UNIT-4
TRACKING RADAR

- **Tracking with Radar**
- **Sequential Lobing**
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- **Amplitude Comparison Monopulse (One and two coordinate)**
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TRACKING RADAR

Tracking with Radar:

Tracking is the process of continuously maintaining the antenna beam on the target and also the echo signal within the range gate (present Range value). The antenna beam in the continuous tracking radar is positioned in angle by a servomechanism actuated by an error signal. The various methods for generating the error signal are classified as sequential lobing, conical scan, and simultaneous lobing or monopulse. The range and Doppler frequency shift are continuously tracked, by a servo-control loop actuated by an error signal generated in the radar receiver.
The tracking radar must first find and acquire its target before it can track. This is explained in detail subsequently under the heading ***'Acquisition and Scanning Patterns'***.

Sequential Lobing:

The antenna pattern commonly employed with tracking radars is the symmetrical pencil beam in which the, elevation and azimuth beam widths are approximately equal. However, a simple pencil-beam antenna is not suitable for tracking radars unless means are provided for determining the magnitude and direction of the target's angular position with respect to some reference direction, usually the axis of the antenna. The difference between the target position and the reference direction is the angular error. The tracking radar attempts to position the antenna to make the angular error zero. When the angular error is zero, the target is located along the reference direction.
One method of obtaining the direction and the magnitude of the angular error in one coordinate is by alternately switching the antenna beam between two positions **(Fig 1).**This is called ***lobe*** switching sequential switching, or **sequential** lobing. Fig **1-a** is a polar representation of the antenna beam (minus the side lobes) in the two switched positions. A plot in rectangular coordinates is shown in **Fig.1-b,** and the error signal obtained from a target not on the switching axis (reference direction) is shown in **Fig.1-c.**The difference in amplitude between the voltages obtained in the two switched positions is a measure of the angular displacement of the target from the switching axis. The sign of the difference determines the direction the antenna must be moved in order to align the switching axis with the direction of the target. When the voltages in the two switched positions are equal, the target is on axis and its position is determined from the antenna direction.

Two additional switching positions are needed to obtain the angular error in the orthogonal coordinate.

Thus a two-dimensional sequentially lobing radar consists of a cluster of four feed horns illuminating a single antenna, arranged so that the right-left, up-down sectors are covered by successive antenna positions. Both transmission and reception are accomplished at each position. A cluster of five feeds might also be employed, with the central feed used for transmission while the outer four feeds are used for receiving. High-power RF switches are not needed since only the receiving beams, and not the transmitting beam, are stepped in this five-feed arrangement.

