

ULTRASONICS

INTRODUCTION

- The word *ultrasonic* combines the Latin roots
ultra - '*beyond*'
sonic - *sound*.
- Having frequencies above the audible range
i.e. above 20000Hz
- Have applications for imaging, detection and navigation.
- The broad sectors of society that regularly apply ultrasonic technology
are the medical community, industry and the military.

PROPERTIES

- High energy content.
- Like ordinary sound waves, ultrasonic waves get reflected, refracted and absorbed.
- Transmitted over large distances with no appreciable loss of energy.
- Form stationary waves in a liquid, it serves as a diffraction grating, called an *acoustic grating*.
- Produce intense heating effect when passed through a substance.

PRODUCTION OF ULTRASONIC WAVE

- (1) Magnetostriction generator or oscillator
- (2) Piezo-electric generator or oscillator

MAGNETO-STRICTION GENERATOR

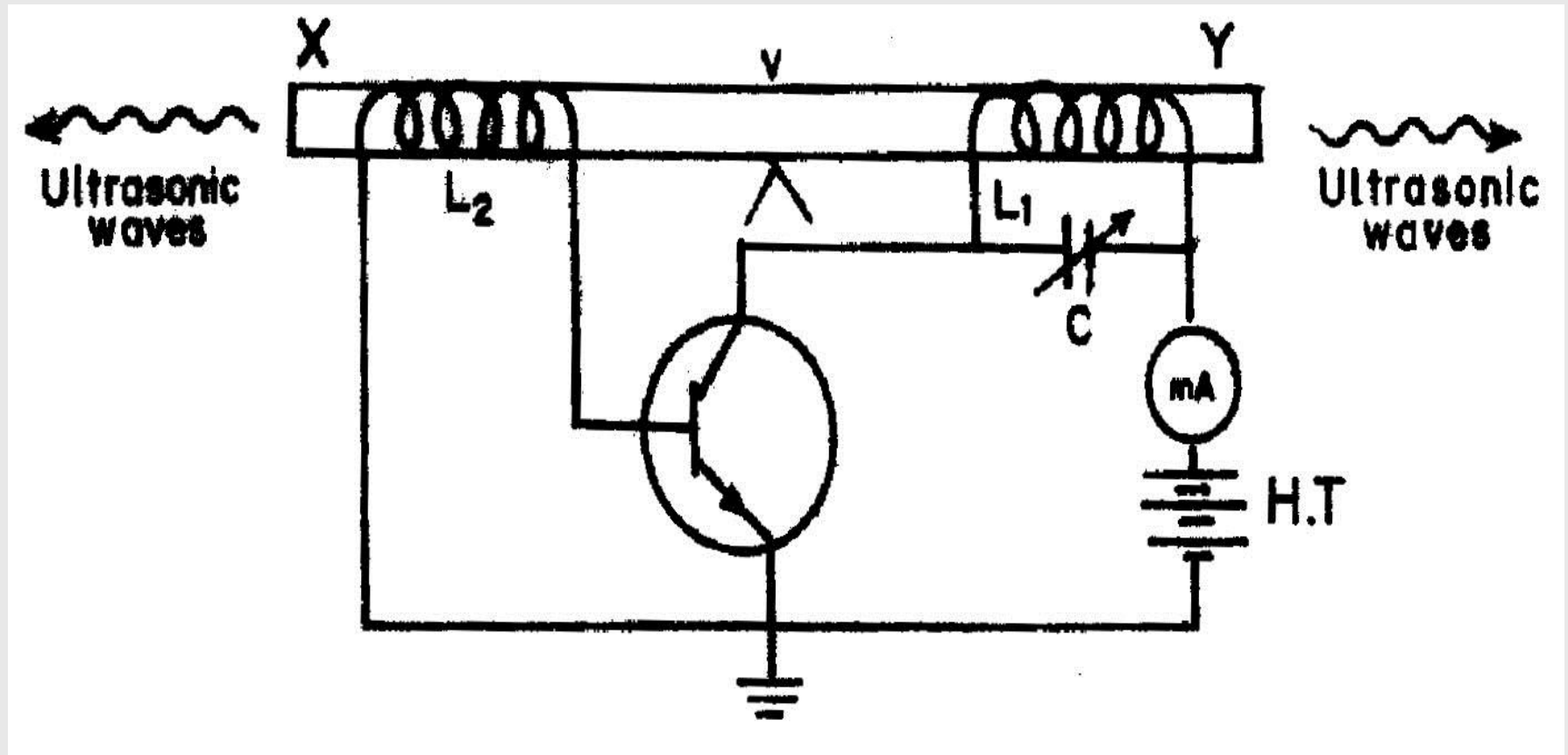
Principle: Magnetostriction effect

When a ferromagnetic rod like iron or nickel is placed in an alternating magnetic field parallel to its length, the rod experiences a small change in its length.

The change in length (increase or decrease) produced in the rod depends upon

- (i) the strength of the magnetic field
- (ii) the nature of the materials and
- (iii) independent of the direction of the magnetic field applied.

Construction



At Resonance condition

frequency of collector circuit = frequency of vibration of the rod

$$f = \frac{1}{2\pi\sqrt{L_1 C}}$$

$$f = \frac{1}{2l} \sqrt{\frac{Y}{\rho}}$$

Advanatages

- very simple design
- production cost is low
- large power output without the damage of the oscillatory circuit.

Disadvanatges

- cannot generate ultrasonic frequency above 3000 kHz (3MHz).
- frequency of oscillations depends on temperature.
- energy loss due to hysteresis and eddy current.

PIEZO ELECTRIC METHOD

PRINCIPLE

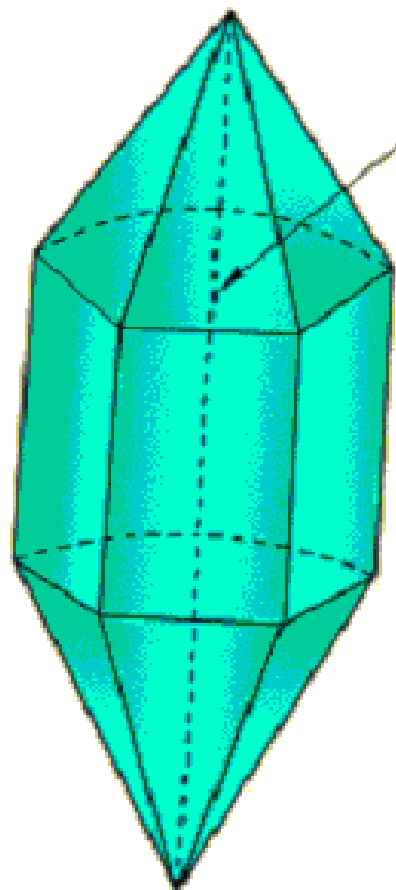
Piezo electric effect:

If one pair of opposite face of a crystal is subjected to pressure, the other pair of opposite faces develops electric charge.

