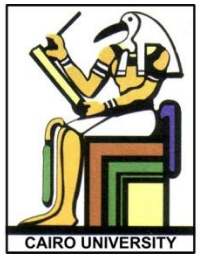


MEDICAL EQUIPMENT (4)

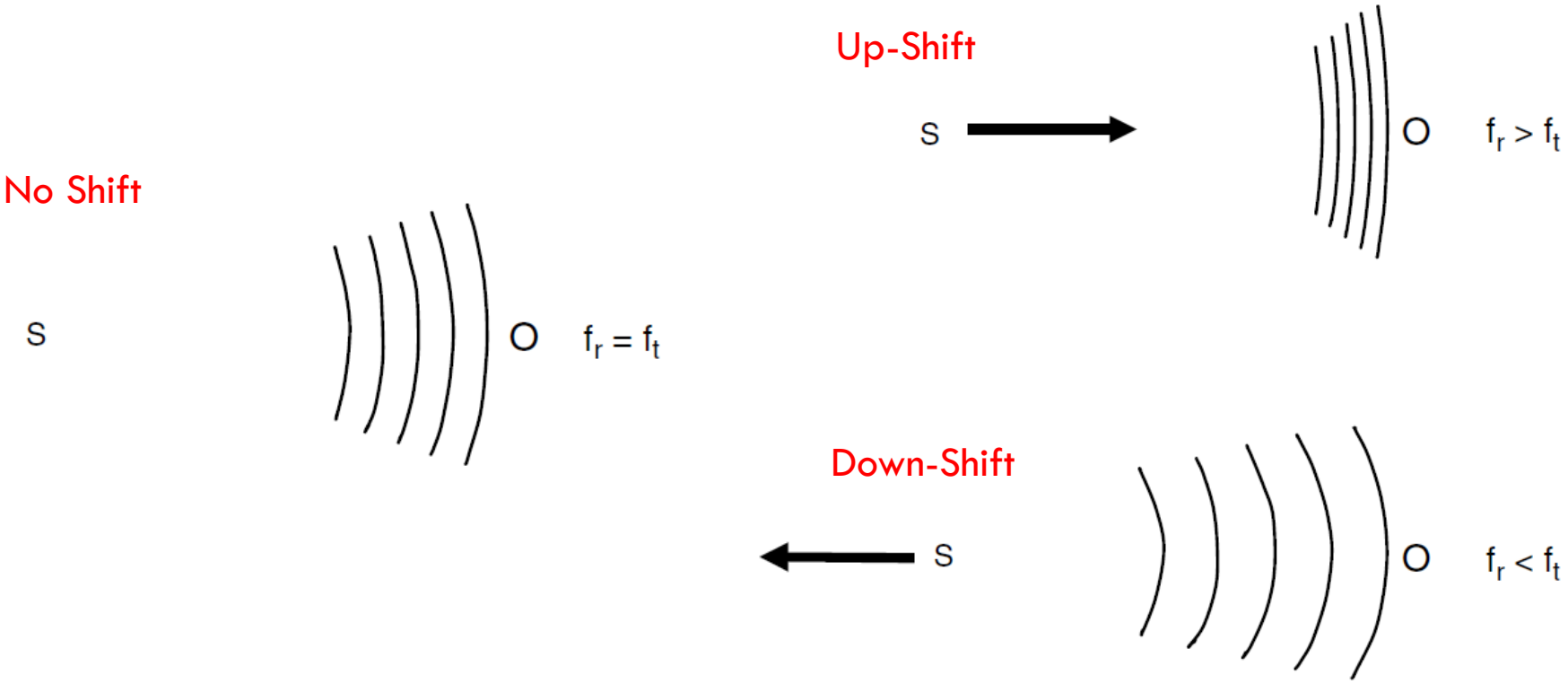
TOPIC 1: ULTRASOUND IMAGING-2

Term 2 - 2013

Prof. Yasser Mostafa Kadah

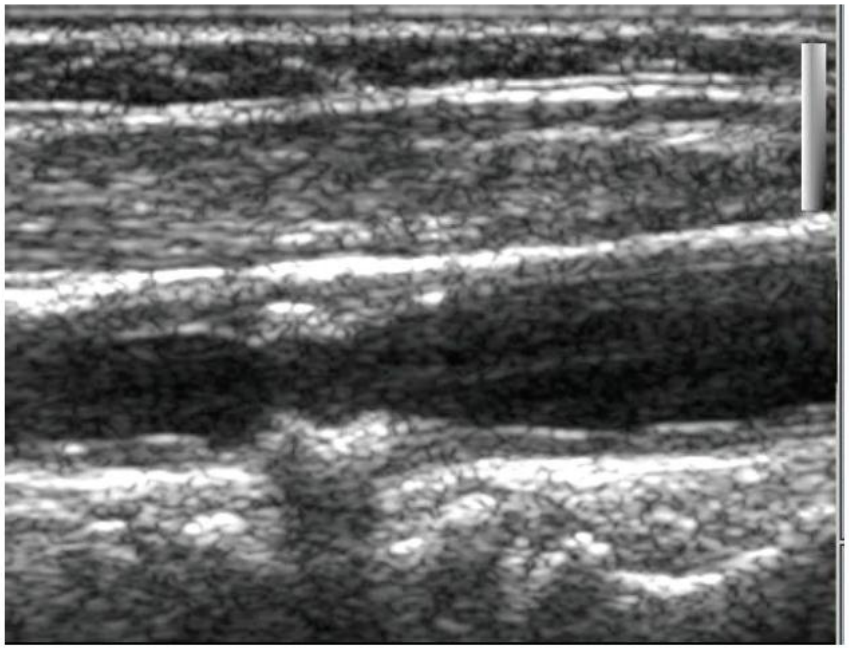
Doppler Ultrasound

- **Doppler effect**: Change in the observed frequency of the sound wave compared to the emitted frequency which occurs due to relative motion between observer and source

