ULTRASONIC IMAGING SYSTEM

INTRODUCTION

- The application of ultrasound in medical diagnosis is imaging of the internal organs or internal structures of the body. Ultrasonic images provides valuable information regarding the size, location, displacement or velocity of a selected structure inside the body.

- Ultrasonic waves are sound waves but its frequency range is above audible range (>20kHz). They are directional waves and ultrasonic beams are obtained with little spreading(focusing will be simple).

- The wavelength used to investigate small structures should be of the same order, hence it can be used to investigate the very small dimensional defects. Its wave length is shorter, hence it can be used to investigate the properties of very small internal structures.

- Ultrasonic waves can be transmitted in longitudinal, transverse or shear modes. For the purpose of medical imaging longitudinal waves alone can be used since it can propagate in all types of medium like liquid, solid & Gas

INTRODUCTION

- Wavelength & Frequency

  The relation between the ultrasonic wavelength λ and frequency n is V=n λ where V is the Velocity of propagation of ultrasonic sound. Ultrasonic wave used for medical applications are in the range of 1MHz to 15MHz.

- Velocity of Propagation

  the time taken by the ultrasonic wave to travel from source to the organ and the reflected back to the source is used to calculate the depth of penetration in the medium to reach the organ.

  Depth of penetration to reach the organ =

  (Velocity of sound in that medium * Time)/ 2

ABSORPTION OF ULTRASONIC ENERGY

Amplitude of the received ultrasonic wave decreases due to absorption of energy by the medium when it passes through it. The absorption will be due to reflection, refraction, scattering, diffraction etc. The units for relative intensity and attenuation (or absorption coefficient) of an ultrasound wave are dB and dB/cm.

Table 9.1 Velocity, Characteristic Impedance, Absorption Coefficient of Human Organs

S. No.	*Material*	*Velocity* m/sec	*Impedance* $kg/m^3/sec \times 10^{-4}$	*Absorption coefficient* dB/cm at 1 MHz
1	Air at 20°C	343	4×10^{-4}	12.0
2	Water	1480	1.48	0.002
3	Fat	1450	1.38	0.6
4	Brain	1541	1.58	0.85
5	Liver	1549	1.65	0.9
6	Kidney	1561	1.62	1.0
7	Blood	1570	1.61	0.2
8	Muscle	1585	1.70	2.3
9	Skull bone	4080	7.80	13.0
10	Eye lens	1620	1.84	2.0
11	Soft tissue	1540	1.63	0.8

BASIC PULSE ECHO SYSTEM

- A creation of an image from sound is done in three steps

✓ **Producing a sound waves**

A sound wave is typically produced by a piezoelectric transducer. A piezoelectric crystals have the property that , an induced electric field produces a strain which in turn causes an acoustical wave. They also satisfy the reciprocal property that, a mechanical displacement creates an electric potential, which means that they can also sense an acoustical wave. The crystal produces a voltage across the surfaces when deformed. **Lead Zirconate Titanate** (PbZT) is the piezoelectric material used in nearly all medical ultrasound transducers.

The sound wave is typically produced by a piezoelectric transducer. Strong electrical pulses from the ultrasound machine make the transducer oscillate at desired frequency. The sound is focused to the concerned body part either by the shape of the transducer or by the process called beam forming.

This focusing helps the wave travel into the body and focus at a desired depth. The sound wave is partially reflected from the layers between different tissues. Some of the reflections return to the transducer.