Inverse Piezo electric effect:

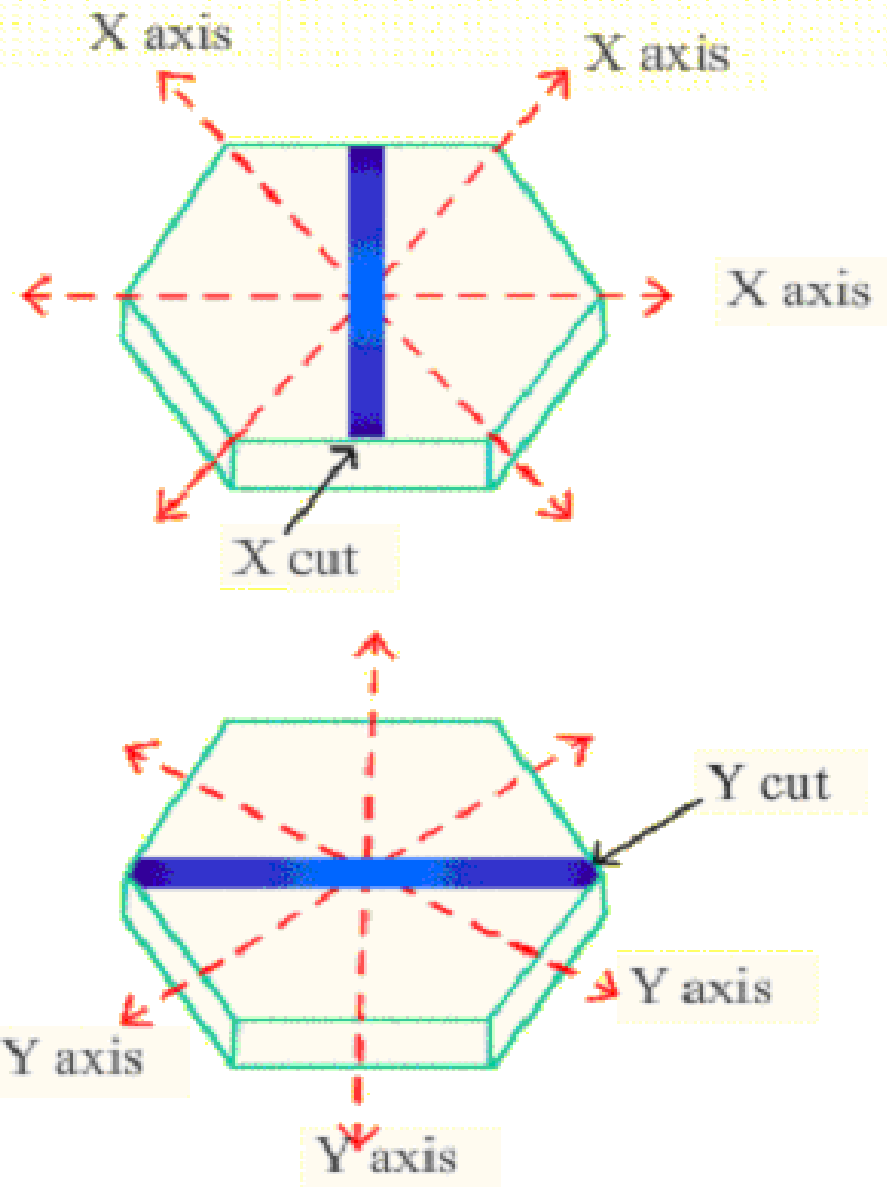
If the alternating voltage is applied to one pair of faces, the opposite faces expands and contracts periodically thereby generating elastic waves.

Example: Quartz, tourmaline and Rochelle salt

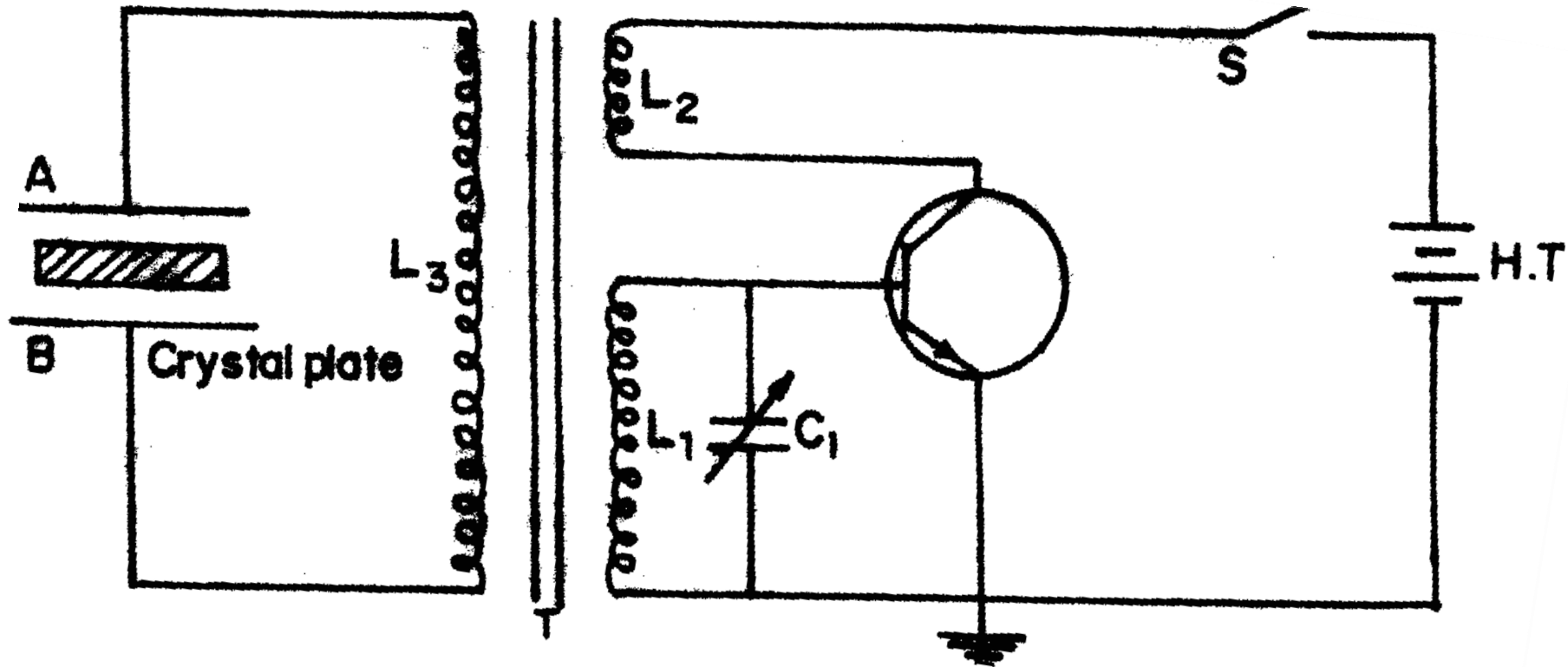


z-axis

Neutral crystal



Construction



At Resonance condition

frequency of collector circuit = frequency of vibration of the crystal

$$f = \frac{1}{2\pi\sqrt{L_1 C}}$$

$$f = \frac{P}{2l} \sqrt{\frac{Y}{\rho}}$$

where $P = 1, 2, 3, 4 \dots$ etc. for fundamental, first over tone, second over tone etc.,

Advantages

- Ultrasonic frequencies as high as 500 MHz can be obtained
- Output of this oscillator is very high.
- Not affected by temperature and humidity.