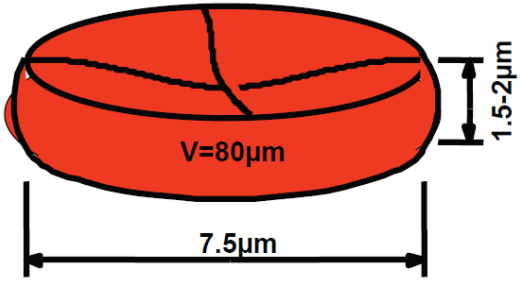


Doppler Ultrasound

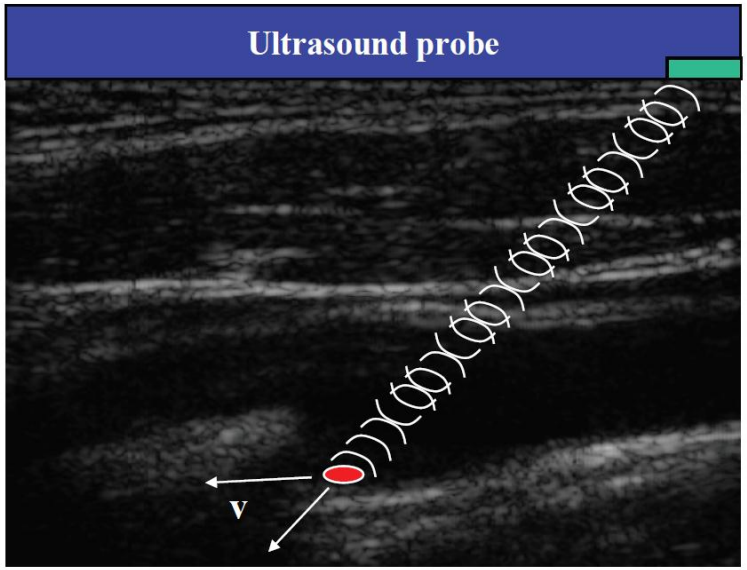
- RBCS in blood are hardly visible in ultrasound images
  - Scattering because of its very small size



Carotid artery with calcified plaque



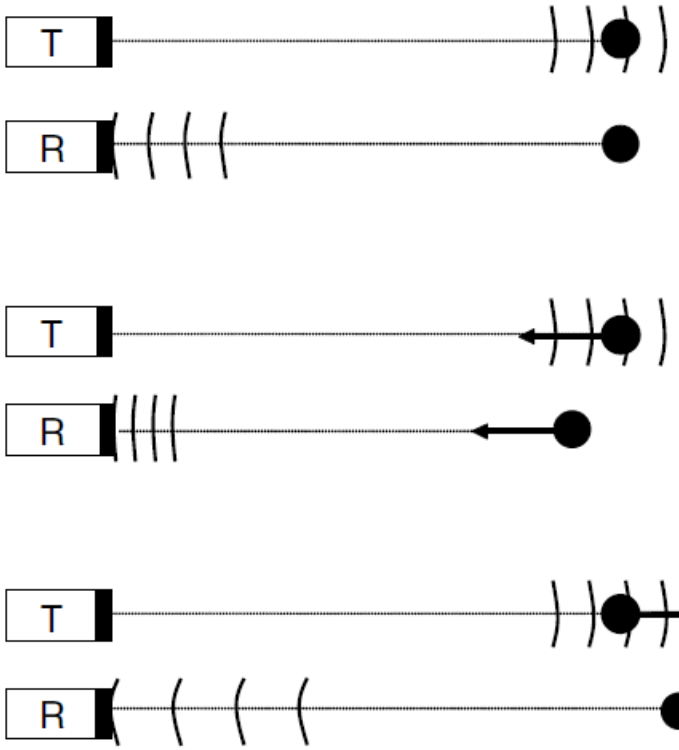
Red blood cell



Doppler Ultrasound

- Doppler Shift Equation

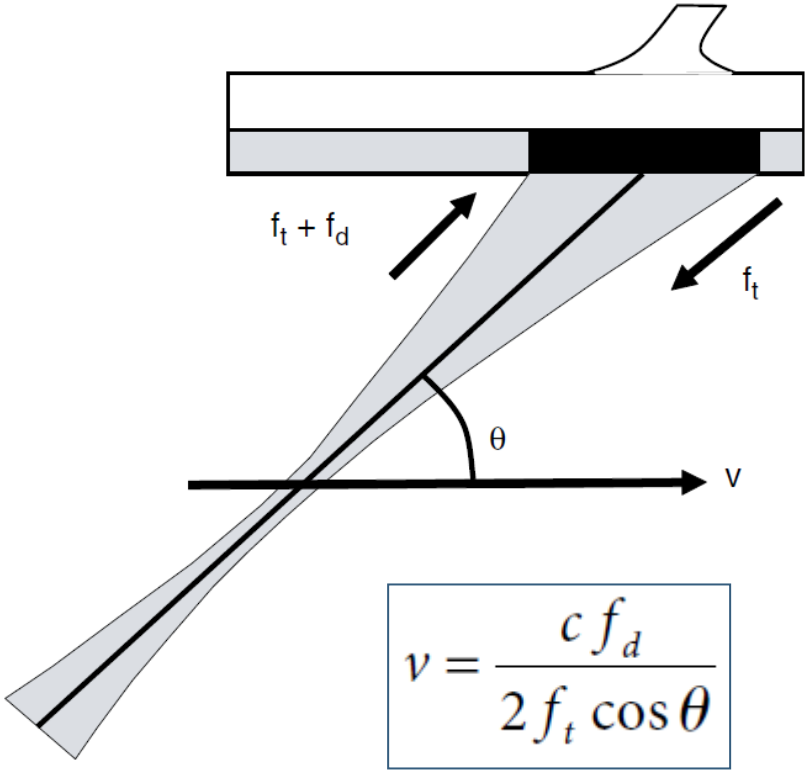
$$f_d = f_r - f_t = \frac{2 f_t v \cos\theta}{c}$$