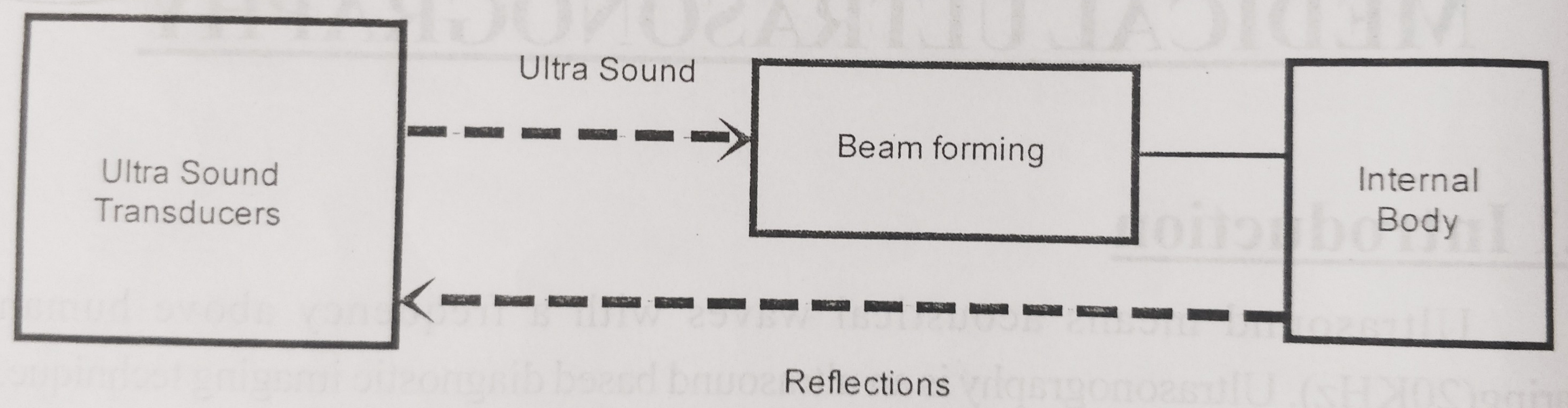

Figure 7.2 : **Producing a sound wave**

✓ **Receiving the echoes**

The returning reflections make the transducer to vibrate and these vibrations are converted into electrical pulses. The pulses are passed through an ultrasonic scanner and they are processed and transformed into digital images.

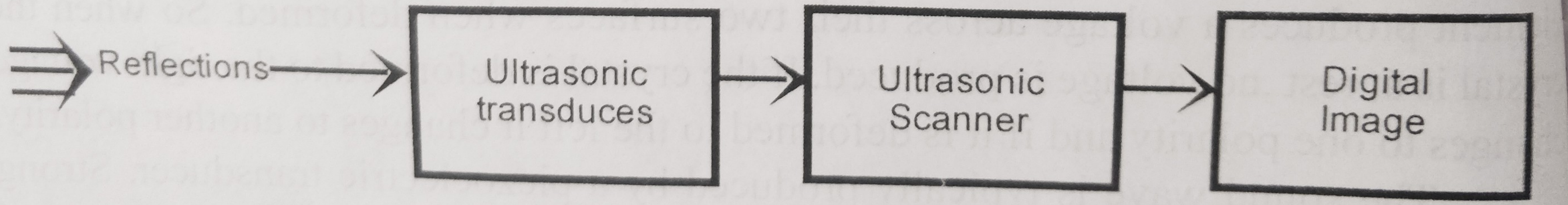

Figure 7.4 : **Receiving the echoes**

- ✓ **Forming the images**

The ultrasonic scanner determines how long it took the echoes to return back to the transducer after the sound waves was sent. It will also determine the strength of the echo. The time taken by the echo to travel back to the probe are measured and it is used to calculate the depth of the tissue interface causing the echo. After this reception of echoes the ultrasonic scanner produces a digital image.

Generally Ultrasound imaging can be operated in three modes depending upon the applications. These are 1) A scan Imaging

2) B scan Imaging 3) M scan Imaging

SCAN MODES

1. A-SCAN MODE

This method is the simplest and oldest among other methods. It gives only one dimensional information. A scan mode a single transducer fires sound pulses into the tissue and the echoes are analysed. The echoes are applied to the Y plates of the CRT so that they are displayed as vertical deflections on the CRT screen. The vertical sweep is calibrated in units of distance and provides vertical deflections in various ranges depending upon the distance of the interface.

Generally the transducer is kept stationary so that any displacement of echoes will result due to movement of targets. Echo encephalogram is a typical example of A scan display.

In A scan display, the vertical displacement is proportional to the strength of the echo and the horizontal distance , at which the vertical deflection occurs, is proportional to the time taken by the ultrasonic wave to travel in human tissue. The horizontal distance permits the accurate measurement of tissue depth.