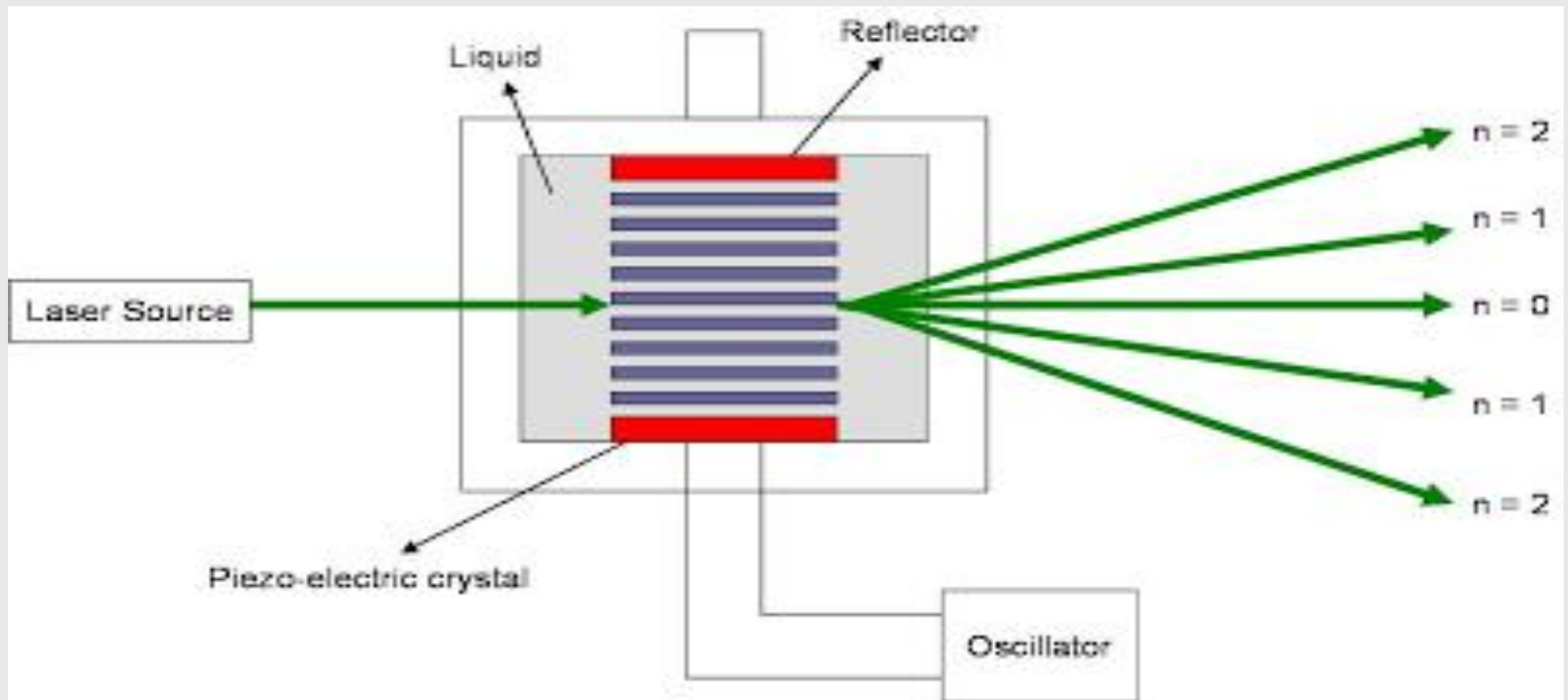
Disadvantages

- Cost of piezo electric quartz is very high
- Cutting and shaping of quartz crystal are very complex

ACOUSTING GRATING

Principle:

In the presence of ultrasonic waves, the density of the liquid varies layer by layer due to the variation in pressure and hence the liquid will act as a diffraction grating



According to the theory of diffraction,

$$d \sin \theta_n = n \lambda \quad \text{---(1)}$$

where $n = 0, 1, 2, 3, \dots$ is the order of diffraction

λ = wavelength of light used

d = distance between two adjacent nodal or anti-nodal planes.

If λ_a is the wavelength of the ultrasonic waves through the medium, then

$$\lambda_a = 2d \text{ (or) } d = \lambda_a/2 \quad \text{---(2)}$$

Subst. (2) in (1)

$$(\lambda_a/2) \sin \theta_n = n \lambda$$

$$\lambda_a = \frac{2n\lambda}{\sin \theta_n} \quad \text{---(3)}$$

velocity of the ultrasonic waves

$$V = f \lambda_a.$$

$$V = \frac{2 n f \lambda}{\sin \theta_n}$$

From these measurements, many parameters of the liquid such as free volume, compressibility, etc., can be calculated.

NON DESTRUCTIVE TESTING

What is NDT?

- a method of finding defects in an object without harming the object.

