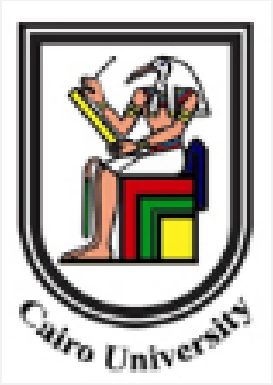

Department of Systems and Biomedical Engineering

Medical Equipment: Ultrasound Imaging (4)

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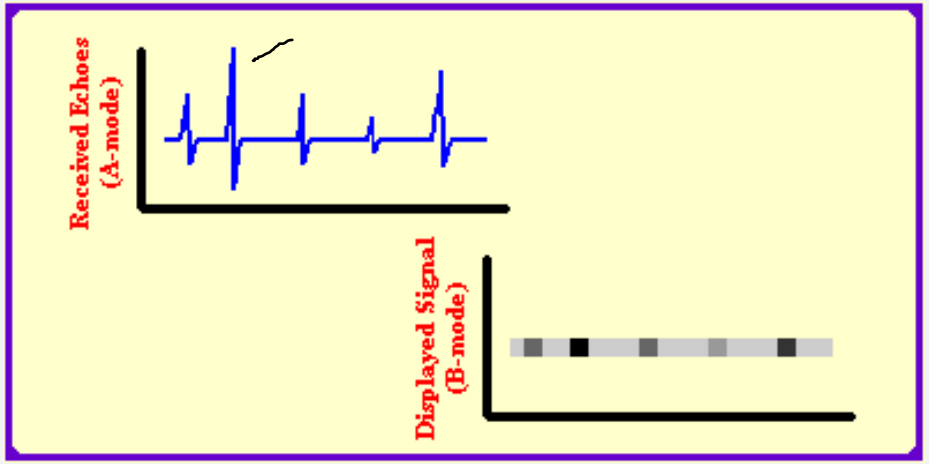
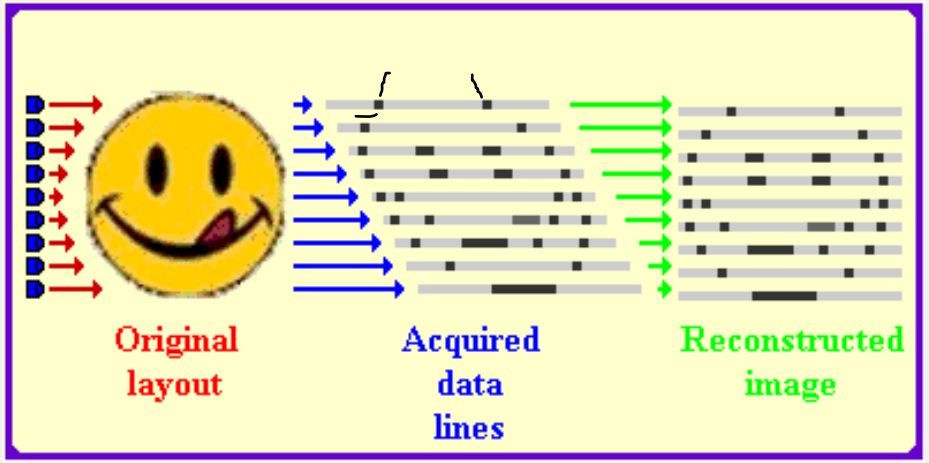
B-Mode Image Reconstruction

- The brightness of the image at each point along the B-mode line is determined by the amplitude of the echo signals received at the transducer.
- The distance between these spikes can be measured by dividing the speed of sound in tissue (1540 m/sec) by half the sound travel time.





Block Diagram of B-mode System

- Echo signals must be processed to produce the final image brightness.