SCAN MODES – A-SCAN MODE

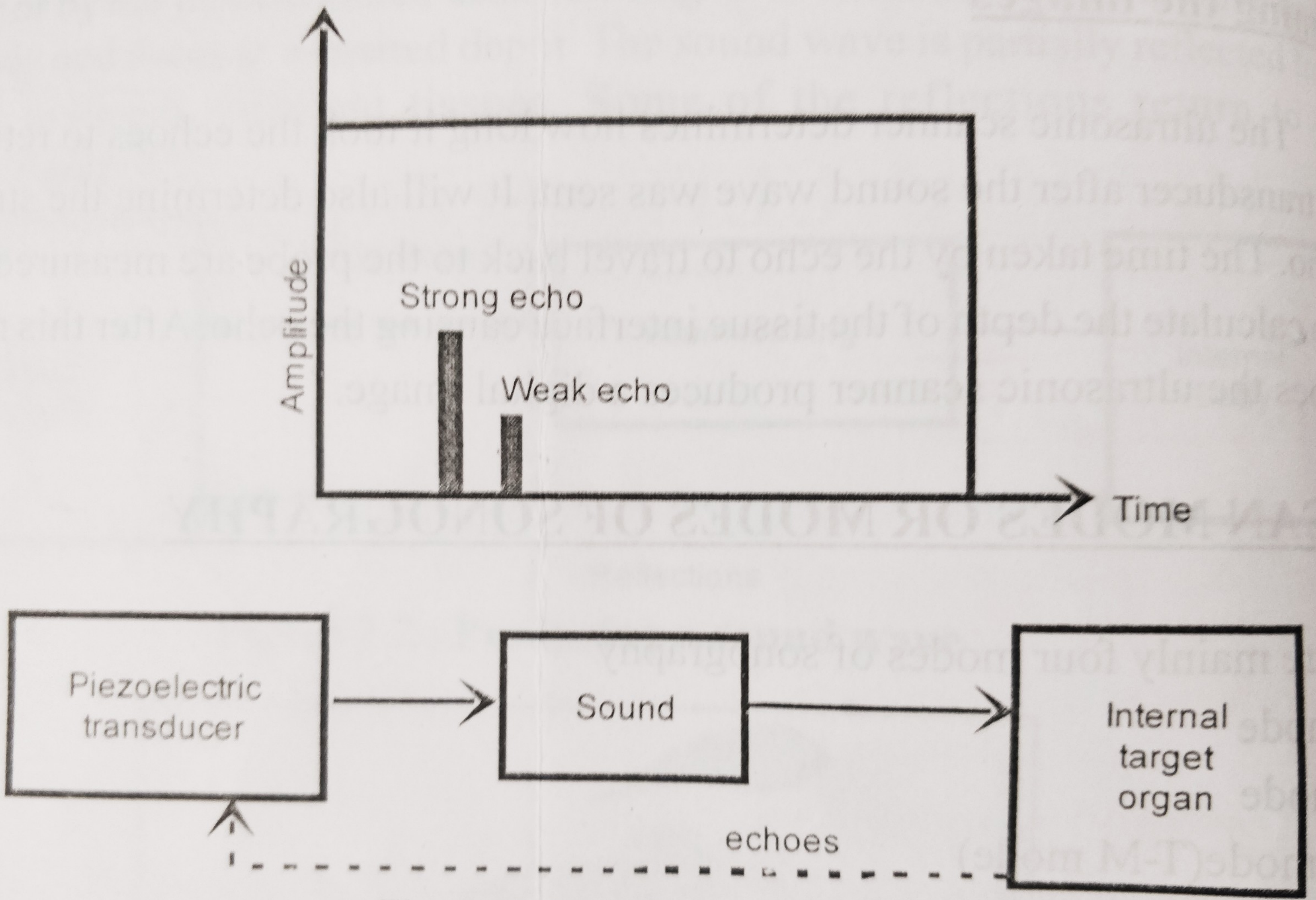

Figure 7.5 : **A-Scan mode**

SCAN MODES

2. B-SCAN MODE

B stands for Brightness. B scans give two dimensional information. If A scan echoes are rotated electronically 90degree towards the viewer, the echoes can be viewed along the horizontal axis as bright and dim dots which depend upon the strength of the echoes as shown in fig 9.2(b).

The distance between the bright and dim dots represents the depth of the tissue and brightness of the dots represents the strength of the echoes. In other words the brightness represents the nature of tissue.

3. M-MODE SCAN

M stands for motion. If the echoes are obtained from a moving structure, then the B scan image for that moving structure will be oscillating. If the dots are moved along vertical direction at a particular speed, then moving dots will trace a displacement pattern of the moving structure. This type of image display is known as M scan display.

