RADAR

BY DR. G G SARATE

Principle:

- Radar consists of a transmitter and a receiver, each connected to a directional antenna.
- The transmitter transmit signal.
- Receiver collects energy from the echoes reflected in its direction by the target and then processes and displays the information.
- The receiving antenna is same as the transmitting antenna.

Basic radar system:

A master timer controls the pulse repetition frequency (PRF) or pulse repetition rate (PRR).

These pulses are transmitted by a highly directional parabolic antenna at the target, which can reflect some of the energy back to the same antenna. The antenna is switched from a transmit mode to a receive mode by a duplexer.

Range= $\Delta t/12.36$ miles

Pulse repetition time (PRT): sufficient time requirement for an echo to return to the transmitter after the radar pulse is transmitted, in order to not interfere with the next transmitting pulse. (miles)

It determines the maximum distance to the target to be measured.

Mur :

The range beyond which objects appear as second return echo is called the maximum unambiguous range (mur)

Mur= PRT/12.2 miles.

Radar performance factor:

Radar range equation: $$r_{max} = \left[\frac{P_t A_p^2 \lambda^2 S}{4(\pi)^3 \, P_{min}}\right]^{1/4}$$

Where P_t = transmitted power peak value.

A_p= max power gain of antenna.

S= radar cross section or effective area.

λ= wavelength

P_{min} =minimum receivable power of the receiver.

Factor influencing maximum range:

a) Max range is proportional to forth root of the peak transmitted pulse power. If max range is to be doubled the peak power must be increased 16^{th} fold All other factors being constant. (not economical).

b) P(min) is governed by sensitivity of receiver. The min receivable power may be reduced by gain increase of the receiver that is reduction in the noise at its input – radar jamming and interference.

c) R(max) is inversely proportional to the forth power of transmitted peak power. Means that the signals are subjected twice to the operation of inverse square law.

d) R(max) is proportional to the square root capture area of the antenna therefore directly proportional to its diameter. To double the r(max) the diameter of antenna is to be doubled.

e) R(max) depends on target area.

Effect of noise: noise figure is given by

$$F = \frac{(S/N)_i}{(S/N)_o} = \frac{S_i N_o}{S_o N_i} = \frac{S_i}{G S_i} = \frac{G(N_i + N_r)}{N_i} = 1 + \frac{N_r}{N_i}$$

S_i = input signal power

N_i = input noise power

S_o = output signal power

N_o = output noise power

G = power gin of the receiver

We have, $\frac{N_r}{N_i} = F-1$

$N_r = (F-1)\, N_i = kT_0\delta f(F-1)$

$kT_0\delta f(F-1)$ = noise input power of receiver

k = Boltmann's constant = 1.38×10^{-23} J/K

T_0 = standard ambient temperature = 17°C = 209K

δf = bandwidth of receiver

$$r_{max} = \left[\frac{P_t A_0 S}{4\pi \lambda^2 k T_0 \delta f(F-1)}\right]^{1/4}$$

$$= \left[\frac{P_t D S}{\pi^2 \delta f(F-1)}\right]^{1/4}$$

r_{max} = max radar range, km

P_t = peak pulse power, W

D= antenna diameter, m

S= effective cross section area of target, m^2

PULSE RADAR SYSTEMS:

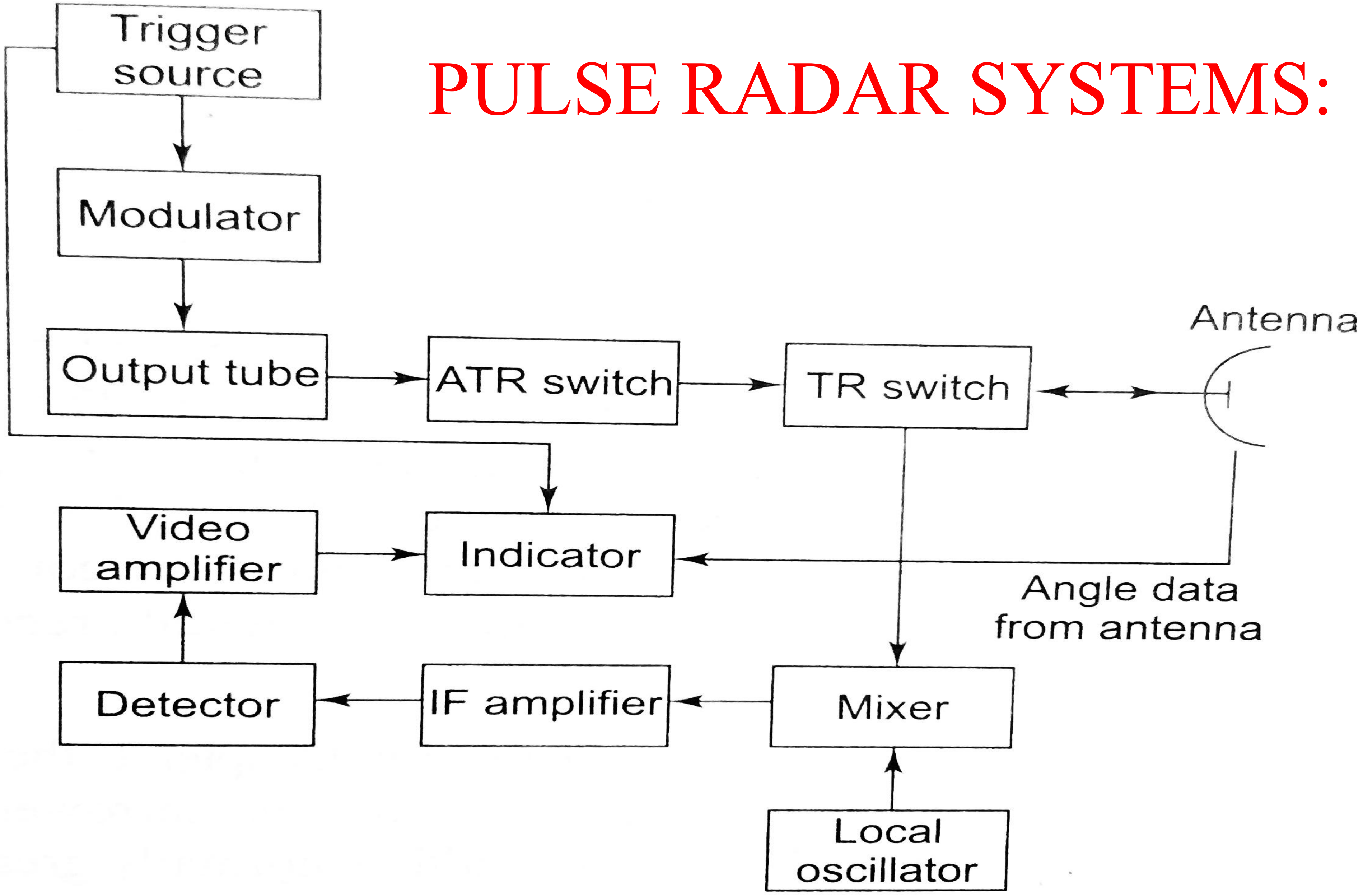


Fig. 15.4 Pulsed radar block diagram.