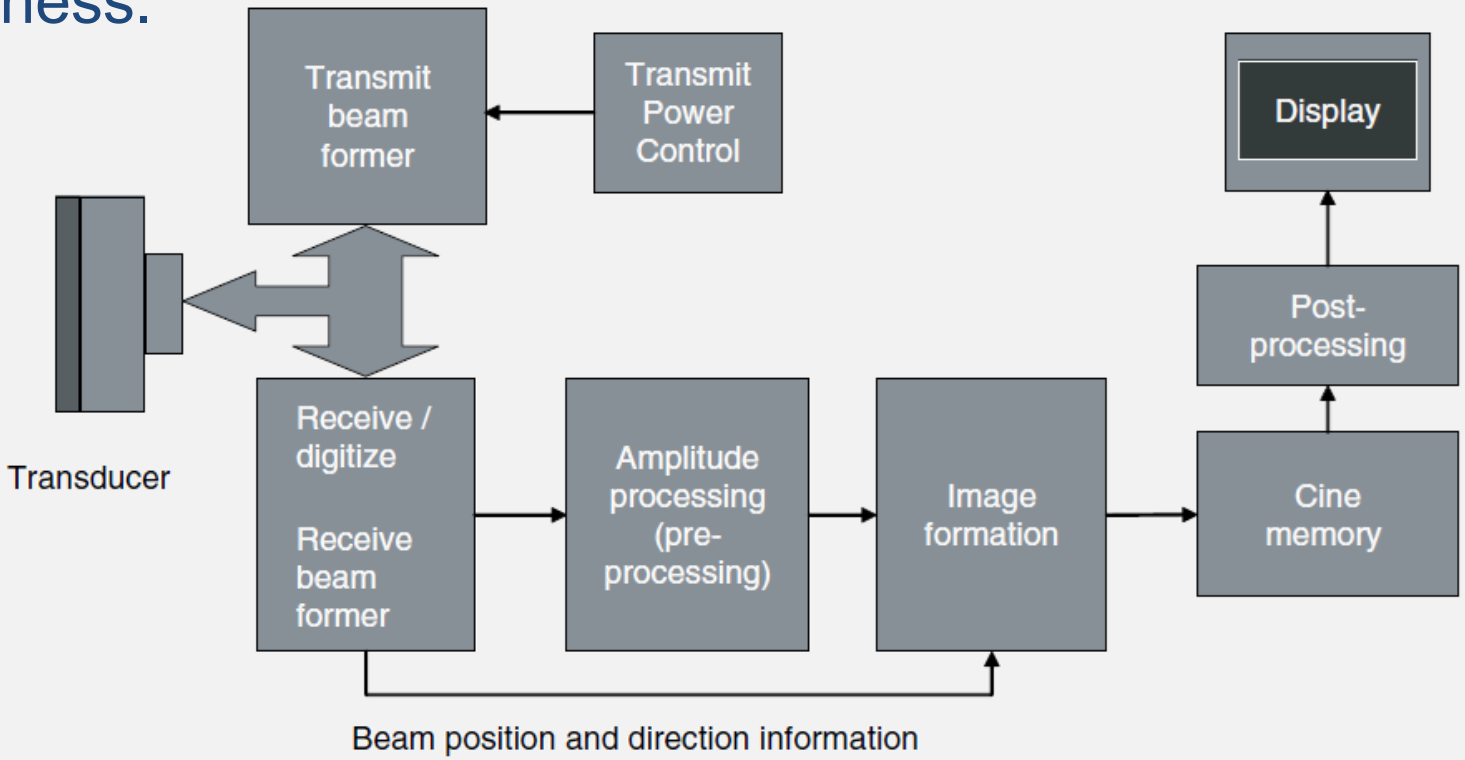


Fig. 4.1 The amplitude of the echo signals must be processed before storage in the image memory. Some amplitude processing also takes place before beam-forming.

Processing Procedures

Amplification:

- Electronic amplifiers are used to increase the amplitude of the echo signals that are generally too small at the transducer elements.
- An amplifier is used to amplify all echo signals equally, irrespective of when they return to the transducer.
- The overall gain control, available to the user on most B-mode systems, applies this type of gain to the echo signals.
- The effect on the image is to make all echoes brighter or darker, whatever their depth in the image.

Processing Procedures

Transmit Power Control:

- This control is often labeled as ‘transmit power’ and allows the user to change the transducer output level in steps of several decibels (e.g. 0, −3, −6, −9 dB).
- This changes the amplitude of the voltage used to drive the transducer, and hence the amplitude of the transmitted pulses.
- Reducing the transmit power reduces patient exposure to ultrasound (US) and the risks of any adverse effects.
- The reduction in echo amplitudes can be compensated by increasing the overall gain.

Processing Procedures

Time Gain Compensation (TGC):

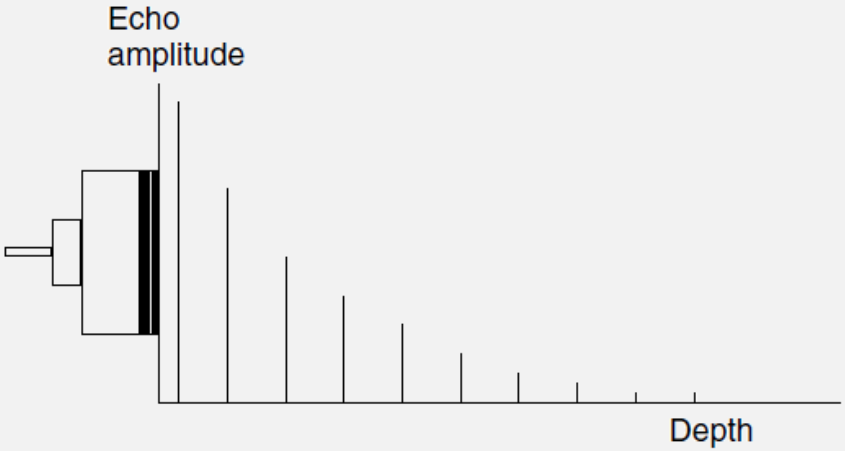
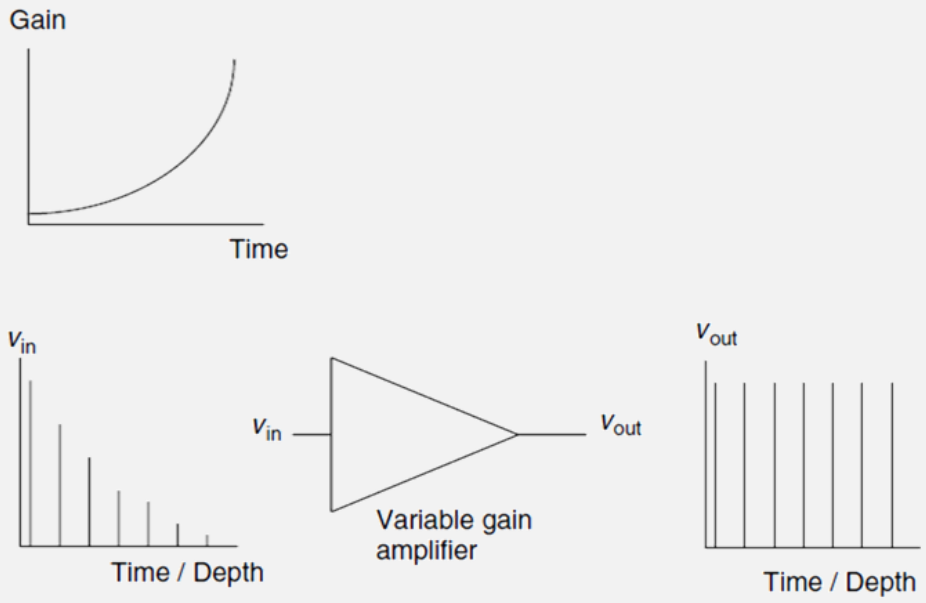


Fig. 4.3 Attenuation results in echoes from interfaces at large depths being smaller than those from similar interfaces near the transducer.