Echocardiograph is an instrument based on M Scan display.

SCAN MODES – B-SCAN MODE

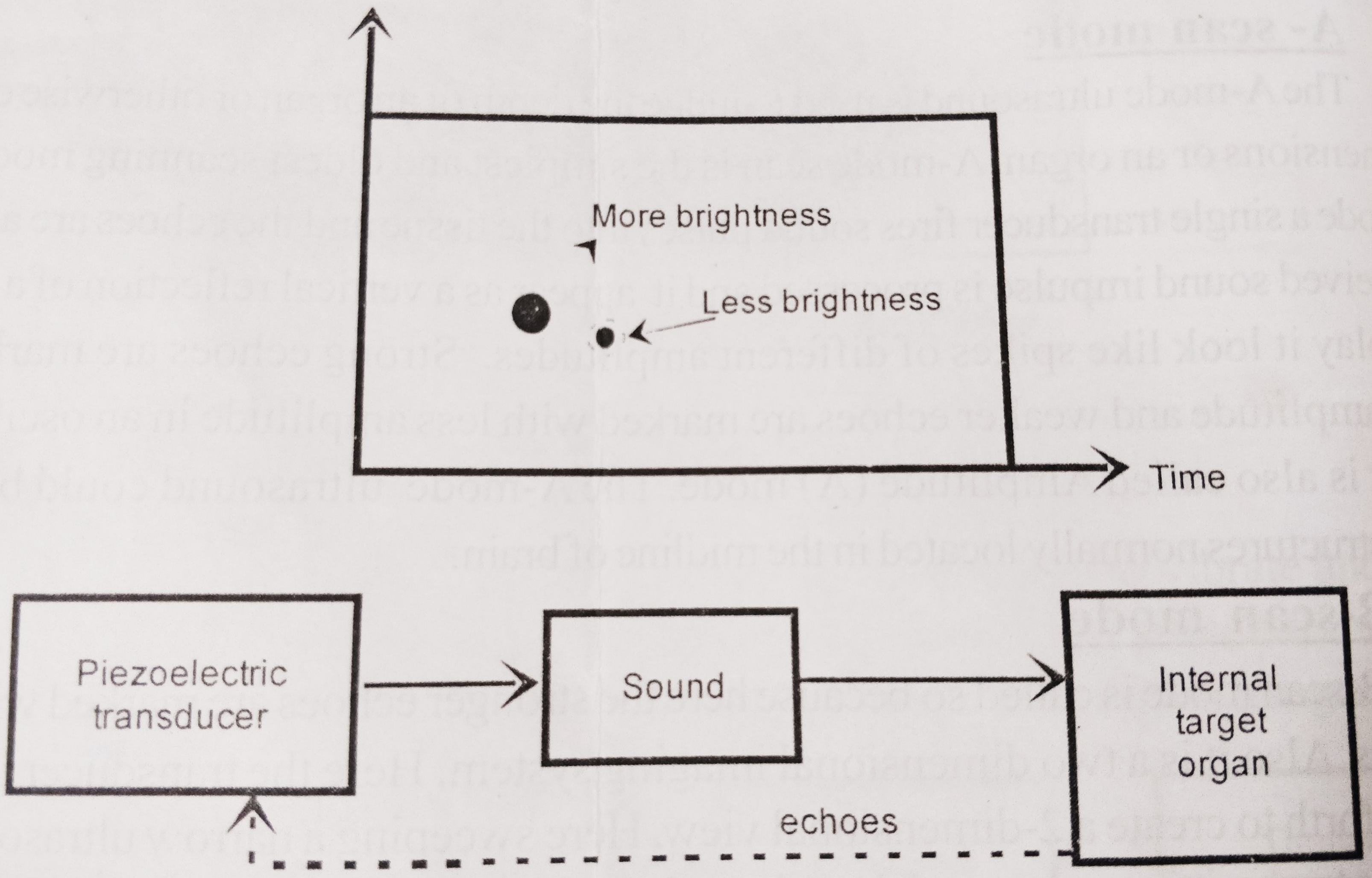

Figure 7.6 : **B-Scan mode**

COMPARISON OF A-SCAN & B-SCAN

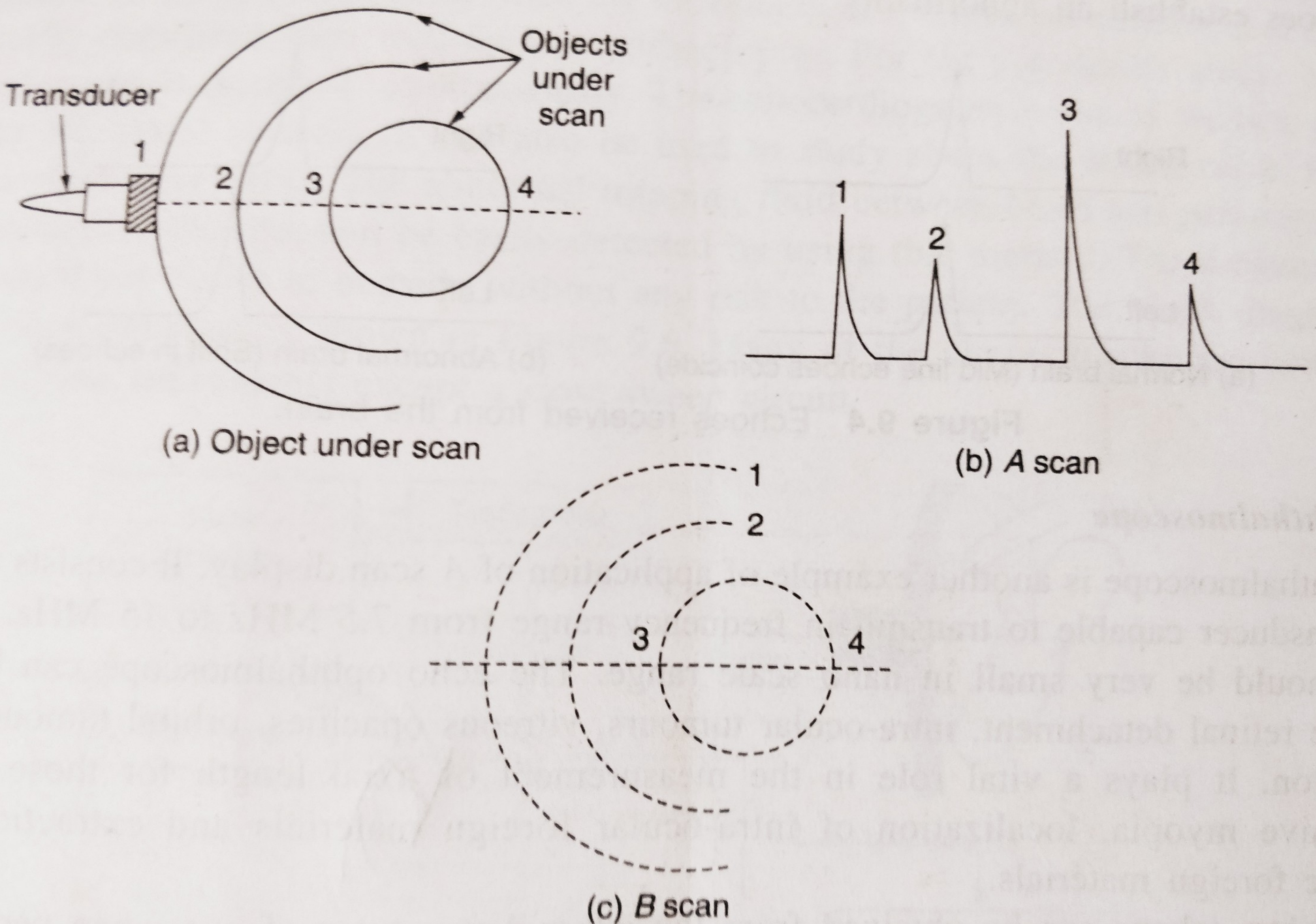

Figure 9.3 Difference between *A* scan and *B* scan displays.

ECHOCARDIOGRAPH

- Echocardiograph is an instrument based on M scan display.
- It is widely used for carrying out cardiac examination and assessment of many cardiac diseases.
- This instruments made possible detection of intra cardiac structures. The movement of the internal heart structure can be recorded without doing invasive angiographic technique. The instrument gives dynamic information with respect to time about heart internal structures.
- The probe of echocardiograph will be placed between third and fourth ribs on the outer chest wall.
- The probe emits a low intensity ultrasonic beam towards the heart area and the echoed signal from the heart are obtained.