PULSE RADAR SYSTEMS……

Trigger source: provides pulses for modulators.

Modulator: provide rectangular voltage pulses used as the supply voltage for the output tube.

Output tube: may be magnetron, klystron, twt.

ATR switch TR switch: duplexer.

Radar antennas and scanning.

Radar antenna: they are used to scan given area of the surrounding space.

There are mainly four types of scanning patterns. And these patterns depends upon the application.

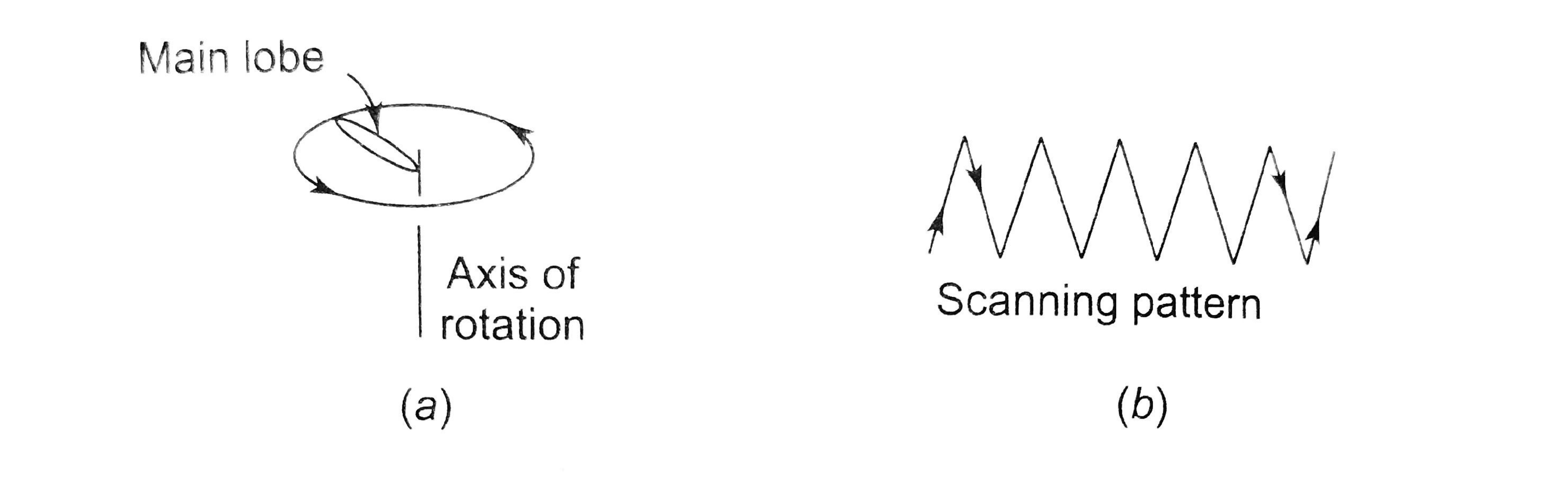
The four types of:

1. Horizontal pattern
2. Nodding pattern
3. Helical pattern
4. Spiral pattern

1. **Horizontal scanning**: It is the simplest type of scanning. It scans only in horizontal plane which is only its disadvantages.

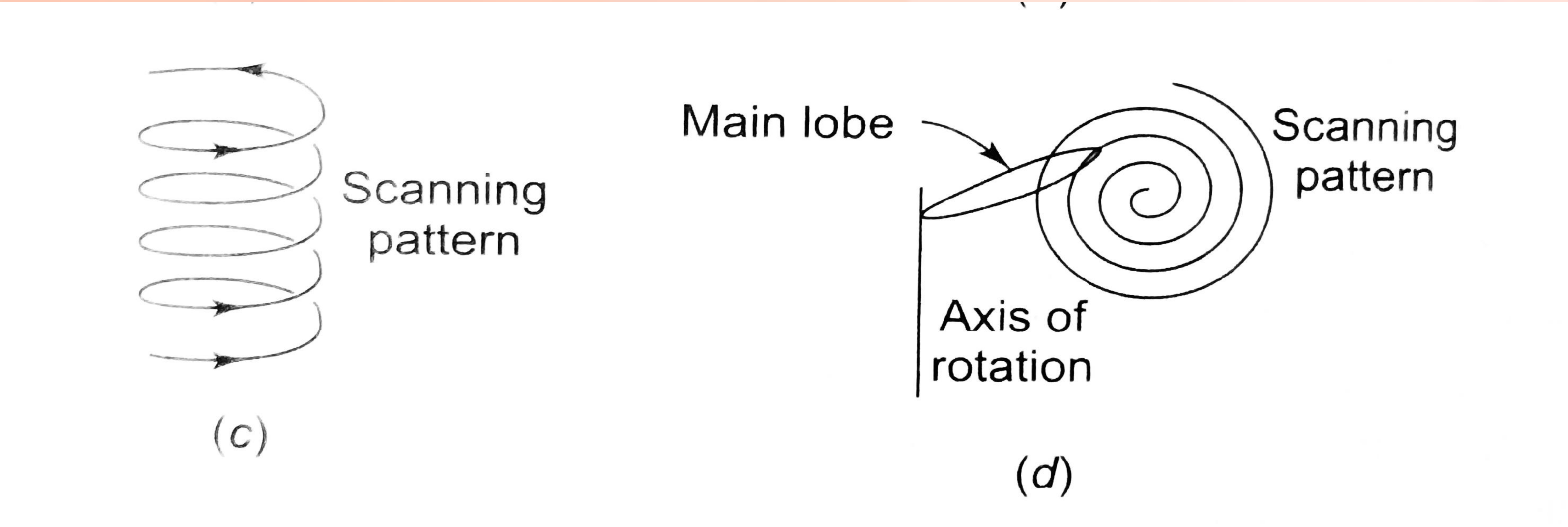
It is used in searching the horizon e.g., ship to ship radar.

