Department of Systems and Biomedical Engineering

Medical Equipment: Ultrasound Imaging (4)

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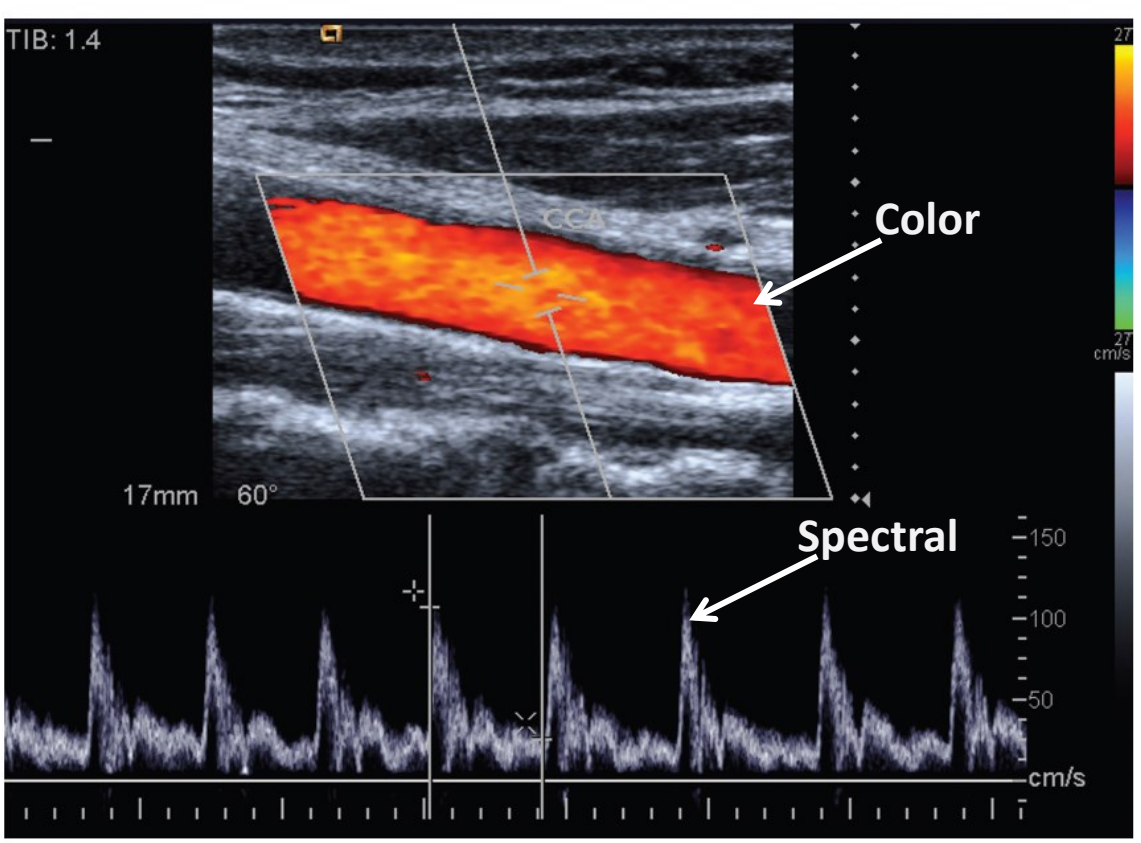
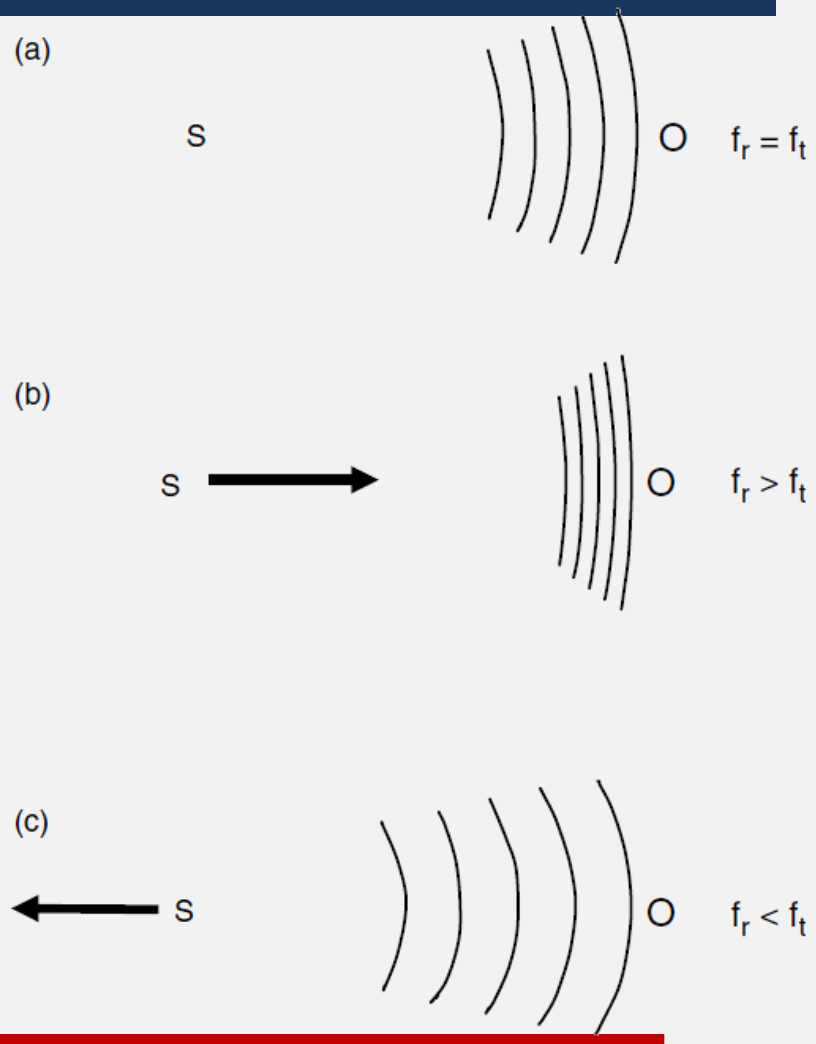
Doppler Ultrasound

- The Doppler effect enables ultrasound to be used to detect the motion of blood and tissue.
- Most Doppler ultrasound systems provide both spectral Doppler displays and color Doppler images.