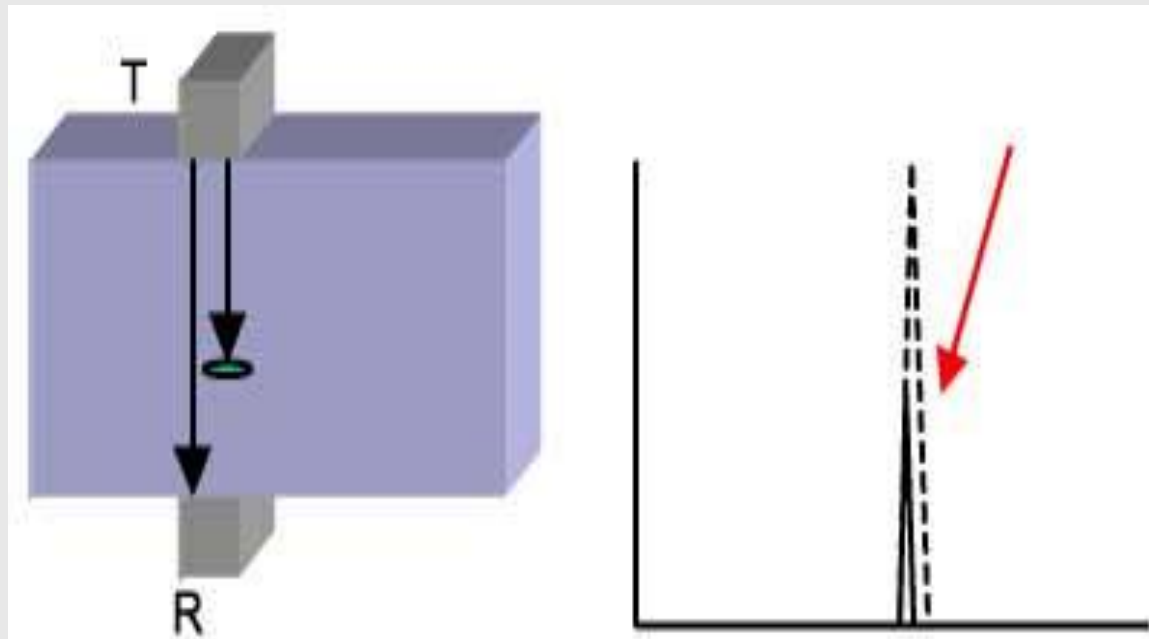
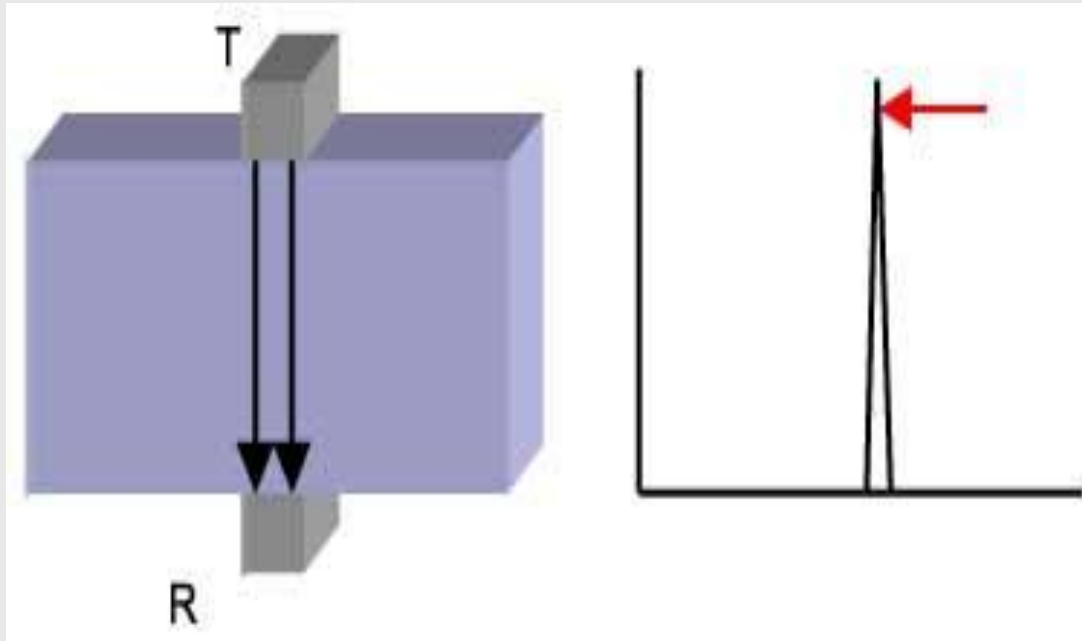
Most Common NDT Methods

- Visual Inspection Method
- Liquid Penetrant Method
- Magnetic Particle Inspection
- Ultrasonic Flaw Detection
- Eddy Current Testing
- X-Ray Diffraction Method

How is ultrasound used in NDT?

- Ultrasonic waves are emitted from a transducer into an object and the returning waves are analyzed.
- If an impurity or a crack is present, the sound will bounce off of them and be seen in the returned signal.
- There are two methods of receiving the ultrasound waveform:
 - Attenuation (or through-transmission) and
 - Reflection (or pulse-echo) mode

THROUGH TRANSMISSION METHOD



Advantages

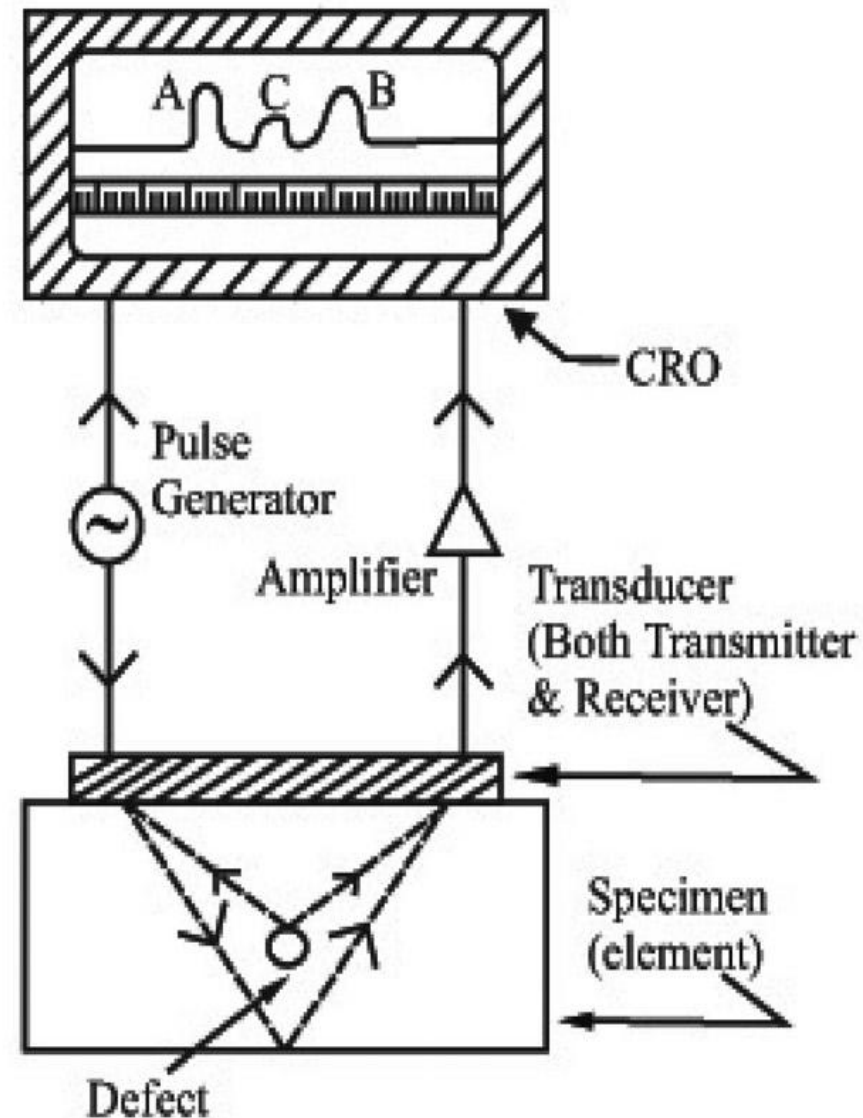
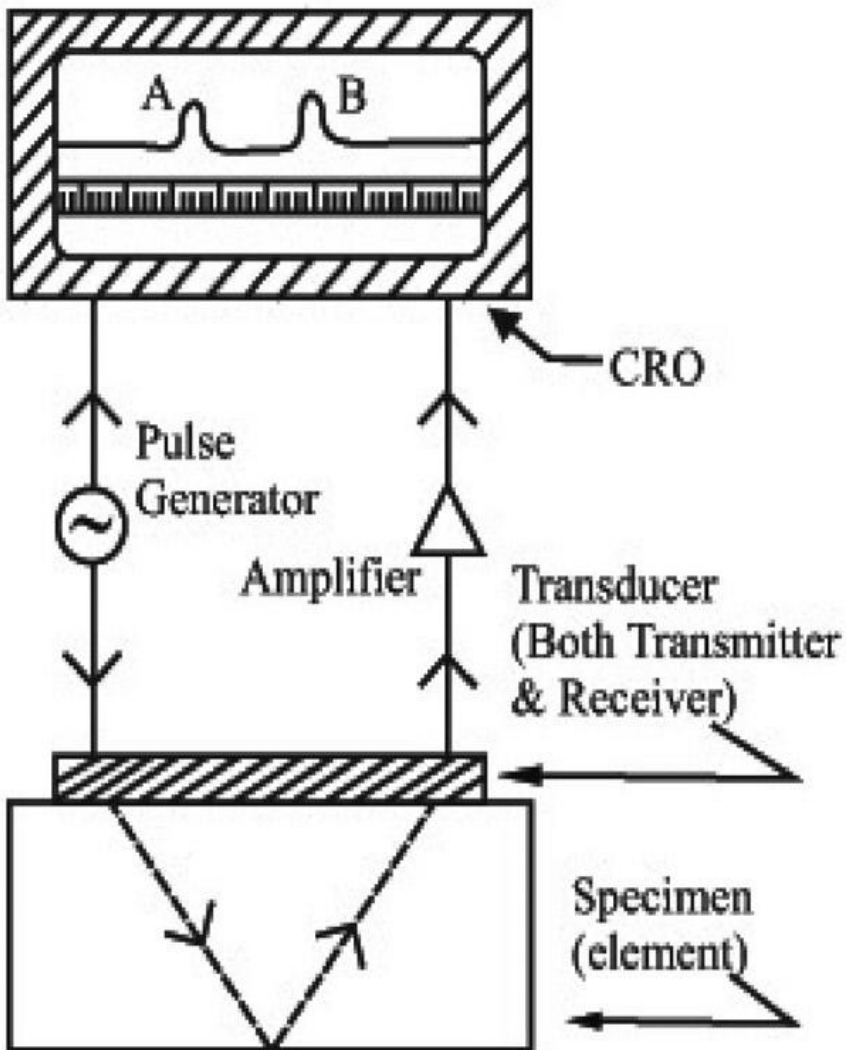
- Less attenuation of sound energy
- No dead zone on the screen
- orientation of a defect does not matter in the way that it does on the pulse echo display.