- The gain applied by the TGC amplifier increases with time after transmission to compensate for the greater attenuation of echoes from larger depths.
- After TGC, echoes from similar interfaces should be equal in amplitude regardless of depth.

Processing Procedures

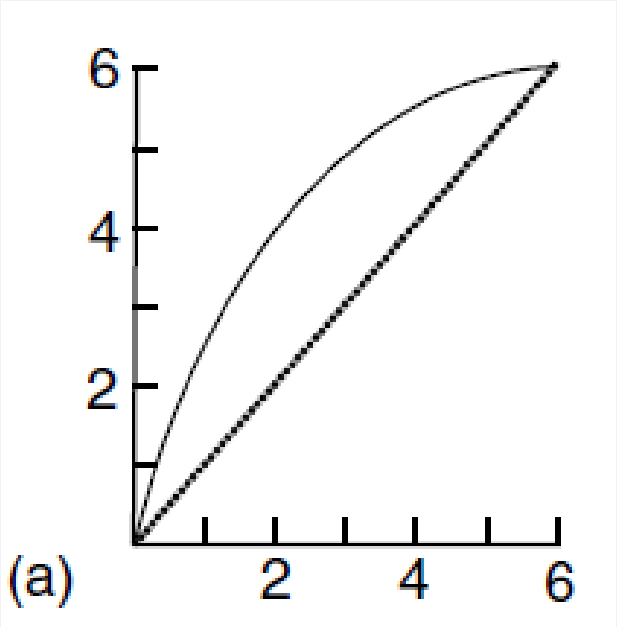
Dynamic range of echoes :

- The intensities of echoes received from small scatterers depend strongly on the size of the scatterer and the ultrasound wavelength but are usually much smaller than echoes from large interfaces.
- The dynamic range is defined as the ratio of the largest echo amplitude to the smallest that can be distinguished from noise. The dynamic range is expressed in decibels.

Processing Procedures

Compression :

- An amplifier is used to compress the signal range with a logarithmic characteristic, so that the output voltage is related to the logarithm of the input voltage.
- Using this type of amplifier, weak echoes from scattering within the tissue can be boosted more than the large echoes from interfaces, so that both types of echo can be displayed at the same time.



Processing Procedures

Analogue-to-digital conversion :

- The most important advantage of digitization for B-mode imaging is that it makes digital processing of echo information possible.
- Using built-in, dedicated computing devices, digital echo information can be processed by powerful mathematical techniques to improve the image quality.

Processing Procedures

Post-Processing :

- **Frame Averaging**: Frame averaging is effective in suppressing random image noise, making it easier to study areas of anatomy that generate weak echoes, e.g. weakly scattering or deep tissues.
- **Gray level transfer curves**.

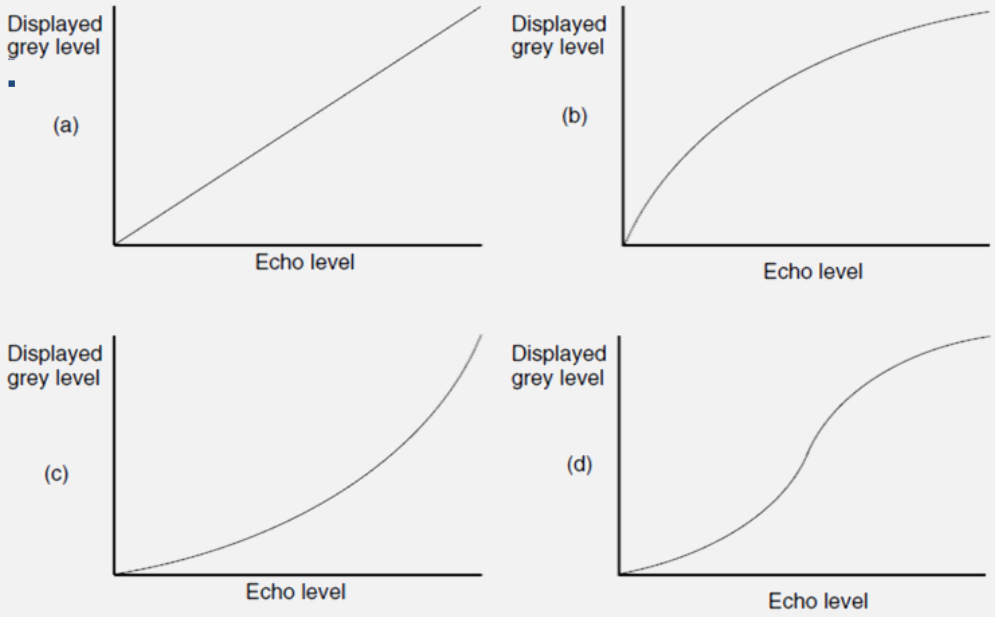


Fig. 4.20 Grey-scale post-processing curves. (a) Linear, (b) small echo contrast enhancement, (c) high echo contrast enhancement, (d) mid echo contrast enhancement.

