ULTRASOUND IMAGING

Outline

Part 1

- History
- Physics of Ultrasound
- Interactions of Ultrasound with tissue
- Principles of Ultrasound
- Production of Ultrasound

Part 2

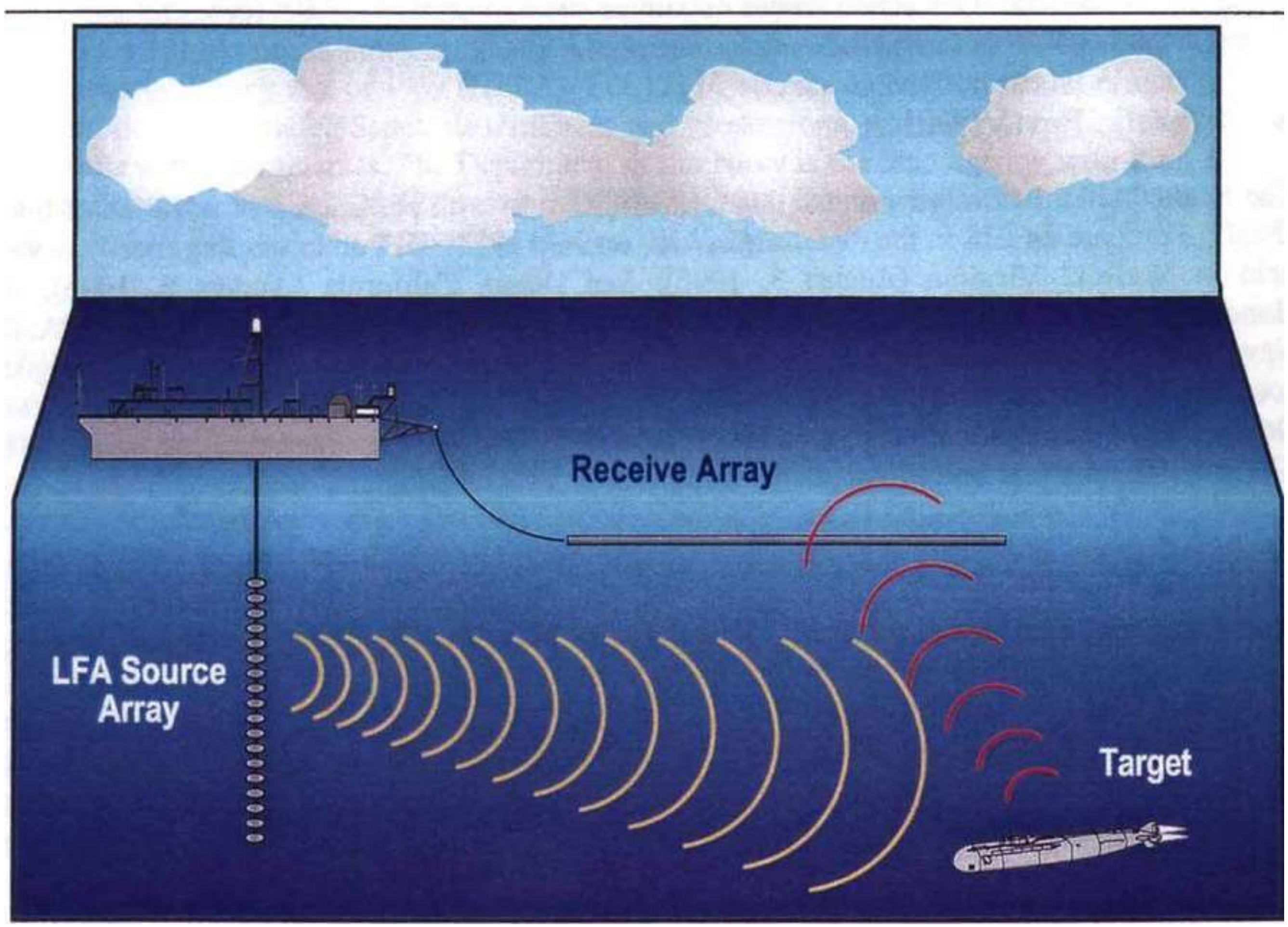
- Ultrasound Machine
- Parts of Ultrasound Machines
- Transducer and its Types
- Image Construction
- Block Diagram
- 2D, 3D, 4D Ultrasound machines

Part 3

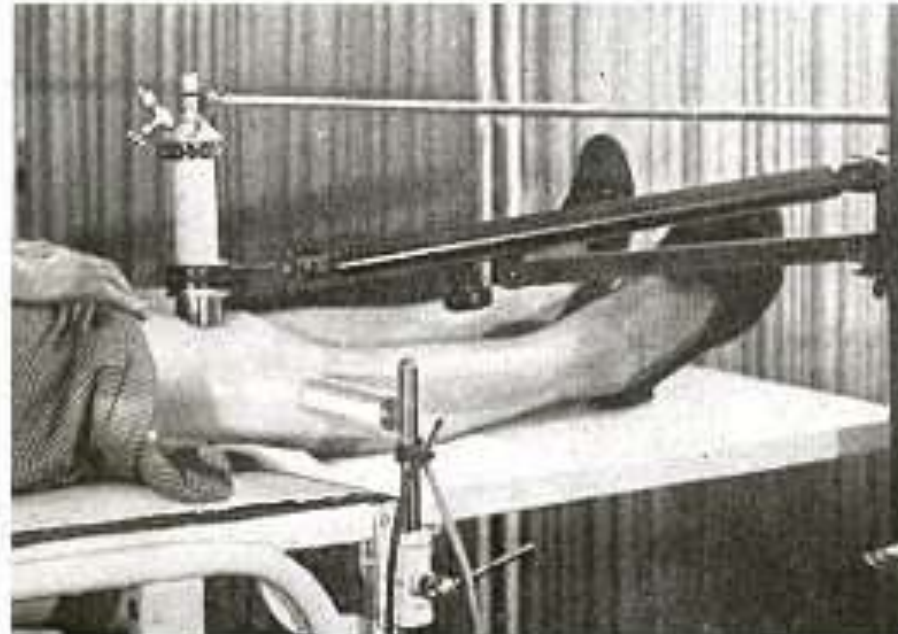
- Applications of Ultrasounds
- Advantages of Ultrasounds
- Future of Ultrasounds

History

First successful application → SONAR in world war 2 (Sound Navigation And Ranging)



History

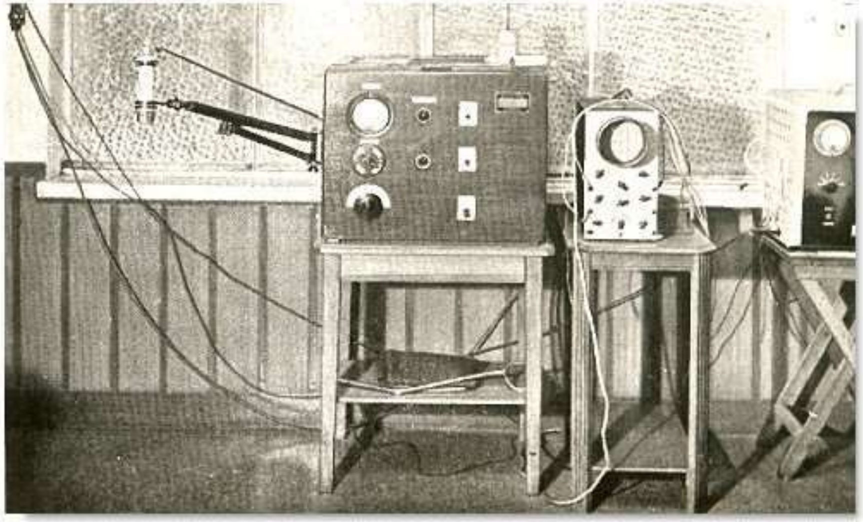


Uses of ultrasonic energy in the 1940s. Left, in gastric ulcers. Right, in arthritis

Ultrasonic therapy generator, the "Medi-Sonar" in the 1950s.