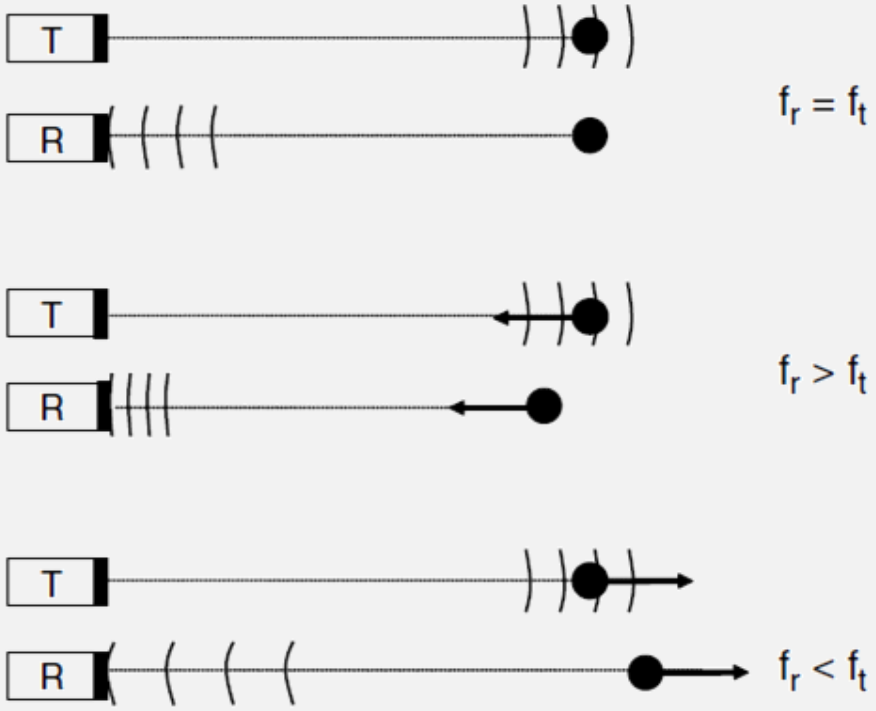
Doppler Effect

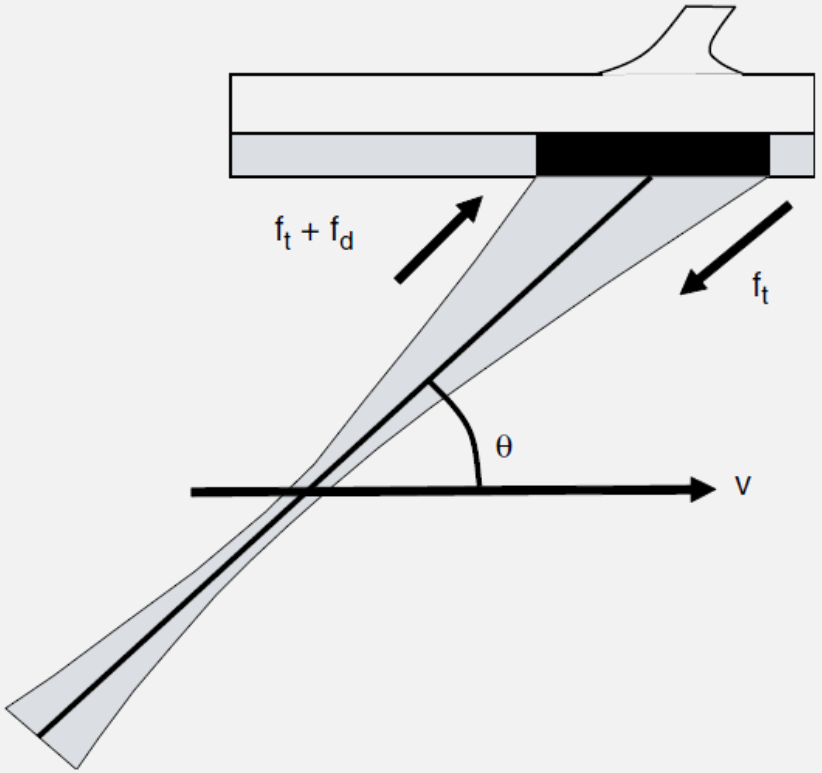
- Doppler effect as a result of motion of the source (S) relative to a stationary observer (O).



Doppler Effect due to Blood Motion

$$f_d = f_r - f_t = \frac{2 f_t v \cos\theta}{c}$$





Doppler Effect due to Blood Motion

- If the angle of insonation of the ultrasound beam is known it is possible to use the Doppler shift frequency to estimate the velocity of the blood using the Doppler equation.

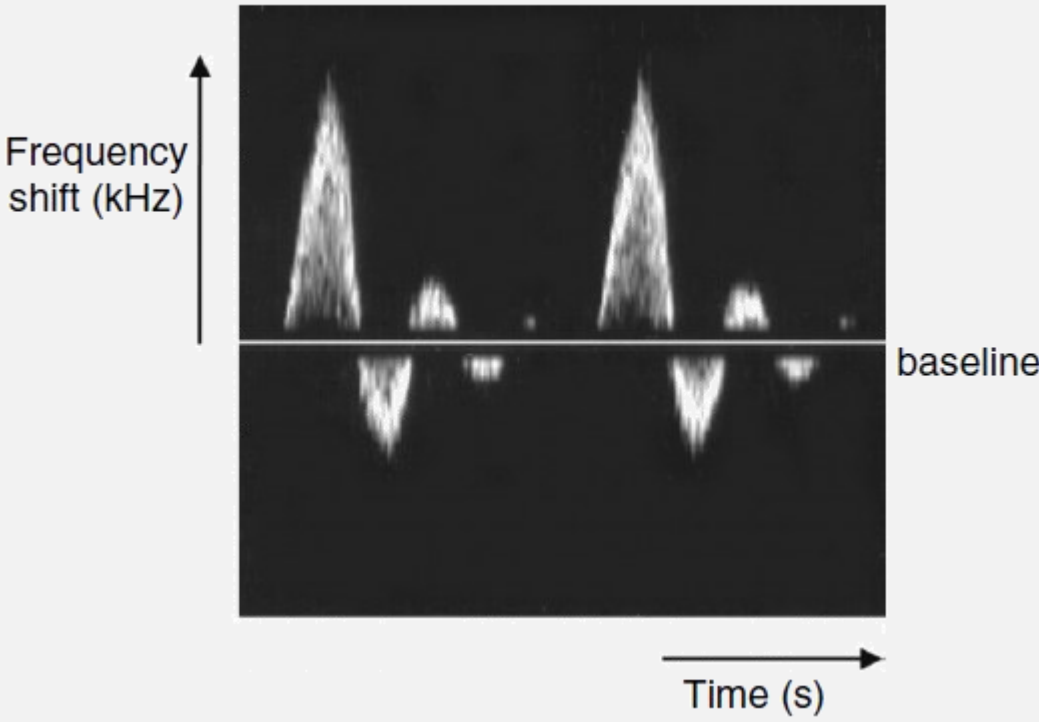
$$v = \frac{c\, f_d}{2 f_t \cos\theta}$$