$f_r = f_t$

$f_r > f_t$

$f_r < f_t$

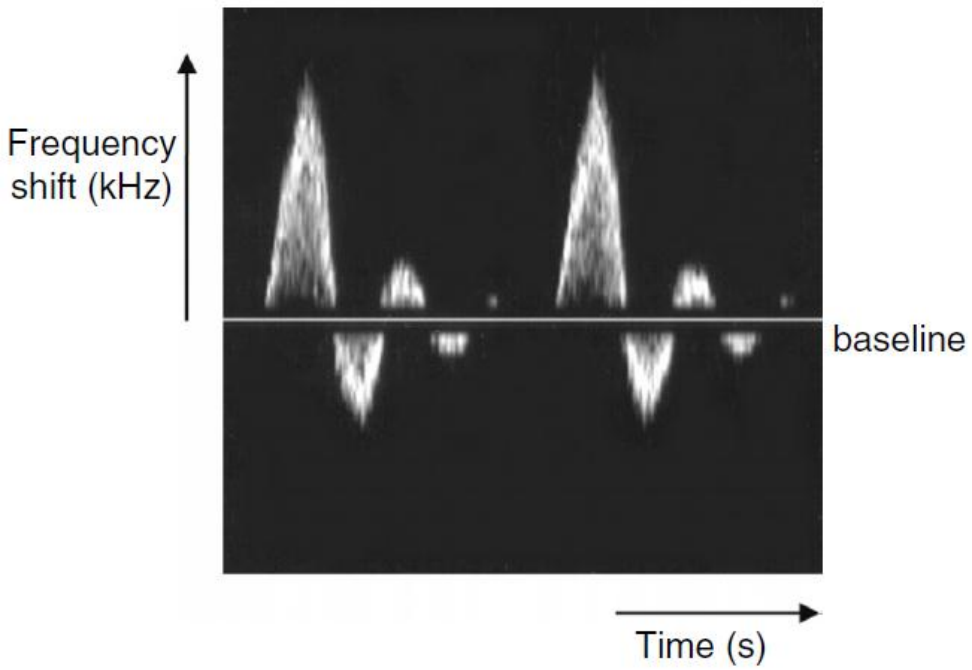


$$v = \frac{c f_d}{2 f_t \cos\theta}$$

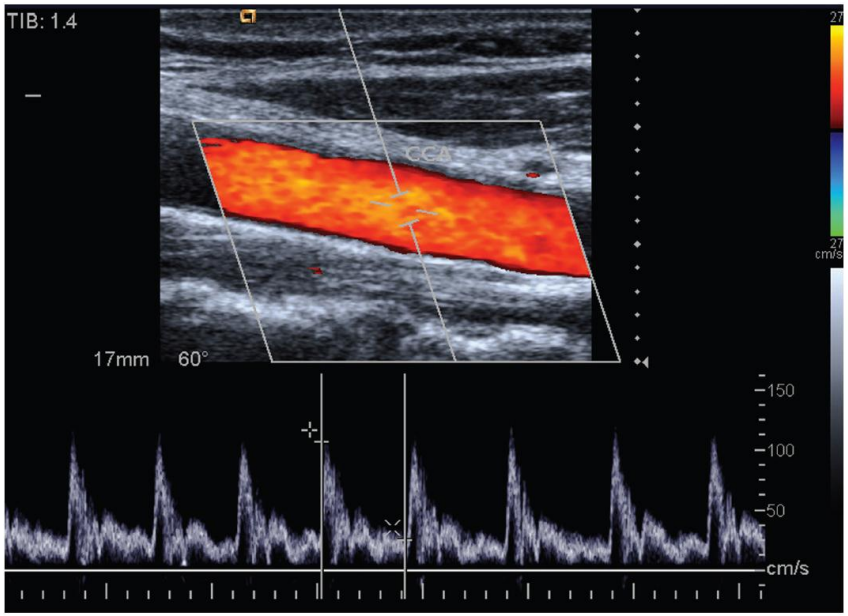
Doppler Ultrasound

- Doppler display modes

Spectral Doppler

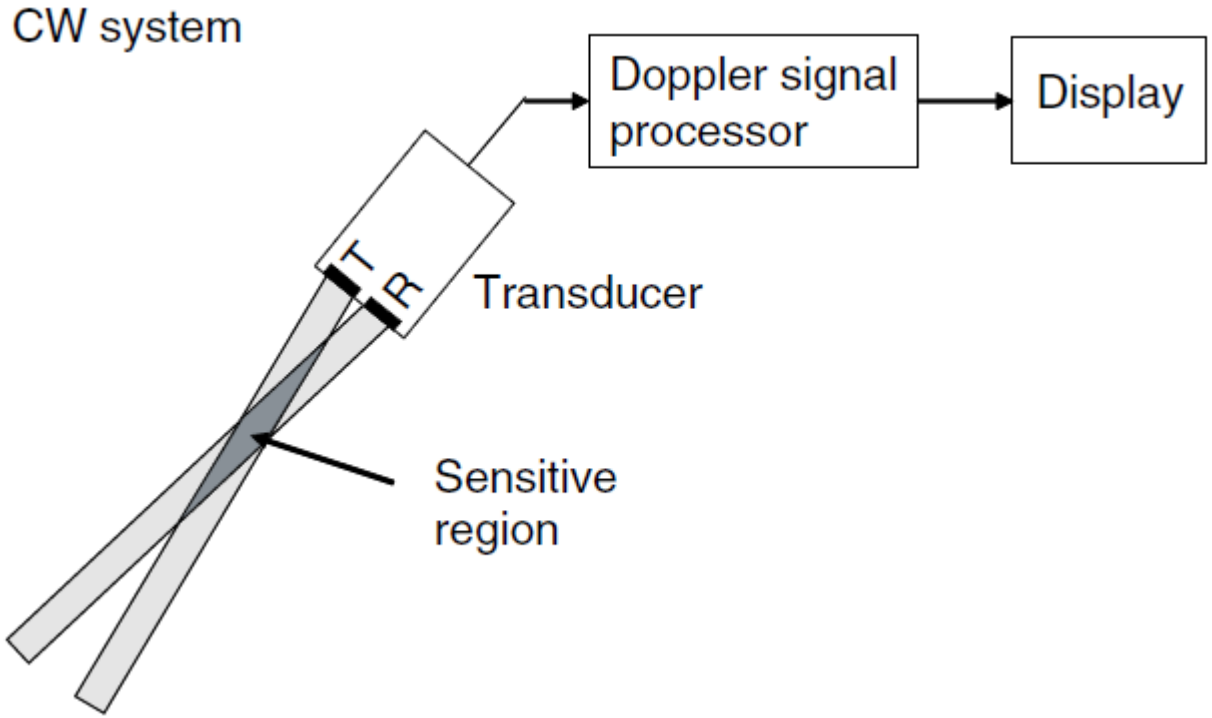