2. Nodding scanning: The antenna is rocked rapidly in elevation while it rotates slowly on in azimuth. Hence scanning in both planes is acquired. It is used to scan a limited sector, also it can be extended to cover the whole



3. Helical scanning: the elevation of the antenna is raised slowly while is rotates more rapidly in azimuth. The antenna is then returned to its starting point at the completion of the scanning cycle. And typical speeds are a rotation of 6rpm accompanied by a rise rate of 20°/minute. It is used to search the complete hemisphere.

4. Spiral scanning: it scans a limited area of circular shape.



Antenna tracking

It is used to locate the exact position of an target.

There are two methods of antenna scanning.

1) Lobe switching or sequential lobing.

The direction of the antenna beam is rapidly switched between two positions so that the strength of the echo from the target will fluctuate at the switching rate. when the target is exactly midway between the two directions the echo strength will be same for both antenna position and the target will have been tracked with greater accuracy. Sequential lobing is accurate in only one plane.

2) Conical scanning:

The parabolic antenna is mounted slightly off centre and is rotated about the axis of the parabola, the rotation is slow as compared to PRF. It is from the surface described in space by the pencil radiation pattern of the antenna as the tip pf the pattern moves in a circle. Conical scanning is accurate in both the planes (elevation and azimuth).

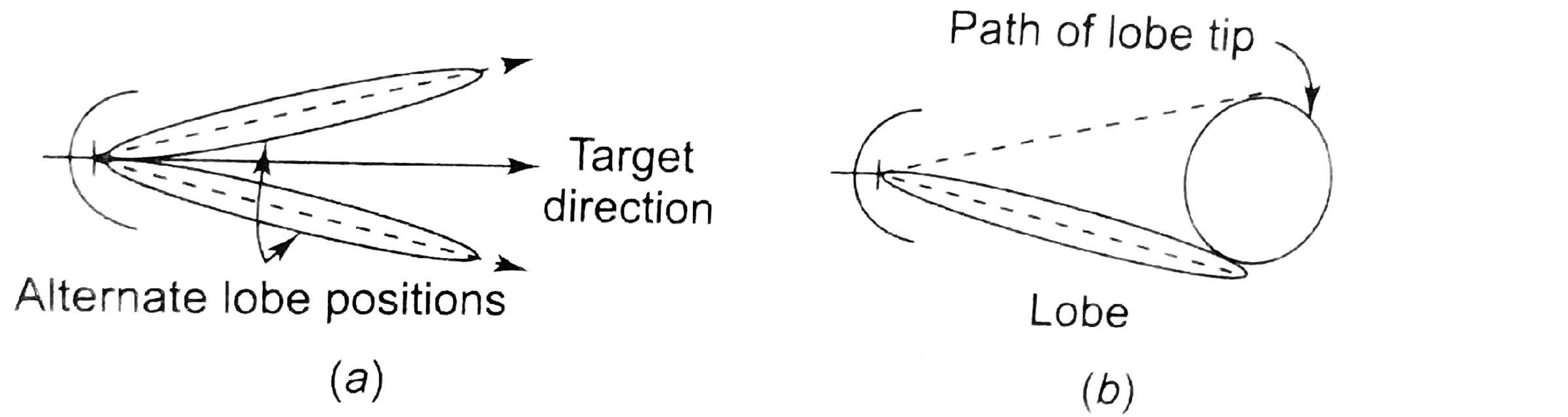


Fig. 15.6 Antenna tracking, (a) Lobe switching; (b) conical scanning.

Disadvantages of both the types:

1) Motion of the antenna is more complex. And additional servomechanisms are required.
2) More that one retured pulse is required to locate a target accurately.

Display methods :

There are 3 types of display methods that are most commonly used.

1) Deflection modulation of a cathode ray tube screen as in A scope:

A scope:

- The operation of display is similar to oscilloscope. A sweep waveform is applied to the horizontal deflection plate of the CRT and moves the beam slowly from left to right across the face of the tube and back to the starting point.
- The flyback period is rapid and occurs with the beam blacked out. In the absence of any received signal, the display is simply a horizontal straight line. The demodulated receiver output is applied to the vertical deflection plates and causes the departure from the horizontal line.

- The horizontal deflection sawtooth waveform is synchronized with the transmitted pulses so that the width of the CRT screen corresponds to the time travel between successive pulses.
- Displacement from the left hand side of the CRT corresponds to the range of the target. The first blip is due to the transmitted pulses, part of which is deliberately applied to the CRT for reference. Various strong blips are due to reflections from the ground and nearby objects, followed by noise called as ground clutter.
- Various target show up as large blip, again interspersed with grass. The height of each blip corresponds to the strength of the returned echo, while its distance from the reference blip is a measure of its range.
- As the distance increases the size of echo decreases. It would take a large target to produce same size of echo as of a small target which is much closer.