- In diseased arteries the lumen will narrow and the blood velocity will increase. This provides the means by which the lumen diameter may be estimated using Doppler ultrasound.

Doppler Displays

Spectral Doppler:

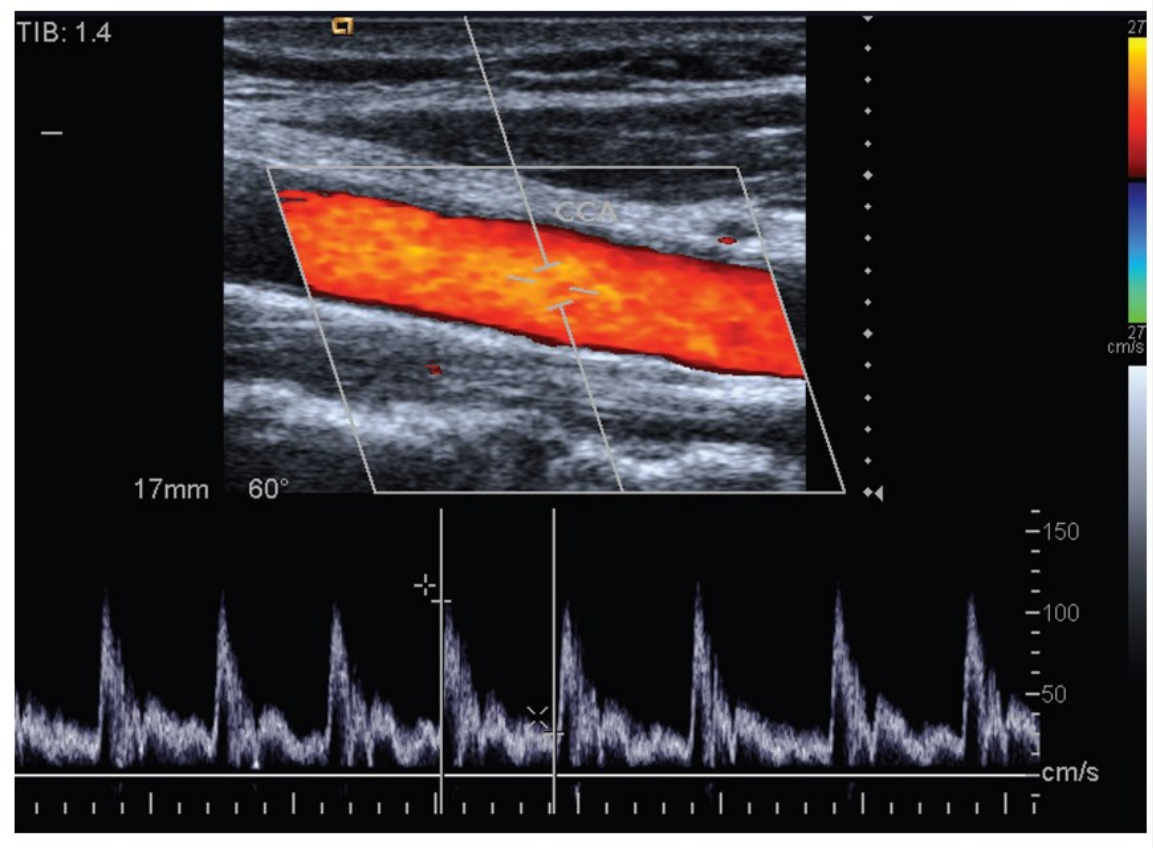
- Velocity information detected from a single location within the blood vessel is displayed in the form of a frequency shift – time plot.
- Vertical distance from the baseline corresponds to Doppler shift, while the grey scale indicates the ultrasound amplitude detected at that frequency.



Doppler Displays

2D color flow imaging:

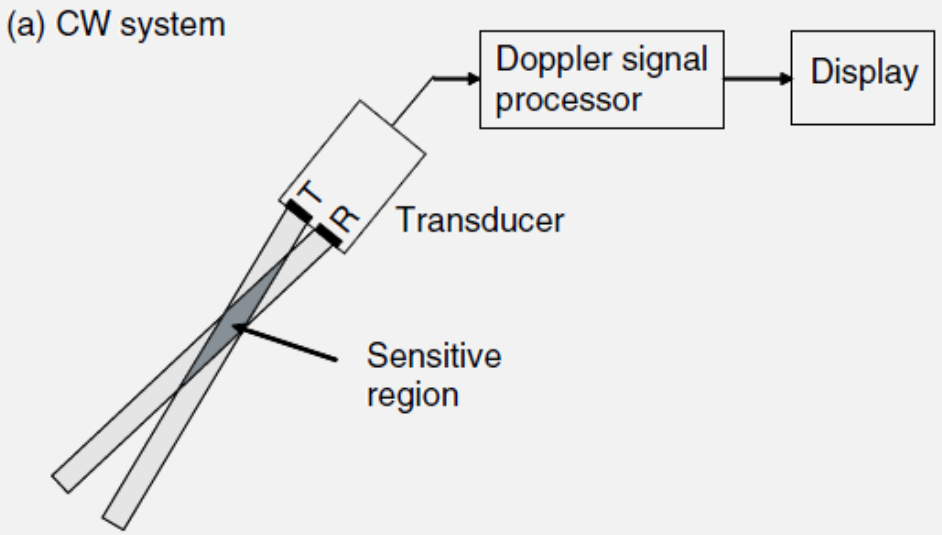
- The Doppler signal is displayed in the form of a 2D color image superimposed on the B-scan image.
- Color represents the Doppler shift for each pixel, averaged over the area of the pixel.