Color Doppler



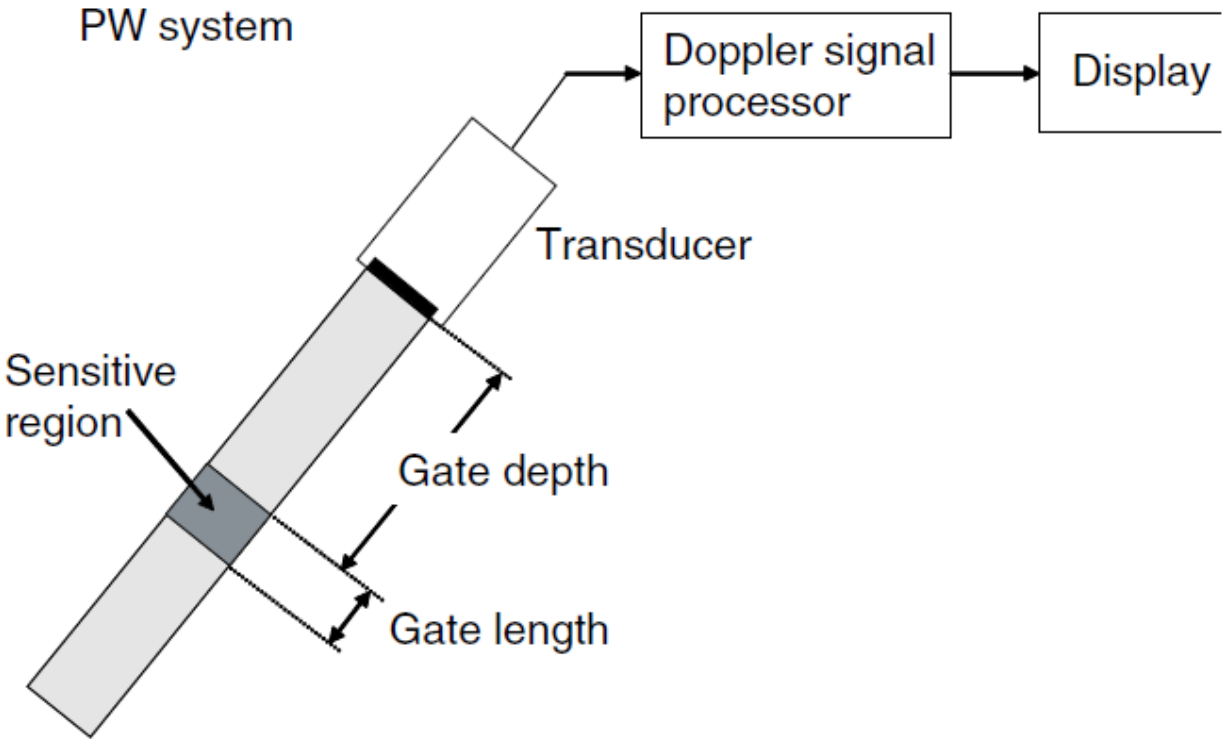
Doppler Ultrasound

- Continuous Wave (CW) Doppler
  - Only a small region for Doppler sensitivity
  - No range information
  - No limitation on maximum velocity and high velocity accuracy