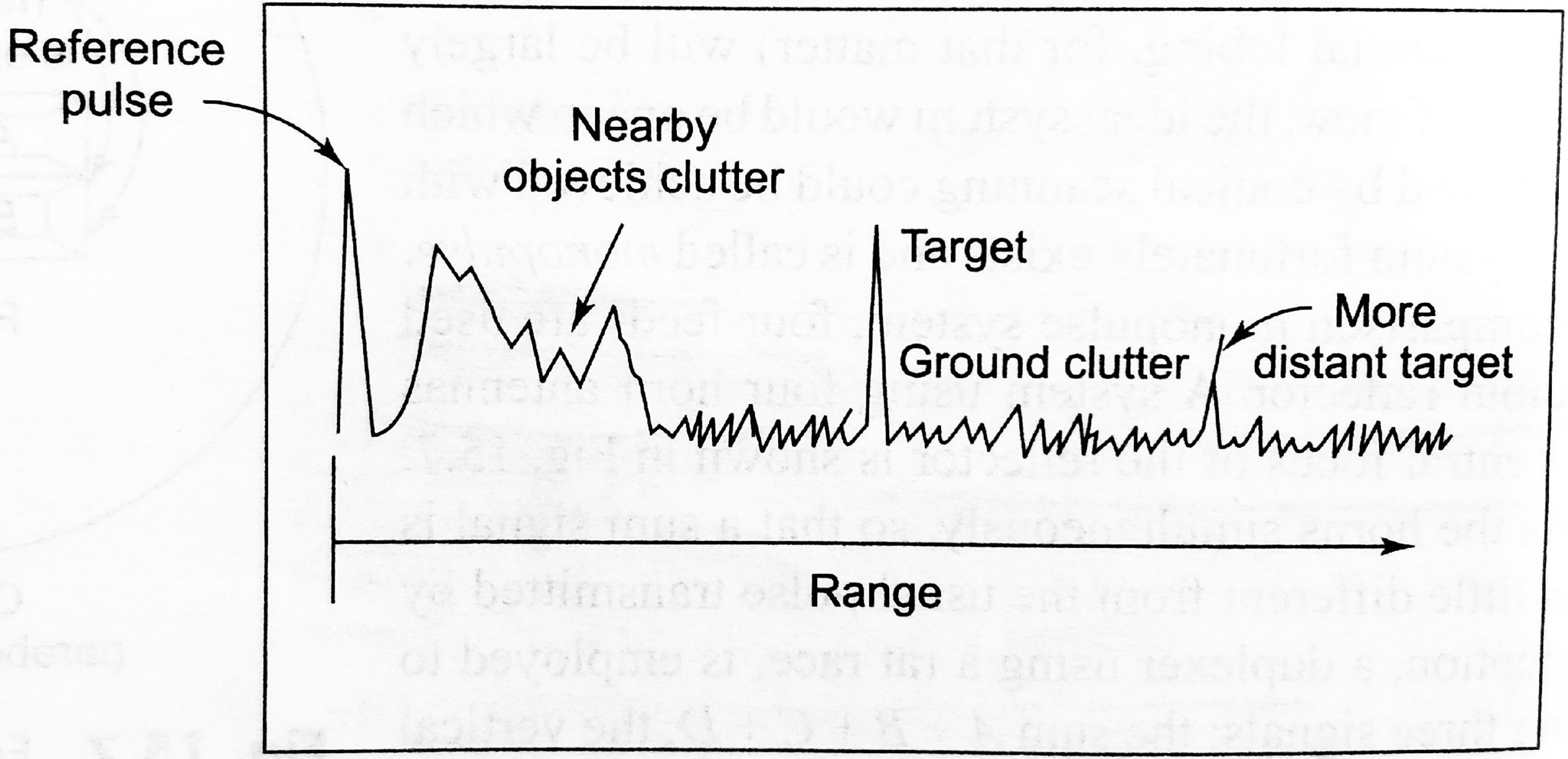


Fig. 15.8 A scope display.

2) Intensity modulation of a CRT as in the plan position indicator (PPI):

Plan position indicator:

- As the CRT is now intensity modulated, the signal from the receiver after demodulation is applied to the grid of the cathode ray tube. The CRT is biased slightly beyond cutoff, and only blips corresponding to targets permit beam current brightening the screen.
- The scanning waveform is now applied to a pair of coils on opposite sides of the neck of the tube, so that magnet deflection is used, and a sawtooth current is required.
- The coils, situated in a yoke similar in appearance to that around the neck of a television picture tube, are rotated mechanically at the same angular velocity as the antenna. Hence the beam is not only deflected radially outward from the center and then back again rapidly but also rotates continuiousely around the tube.

- The brightness at any point on the screen indicated the presence of any object, with its corresponding to its actual physical position and its range being measured radially out from the centre.
- Long persistence phosphors are normally used to ensure that the face of PPI screen does not flicker. The scanning speed is rather low compared to the 60 fields per second used with television , so that various portions of the screen go dim between successive scans.
- The resolution on the screen depends on the beamwidth of the antenna, the pulse length, the transmitted frequency, and even on the diameter of the CRT beam. Circular screens are used with diameters ranging up to 40cm, but 30 cm is most often used.

Application: It is used with searching radars and are suitable for circular scanning.

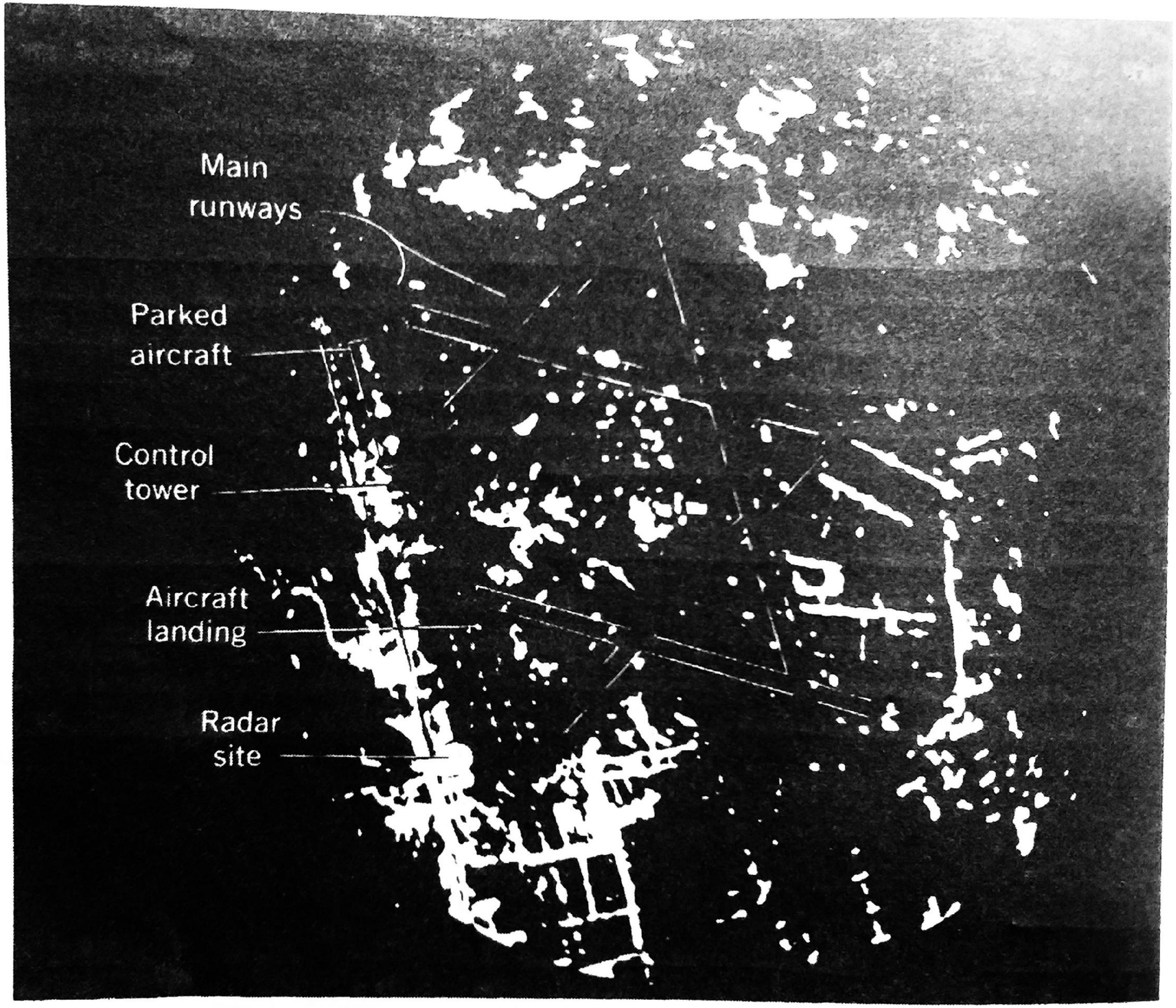


Fig. 15.9 PPI display, (a) Radar map of London's Heathrow Airport (British Information Services (BIS) Pictures); (b) Portable modern marine radar set. (Courtesy of AWA Australia.)