Types of Doppler Systems

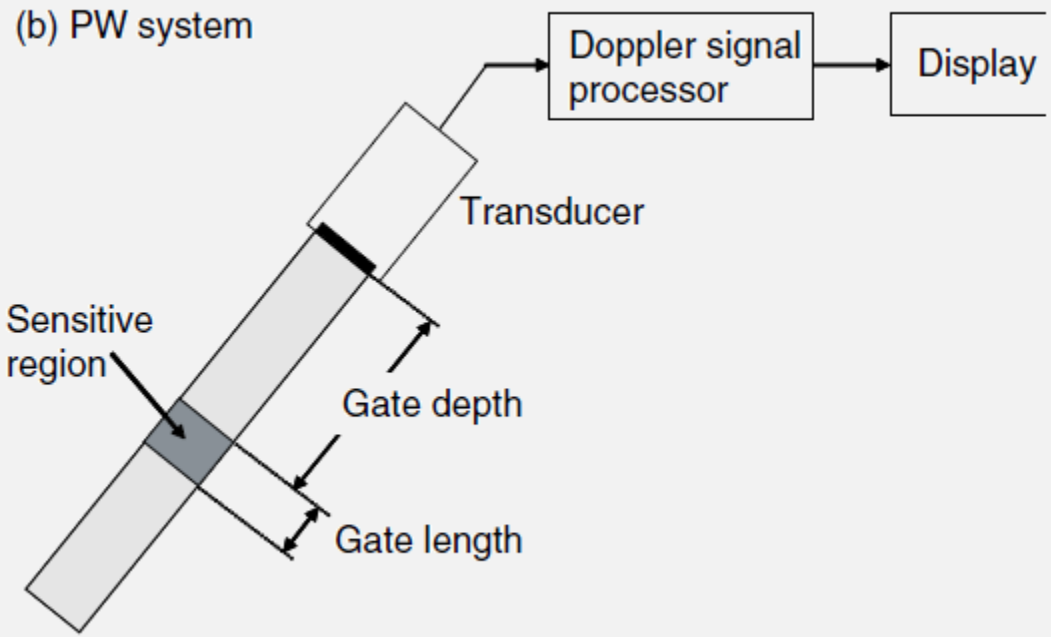
- **Doppler systems are divided into two types:**

1- Continuous Wave (CW) Doppler: Two elements are used, one transmits continuously and the other receives continuously. The region from which Doppler signals are obtained is determined by the overlap of the transmit and receive ultrasound beams.



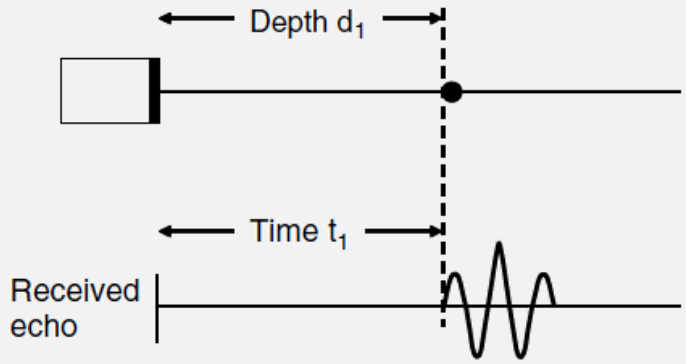
Types of Doppler Systems

2- Pulsed Wave (PW) Doppler: In a PW system, one element is needed, serving both the transmit and receive functions. The region from which Doppler signals are obtained is determined by the depth of the gate and the length of the gate, which can both be controlled by the operator.



Blood Velocity and PRF

(a) First pulse, time t_1

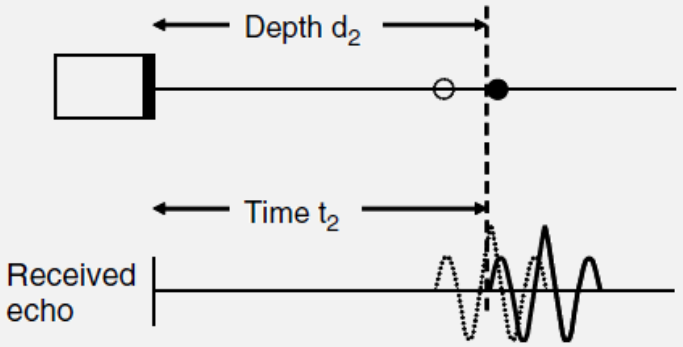


$$d_1 = c\,t_1/2, \qquad d_2 = c\,t_2/2$$

$$d_m = d_2 - d_1$$

$$d_m = c(t_2 - t_1)/2$$

(b) Second pulse, time t_2



$$\mathrm{PRI} = t_2 - t_1 \qquad \mathrm{PRI} = 1/\mathrm{PRF}$$

$$v = d_m / \mathrm{PRI} = (t_2 - t_1)\, c\, \mathrm{PRF}/2$$

Quality Assurance

The term quality assurance (QA) most often refers to schemes for maintaining the outcomes of some process or activity as measured against a required standard.