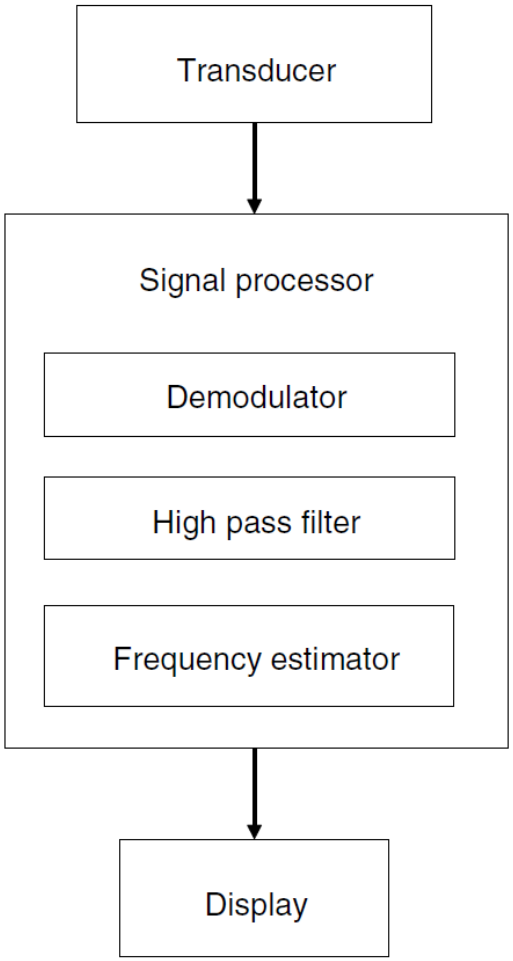
Doppler Ultrasound

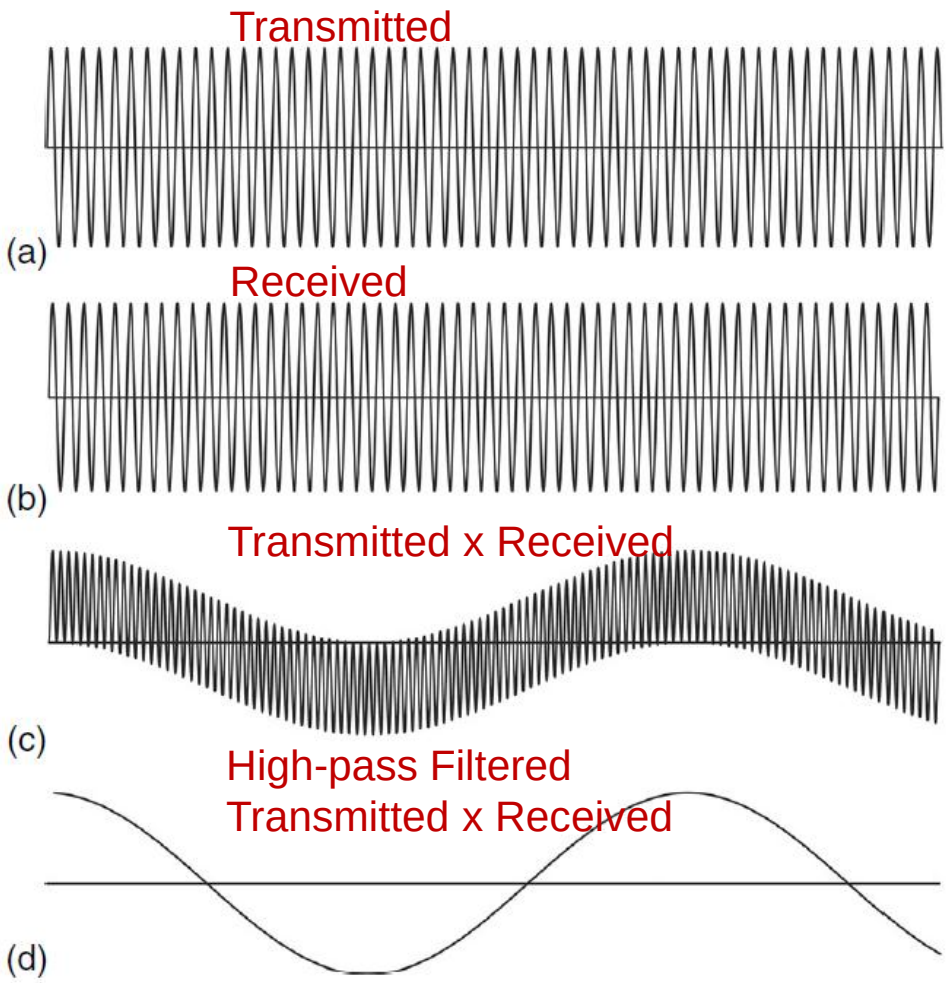
- Pulsed-Wave (PW) Doppler
  - Range information is available and region is selectable by user
  - Limitations on maximum velocity and accuracy