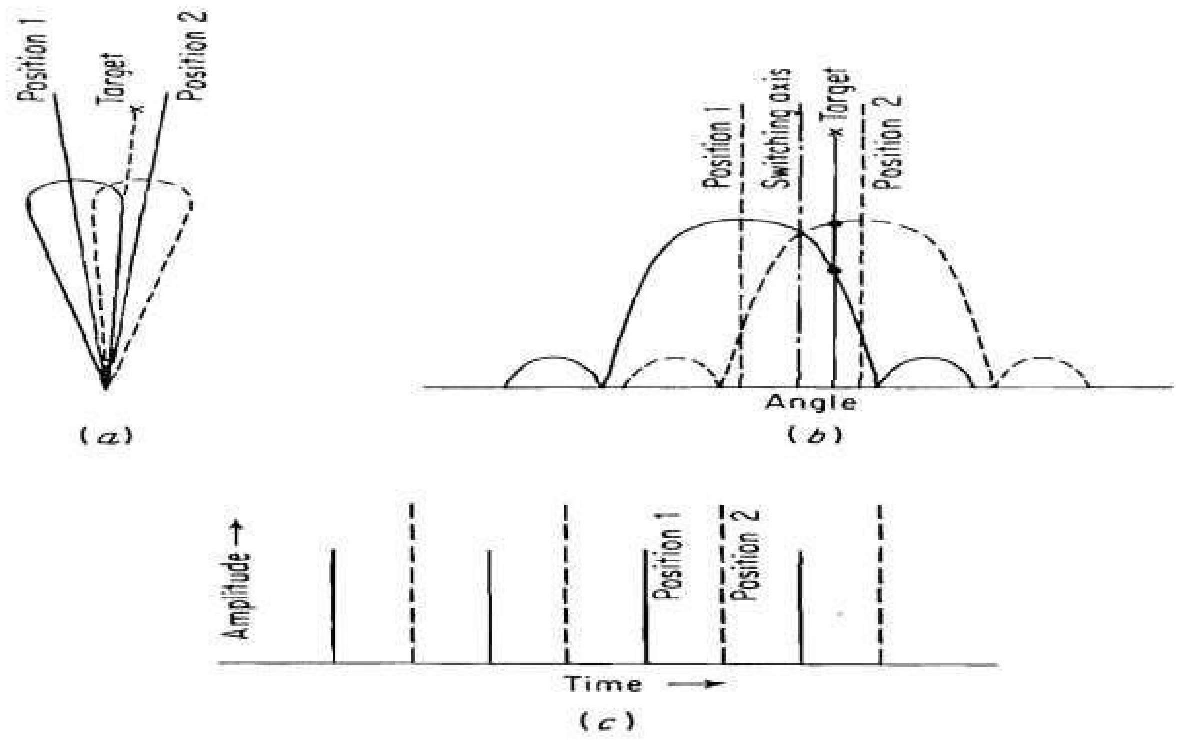

Figure 1: Lobe-switching antenna patterns and error signal (one dimension) (a) Polar representation of switched antenna patterns(b)rectangular representation (c)error signal

An important feature of sequential lobing (as well as the other tracking techniques to be discussed) is that the target-position accuracy can be far better than that given by the antenna beam width. The accuracy depends on how well equality of the signals in the switched positions can be determined. The fundamental limitation to accuracy is system noise caused either by mechanical or electrical fluctuations.

Conical Scan:

A logical extension of the ***simultaneous lobing*** technique described in the previous section is to rotate continuously an offset antenna beam rather than discontinuously step the beam between four discrete positions. This is known as conical scanning **(Fig.2).** The angle between the axis of rotation (which is usually the axis of the antenna reflector) and the axis of the antenna beam is called the ***Squint Angle***. Consider a target at position **A.** The echo signal amplitude will be modulated at a frequency equal to the rotation frequency of the beam. The amplitude of the echo signal modulation will depend upon the shape of the antenna pattern, the squint angle and the angle between the target line of sight &the rotation axis. The phase of the modulation depends on the angle between the target and the rotation axis. The conical scan modulation is extracted from the echo signal and applied to a servo-control system which continually positions the antenna on the target. [Note that two servos are required because the tracking is required in two-dimensions. When the antenna is on target, as in **B** of **Fig. 2,** the line of sight to the target and the rotation axis coincide, and the conical-scan modulation is zero.

A block diagram of the angle-tracking portion of a typical conical-scan tracking radar is shown in **Fig.3**. The antenna is mounted so that it can be positioned in both azimuth and elevation by separate motors. The antenna beam is offset by tilting either the feed or the reflector with respect to one another.

One of the simplest conical-scan antennas is a parabola with an offset rear feed rotated about the axis of the reflector. **A** typical conical-scan rotation speed is 30 r/s. The same motor that provides the conical-scan rotation of the antenna beam also drives a two-phase reference generator with two sinusoidal outputs **90^0**apart in phase. These two outputs serve as a reference to extract the elevation and azimuth errors. The received echo signal is fed to the receiver from the antenna via two rotary joints (not shown in the block diagram). One rotary joint permits motion in azimuth and the other, in elevation.

The receiver is conventional super heterodyne except for features peculiar to the conical-scan tracking radar. One feature not found in other radar receivers is a means of extracting the conical-scan modulation, or error signal. This is accomplished after the second detector in the video portion of the receiver. The error signal is compared with the elevation and azimuth reference signals in the angle-error detectors, which are phase-sensitive detectors for generating the Azimuth and Elevation errors separately.

