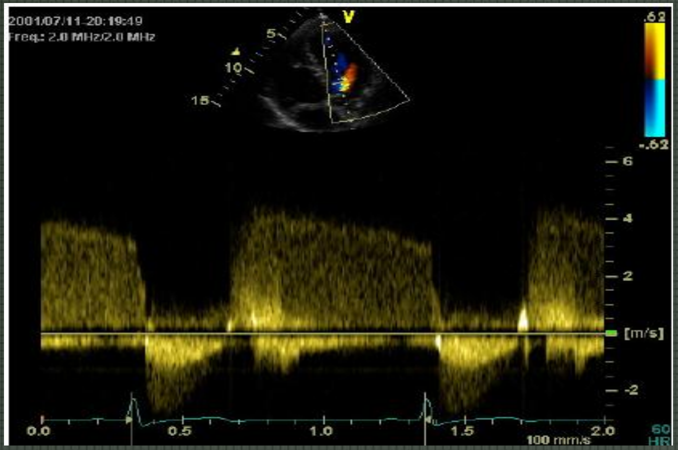
Ultrasound imaging modes

- Doppler:
  - CW Doppler
  - Pulse Mode Doppler
  - 4D d





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