Doppler Ultrasound

- CW Signal Processing

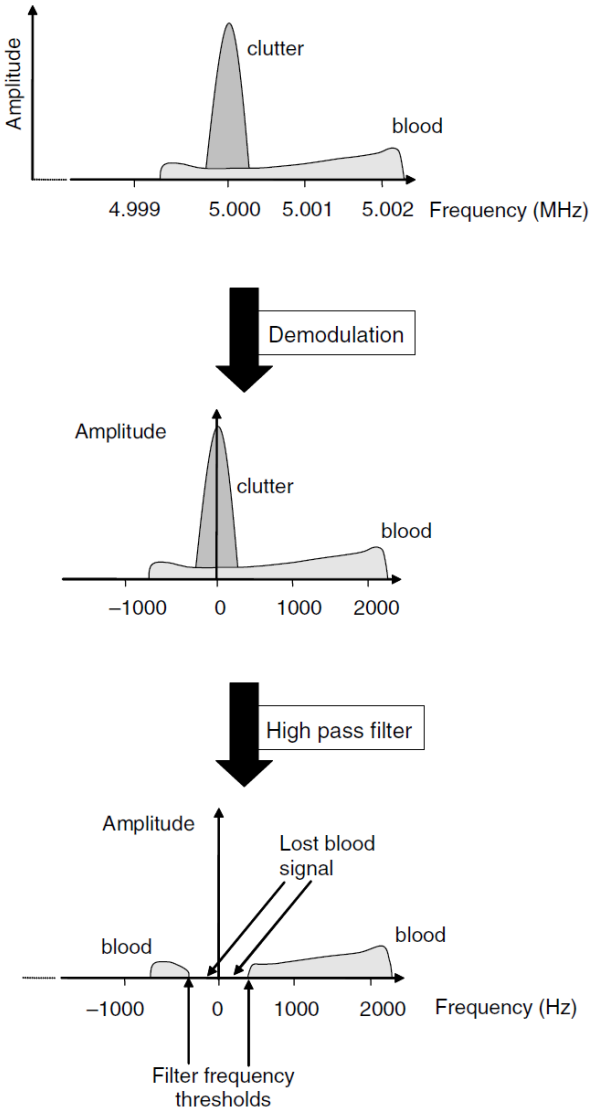




Doppler Ultrasound

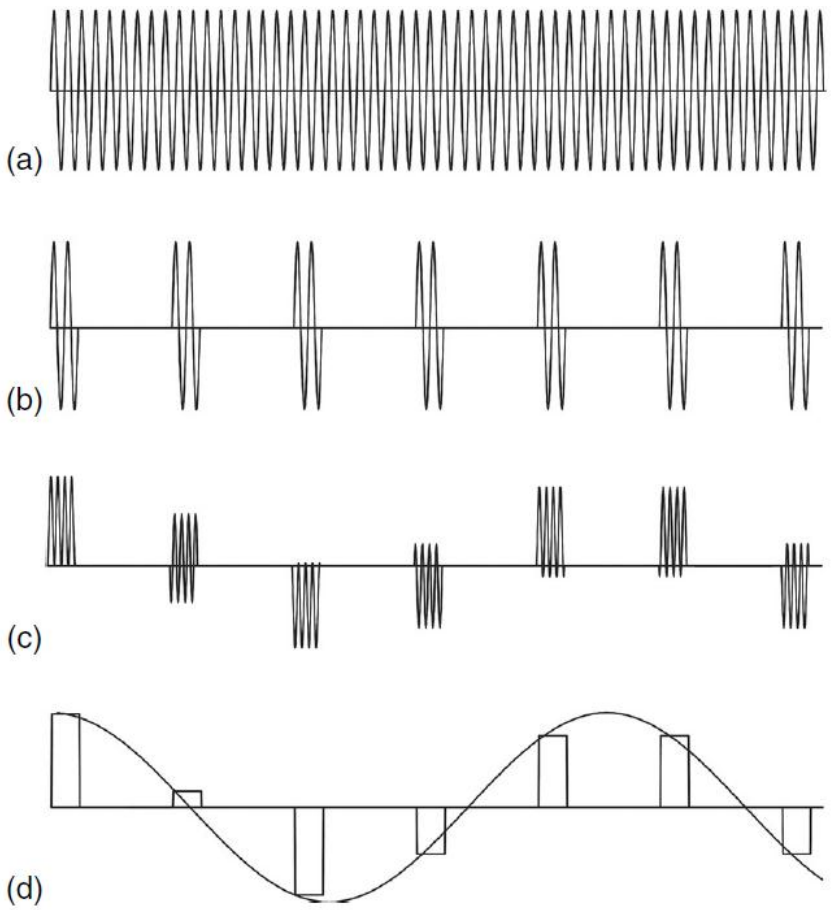
- Clutter: signal from stationary tissues
  - Low Doppler shift and much stronger signal
  - Signal from stationary tissue and wall motion
  - Critical step in Doppler processing

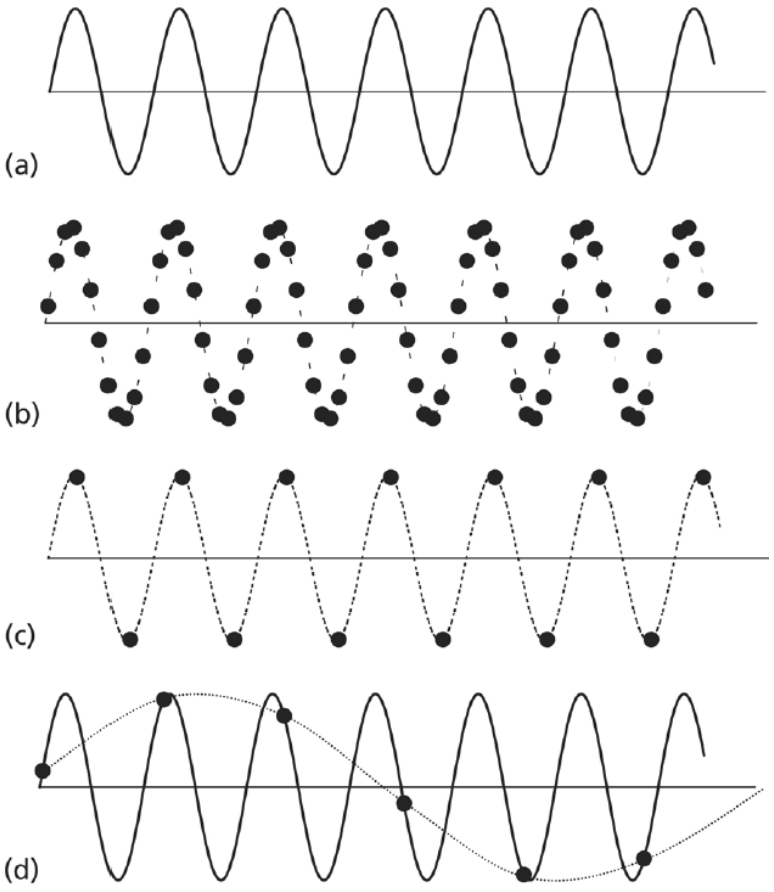
	Velocity ranges	Signal intensity
Blood	0–600 cm s^{-1}	Low
Tissue	0–10 cm s^{-1}	40 dB higher than blood



Doppler Ultrasound

- PW Doppler processing: Sampled version of CW Doppler
  - Aliasing may occur

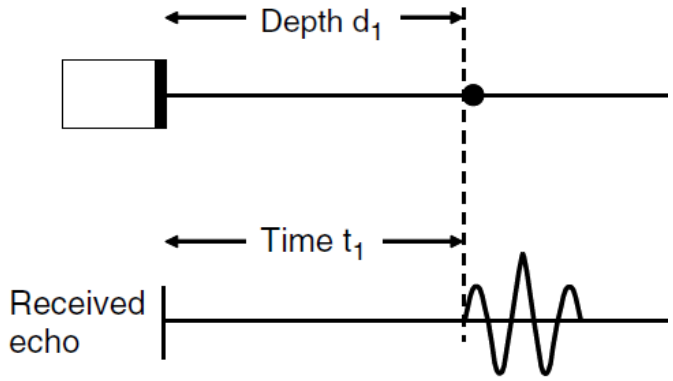




Doppler Ultrasound

- Time-domain PW processing techniques

(a) First pulse, time t_1



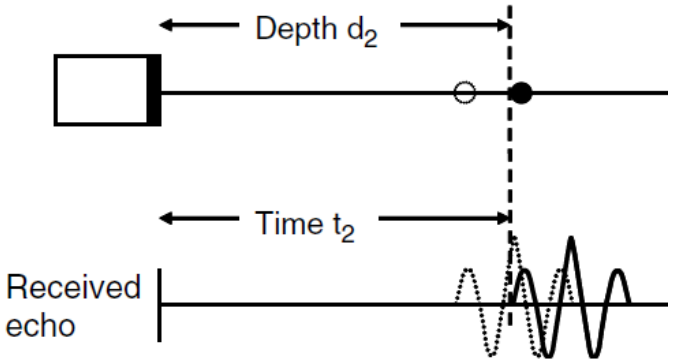
$$d_1 = c\,t_1/2, \qquad d_2 = c\,t_2/2$$