RADAR ANTENNA:

Antenna with parabolic reflectors:

- The parabola is a plane curve. It is the locus of a point which moves so that its distance from focus plus its distance from a straight line (directrix) is constant.
- A practical reflector will be a three-dimensional bowl-shaped surface, obtained by revolving the parabola about the axis AB. The resulting geometric surface is the paraboloid, often called a parabolic reflector or microwave dish. It is reciprocity.
- The reflector is directional for reception because only the rays arriving from the BA direction, that is normal to the directrix, are bought together at the focus. Rays from any other direction are cancelled at that point, again owing to path-length differences.
- The reflectors provide high gain as it collects radiations from a large area and concentrates it all at the focal point.

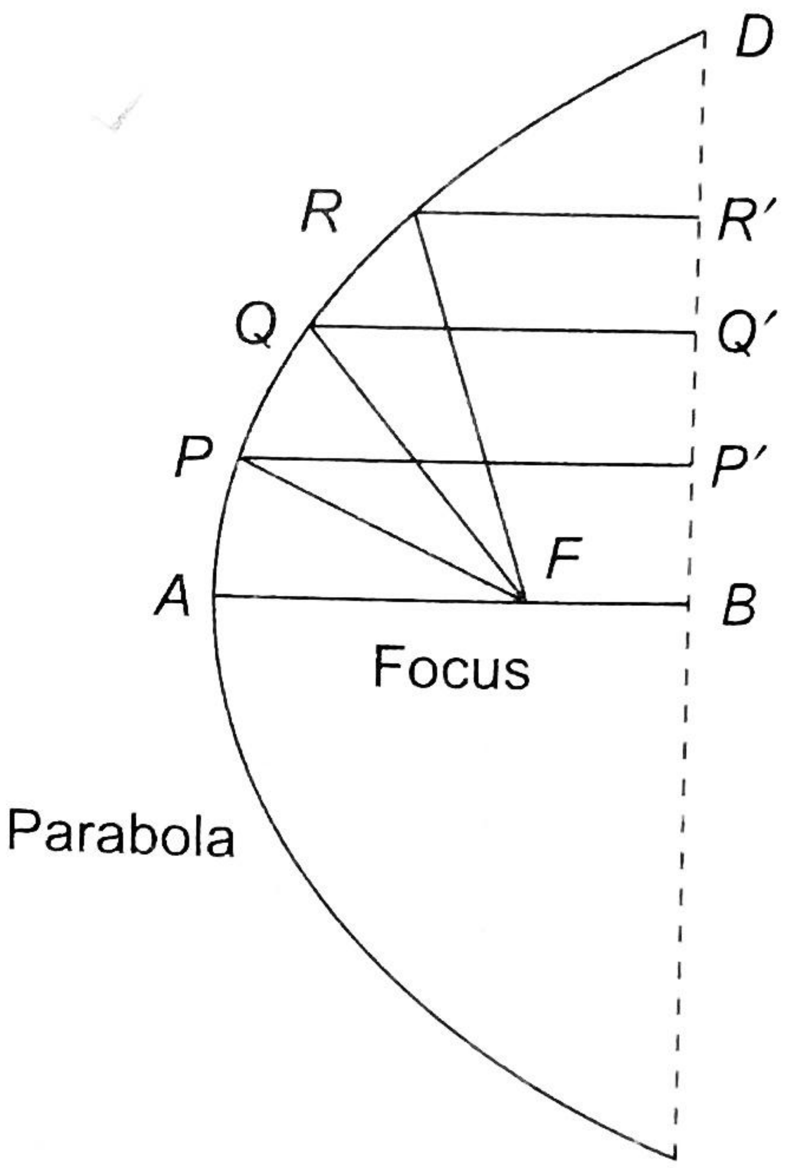


Fig. 11.26 Geometry of the parabola.

Properties of parabolic reflectors

The directional; pattern of an antenna using a paraboloid reflector has a very sharp main lobe surrounded by a number of minor lobes which are much smaller.

Width of the radiation beam:

$$\phi = \frac{70\lambda}{D}$$

$$\phi_0 = 2\phi$$

Where, ϕ= beamwidth between two half power points, degrees.

ϕ_0 = beamwidth between nulls, degrees.

λ= wavelength, m

D= mouth diameter, m

Feed mechanisms:

- The primary antenna is placed at the focus of the paraboloid in transmission or reception. The direct radiation from the feed, which is not reflected by the paraboloid, tends to spend out in directions and hence partially spoils the directivity.
- Methods to prevent this are: 1) provision of the small spherical reflector, 2) using a small dipole array at the focus, pointing at the paraboloid reflector.

Horn antenna: a horn antenna pointing at the main reflector. It has a mildly directional pattern, in the direction in which its mouth points. Direct radiation from the feed antenna is once again avoided.