Processing Procedures

Post-Processing :

- **Edge Enhancement**: To enhance the appearance of the walls of vessels and other anatomical features, a spatial high-pass filter can be applied to the two-dimensional image.
- **Adaptive Image Processing**: The two-dimensional B-mode image is analyzed on a number of scales to identify and map the spatial frequency content and identify structural features. Structural features, e.g. vessel or lesion boundaries, can then be emphasized by applying a smoothing filter along the line of the boundary, while applying an edge enhancement filter across the boundary.

Assessing Ultrasound B-mode System

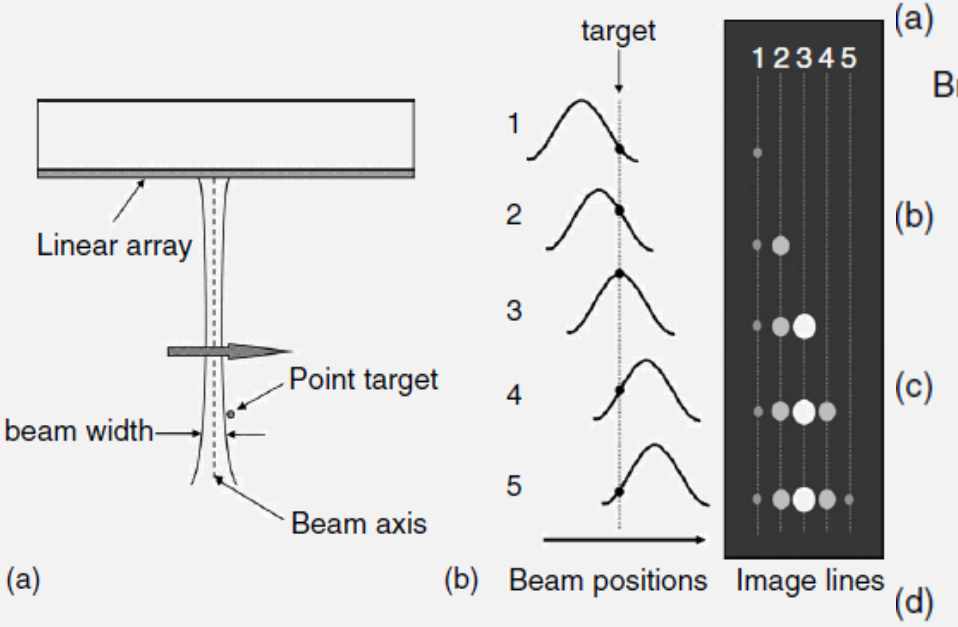
The performance of US systems can be characterized in terms of image properties which fall into three groups:

- **Spatial properties**: The smallest separation of targets which can be resolved.
- **Amplitude properties**: The smallest and largest changes in scattered or reflected echo amplitude which can be detected.
- **Temporal properties**: The most rapid movement that can be displayed.

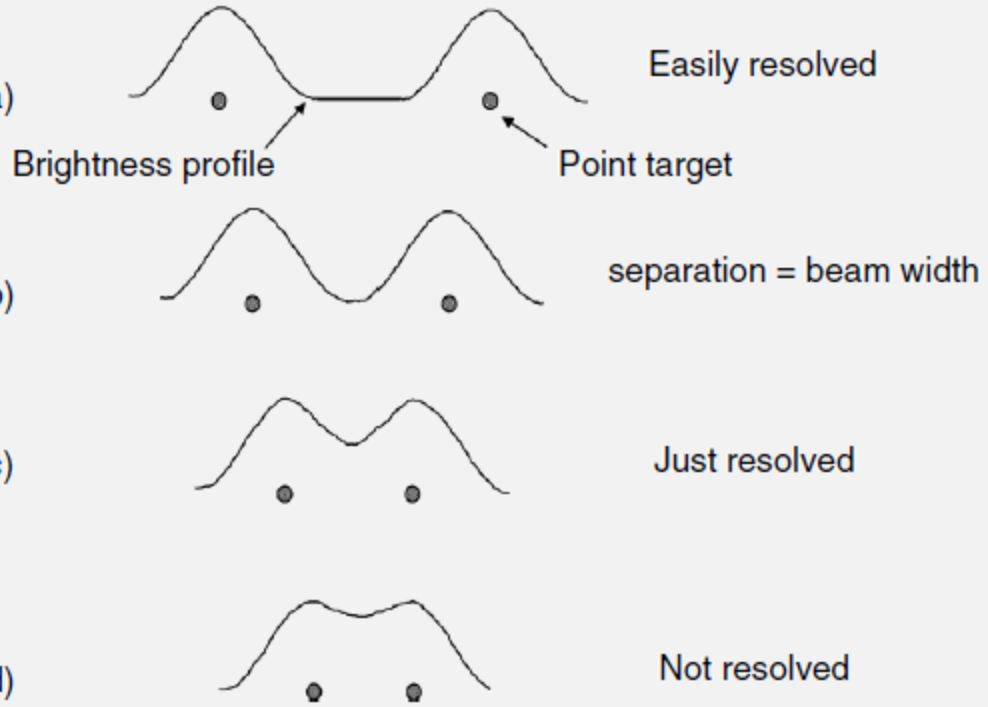
Imaging System Performance

Spatial Properties:

Lateral Resolution



The resulting lateral spread of the image depends on the beam width at the target depth.