$$d_m = d_2 - d_1$$

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

(b) Second pulse, time t_2

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



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

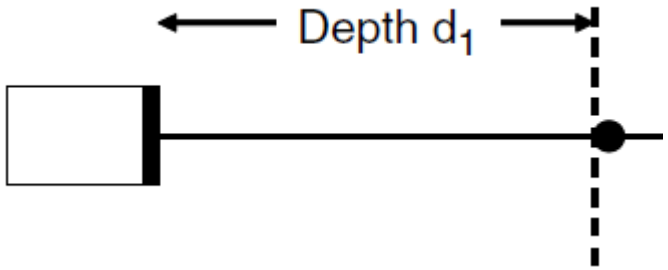
Doppler Ultrasound

- Example: Consider Doppler imaging of a vessel at depth d1= 10 cm. derive the maximum detectible velocity if the transmitted signal frequency was 5 MHz and Doppler angle was 45°.

Time to collect one sample = PRI = 13μs/cm x (10 cm)= 130μs

Sampling frequency = PRF = 1/PRI= 7692 Sa/s = 2 f_d^{max}

$$v = \frac{c f_d}{2 f_t \cos\theta}$$ ⇒ v_{max}=(1540 x 7692/2)/(2x5x10^6xCos(45°))

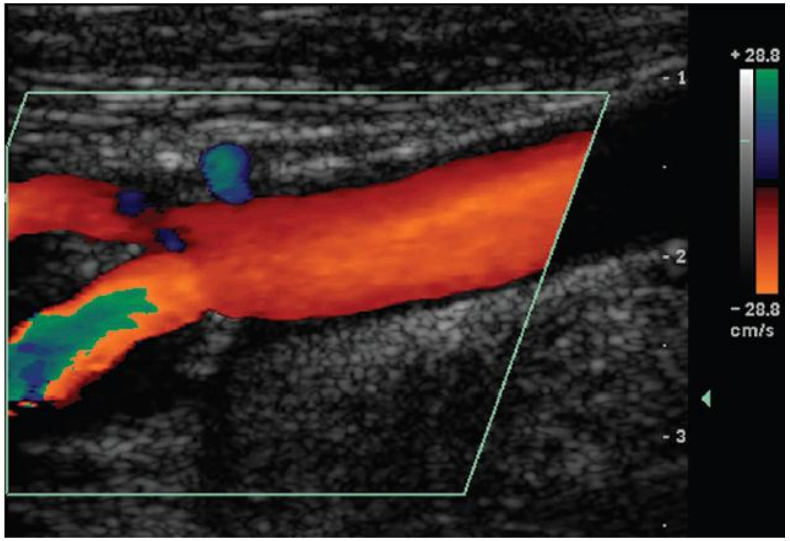


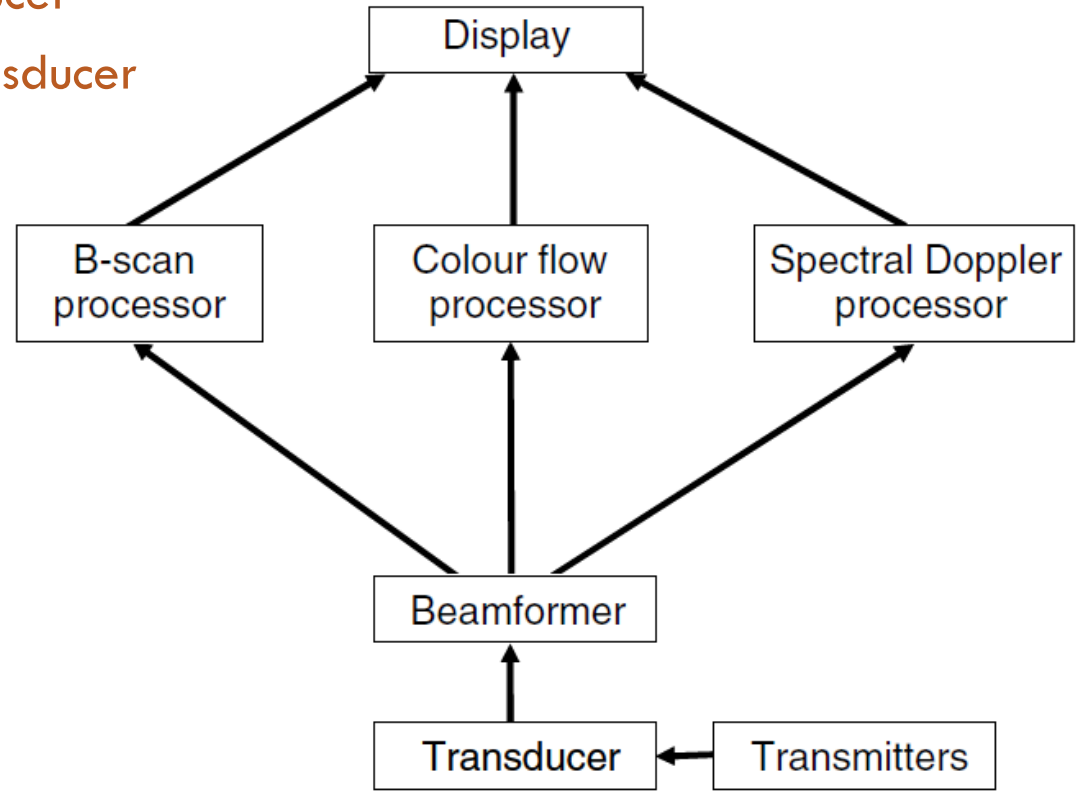
Doppler Ultrasound

- Aliasing
  - Highest Doppler frequency shift that can be measured is equal to PRF/2
- Angle dependence
  - Estimated Doppler shift is dependent on cosine of the angle between the beam and the direction of motion
- Clutter breakthrough
  - Tissue motion giving rise to Doppler frequencies above wall thump or clutter filter may be displayed on spectral Doppler or color flow systems
- Loss of low Doppler
  - Blood velocities which give rise to low Doppler frequencies (as a result of low velocity or angle near to 90°) will not be displayed if value of Doppler frequency is below the level of wall thump or clutter filter