A British ultrasonic apparatus for the treatment of Meniere's disease in the late 1950s

History



Denier's Ultrasonoscopic apparatus with ultrasound generator, emitter transducer and oscilloscope. This can be adapted for both therapeutic and diagnostic purposes

The first hand-held imaging instrument was developed by John Wild and John Reid in the early 1950's

Present

Medical Ultrasound

- High frequency sound waves
- Can’t hear but can be emitted and detected
- To see internal soft body structures
- Tendons, muscles, joints, blood vessels etc.
- Find a source of a disease or to exclude any pathology
- The practice of examining pregnant women using ultrasound is called obstetric ultrasound, and is widely used

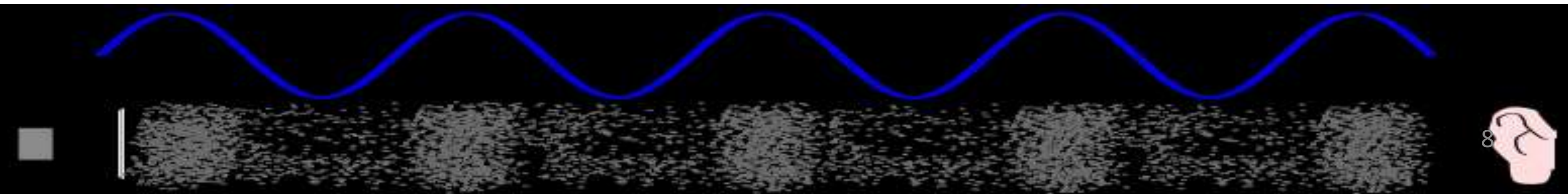
Physics of Ultrasound

Sound

- Mechanical & Longitudinal wave
- Travels in a straight Line
- Human ear range is 20Hz - 20kHz
- Cannot travel through Vacuum

Ultrasound

- Mechanical & Longitudinal wave
- Exceeding the upper limit of human hearing
- > 20,000H or 20kHz.



Characteristics of Ultrasounds

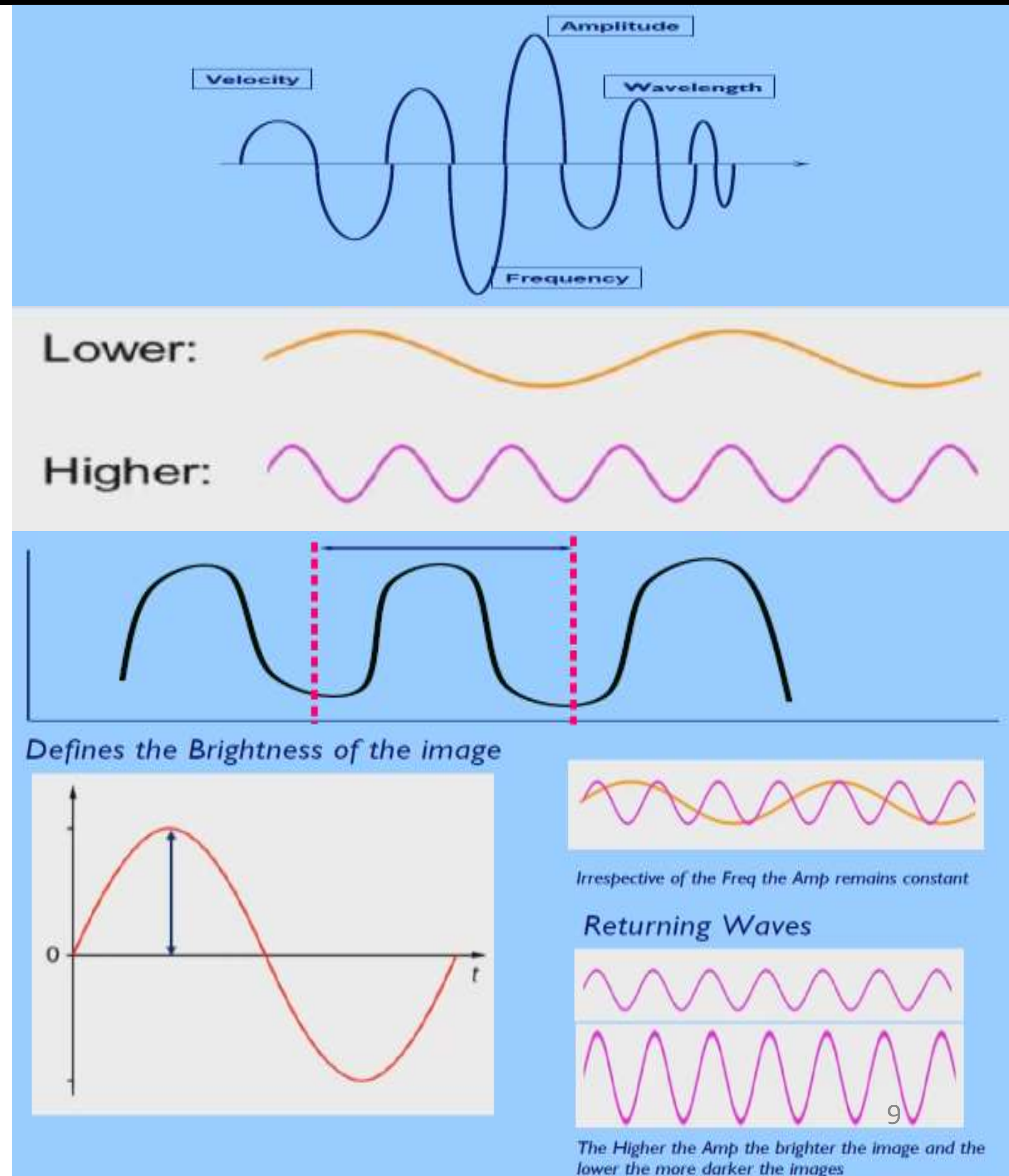
- Velocity
- Frequency
- Wavelength
- Amplitude