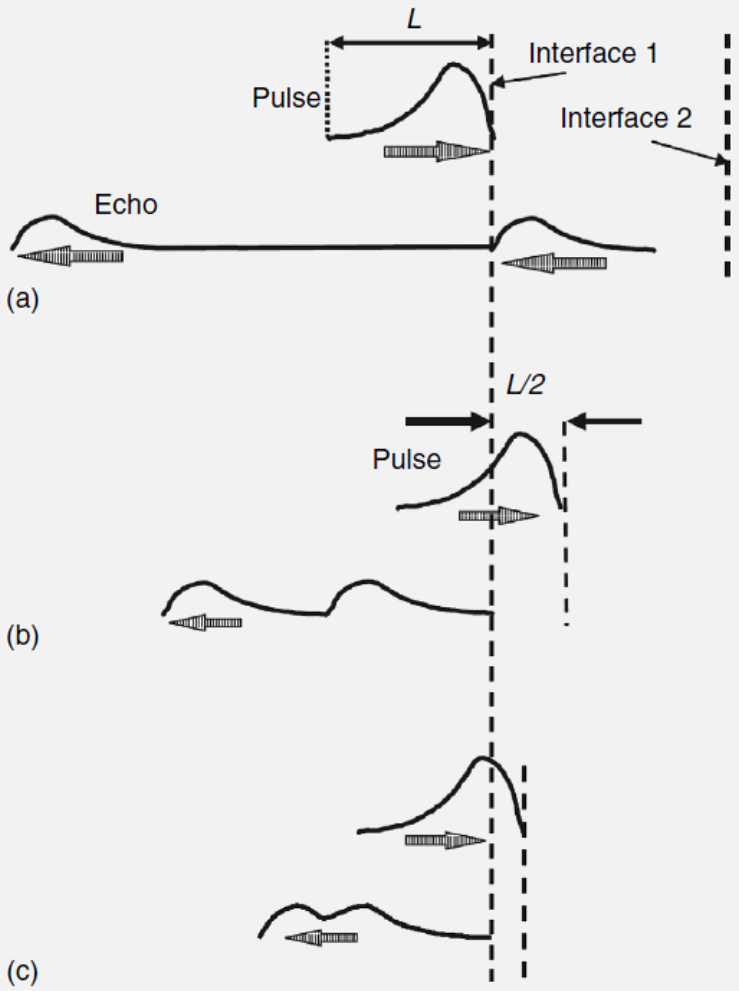


The targets are just resolved in the image when the spacing is about half the beam width.

Imaging System Performance

Axial Resolution

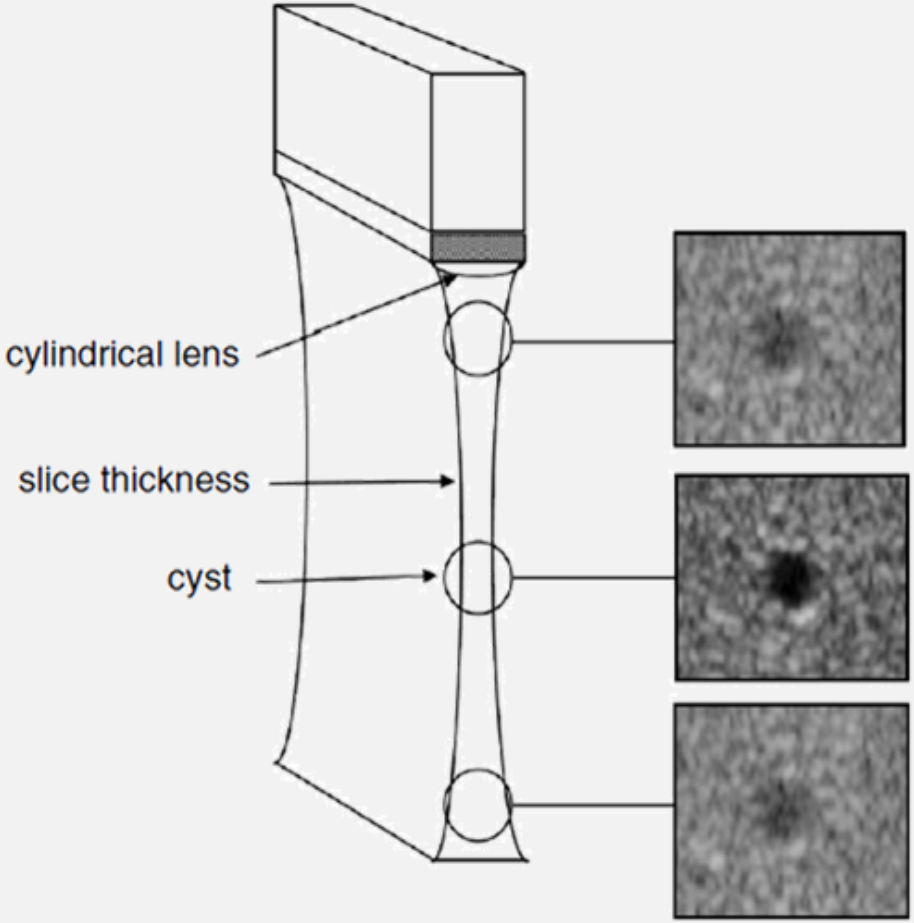
- Axial resolution is defined usually as the smallest separation of a pair of targets on the beam axis which can be displayed as two separable images.
- The axial resolution of a B-mode system is approximately half the pulse length .