Color Doppler

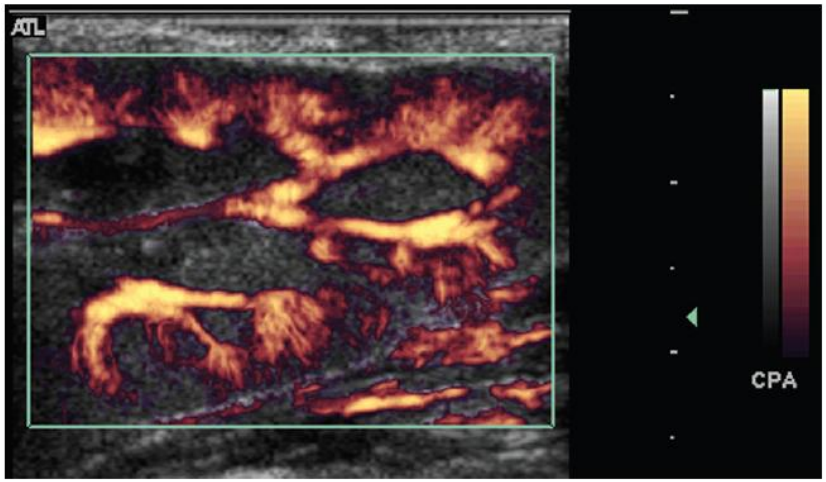
- Maps mean blood velocity at each points and encodes it in color on the usual B&W ultrasound image
  - Red: flow toward transducer
  - Blue floe away from transducer

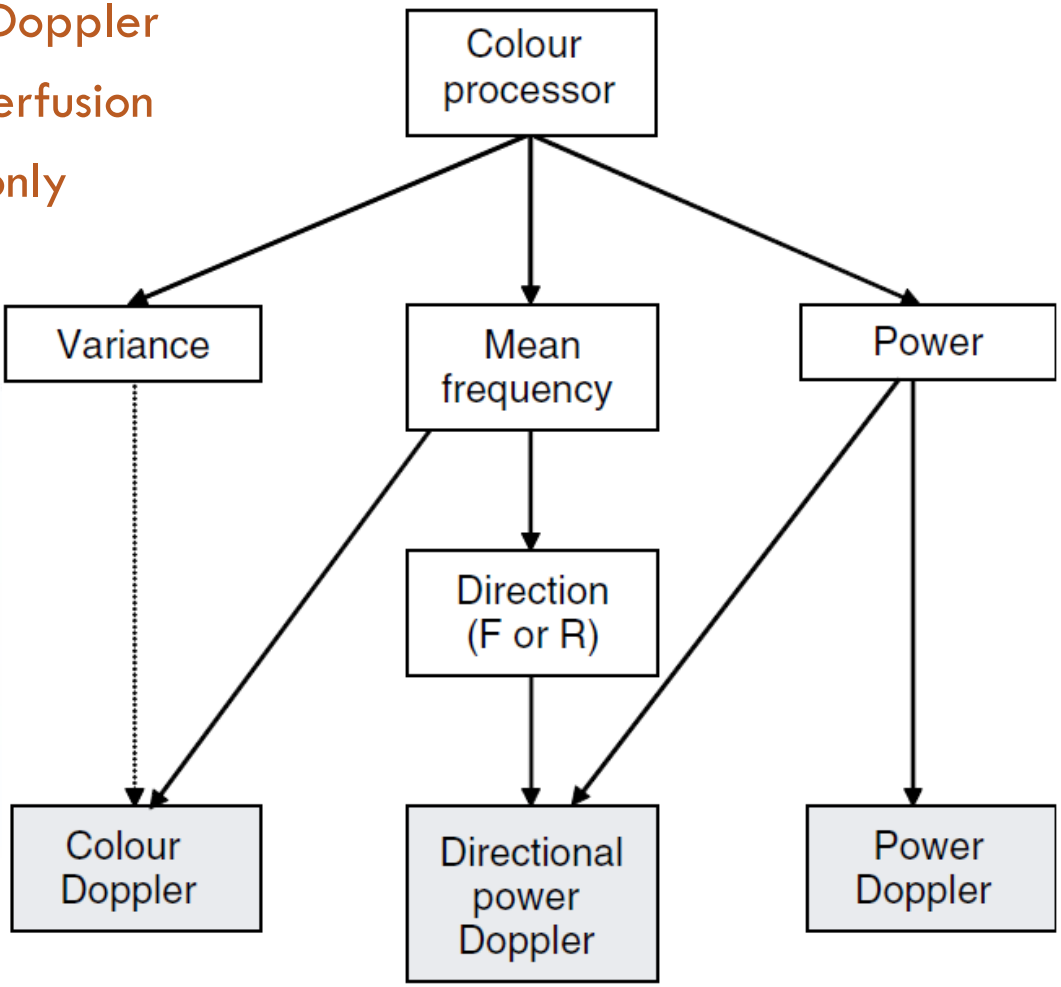




Power Doppler

- Estimate of the power of all shifted components
  - Not just mean like in color Doppler
  - Very useful for assessing perfusion
  - Encoded in shades of red only





Ultrasound Safety

- A fundamental approach to the safe use of diagnostic ultrasound is to use the lowest output power and the shortest scan time consistent with acquiring the required diagnostic information
  - "ALARA" principle (i.e. as low as reasonably achievable)

Assignments

- Chapter 7: problems 3, 4, 5, 6, 7, 8
- Consider Doppler blood flow velocity estimation in a vessel at depth of 5 cm and angle of 60°. Find out whether aliasing will occur when estimating blood velocity if the actual velocity in that vessel is 50 cm/s. Let the transmitted signal frequency be 7 MHz.