Disadvantages

- defect cannot be located
- component surfaces must be parallel
- Vertical defects do not show
- does not provide depth information
- There must be access to both sides of the component.

PULSE-ECHO SYSTEM THROUGH REFLECTION MODE

*Reflected ultrasound (**echoes**) comes from an interface, such as the back wall of the object or from an imperfection within the object*



Advantages

1. High penetrating power
2. High sensitivity (detection of extremely small flaws).
3. Only one surface needs to be accessible.
4. Greater accuracy
5. Some capability of estimating the size, orientation, shape and nature of defects.
6. Non hazardous to operations or to nearby personnel.
7. Capable of portable or highly automated operation.

Disadvantages

1. Manual operation requires careful attention by experienced technicians.
2. Extensive technical knowledge is required
3. Parts those are rough, irregular in shape, very small or thin, or not homogeneous are difficult to inspect.
4. Surface must be prepared by cleaning and removing loose scale, paint, etc.,
5. Couplants are needed to provide effective transfer of ultrasonic wave energy between transducers and parts
6. Inspected items must be water resistant, when using water based couplants that do not contain rust inhibitors.

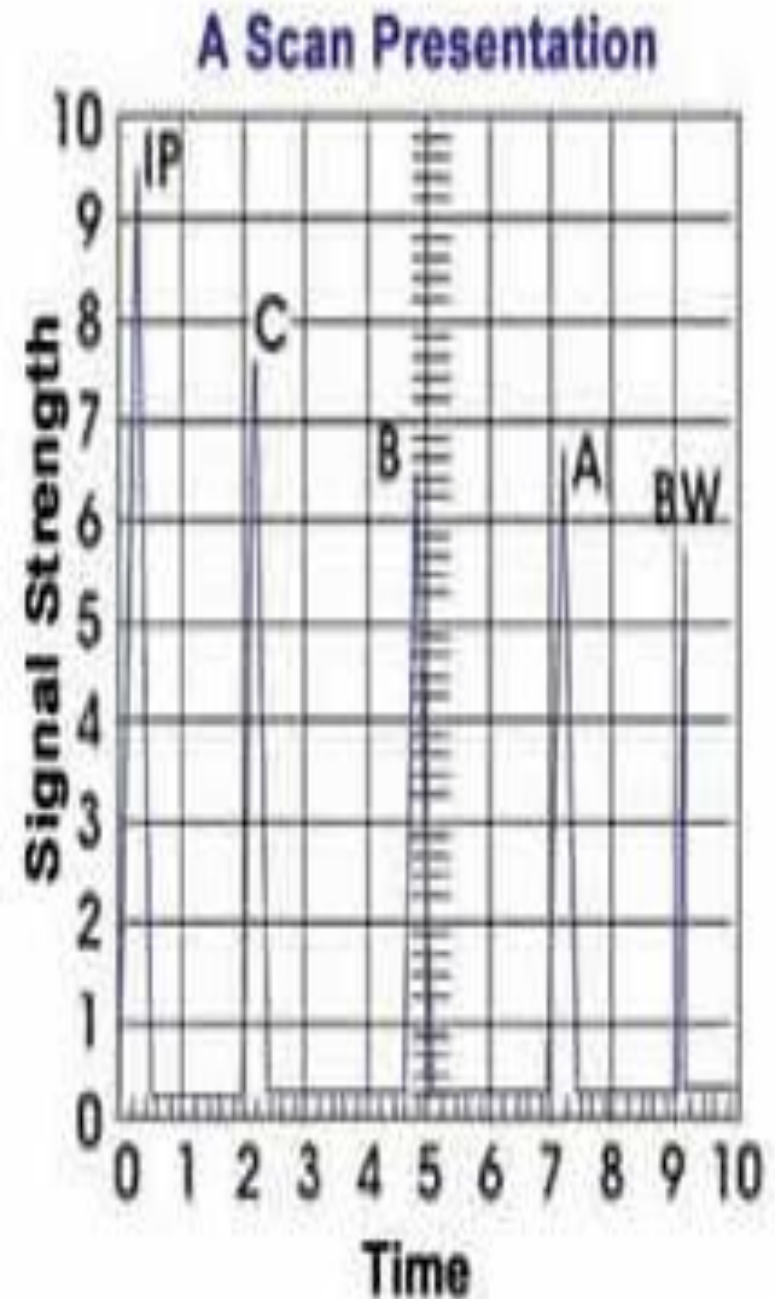
MODE OF DISPLAYS

- Ultrasonic data can be collected and displayed in a number of different formats.
- The three most common formats are known in the NDT world as
 - A-scan
 - B-scan and
 - C-scan presentations.