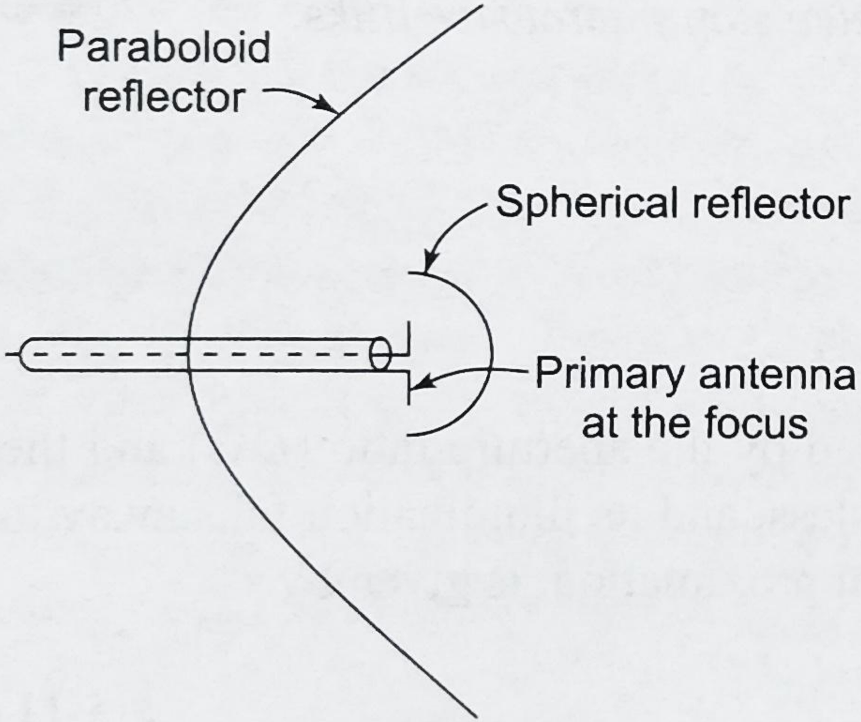


Fig. 11.27 Center-fed paraboloid reflector with spherical shell.

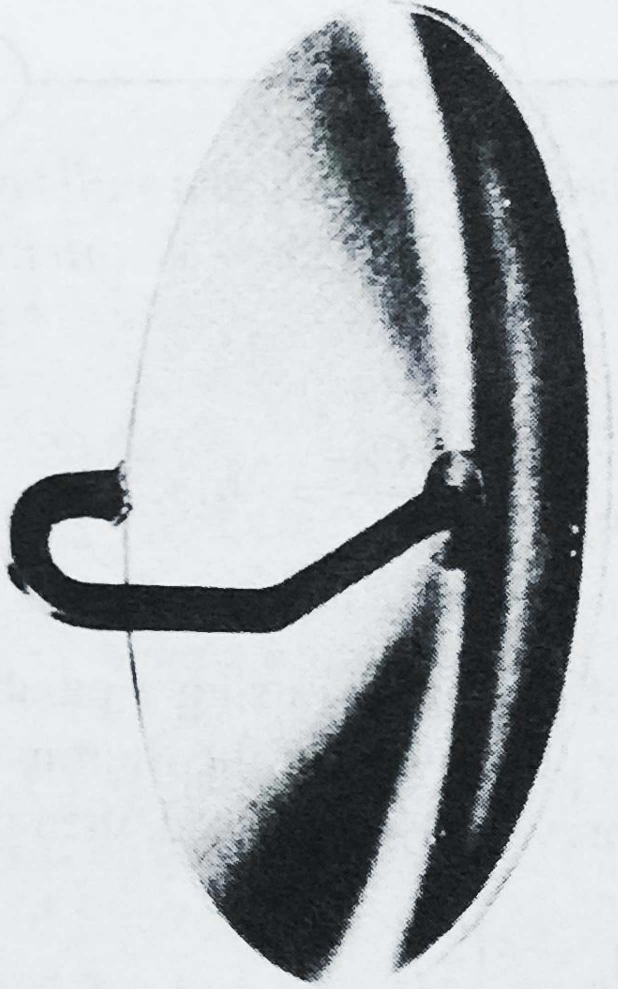


Fig. 11.28 Paraboloid reflector with horn feed. (Courtesy of the Andrew Antennas of Australia.)

Cassegrain feed: it uses a hyperboloid secondary reflector. One of its foci coincides with the focus of the paraboloid, resulting in the action.

It is used when it is desired to place the primary antenna in a convenient position and to shorten the length of transmission line or waveguide connecting the receiver to the primary. This requirement often applies to low-noise receivers, in which the losses in the linear waveguide may not be tolerated.

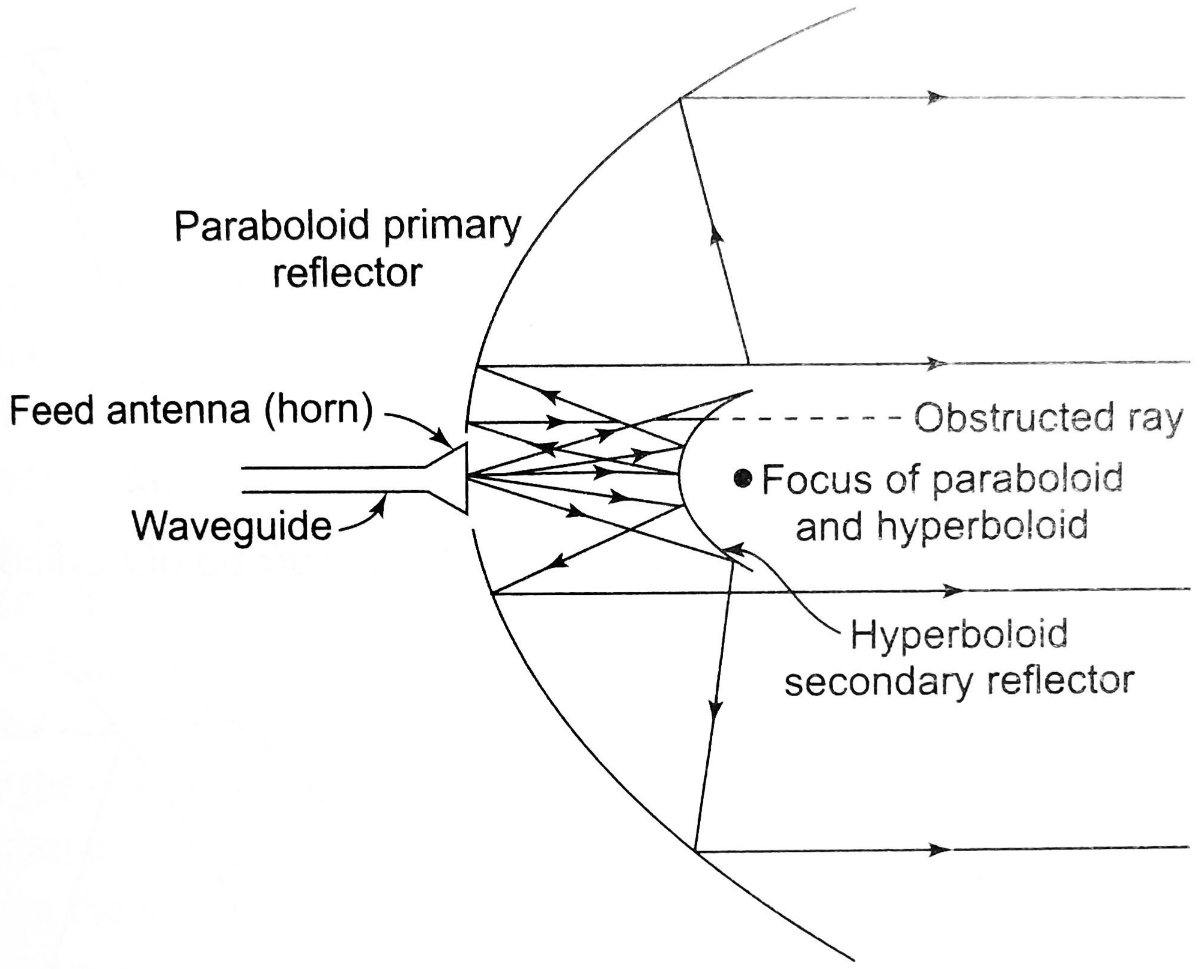


Fig. 11.29 Geometry of the Cassegrain feed.