- The Relationship b/w v, f and λ is:

$$v = f \lambda$$

- Average speed of ultrasound in body is 1540m/sec

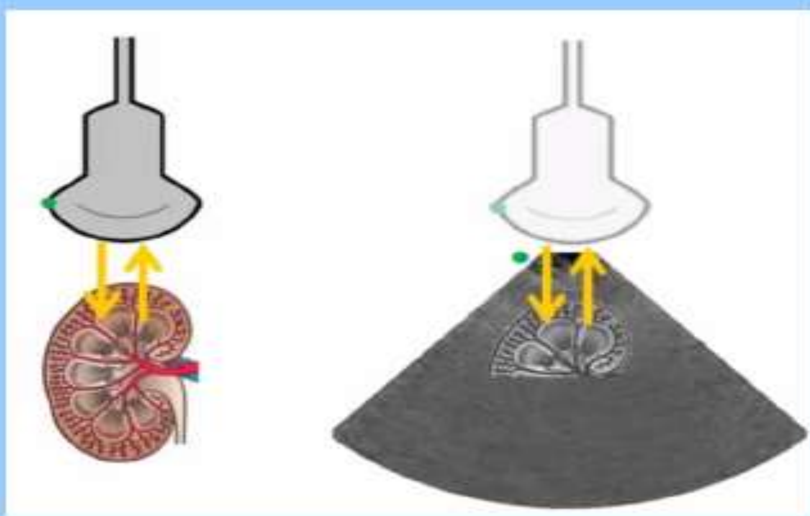
- Imaging range is 2 to 20MHz



Characteristics of Ultrasounds

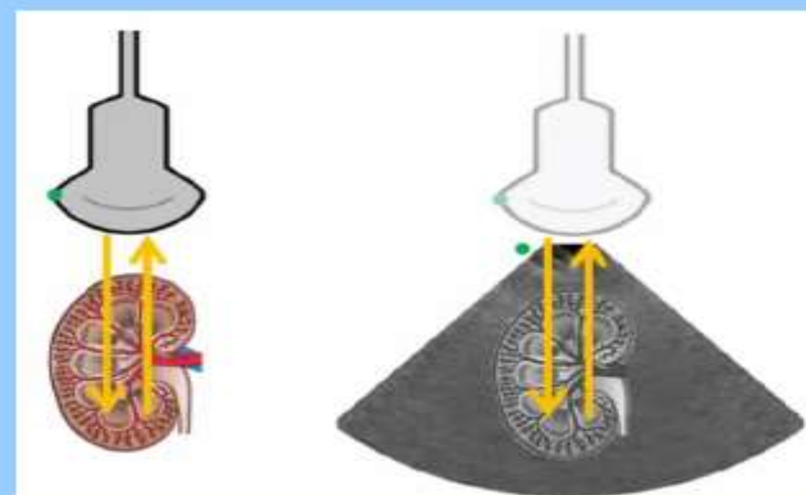
Velocity

Near Field Imaging



Tissues closer appear on top and faster the waves return

Far Field Imaging



Tissues further appear at the bottom & slower the waves return

Interactions of Ultrasound with tissue

- Reflection
- Transmission
- Attenuation
- Scattering

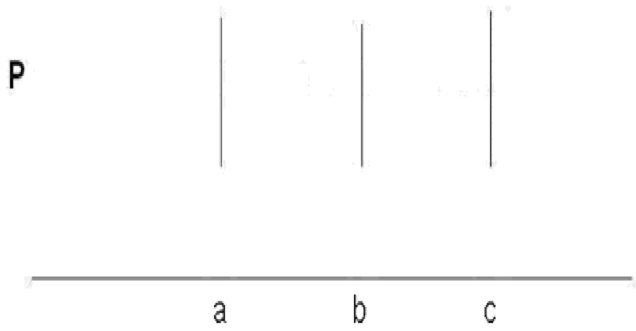
Interactions of Ultrasound with tissue

Reflection

- Occurs at a boundary between 2 adjacent tissues or Media.
- Acoustic impedance (z)
- The ultrasound image is formed from reflected echoes

Transmission

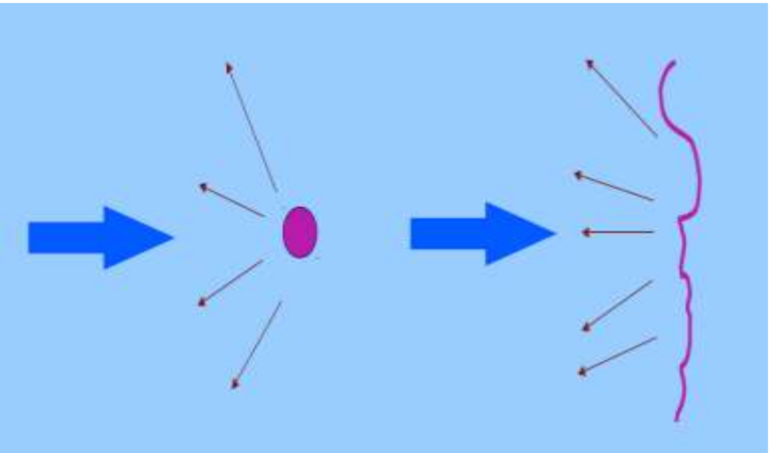
- Not all the sound wave is reflected, some continues deeper into the body
- These waves will reflect from deeper tissue structures



Principle of Ultrasound

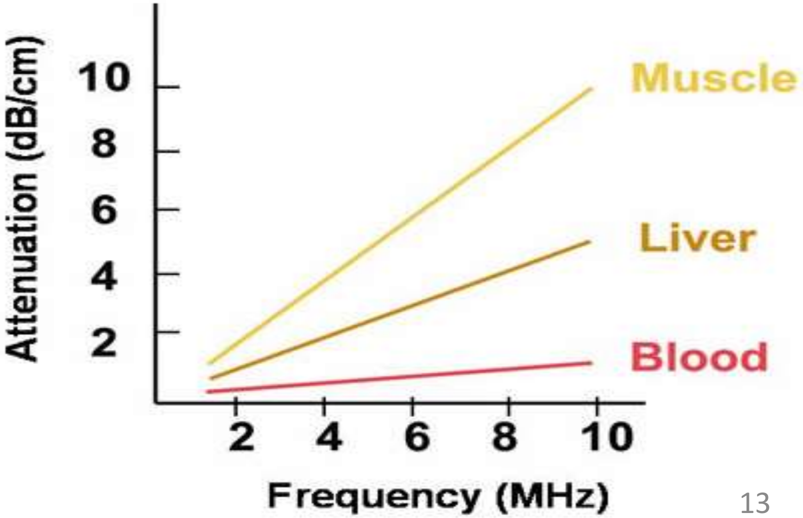
Scattering

- Redirection of sound in several directions
- Caused by interaction with small reflector or rough surface
- Only portion of sound wave returns to transducer