A-Scan (Amplitude mode display)

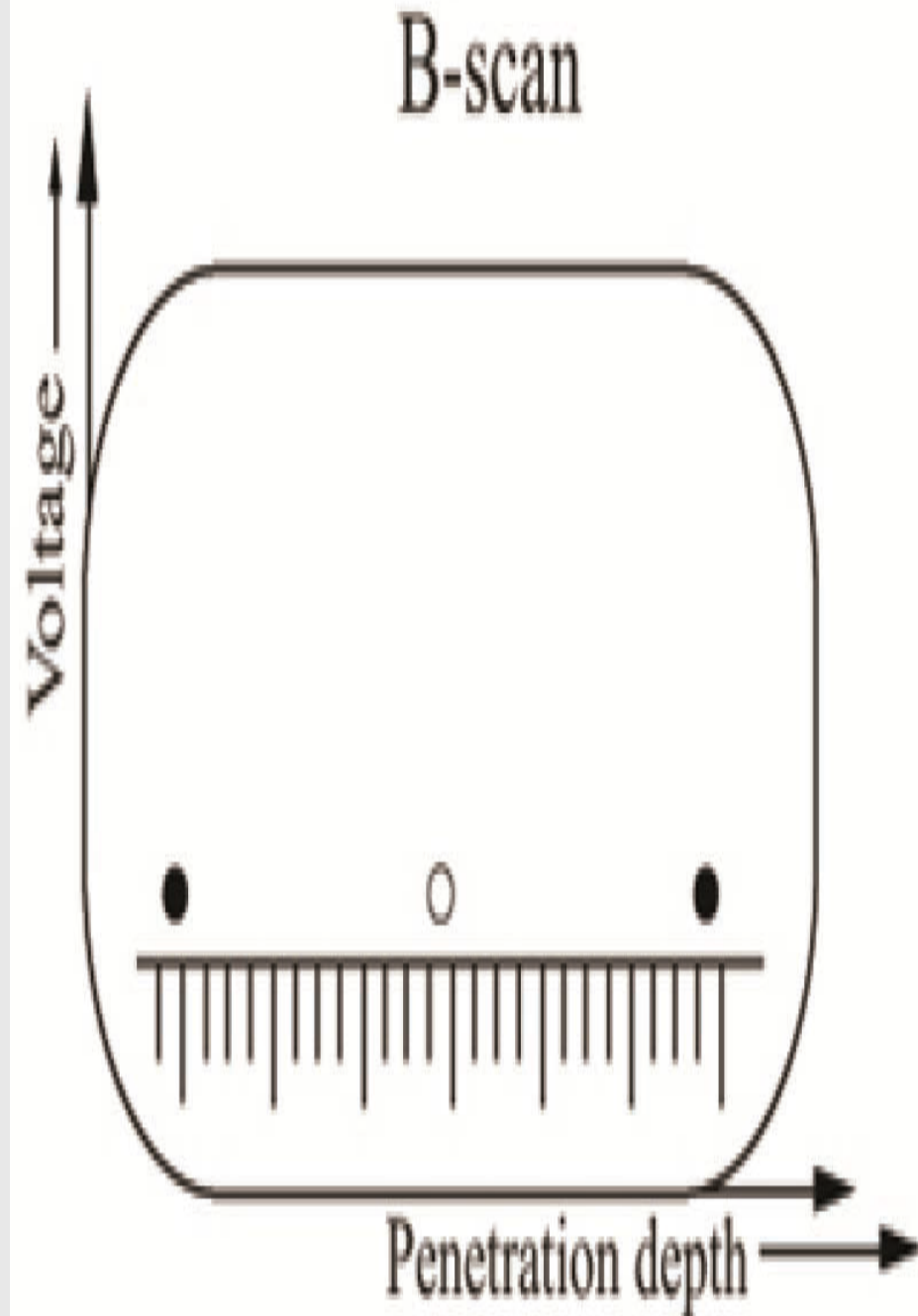
- Gives one dimensional information.
- Echoes are displayed as vertical spikes as a function of depth
- The height of the spike is proportional to the strength of the echo.
- Distance at which the defect present

$$D = V. T$$



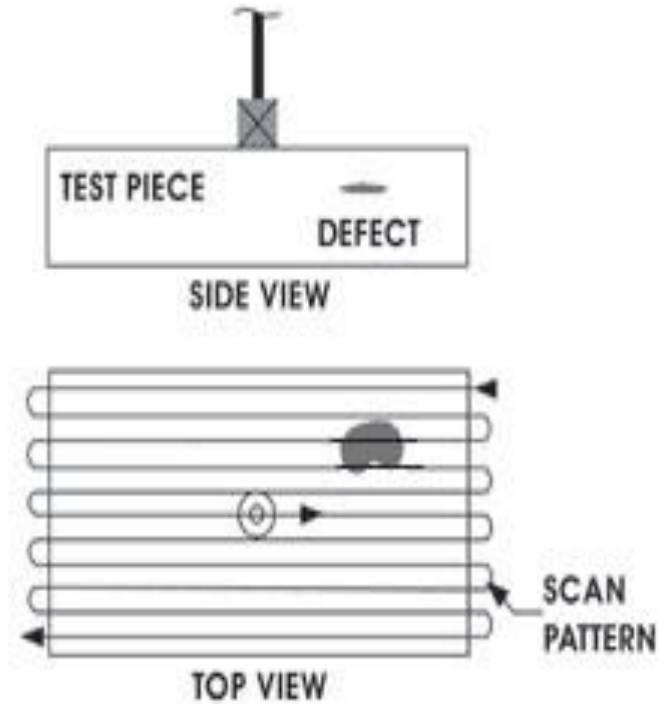
B-scan (Brightness mode display).

- Gives 2-dimensional image
- Transducer can be moved.
- Echoes are displayed as dots
- The brightness and size of the dot depends on the intensity and strength of the reflected echo respectively.



