$$= f \left[\frac{(C - V\cos\Theta)^2}{C^2 - V^2\cos^2\Theta} \right]$$

* Ultrasound blood Flowmeter

Since $C^2 >> V^2$,

$$f' = f \left[\frac{C^2 + V^2\cos^2\Theta - 2CV\cos\Theta}{C^2} \right]$$

$$= f \left[1 + \frac{V^2}{C^2}\cos^2\Theta - 2\frac{V\cos\Theta}{C} \right]$$

$$\Delta f = f - f' = \frac{2fV\cos\Theta}{C}$$

$$\text{(or) } V = \frac{C\Delta f}{2f\cos\Theta}$$

→ Ultrasound blood flowmeter are used to measure the velocity of a stream of blood, a moving heart valve or motion of an artery in response to a pressure pulse.

If $\Theta = 0^\circ$, $V = 100$ mm/s, $C = 1500$ m/s, a 2 MHz ultrasonic beam is shifted in frequency by about 267 Hz on reflection from the moving blood. This shift in frequeney can be easily detected. For practical purposes,

$$\Delta f \propto V.$$

In obstetrics and cardiology $f = 2 - 3$ MHz
In blood flow studies $f = 10$ MHz

(i) Doppler blood flowmeter using continuous waves

In this, the transmitter operates continuously providing a R.F. output of constant amplitude and frequency. The ultrasonic probe contains separate transmitting and receiving transducers. This arrangement is necessary to minimise the direct transfer of energy from the transmitter to the radiofrequency amplifier; otherwise it will overload the receiver. [Now-a-days there are flowmeters in which a single transducer can operate as transmitter and receiver alternatively]. The output from the R.F. amplifier consists of a mixture of signals, some signals having frequency equal to that of the transmitter (these are due to reflections from stationary structures in the ultrasonic field and electrical leakage) and some signals having the frequencies shifted by the Doppler effect due to reflections from the moving structures. These signals are mixed in the demodulator.

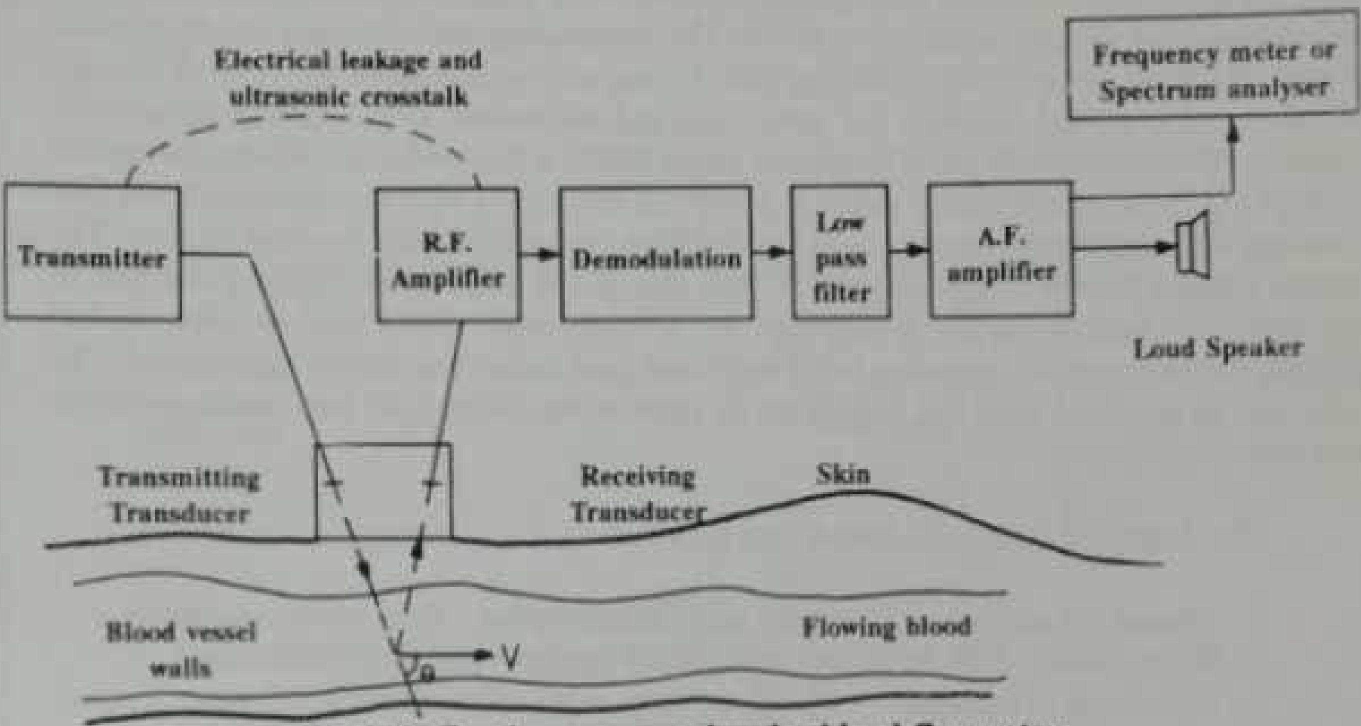

Fig.6.13. Continuous wave doppler blood flowmeter

The output from which contains the difference frequencies between the transmitted ultrasonic wave and the Doppler shifted received waves. The output from the demodulator is filtered to allow these difference frequencies to pass whilst unwanted (higher) frequencies are stopped. The difference frequencies which in general fall in the audible range are amplified. The amplified output may be given to the loud speaker to hear the sound by which a doctor can easily diagnose any abnormality in the blood flow and to spectrum analyser to analyse the frequency components electronically.