Reverberation patterns assess

- Crystal drop out
- Uniformity
- Sensitivity
- Noise

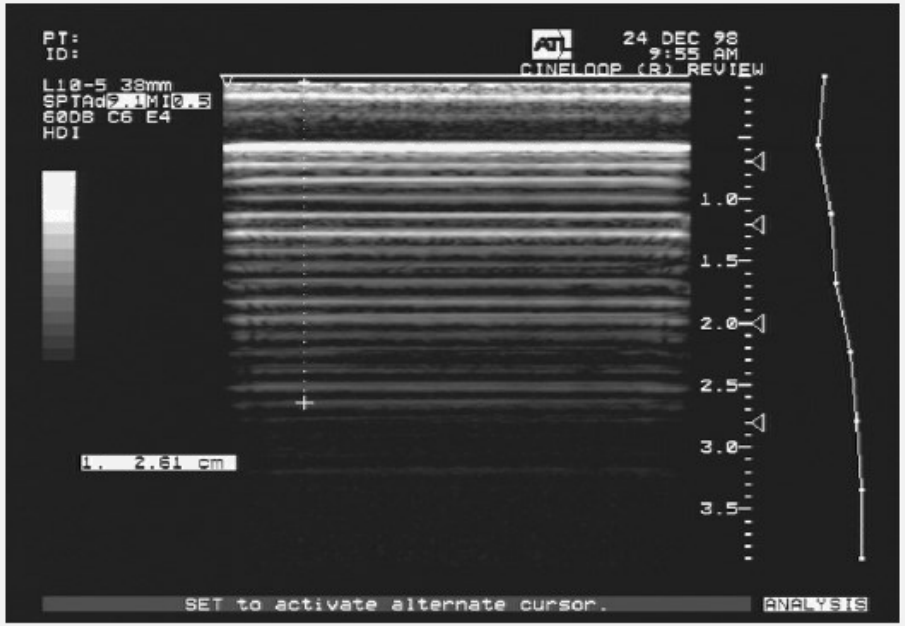
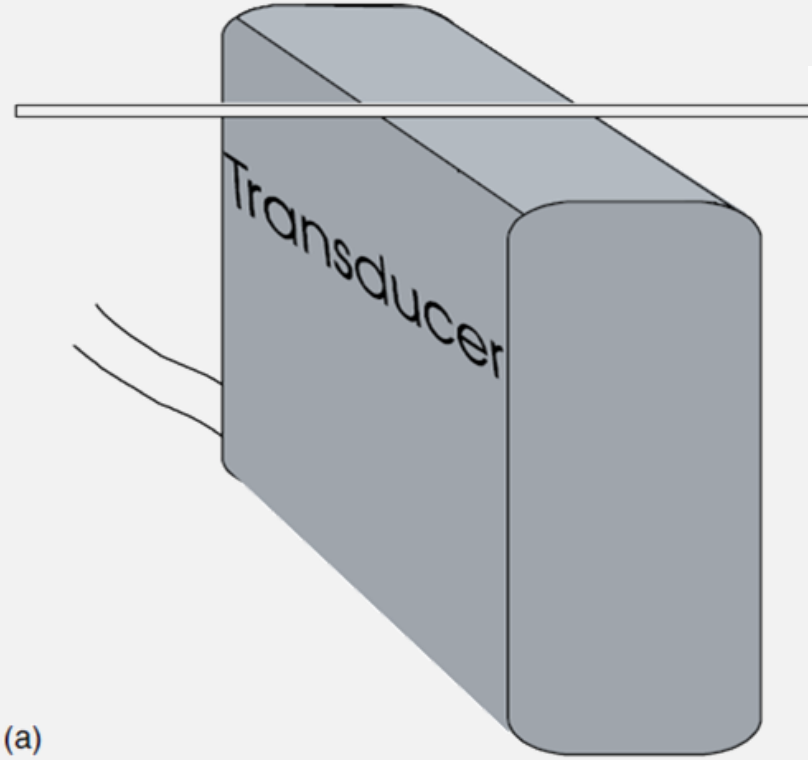
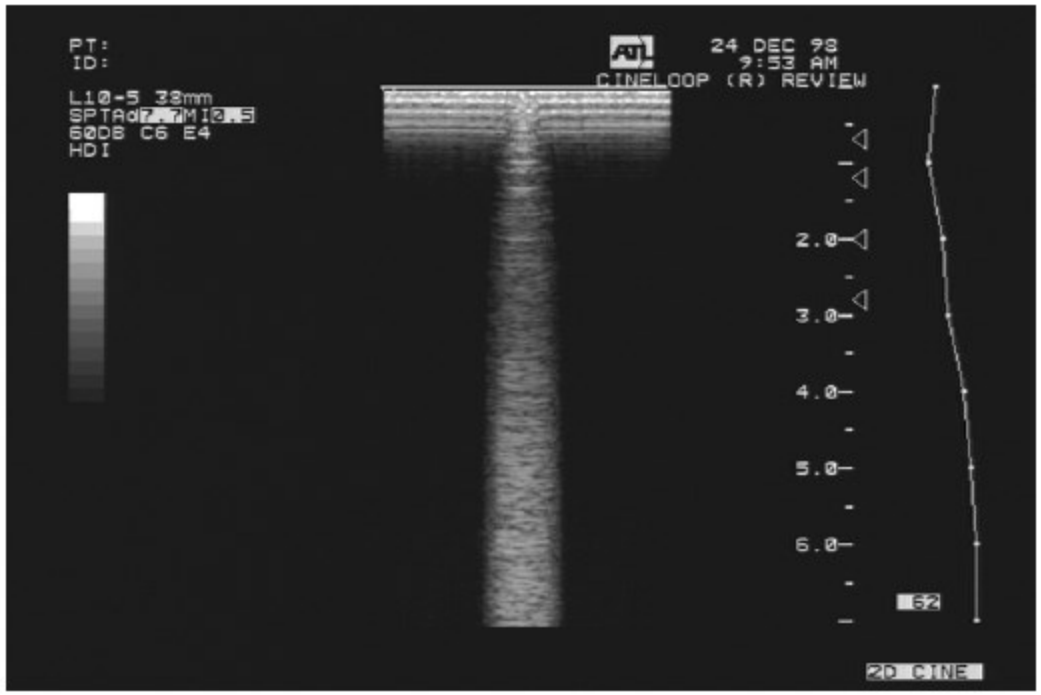


Fig. 11.1 Reverberation pattern seen when a transducer is working into air.