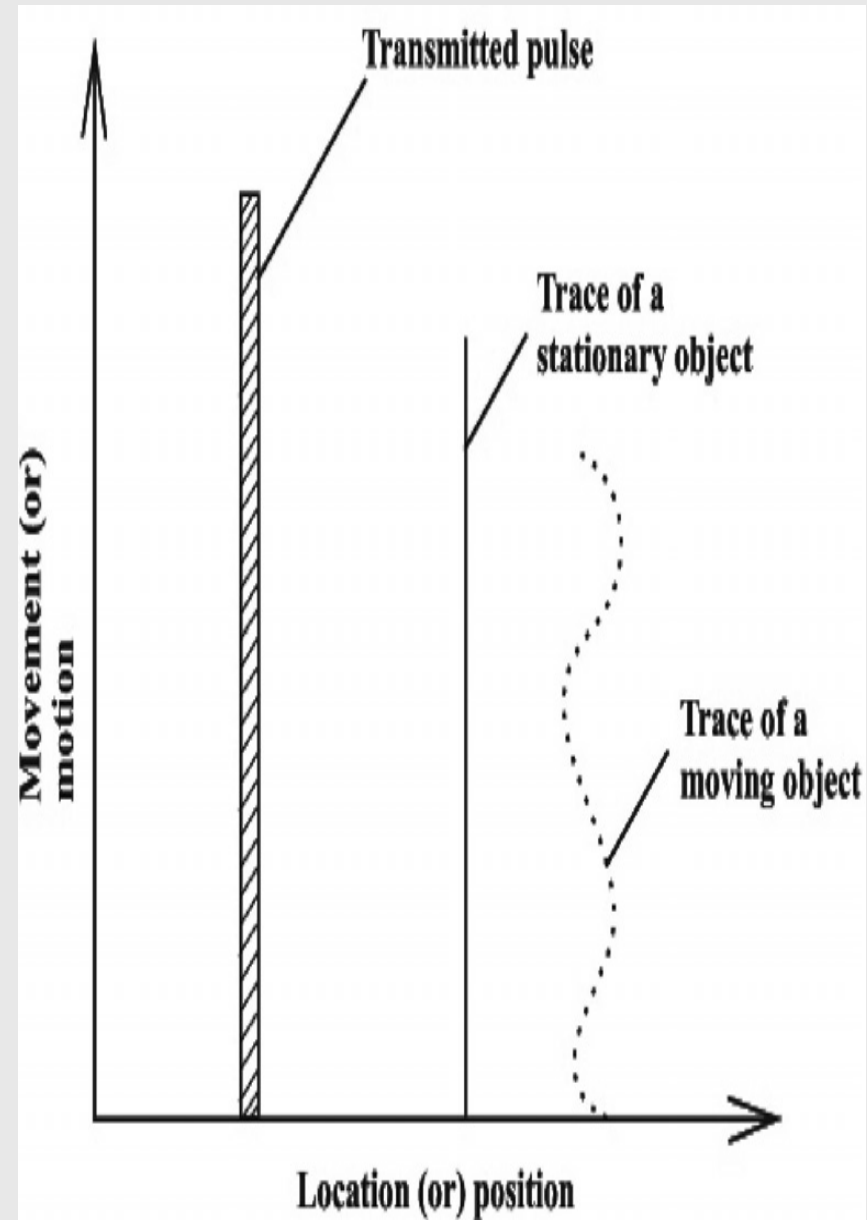
C-scan

- Two-dimensional information that provides the location and size of defect
- Scanned over the test piece.
- The relative signal amplitude is displayed as a shade of gray or a color for each of the positions



T.M. Scan(time-motion mode display).

- Gives three-dimensional image of the specimen.
- Gives information about the moving object
- Transducer is held stationary as in A-scan and echoes appear as dots as in the B-scan.
- Used for analyzing moving body parts commonly in cardiac and fetal cardiac imaging



SONOGRAM

- A medical procedure that uses ultrasound waves to create a picture of interior parts of the body

How it Works

The creation of an image from sound is done in three steps – producing a sound wave , receiving echoes, and interpreting those echoes.

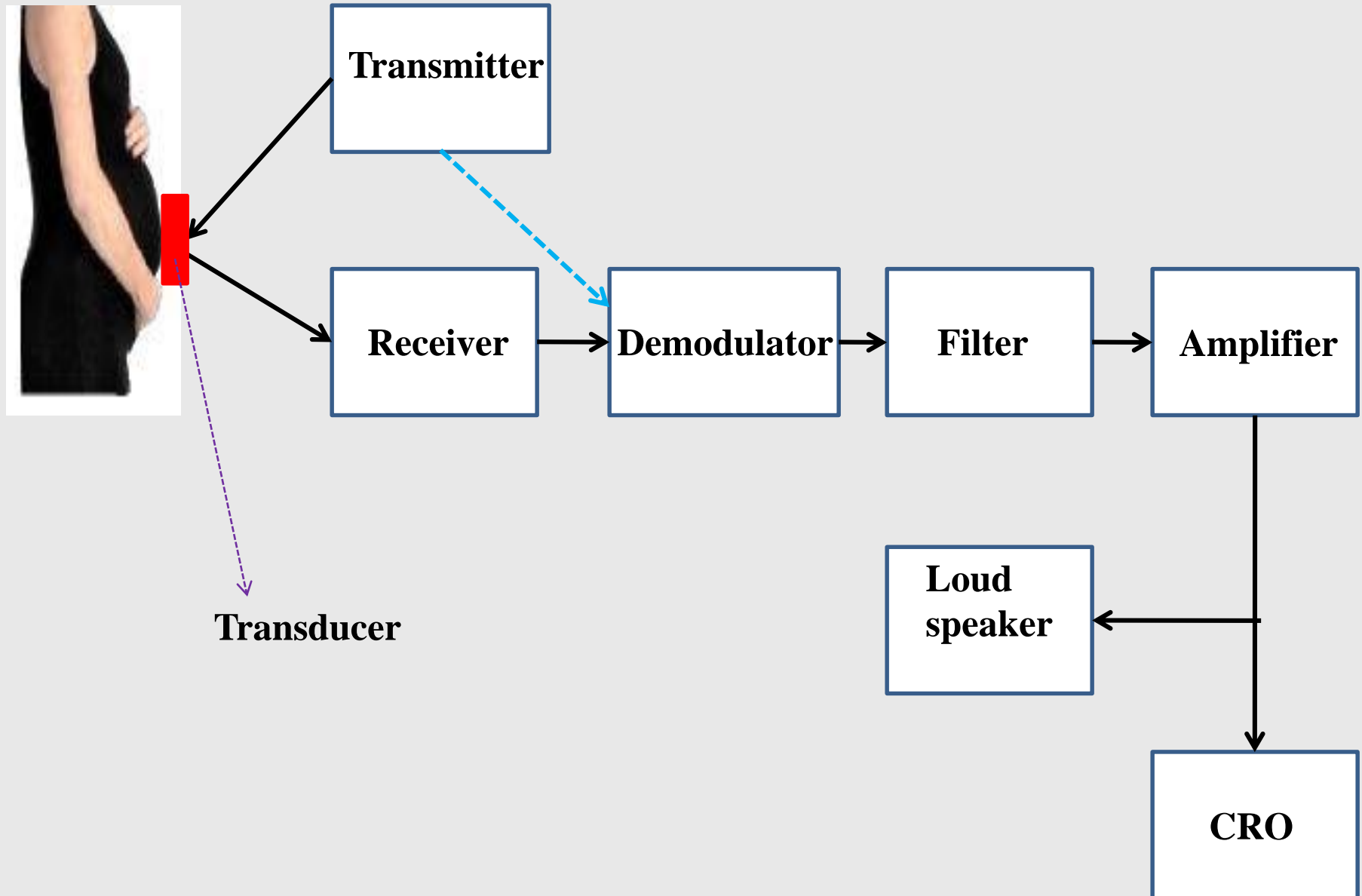
Distance between echoes are calculated in order to generate a very accurate picture, which is displayed on a specialized computer screen.