Imaging System Performance

Slice Thickness

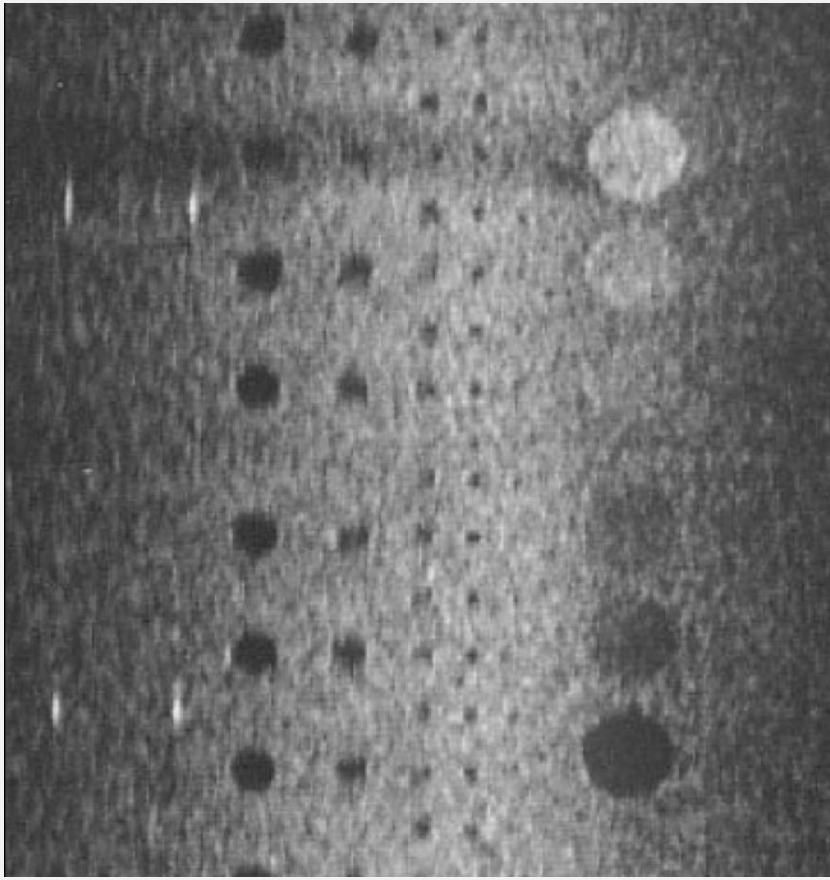
- Slice thickness is determined by the width of the ultrasound beam at right angles to the scan plane (the elevation plane) and varies with range.
- The effect of slice thickness is most noticeable when imaging small liquid areas, such as cysts and longitudinal sections of blood vessels.



Imaging System Performance

Image Contrast

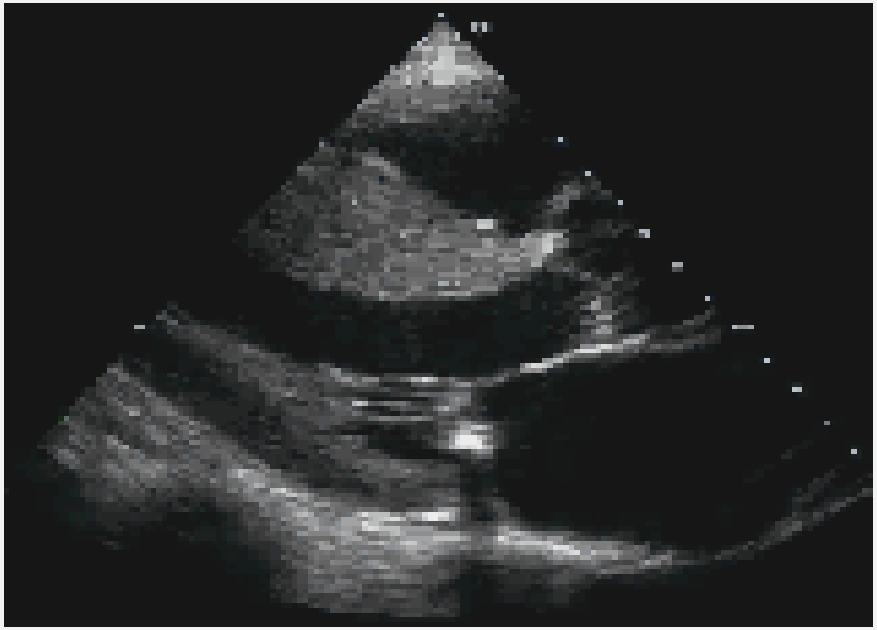
- The ability of the system to identify echoes from different organs.
- The overall relative brightness of echoes within different organs (liver, spleen and kidney) is an aid to identification and can reflect pathological change.
- Small local changes in echo brightness are often related to pathological change in that part of the tissue.



Imaging System Performance

Movement (frame rate)

- To show the movement of a valve leaflet smoothly, the system needs to display it in several positions (say five) between the closed and open positions.