Quality Assurance

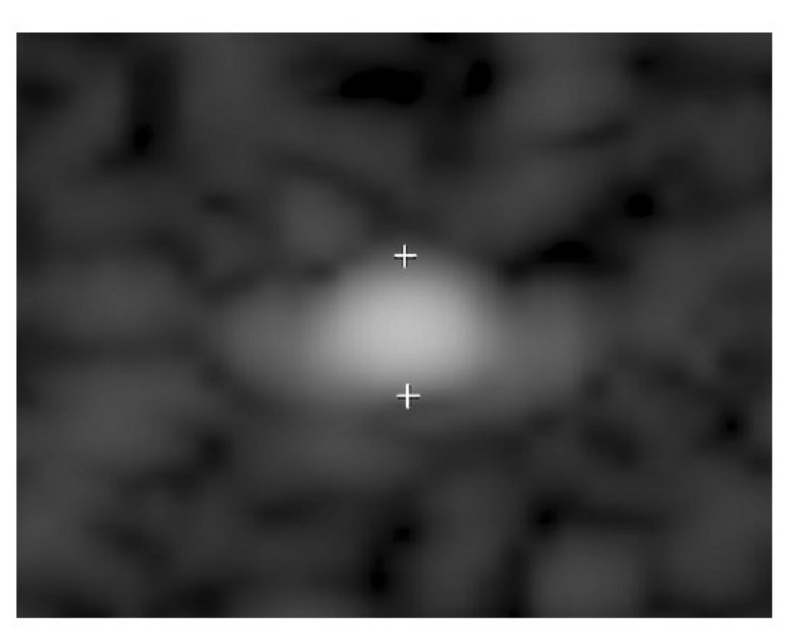


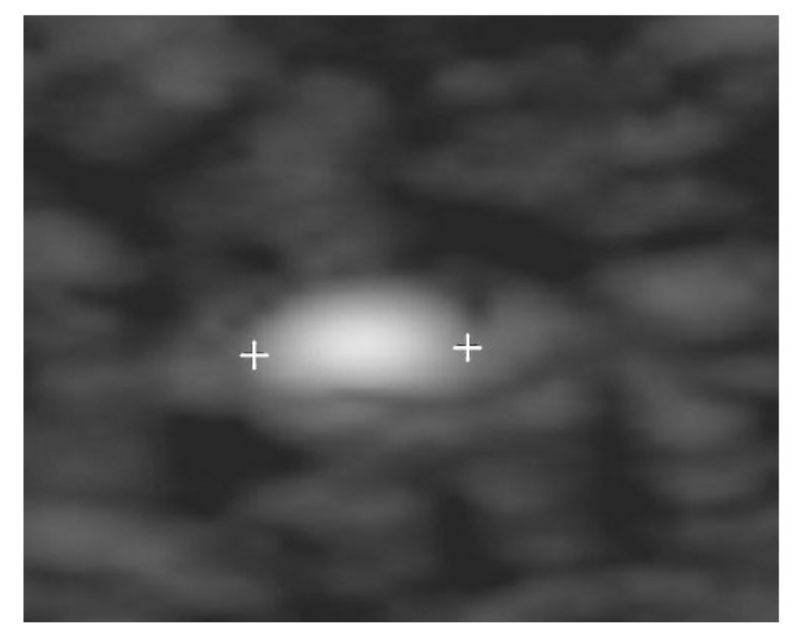


Use of an unfolded paperclip to search for crystal drop-out. (a) Placement of paper-clip; (b) B-mode image.

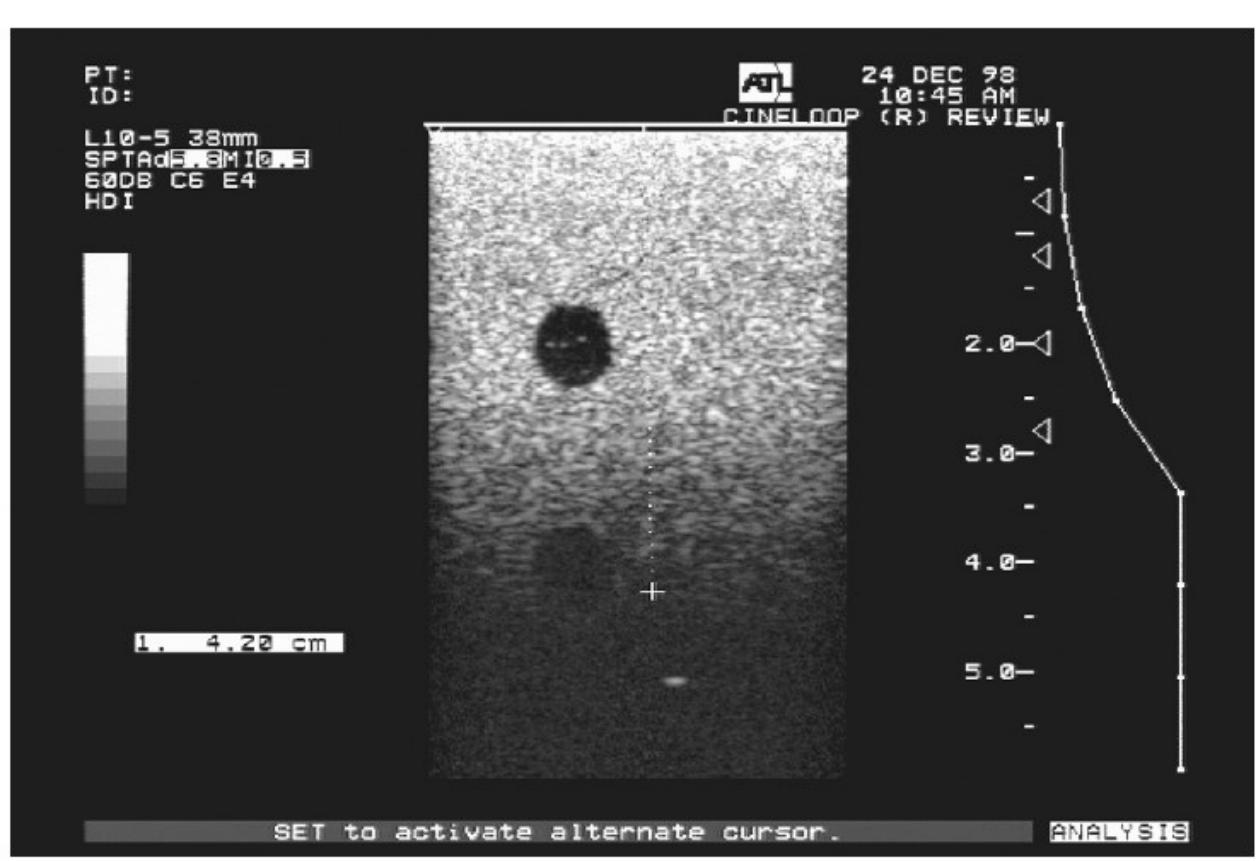
Quality Assurance

The axial and lateral resolution can be measured from the frozen image one of the filaments after zooming in.