b) Recording fetal heart movements and blood circulation using Doppler ultrasonic method

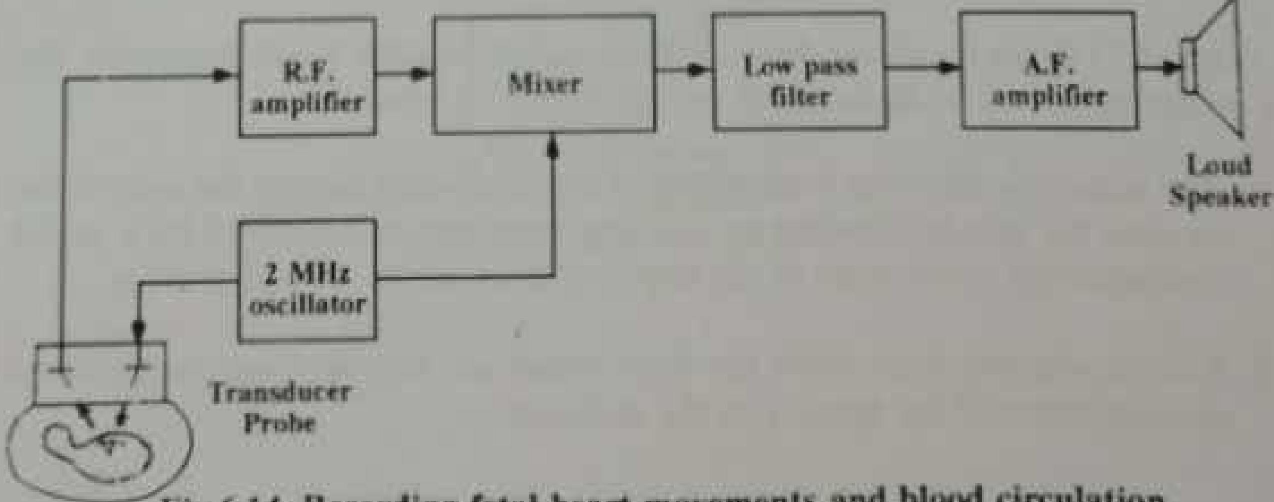

Fig.6.14. Recording fetal heart movements and blood circulation

Figure 6.14 shows the arrangement for recording fetal heart movements and blood circulation using doppler ultrasonic method. The transmitting and receiving transducers are placed in a single probe which is held against the mother's abdominal wall. A small amount of oil or gel is placed between the probe and the adbominal wall to get good acoustic coupling. The ultrasonic beam of frequency about 2MHz is directed at the heart or umbilical cord of the fetus. The reflected signal is amplified and mixed with the emitted signal. The resulting beat frequency is proportional to the blood velocity in the fetus and mother. The mother's blood flow can be distinguished from that of the fetus by the higher pulse rate of the fetus. The beat frequency is amplified and can be heard with a loud speaker. By this method the presence of a pulsating heart and blood flow in the fetus can be determined. The echo can be obtained from the fetal heart as early as the 10th - 12th fetal week and from that time until delivery.

The following diagnostic sounds can be heard.

1. Thump, Thump - low frequency note, rapid rhythm - fetal heart movement.
2. Swish, Swish - high frequency note, rapid rhythm - umbilical cord sound.
3. Thuummp, Thuummp - low frequency note, slow rhythm - mother's body movements due to vibrations transmitted from the heart.
4. Woooch, Woooch - mid frequency note, slow rhythm - mother's arteries.

Thus the status of the fetus in the mother's abdomen can be studied completely without any danger.

c) **Pulsed Doppler blood flowmeter**

Many of the difficulties associated with continuous wave Doppler system can be eliminated if the ultrasonic source is pulsed and the doppler shift of the returning echo is measured. If the return signal is range gated, the distance to the moving interface (or) diameter of the blood vessel as well as blood velocity can be measured accurately.

Figure 6.15 shows the circuit diagram of the pulsed Doppler blood flowmeter. The working of that circuit can be explained in various steps.

1. The pulse repetition rate is controlled by the clock which triggers the monostable to open the gate to allow the transmitting transducer to be excited for a period corresponding to the width of the target volume which is desired to study.