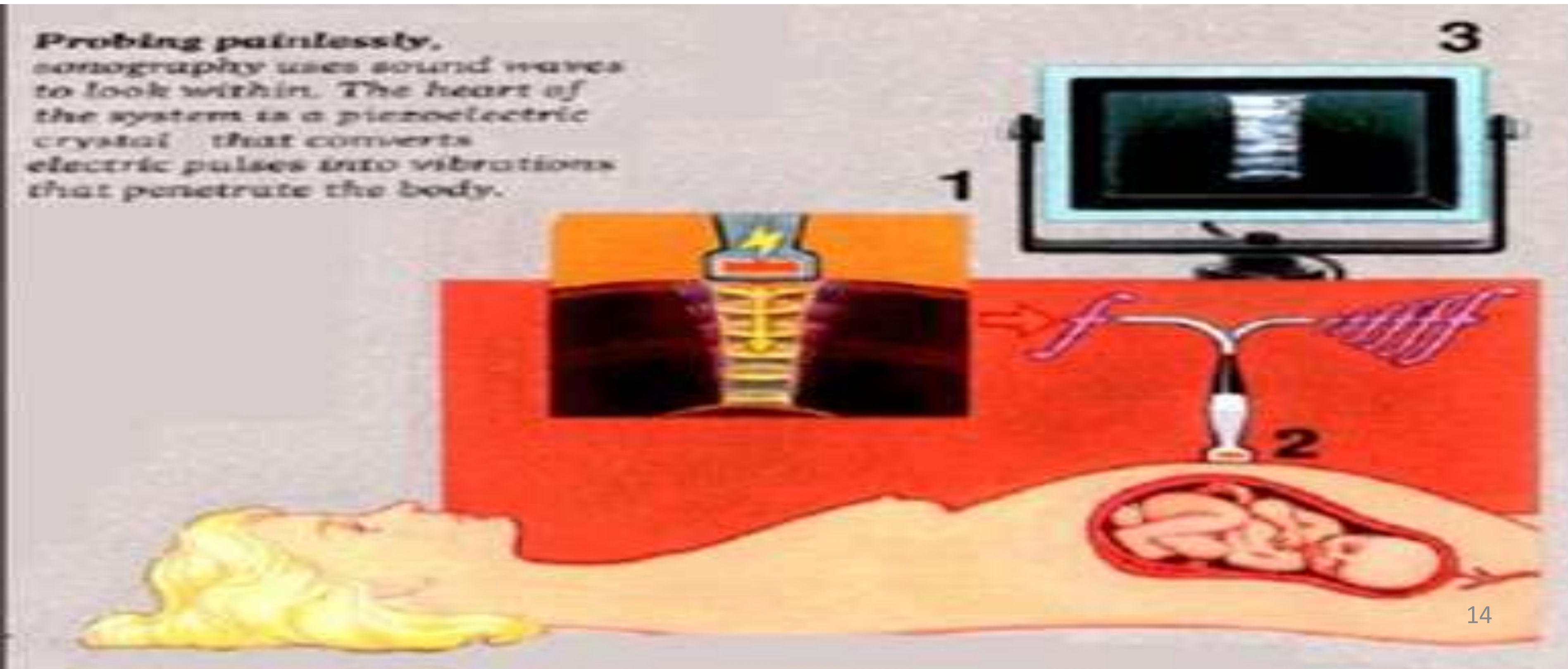
Attenuation

- The deeper the wave travels in the body, the weaker it becomes
- The amplitude of the wave decreases with increasing depth



Principle of Ultrasound

- Ultrasound Imaging is based on the same principles involved in the SONAR used by bats, ships, fishermen and the weather services
- When a sound wave strike a object, it bonces back or echoes



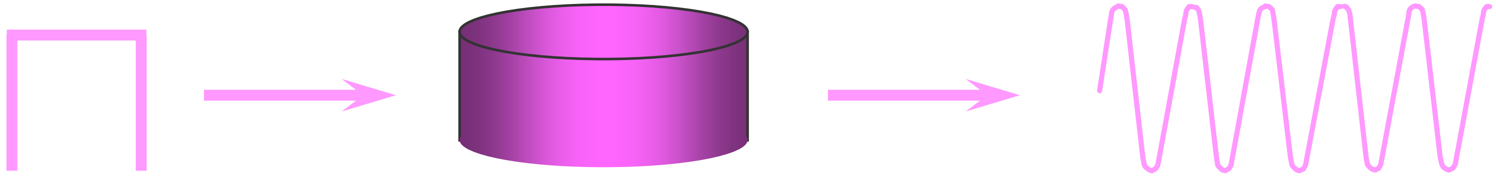
Principle of Ultrasound

- Using known information about the speed of sound in the tissues →
  - Measured time for the echo to be received
  - Distance from the transmitter to organ
  - can be calculated, and used to create an image.
- By measuring these echo waves it is possible to determine
- How far away the object is and its size, shape and consistency

Ultrasound Production

- **Transducer contains**

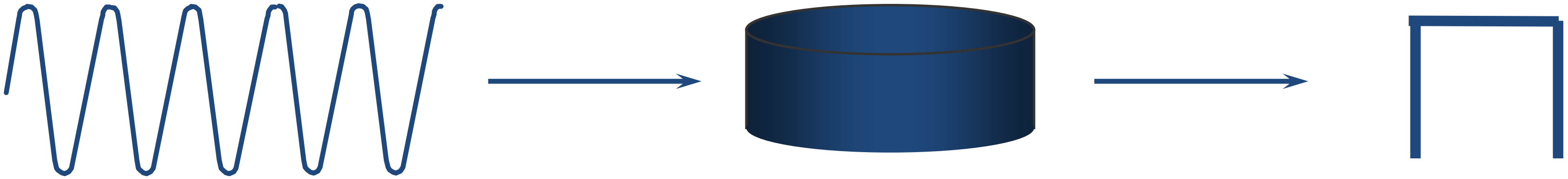
  - Piezoelectric elements/crystals
  - One form of energy to another
  - Produces Ultrasound pulses
  - These elements convert electrical energy into a mechanical ultrasound wave



The Returning Echo

Reflected echoes return to the scan head

- Convert Ultrasound wave into electrical signal
- The electrical signal is then processed by the ultrasound system



Procedure of Ultrasound

- Place a probe on your skin over the part of body to be examined
- Lubricating jelly is put on skin for batter contact with body
- Probe is connected to the wire to the ultrasound machine, which is linked to monitor
- Pluses are sent from the probe through the skin into body

Procedure of Ultrasound

- Ultrasound waves are back as echoes from various structures in the body
- Echoes are detected by probe and sent to ultrasound machine through wire
- They are displayed as a picture on monitor
- Operator moves probe around over surface of the skin to obtain views of different angles
- It can be used to measures the different size

Parts of Ultrasound Machine

Transducer

Probe

Pulse control

CPU (Central Processing Unit)