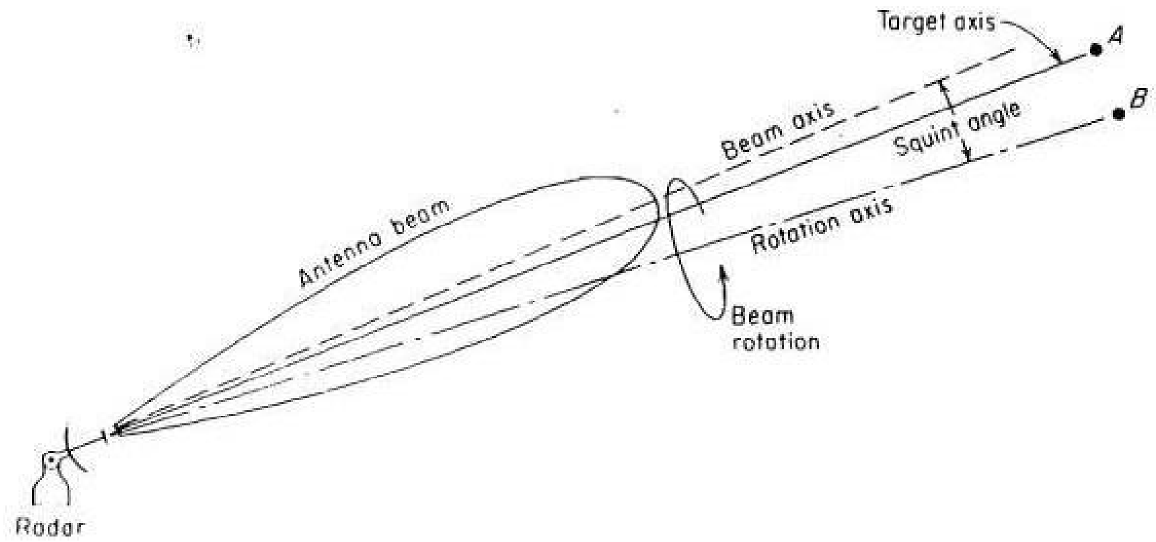

Figure 2:Principle of Conical-scan tracking.

A phase sensitive detector is a nonlinear device in which the input signal (in this case the angle-error signal) is mixed with the reference signal. The input and reference signals are of the same frequency. The output d-c voltage reverses polarity as the phase of the input signal changes through 180^0. The magnitude of the d-c output from the angle-error detector is proportional to the error, and the sign (polarity) is an indication of the direction of the error. The angle-error detector outputs are amplified and fed to the drive system to drive the antenna elevation and azimuth servomotors.

The angular position of the target is determined from the elevation and azimuth positions of the antenna axis. The position is read out by means of standard angle transducers such as synchros, potentiometers, or shaft Encoders.

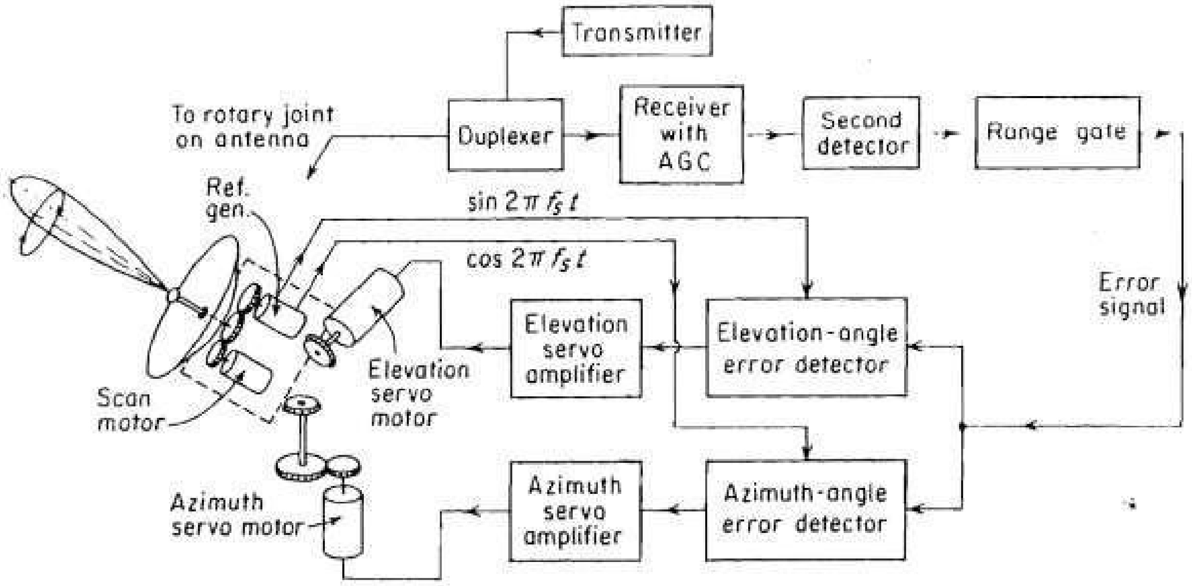

Figure 3: Block diagram of conical-scan tracking radar.

Boxcar generator:

When extracting the modulation imposed on a repetitive train of narrow pulses, it is usually convenient to stretch the pulses before low-pass filtering. This is called ***boxcaring*** or ***sample and hold.*** Here the device is called a ***boxcar generator.*** The boxcar generator was also mentioned in the discussion of the MTI receiver using range-gated filters. In essence, it clamps or stretches the video pulses of **Fig.4**-(**a)**in time so as ***to*** cover the entire pulse-repetition period **(Fig.4-b).** This is possible only in a range-gated receiver (Tracking radars are normally operated with range gates. The boxcar generator consists of an electric circuit that clamps the potential of a storage element, such as a capacitor, to the video-pulse amplitude each time the pulse is received. The capacitor maintains the potential of the pulse during the entire repetition period and is altered only when a new video pulse appears whose amplitude differs from the previous one. The boxcar generator eliminates the pulse repetition frequency and reduces its harmonics. It also has the practical advantage that the magnitude of the conical-scan modulation is amplified because pulse stretching puts more of the available energy at the modulation frequency. The pulse repetition frequency must be sufficiently large compared with the conical-scan frequency for proper boxcar filtering.