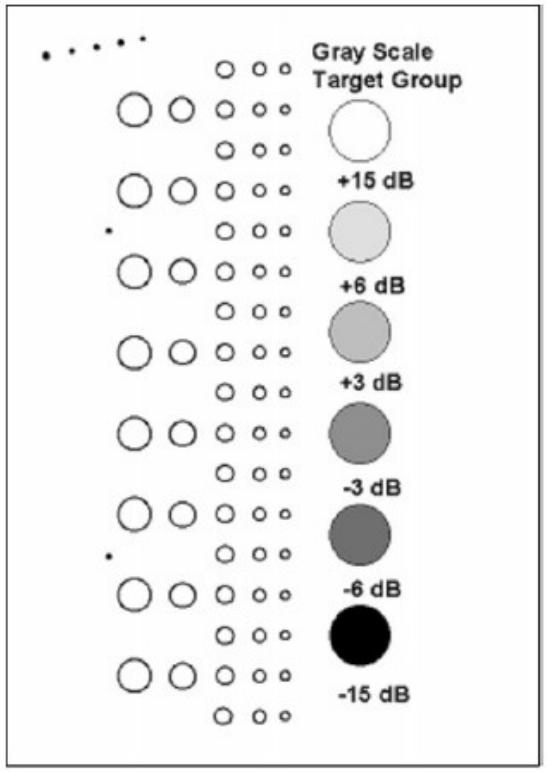


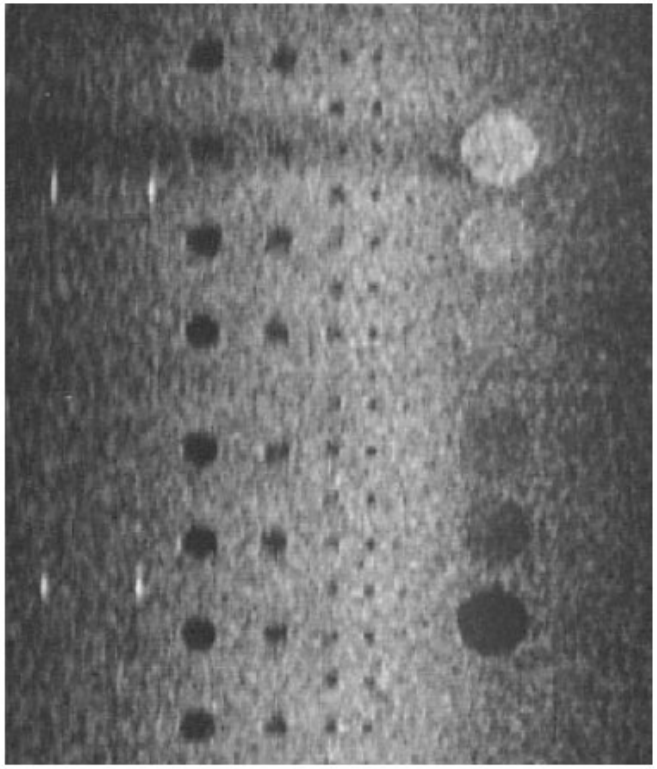
Quality Assurance



Penetration depth measurements

Quality Assurance





Contrast resolution is assessed by imaging a mixture of targets with different contrast and cystic targets of different sizes

Quality Assurance

Phantoms for Doppler Ultrasound Systems

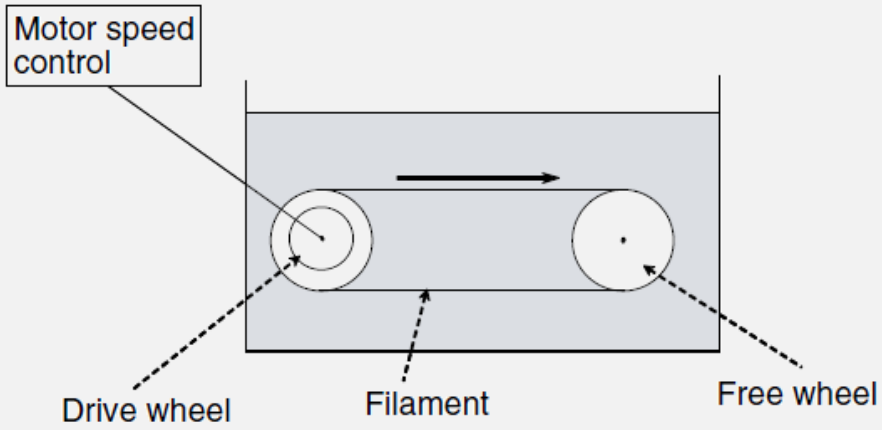


Fig. 11.13 Components of a string phantom. The string is driven in a circuit by a drive wheel. The speed of the drive wheel may be controlled using an external computer to produce waveforms with a physiological appearance.