Key Board

Display

Storage device

Printer

Parts of Ultrasound Machine

Transducer

Transducer Probe

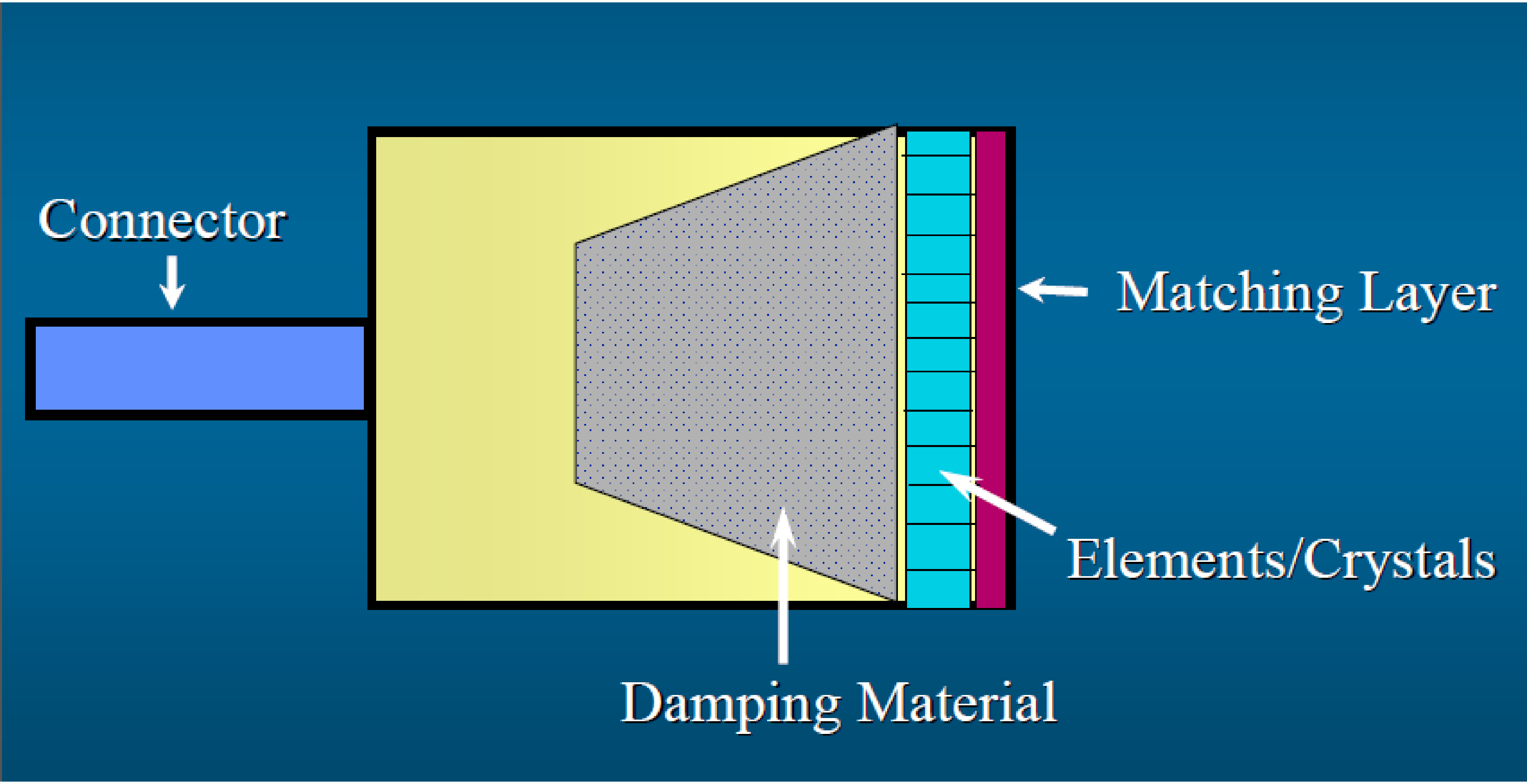
- Mouth and ears of the machine.
- It makes the sound waves and receives the echoes
- Piezoelectric crystals
- Electric current is applied and change shape rapidly
- When sound waves hit the crystals, they emit electrical currents

Transducer

Transducer (pulse controls)

The operator, called the ultra sonographer, changes the amplitude, frequency and duration of the pulses emitted from the transducer probe

Transducer


Connector
Matching Layer
Elements/Crystals
Damping Material

Transducer

Ultrasonic Transducers: Historical Perspective

1880
The Discovery of piezoelectricity
By Curie Brothers

1917
The ultrasonic submarine detector
By P. Langevin

1940
Piezoelectric ceramics

1969
A piezoelectric polymer: PVDF

1980
Piezocomposites

1915
Electrostatic transducers considered
for the ultrasonic submarine detector
by P. Langevin

1970-1990
Advances in microelectronics

1994
Micromachined electrostatic
transducers by M. Haller and
B.T.Khuri-Yakub

Transducer

Matching Layer

- Has acoustic impedance between that of tissue and the Piezoelectric elements
- Reduces the reflection of ultrasound at the scan head surface

Piezoelectric Elements

- Produce a voltage when deformed by an applied pressure
- Quartz, ceramics, man-made material

Damping Material

- Reduces “ringing” of the element
- Helps to produce very short pulses

Piezoelectric Crystals and Frequency

The frequency of the scan head is determined by the thickness of the crystals

Thinner elements

↓

Higher frequency (10MHz)

↓

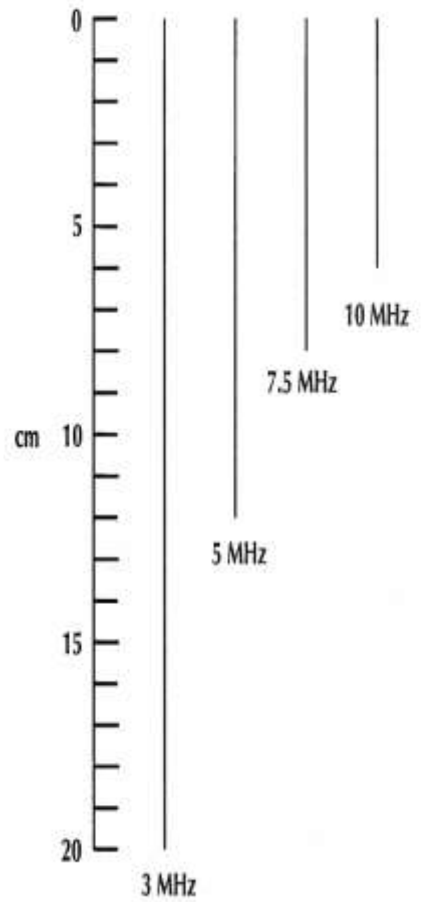
Shorter Wavelength

↓

Less Penetrate

↓

Better Resolution



Thicker elements

↓

Lower frequency (3MHz)

↓

Longer Wavelength

↓

Deeper penetration

↓

Poorer resolution

Selection of Transducer

Superficial vessels and organs (1 to 3cm depth)