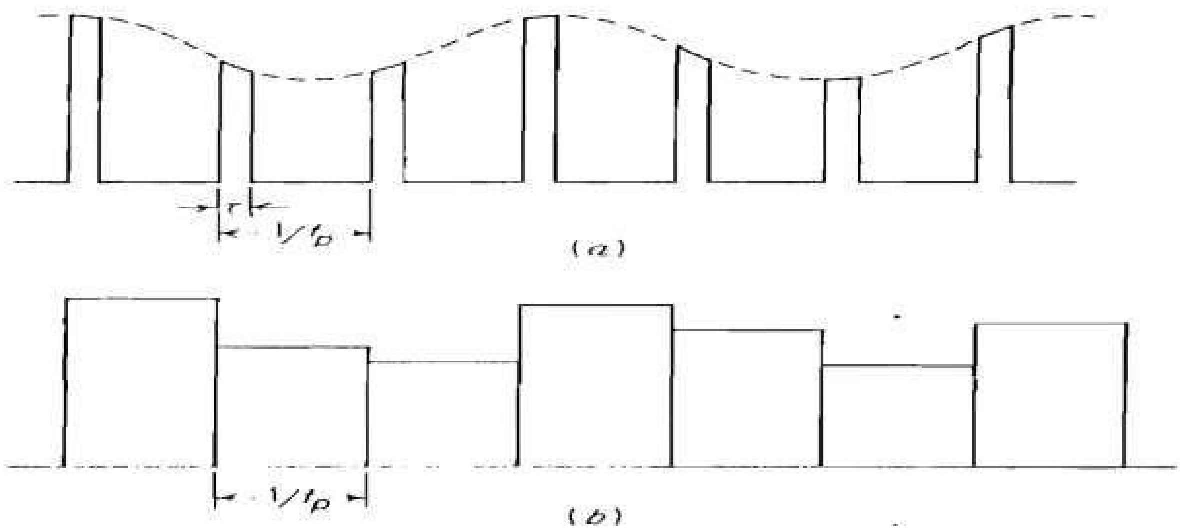

Fig 4: (a) Pulse train with conical scan modulation (b) same pulse train after passing through boxcar generator.

Automatic Gain Control (AGC) :

The echo-signal amplitude at the tracking-radar receiver will not be constant but will vary with time. The three major causes of variation in amplitude are:

- The inverse-fourth-power relationship between the echo signal and range
- The conical-scan modulation (angle-error signal) and
- Amplitude fluctuations in the target cross Section.

The function of the automatic gain control (AGC) is to maintain the d-c level of the receiver output constant and to smooth or eliminate as much of the noise like amplitude fluctuations as possible without disturbing the extraction of the desired error signal at the conical-scan frequency.

One of the purposes of AGC in any receiver is to prevent saturation by large signals. The scanning modulation and the error signal would be lost if the receiver saturates. In the conical-scanning tracking radar an AGC that maintains the d-c level constant results in an error signal that is a true indication of the angular pointing error. The d-c level of the receiver must be maintained constant if the angular error is to be linearly related to the angle-error signal voltage.

An example of the AGC portion of a tracking-radar receiver is shown in **Fig.5**. A portion of the video-amplifier output is passed through a low-pass or smoothing filter and fedback to control the gain of the IF amplifier. The larger the video output, the larger will be the feedback signal and the greater will be the gain reduction. The filter in the AGC loop should pass all frequencies from direct current to just below the conical-scan-modulation frequency. The loop gain of the AGC filter measured at the conical-scan frequency should be low so that the error signal will not be affected by AGC action. (If the AGC responds to the conical-scan frequency, the error signal will be lost.)

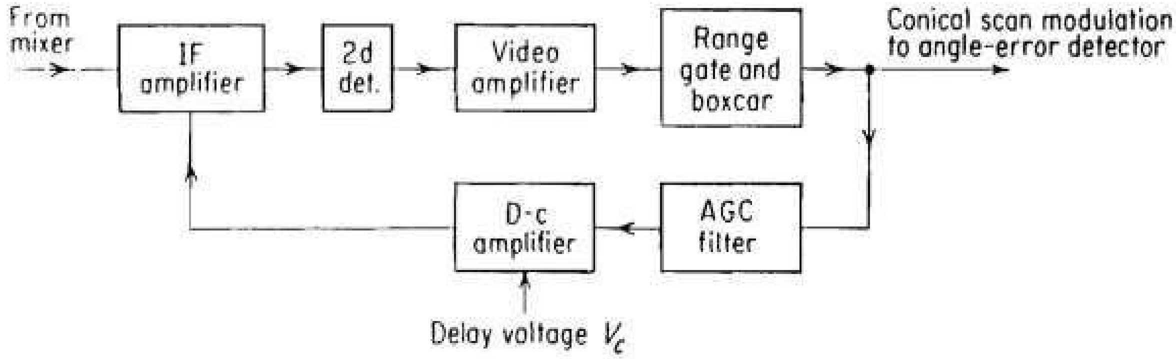

Figure 5: Block diagram of the AGC portion of a tracking-radar receiver.