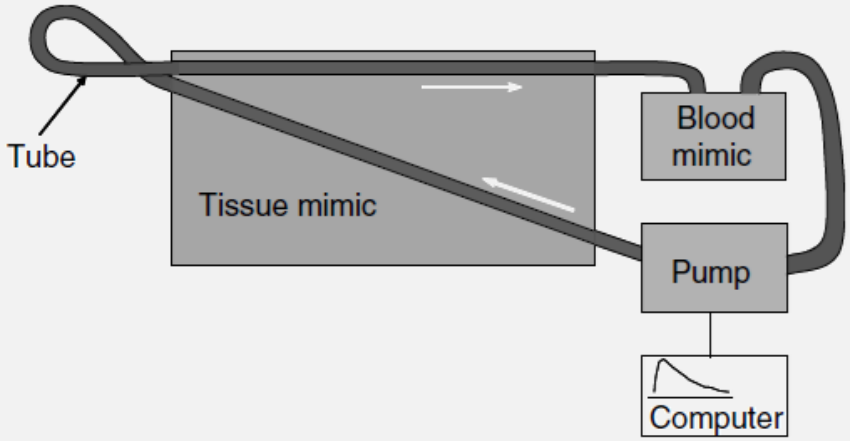


Fig. 11.14 Components of a flow phantom. These are the tissue mimic, tube and blood mimics. The pump may be controlled using a computer to obtain physiological flow waveforms.

Safety of Diagnostic Ultrasound

- During ultrasound scanning, some of ultrasound energy is converted into heat and causes temperature elevation.

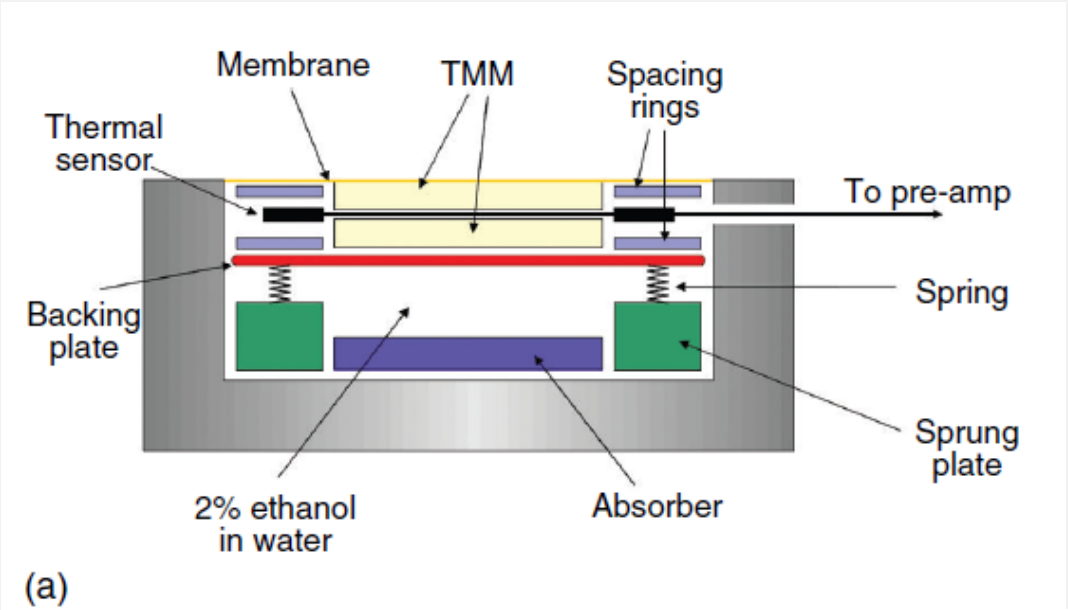
$$q_v = 2\,\alpha_0 f I$$

- According to the American Institute of Ultrasound in Medicine (AIUM) , no significant adverse biological effects were observed due to temperature increases of less than or equal to 2°C above normal for exposure durations up to 50 hours.

- Temperature measurements are performed to ensure there are not adverse temperature effects.

Safety of Diagnostic Ultrasound

Temperature measurements



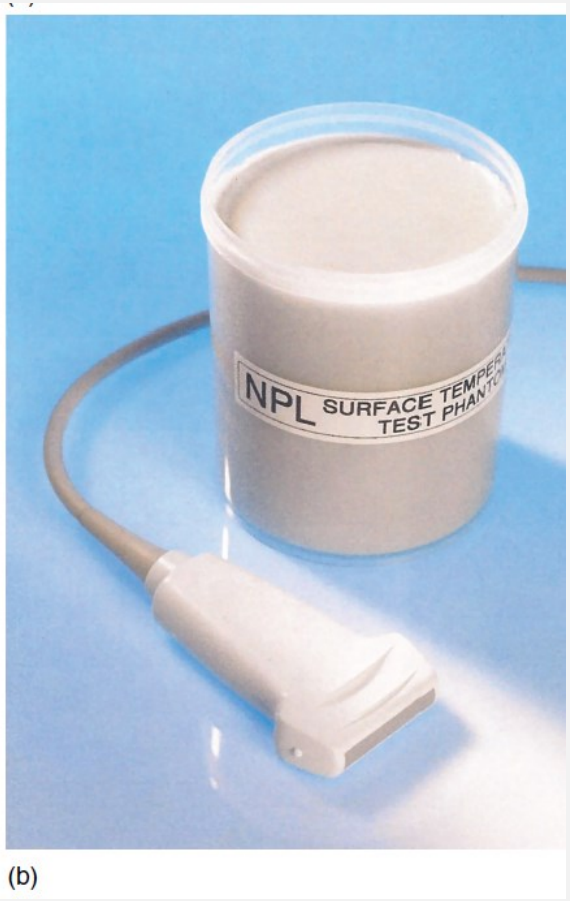


Fig. 12.3 (a) Diagram of a thermal test object. The temperature rise in the middle of the tissue-mimicking material (TMM) is measured with a small thermocouple of less than 0.5 mm in diameter. (b) Photograph of a commercial thermal test object for testing surface temperature rise against the limits specified by the IEC.

Safety of Diagnostic Ultrasound

- When gas bodies inside the body are exposed to ultrasound, they can cause a variety of local mechanical effects that can damage cells or tissue structures.

- Oscillation of the gas surface that causes the mechanical effects is termed ‘acoustic cavitation’ for a free bubble, or ‘gas body activation’ for the more general case.

- The mechanical index (MI) (P_- in MPa divided by the square root of f_c in MHz) be should estimated experimentally.

- It must be below the FDA maximum allowance (MI < 1.9) to avoid adverse biological mechanical effects.

Topics Covered

- Certain topics in chapters 7, 11, and 12 in the book of Hoskins et al.
- Beside slides, study covered topics from the book.