Ultrasonography is of great value in other obstetric conditions such as:

- Confirm fetal viability
- Determine location of fetus
- Check the location of the placenta in relation to the cervix
- Check for the number of fetuses (multiple pregnancy)
- Check for major physical abnormalities.
- Assess fetal growth
- **Check for fetal movement and heartbeat.**
- Determine the sex of the baby.

fetal movement and heart beat.

Principle : Doppler Effect



Strengths

- ☐ It images muscle, soft tissue, and bone surfaces very well
- ☐ Operator can dynamically select the most useful section for diagnosing.
- ☐ No known long-term side effects
- ☐ Small, Relatively inexpensive, easily carried scanners are available

Weaknesses

- ❖ Sonography performs very poorly when there is a gas between the transducer and the organ of interest, due to the extreme differences in [acoustic impedance](#)
- ❖ High level of skill and experience operator is needed
- ❖ There is no scout image as there is with CT and MRI.

Other Medical Applications of Ultrasonics

Ultrasonics waves are noninvasive medical tool.

- Cancer treatment and neurosurgery.
- To clean teeth and also for dental cutting.
- Used for cataract treatment .
- A fetus in the womb can be viewed in a sonogram.
- Focused ultrasound may be used to break up kidney stones.
- Low-intensity ultrasound has the ability to stimulate bone-growth.
- Ultrasonics guides the blind person who uses ultrasonic guiding stick as a guiding tool

OTHER THAN SYLLABUS

DETECTION OF ULTRASONIC WAVES

- **Quartz crystal method:**

Principle : piezoelectric effect.

- **Thermal Detectors:**

Change in temperature brings about changes in the electric resistance of the platinum wire

antinode : No change in temperature

node : Change in temperature

- **Kundt's tube method**

node : lycopodium powder collects in the form of heaps.

- **Sensitive flame method:**

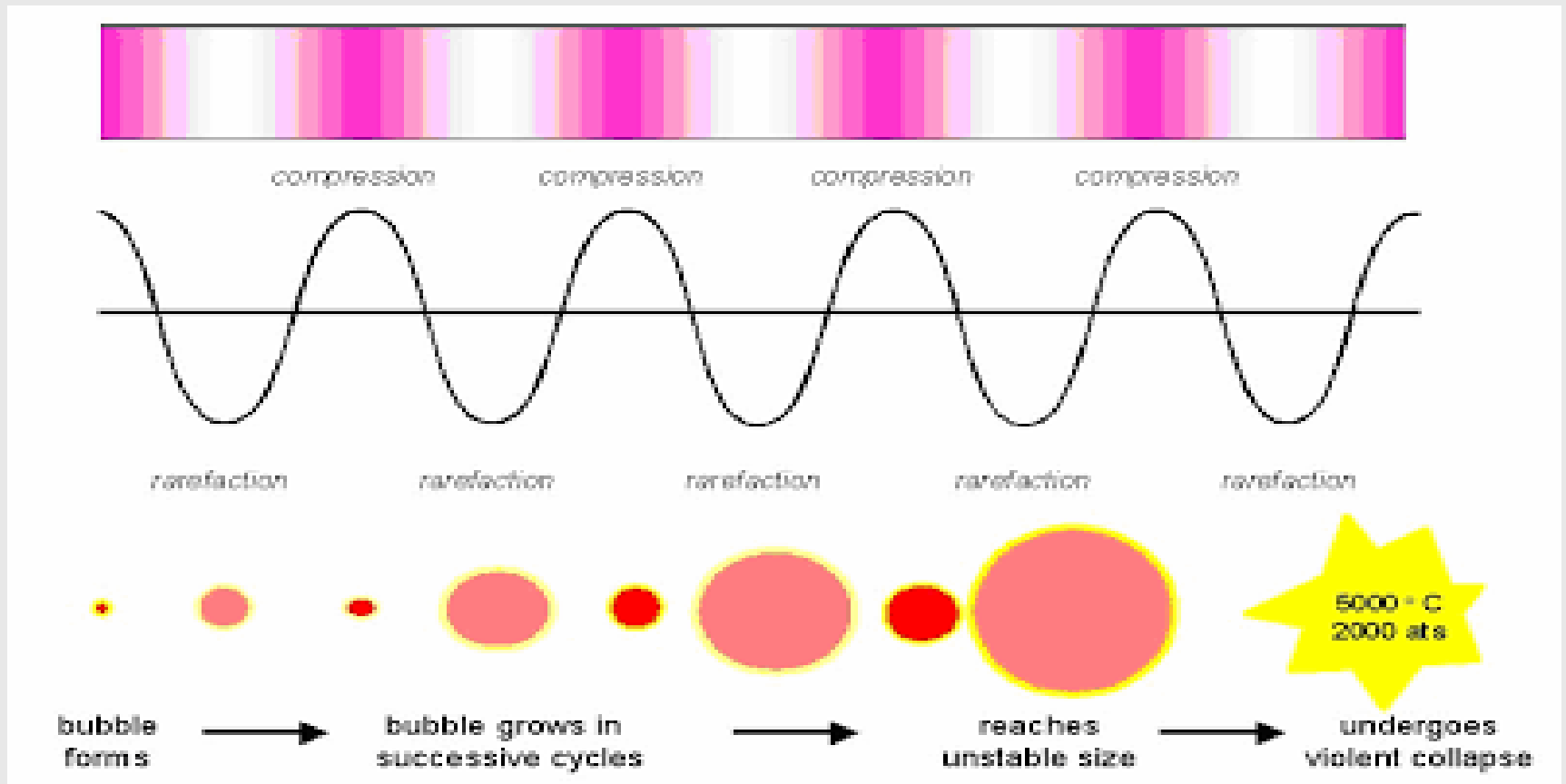
antinodes : the flame is steady.

node : the flame flickers (change in pressure).

CAVITATION:

Rarefaction results in sudden drop in pressure causing growth and collapse of gas bubbles.

When the bubble collapse the pressure increases about 1000 of atmosphere and temperature about $10,000^{\circ}\text{C}$.



APPLICATIONS:

- It is used in ultrasonic cleaning.
- To accelerate chemical reactions.
- To locate mineral and oil deposits.
- It is used for emulsification.

SONAR : SOund Navigation And Ranging.

Principle : echo effect.

To find the depth of sea, direction and distance of a submarine
Distance travelled by the sound wave $2d = VT$.