The phase shift of this filter must be small if its phase characteristic is not to influence the error signal. A phase change of the error signal is equivalent to a rotation of the reference axis and introduces cross coupling, or "cross talk," between the elevation and azimuth angle-tracking loops. Cross talk affects the stability of the tracking and might result in an unwanted nutating motion of the antenna. In conventional tracking radar applications, the phase change introduced by the feedback-loop filter should be less than **10^0** and in some applications, it should be as little as **2^0.** For this reason, a filter with a sharp attenuation characteristic in the vicinity of the conical-scan frequency might not be desirable because of the relatively large amount of phase shift which it would introduce.

Other considerations:

- In both the sequential-lobing and conical-scan techniques, the measurement of the angle error in two orthogonal coordinates (azimuth and elevation) requires that a minimum of three pulses be processed.
- In practice, however, the minimum number of pulses in sequential lobing is usually four-one per quadrant. Although a conical scan radar can also be operated with only four pulses per revolution, it is more usual to have ten or more per revolution. This allows the modulation due to the angle error to be more like a continuous sinewave.
- Thus, the **PRF** is usually at least an order of magnitude greater than the conical-scan frequency.
- The scan frequency also must be at least an order of magnitude greater than the tracking bandwidth.

A **CO**nical-**S**can-on-**R**eceive-**O**nly (COSRO) tracking radar radiates a non-scanning transmit beam, but receives with a conical scanning beam to extract the angle error. The analogous operation with sequential lobing is called **L**obe-**O**n-**R**eceive-**O**nly (LORO)**.**

Monopulse tracking radar:

Disadvantages of The conical-scan and sequential-lobing tracking radars:

- They require a minimum number of pulses to extract the angle-error signal.
- In the time interval during which a measurement is made with either sequential lobing or conical scan, the train of echo pulses must not contain amplitude-modulation components other than the modulation produced by scanning. If the echo pulse-train contains additional

modulation components, caused, for example, by a fluctuating target cross section, the tracking accuracy will be degraded, especially if the frequency of the fluctuations is at or near the conical-scan frequency or the sequential-lobing rate.

- The fluctuating echo can severely limit the accuracy of those tracking radars which require many pulses to be processed to extract the error signal.

These disadvantages are over come in the Monopulse Tracking Radar.

Pulse-to-pulse amplitude fluctuations of the echo signal have no effect on tracking accuracy if the angular measurement is made on the basis of one pulse rather than many. There are several methods by which angle-error information might be obtained with only a single pulse. More than one antenna beam is used simultaneously in these methods, in contrast to the conical-scan or lobe-switching tracker, which utilizes one antenna beam on a time-shared basis. The angle of arrival of the echo signal may be determined in a single-pulse system by measuring the relative phase or the relative amplitude of the echo pulse received in each beam. The names **simultaneous lobing** and **monopulse** are used to describe those tracking techniques which derive angle-error information on the basis of a single pulse.

In this technique, the RF signals received from two offset antenna beams are combined so that both the sum and the difference signals are obtained simultaneously. The sum and difference signals are multiplied in a **phase-sensitive detector** to obtain both the magnitude and the direction of the error signal. All the information necessary to determine the angular error is obtained on the basis of a single pulse; hence the name **monopulse**.

Amplitude-comparison monopulse:

The amplitude-comparison monopulse employs two overlapping antenna patterns (**Fig. 6-a**) to obtain the angular error in one coordinate. The two overlapping antenna beams may be generated with a single reflector along with two adjacent feed horns. (A cluster of four feeds will be used if both elevation- and azimuth-error signals are wanted.) The sum of the two antenna patterns of **Fig.6(a)**is shown in **Fig. 6(b),** and the difference in **Fig.6(c).**The sum pattern is used for transmission, while both the sum pattern and the difference pattern are used on reception. The signal received with the difference pattern provides the magnitude of the angle error. The sum signal is used for the range measurement and is also used as a reference to extract the sign of the error signal. Signals received from the sum and the difference patterns are amplified separately and combined in a phase-sensitive detector to produce the error-signal characteristic shown in **Fig. 6(d).**
A block diagram of the amplitude-comparison-monopulse tracking radar for a single angular coordinate is shown in **Fig.7.** The two adjacent antenna feeds are connected to the two arms of a ***hybrid junction*** such as a ***"magic T",*** a ***"rat race,"*** or a ***"short-slot coupler".*** The sum and difference signals appear at the two other arms of the ***hybrid***. On reception, the outputs of the sum arm and the difference arm are each heterodyned to an intermediate frequency and amplified as, in any super heterodyne receiver. The transmitter is connected to the sum arm. Range information is also extracted from the sum channel. A duplexer is included in the sum arm for the protection of the receiver. The output of the phase-sensitive detector is an error signal whose magnitude is proportional to the angular error and whose sign is proportional to the direction. The output of the monopulse radar is used to perform automatic tracking. The angular error signal actuates a servo-control system to position the antenna, and the range output from the sum ***channel feeds*** into an automatic-range-tracking unit.