- 7.5 to 15 MHz

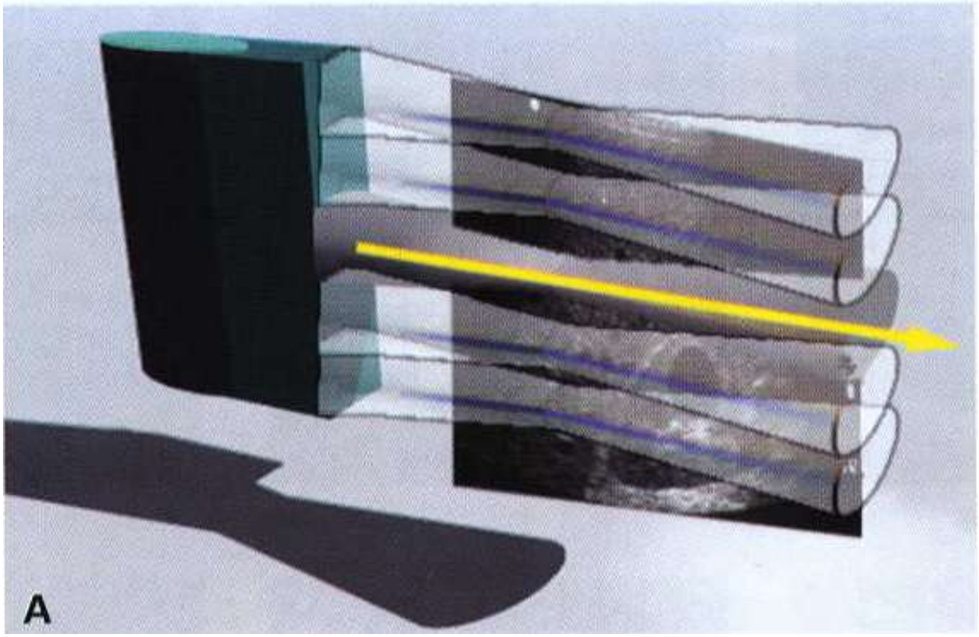
Deeper structures in abdomen and pelvis (12 to 15cm)

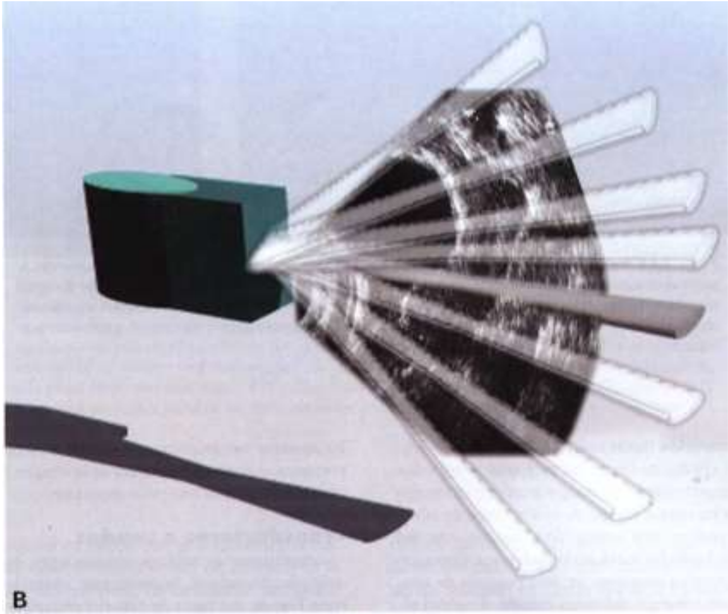
- 2.25 to 3.5 MHz

TYPES OF ELECTRONIC Probes

Linear Array

Phased Array





TYPES OF TRANSDUCERS

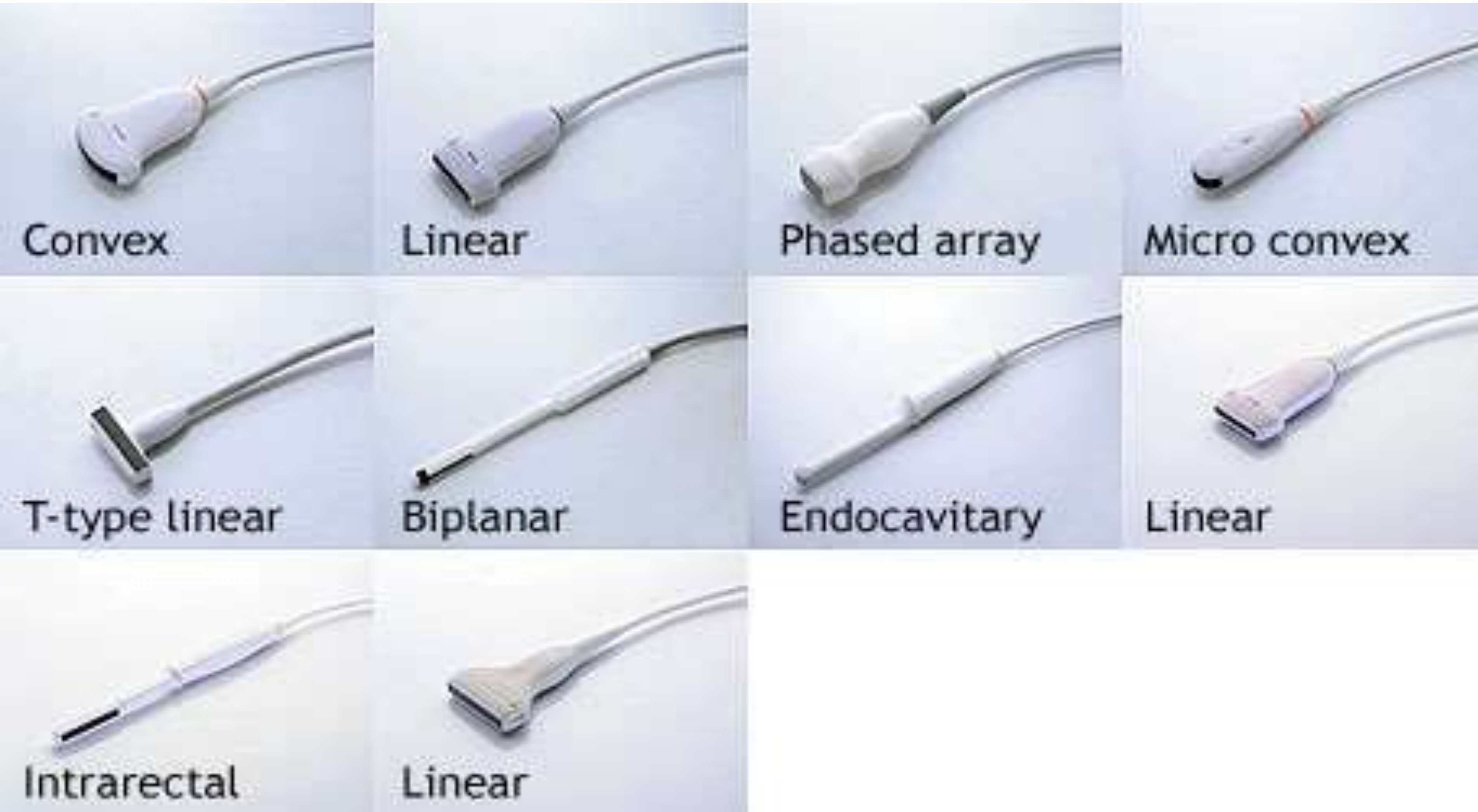
The ultrasound transducers differ in construction according to