ECHOCARDIOGRAPH

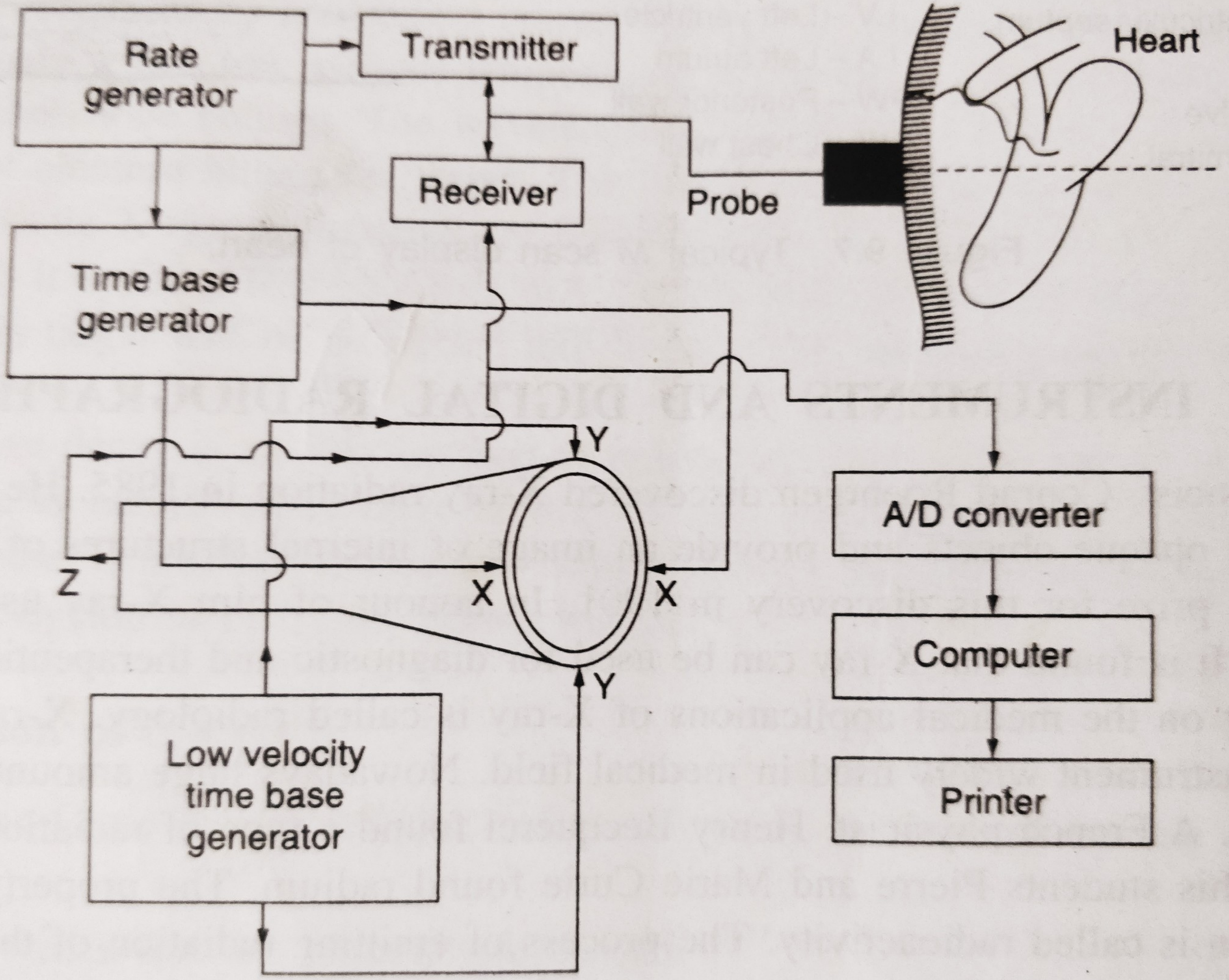

Figure 9.6 Block diagram of an echocardiograph system.

ADVANTAGES

- Can measure velocity of moving objects
- Fast Imaging technique
- No radiation exposure
- Non – invasive and safe
- Inexpensive
- Can measure the reflectivity of tissue to sound waves.