The sign of the difference signal (and the direction of the angular error) is determined by comparing the phase of the difference signal with the phase of the sum signal. If the sum signal in the IF portion of the receiver were $A_s \cos(\omega_{IF}t)$ the difference signal would be either $A_d \cos(\omega_{IF}t)$ or $-A_d \cos(\omega_{IF}t)$ $(A_s>0, A_d>0)$, depending on which side of center is the target. Since $-A_d \cos(\omega_{IF}t) = A_d \cos \omega_{IF}(t+\pi)$, the sign of the difference signal may be measured by determining whether the difference signal is in phase with the sum or **180^0** out of phase.

Although a phase comparison is a part of the amplitude-comparison-monopulse radar, the angular-error signal is basically derived by comparing the echo amplitudes from simultaneous offset beams. The phase relationship between the signals in the offset beams is not used. The purpose of the phase-sensitive detector is **only** to conveniently furnish the ***sign*** of the error signal.

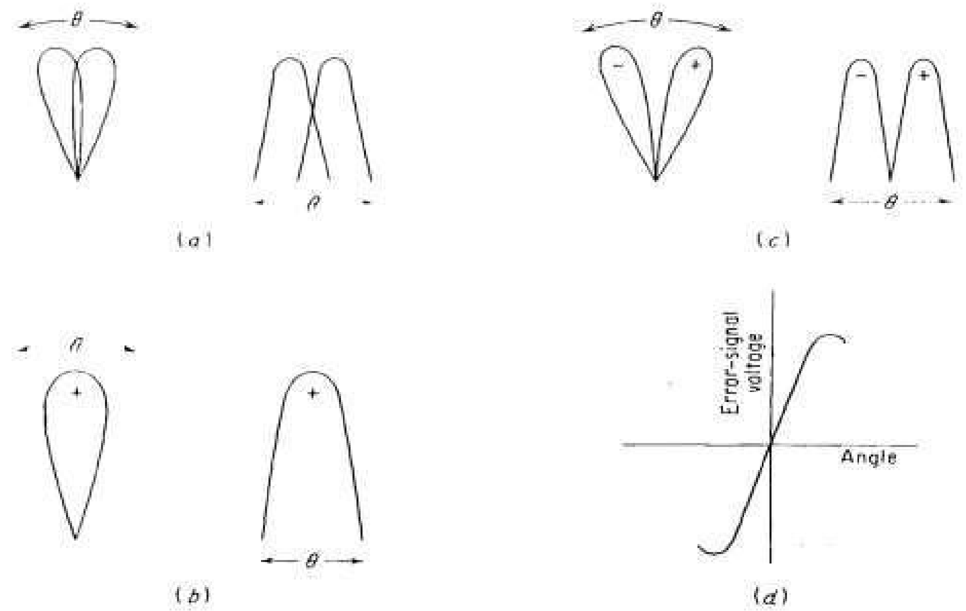

Figure 6: Monopulse antenna patterns and error signal. Left-hand diagrams in (a-c) are in polar coordinates. Right-hand diagrams are in rectangular coordinates. (a) Overlapping antenna patterns (b) sum pattern (c) difference pattern (d) product (error) signal.