- Piezoelectric crystal arrangement
- Aperture (footprint)
- Operating frequency (which is directly related to the penetration depth)

Types of Ultrasound Transducer

	Sector Transducer	Linear Transducer	Convex Transducer
Crystal Arrangement	phased array	linear	Curvilinear
Footprint Size	small	Big (small for hockey transducers)	Big(small for the micro convex
Frequency	1-5 MHz	3-12 MHz	1-5 MHz
Beam Shape	sector, almost triangular	rectangular	Convex
Applications	small acoustic windows ,mainly ECHO, gynecological ultrasound, upper body ultrasound	USG of superficial structures e.g. obstetrics ultrasound , breast, thyroid, vascular ultrasound	useful in all USG types except ECHO, typically abdominal ,pelvic and lung (micro convex transducer

Types of Ultrasound Transducer

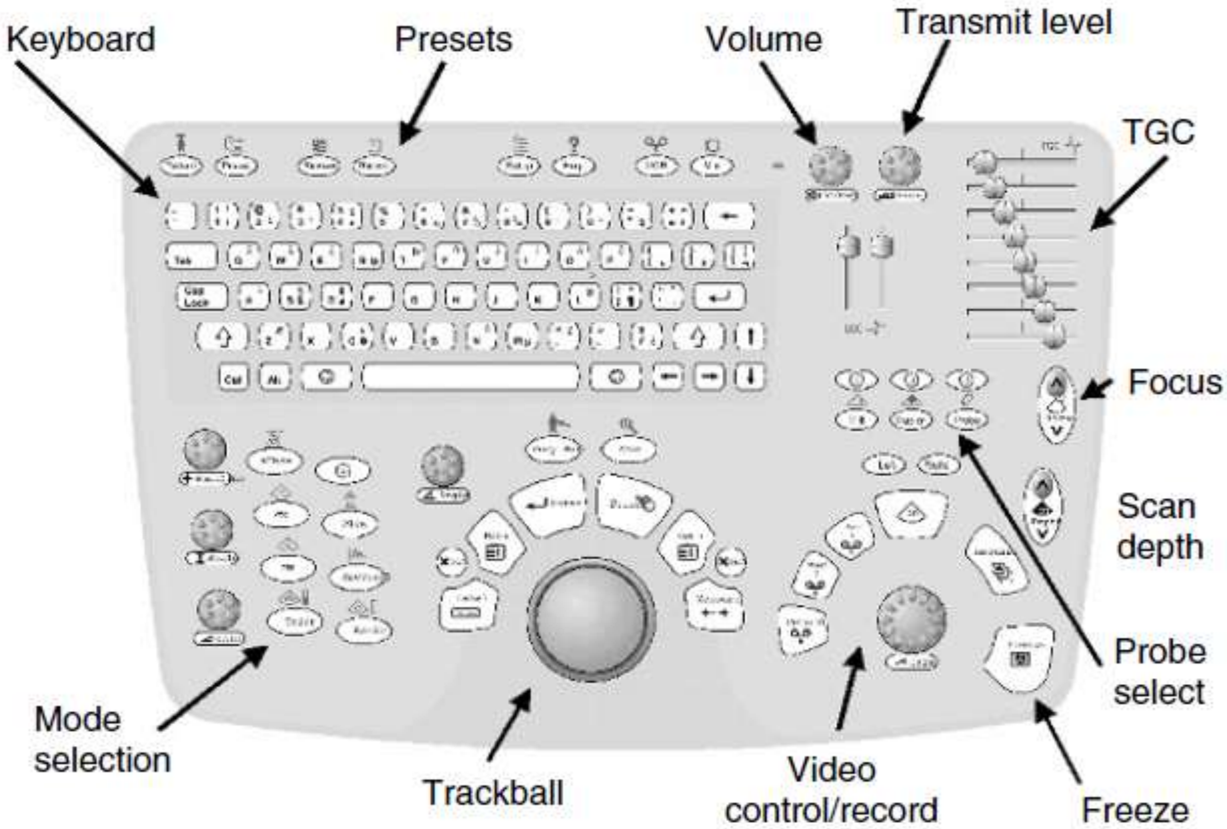


Central Processing Unit (CPU)

- Brain of an ultrasound machine
- Contains the microprocessor, memory and amplifiers
- The transducer receives electrical currents from the CPU and sends electrical pulses that are created by returning echoes

Keyboard/Cursor

It allows the operator to add notes and to take measurements of the image



Display

- Displays the image from the ultrasound data processed by the CPU
- This image can be either in black-and-white or color, depending upon the model of the ultrasound machine

How is an image formed on the monitor?

- The **amplitude** of each reflected wave is represented by a dot
- The **position** of the dot represents the depth from which the echo is received
- The **brightness** of the dot represents the strength of the returning echo
- These dots are combined to form a complete image

How is an image formed on the monitor?