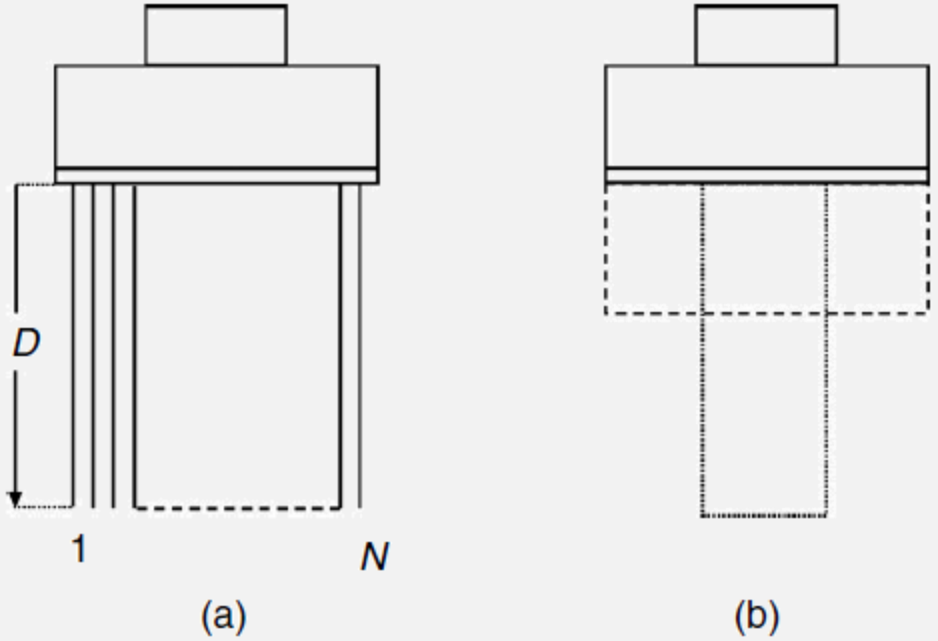
Imaging System Performance

Movement (frame rate)

- As the leaflet takes only about 0.1 s to open, five images are needed in every 0.1 s, a frame rate of 50 Hz.

The frame rate is proportional to the imaging depth (D) and the number of lines (N).

The total time to form N lines is *2DN/c*



Imaging Artifacts

- When forming a B-mode image, the imaging system makes a number of assumptions about ultrasound propagation in tissue.

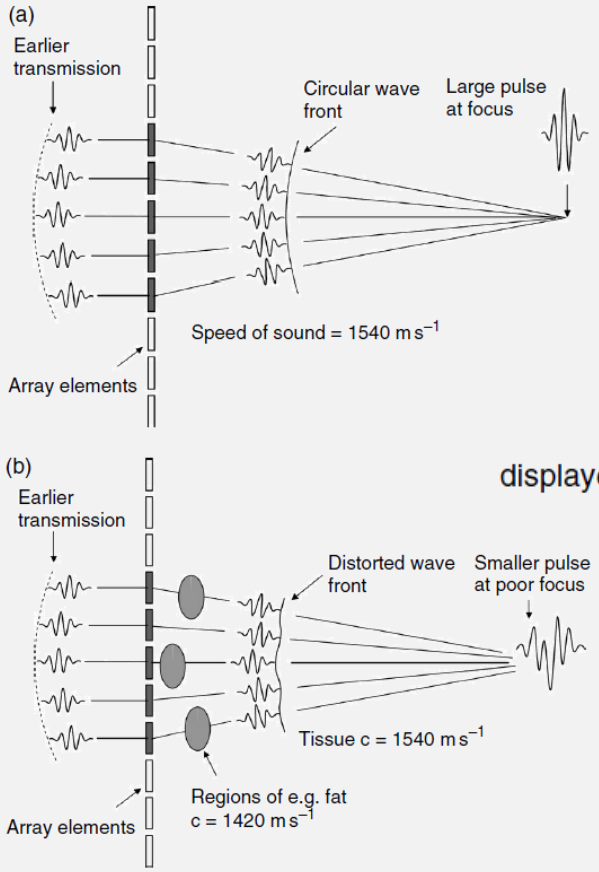
These assumptions include:

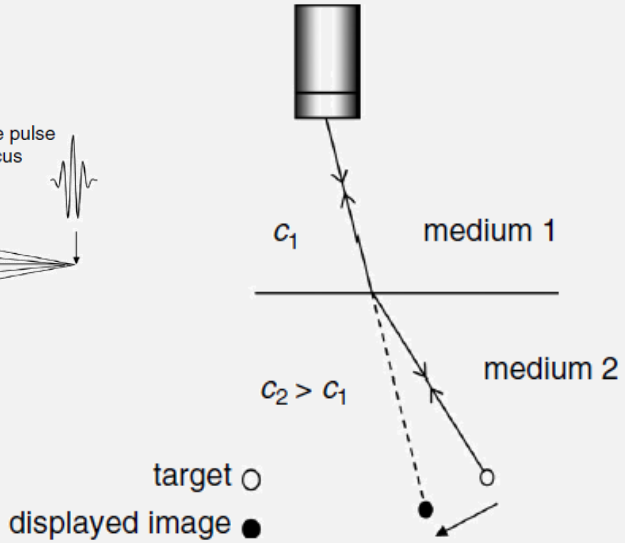
- Constant speed of sound,
- The beam axis is straight,
- Constant attenuation in tissue, and
- The pulse travels only to targets that are on the beam axis and back to the transducer.