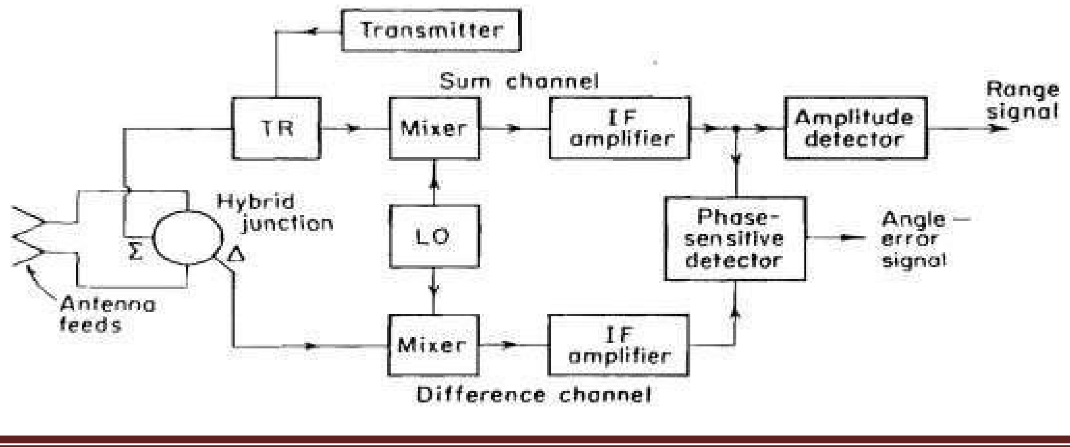

Figure 7: Block diagram of an Amplitude-comparison Monopulse radar (one angular coordinate).

A block diagram of a monopulse radar with provision for extracting error signals in both elevation and azimuth is shown in **Fig. 8**. The cluster of four feeds generates four partial overlapping antenna beams. The feeds are mostly used with a parabolic reflector, Cassegrain antenna.

- All four feeds generate the sum pattern.
- The difference pattern in one plane is formed by taking the sum of two adjacent feeds and subtracting this from the sum of the other two adjacent feeds.
- The difference pattern in the orthogonal plane is obtained by adding the differences of the orthogonal adjacent pairs.
- A total of four hybrid junctions generate the sum channel, the azimuth difference channel, and the elevation difference channel.
- Three separate mixers and IF amplifiers are shown, one for each channel. All three mixers operate from a single local oscillator in order to maintain the phase relationships between the three channels.
- Two phase-sensitive detectors extract the angle-error information, one for azimuth, the other for elevation.
- Range information is extracted from the output of the sum channel after amplitude detection.

*Since a phase comparison is made between the output of the sum channel and each of the difference channels, it is important that the phase shifts introduced by each of the channels be almost identical and must be maintained to within **25^0** or better for reasonably proper performance. The gains of the channels also must not differ by more than specified amounts.*

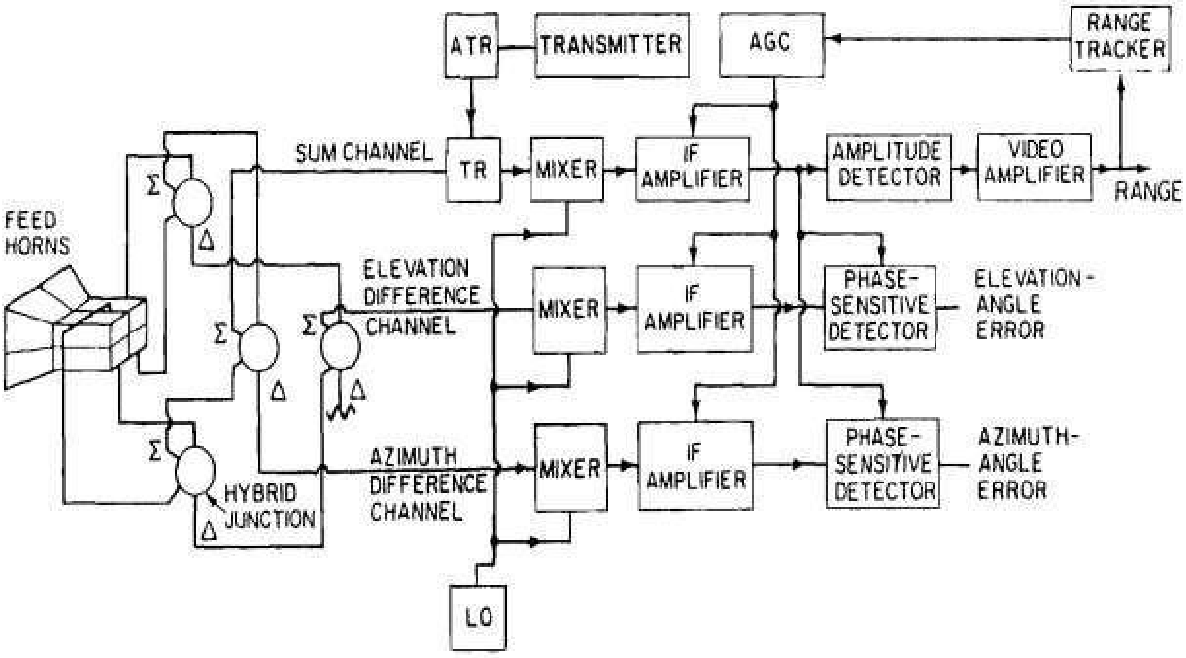

Figure 8: Block diagram of two-coordinate (azimuth and elevation) amplitude-comparison Monopulsetracking radar.