- **Strong Reflections** = White dots

Pericardium, calcified structures, diaphragm

- **Weaker Reflections** = Grey dots

Myocardium, valve tissue, vessel walls, liver

- **No Reflections** = Black dots

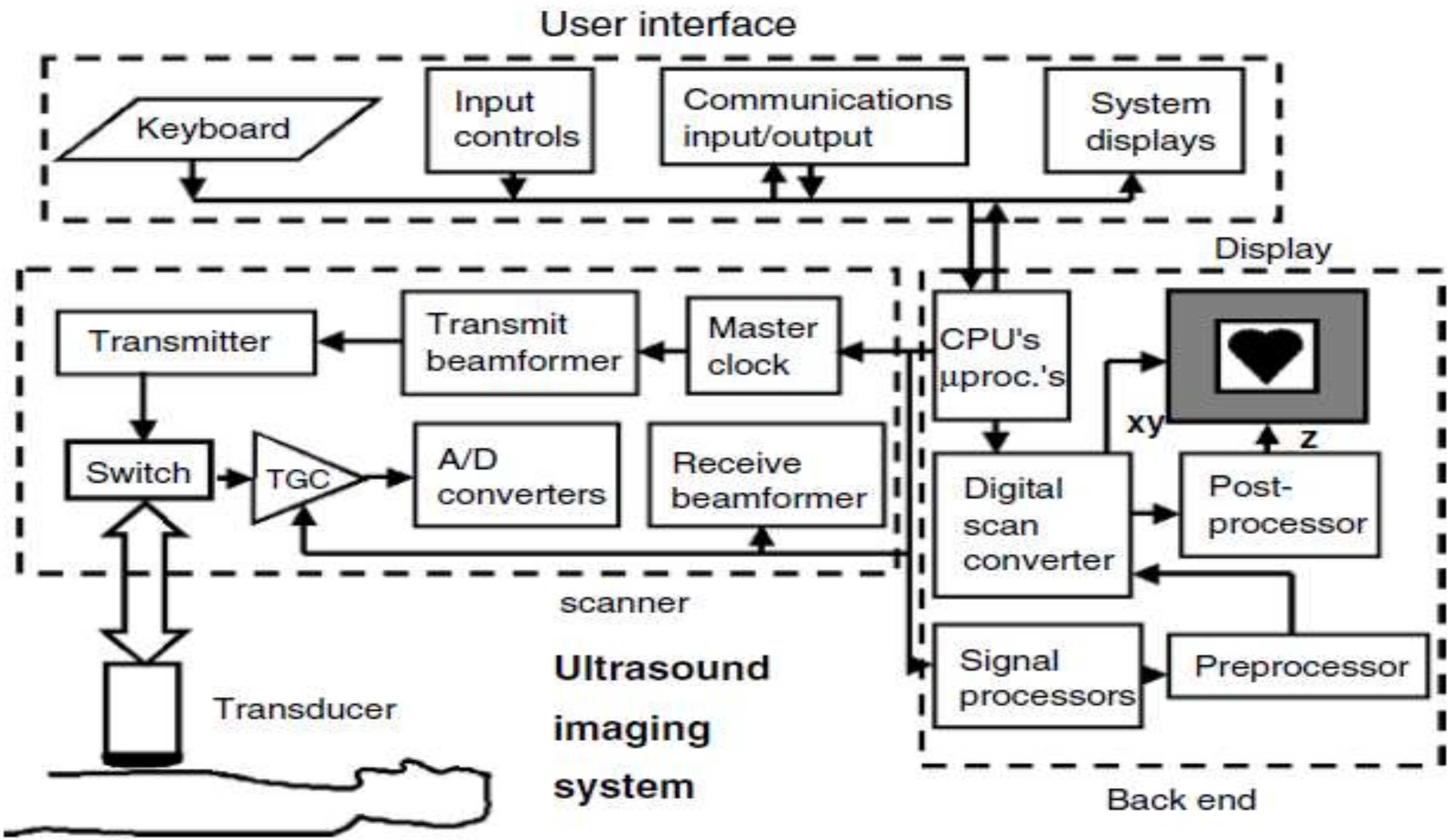
Intra-cardiac cavities, gall bladder

Disk Storage & Printers

The processed data and images can be stored on disks

- Hard disks, floppy disks, compact disks (CDs), or digital video disks (DVDs)
- Most of the time, ultrasound scans are filled on floppy disks and stored with the patient's medical records
- Most ultrasound machines have printers which are thermal

Block Diagram

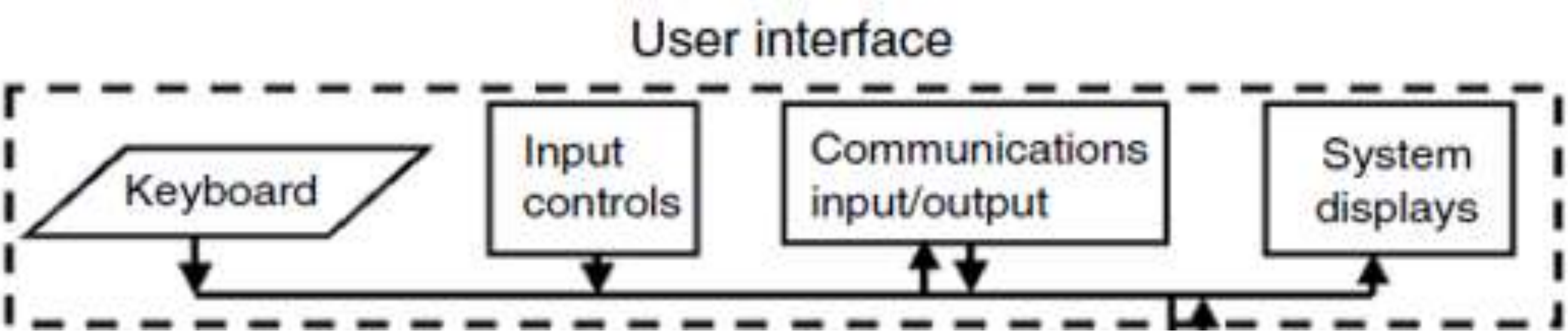


Main Parts of Block Diagram

- User interface
- Controller
- Front End
- Scanner(beamforming and signal processing)
- Back End

User interface

- Desired mode of operation
- Information in and out of the system through connectors to the system
- VCRs & memory storage devices such as read/write CD-ROMs and DAT drives



Controller

- System have one or more microprocessors
- Senses the settings of the controls and input devices
- Control the hardware to function in the desired mode.
- Estimate the level of acoustic output in real time

Front End

- This grouping within the scanner is the gateway of signals going in and out of the selected transducer
- Pulses are sent to the transducer from the transmitter circuitry
- Pulse-echo signals from the body are received by array elements These signals then pass on to the receive beam former.

Front End

- Organizing the many signals of the elements
- The transmit beamformer sends pulses to the elements
- Analog to Digital Converter
- Filters

Scanner(beamforming and signal processing)

- This grouping of functions is associated with image formation, display and image metrics
- Image formation is achieved by organizing the lines and putting them through a digital scan converter that transforms them into a scan format for display on a video or PC monitor.
- Image overlays containing alpha-numeric characters and other information are added in image planes

2D Ultrasound

- Traditional ultrasound scanning
- Probe sends and receives ultrasound frequency waves in one plane
- Waves which are reflected back are black-and-white images of the fetus in a flat plane.
- The ultrasound transducer Toshiba is moved across the stomach to enable numerous viewing planes

3D Ultrasound

- More advanced development of imaging technology has promoted volume data or differing two-dimensional images which are created by reflected waves at angles which different from one another
- High-speed computing software then integrates this information to create a 3D image

4D Ultrasound

- This Ultrasound technology enables live streaming of 3D images
- In other words, patients can view the live motion of the fatal valves, heart wall blood flow, etc.
- 4D ultrasound technology is 3D ultras motion.
- A 3D transducer is utilized
- GE’sVoluson E10 4D ultrasound macl

Applications

- Gynecology
- Anesthesiology
- Cardiology
- Gastroenterology
- Obstetrics
- Urology

Gynecology

Gynecologic sonography is used extensively

- To assess pelvic organs
- To diagnose and manage gynecologic problems including, leiomyoma, ovarian cysts and lesions,
- To Identify Pregnancy,
- To Diagnose Gynecologic Cancer

Advantages of Ultrasounds

- No needles or injections and they are usually painless
- They are less expensive
- No ionizing radiation
- Gives a clear picture of soft tissues
- It has been used to evaluate pregnancy for nearly forty years.
- Doctors are provided with lots of useful information from the ultrasound

The Future OF Ultrasound

HIGH POWER ULTRASOUND TECHNOLOGY

- Reduce or eliminate the need for chemicals or heat application in a variety of industrial processes
- Food safety related areas
- Innovative Ultrasonic company
- The use of high-power ultrasonic in industry is rapidly expanding throughout Europe and North America