- These assumptions result in different artifacts that will be discussed in the following slides

Imaging Artifacts

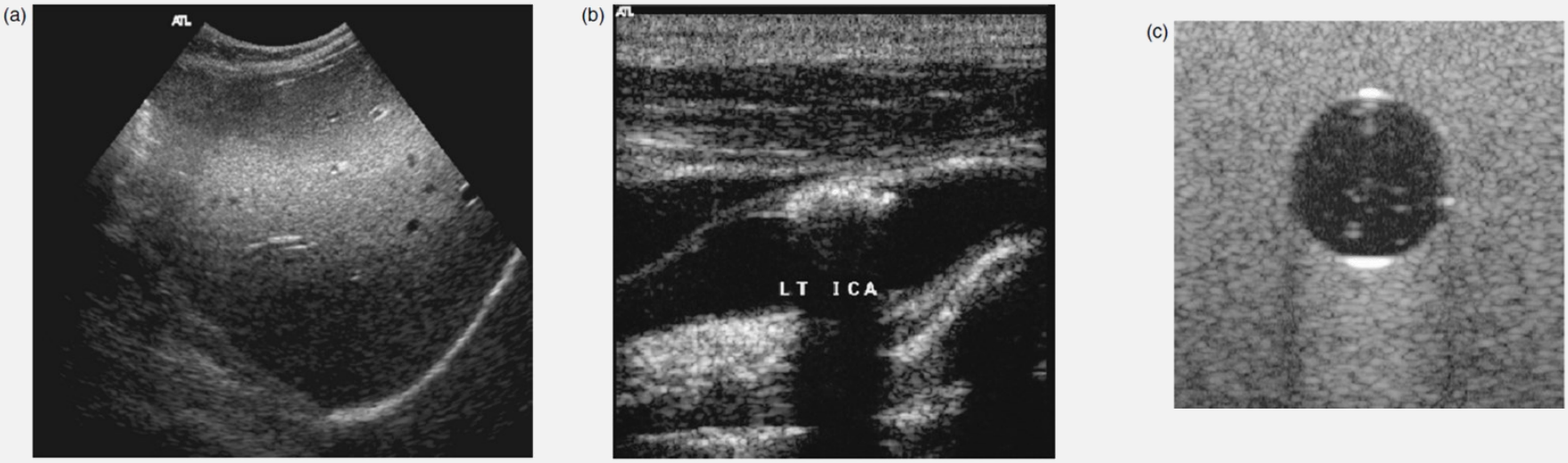
- **Range errors**: These include 1-misregistration of targets, 2-distortion of interfaces, 3-errors in size, and defocusing of the ultrasound beam (phase aberration).





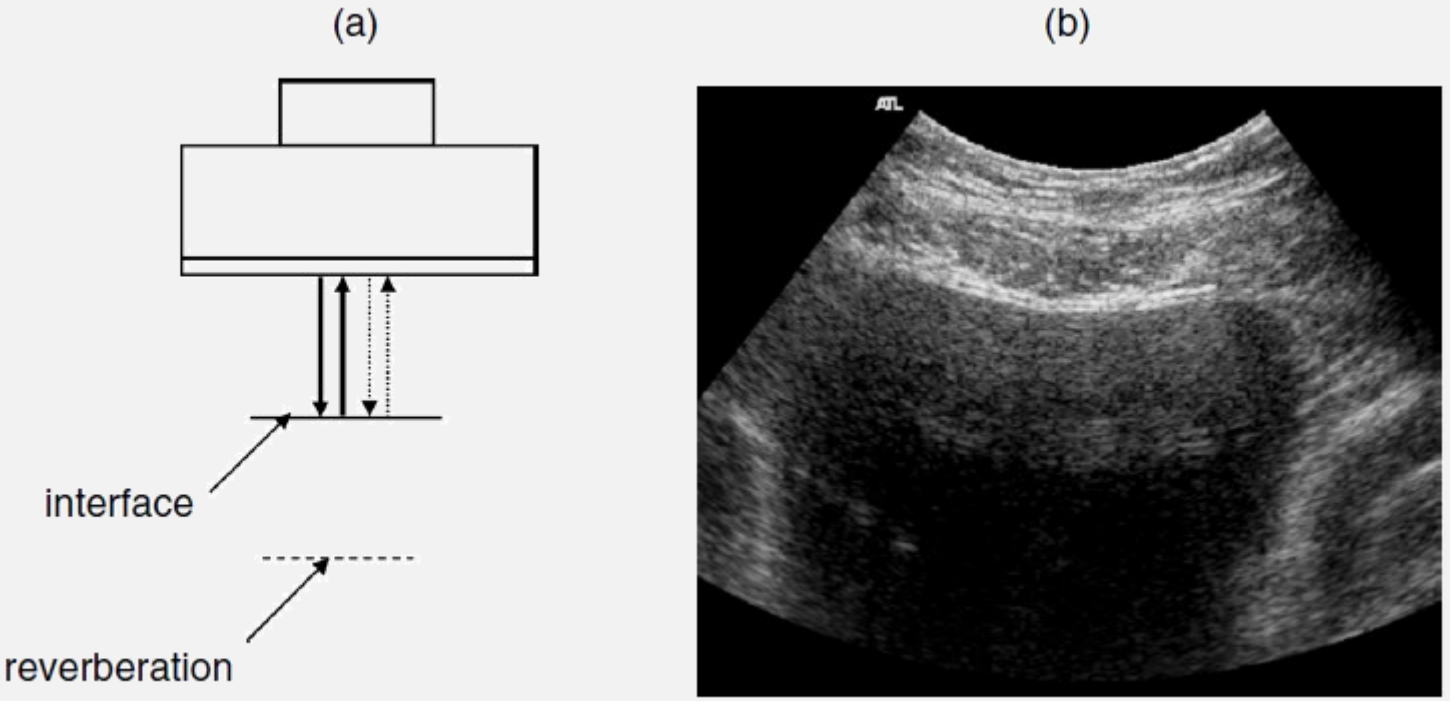
Imaging Artifacts

- **Attenuation artifacts**



Imaging Artifacts

- **Reflection artifacts**



Topics Covered

- This lecture covered major parts in chapters 4 and 5 in the book of Hoskins et al.
- Study only parts mentioned in the slides.