Moving target indication:

Doppler effect: the apparent frequency of electromagnetic or sound waves depends on the relative radial motion of the source and the observer.

If source and observer are moving away from each other, the apparent frequency will decrease.

If source and observer are moving towards each other, the apparent frequency will increase.

Doppler frequency of radar is given by:

$F_d = 2f'd$

$$= \frac{2f_t v_r}{v_c}$$

$$= \frac{2v_r}{\lambda}$$

Where, f'd = doppler frequency difference

F_t = transmitting frequency

V_r = relative velocity

V_c = Velocity of light

λ= transmitted wavelength

- The magnitude of the doppler shift will be same in both cases (moving towards or away). But there will a change in frequrncy, it will increasing if the target is moving closer and will decrease if the target moves futher away.
- The doppler effect is only for radial motion and not tangential motion.
- Hence there is no doppler effect if the target moves across the field of view of radar. However, a doppler shift will be seen if the target is rotating and the resolution of radar is sufficient to distinguish its leading edge from its trailing edge.
- With this frequency change we can determine the relative frequency of the target using pulsed radar or CW radar.

Moving target indicator system compare a set of received echoes with those received during the previous sweep. Those echoes whose phase has remained constant are then cancelled out. This applies to echoes due to stationary objects. But those due to moving objects do show a phase change, thus are not cancelled out. The fact that the clutter due to the stationary object is removed makes it easier to to determine which targets are moving and reduces the time taken by an operator to take in the display.

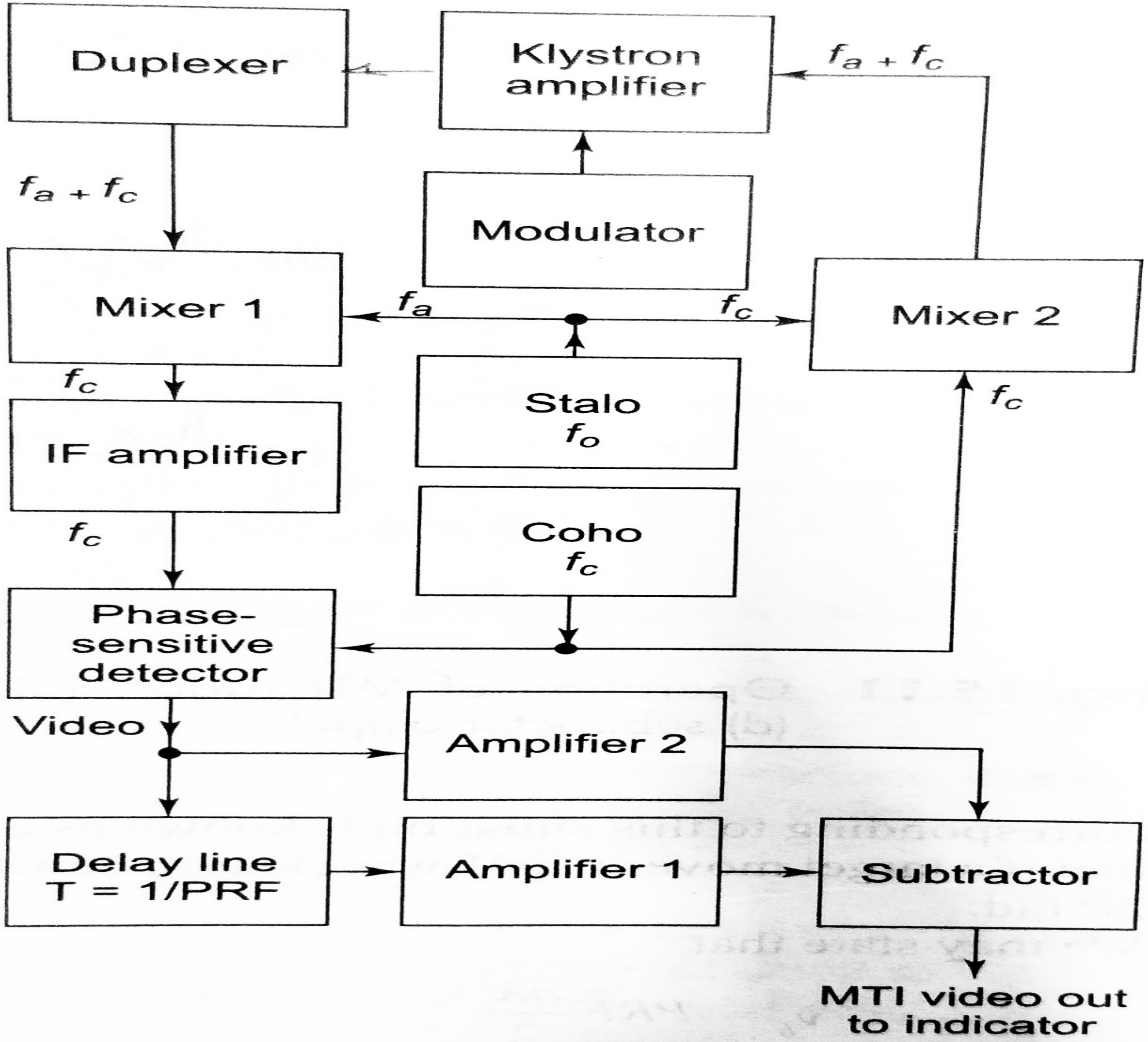


Fig. 15.10 Block diagram of MTI radar using power amplifier output.

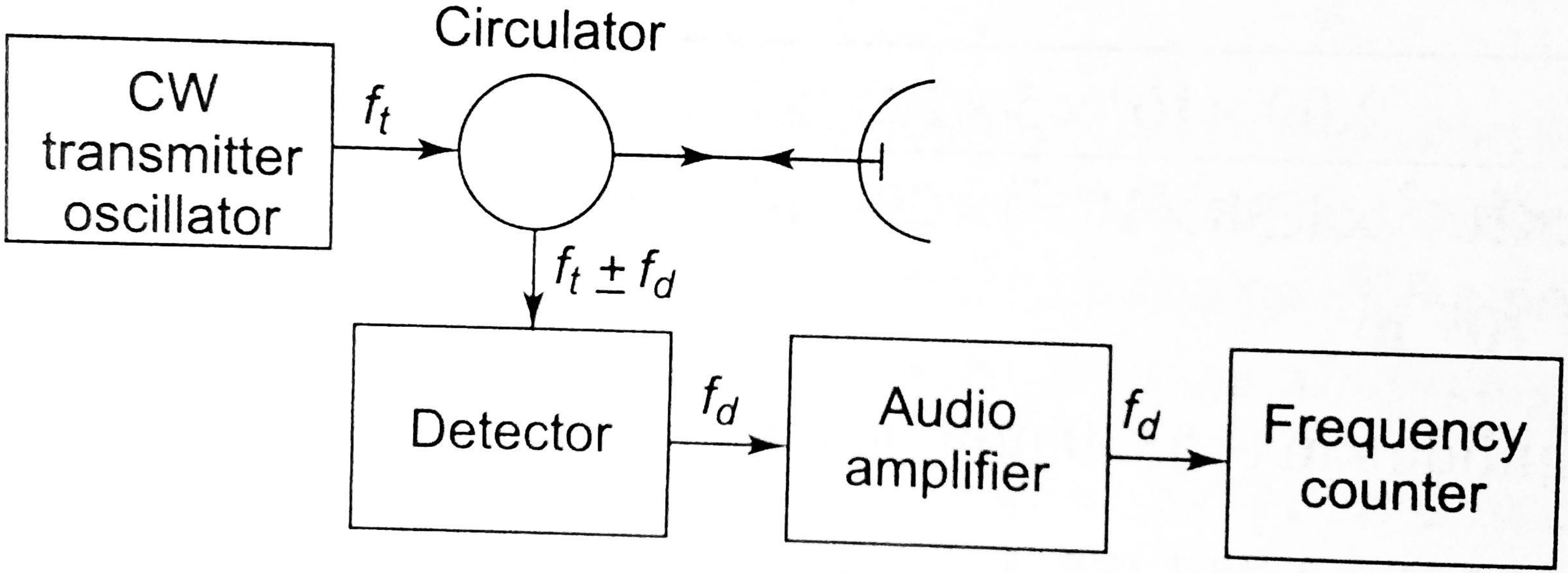


Fig. 15.12 Simple Doppler CW radar.

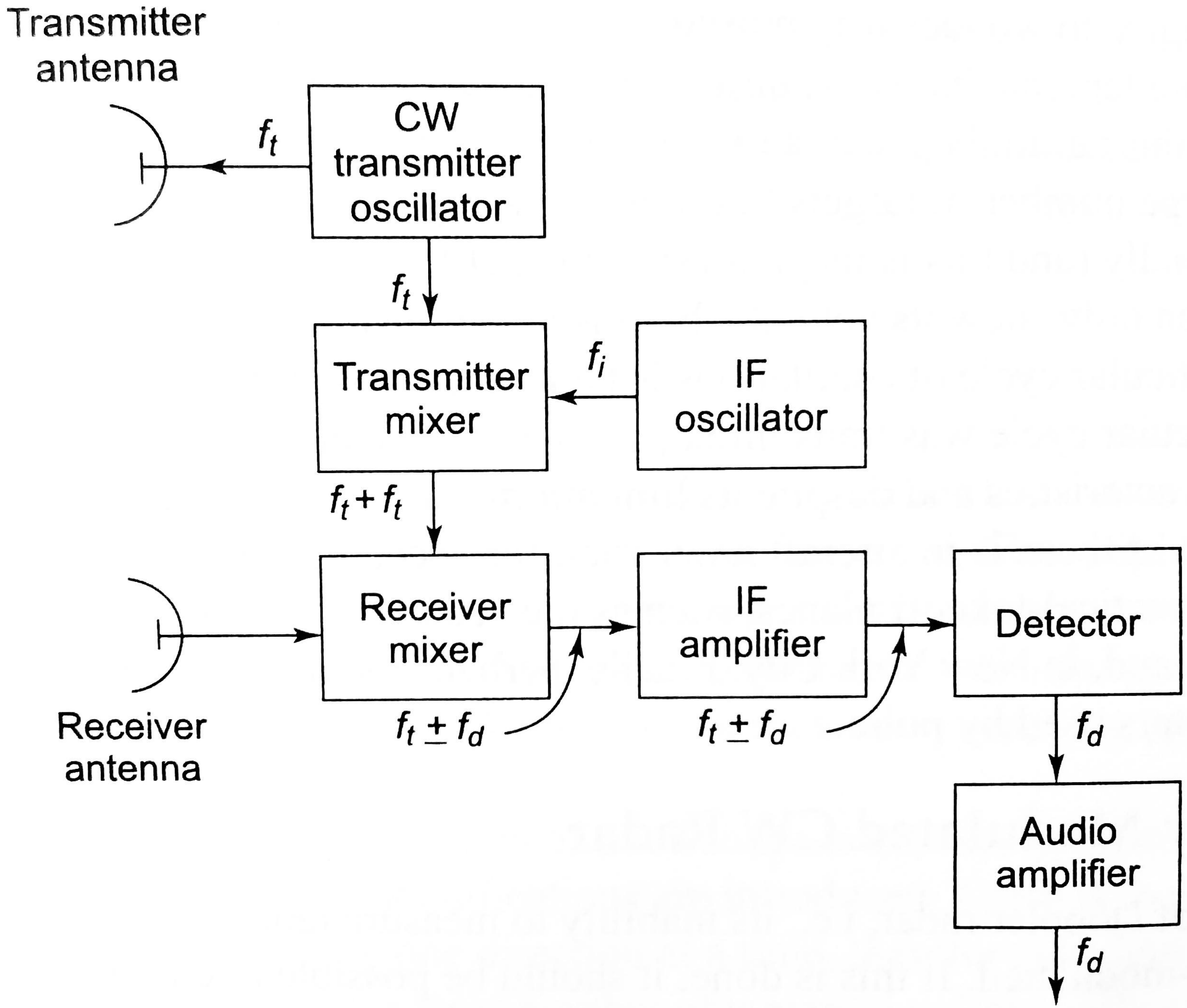


Fig. 15.13 CW Doppler radar with IF amplification.