Automatic gain control (AGC) is required :

- To maintain a stable closed-loop servo system for angle tracking.
- The AGC in a monopulse radar is accomplished by employing a voltage proportional to the sum-channel IF output to control the gain of all three receiver channels.
- The AGC results in a constant angle sensitivity independent of target size and range.
- With AGC, the output of the angle-error detector is proportional to the difference signal normalized (divided) by the sum signal. The output of the sum channel is constant.

Important Requirements of Amplitude-comparison monopulse:

- The monopulse antenna must generate a sum pattern with high efficiency (maximum bore sight gain), and a difference pattern with a large value of slope at the crossover of the offset beams.

The greater the signal-to-noise ratio and the steeper the slope of the error signal in the vicinity of zero angular error, the more accurate is the measurement of angle.

- Furthermore, the side lobes of both the sum and the difference patterns must be low.
- The antenna must be capable of the desired bandwidth, and the patterns must have the desired polarization characteristics.

It is not surprising that the achievement of all these properties cannot always be fully satisfied simultaneously. Antenna design is an important part of the successful realization of a good monopulse radar.

Phase comparison Monopulse:

The angle of arrival (in one coordinate) may also be determined by comparing the phase difference between the signals from two separate antennas. Unlike the antennas of amplitude comparison trackers those used in phase-comparison systems are not offset from the axis. The individual bore sight axes of the antennas are parallel, causing the (far-field) radiation to illuminate the same volume in space. The amplitudes of the target echo signals are essentially the same from each antenna beam, but the phases are different.

A tracking radar which operates with phase information is similar to an active interferometer and is also called ***interferometer radar.*** It has also been called ***simultaneous phase comparison radar*** or ***phase-comparison monopulse***. The latter term is the one which will be used here.

In **Fig.9** two antennas are shown separated by a distance **d**. The distance to the target is **R** and is assumed large compared with the antenna separation **d**. The line of sight to the target makes an angle θ

to the perpendicular bisector of the line joining the two antennas. The distance from antenna **1** to the target is: $R_1 = R + (d/2)\sin\vartheta$

and the distance from antenna **2** to the target is: $R_2 = R - (d/2)\sin\vartheta$

The phase difference between the echo signals in the two antennas is approximately

$$\Delta\phi = 2\pi/\lambda . \sin\vartheta$$

For small angles where $\sin\vartheta \approx \vartheta$, the phase difference is a linear function of the angular error and is used to position the antenna via a servo-control loop.

In the early versions of the phase-comparison monopulse radar, the angular error was determined by measuring the phase difference between the outputs of receivers connected to each antenna. The output from one of the antennas was used for transmission and for providing the range information. with such an arrangement, it was difficult to obtain the desired aperture illuminations and to maintain a stable boresight. A more satisfactory method of operation is to form the sum and difference patterns in the RF and to process the signals as in a conventional amplitude-comparison monopulse radar.

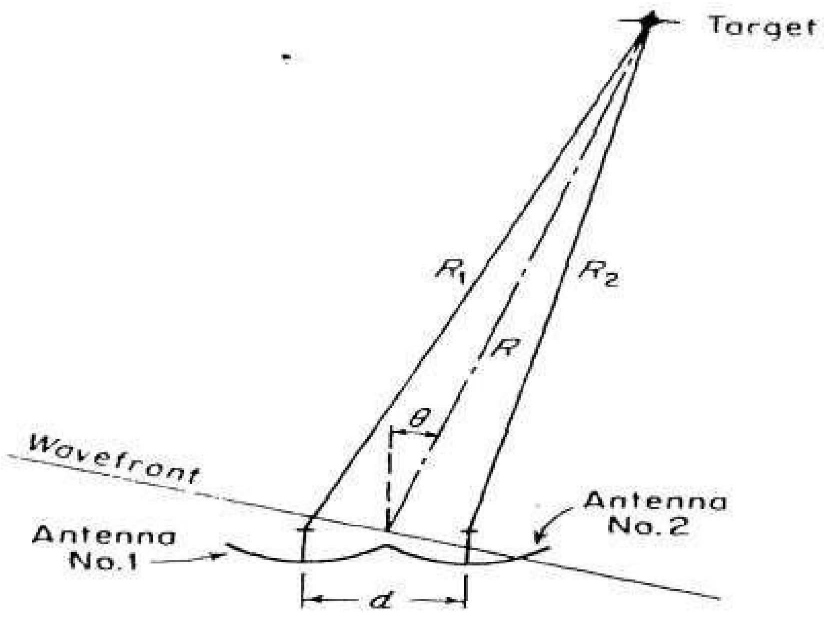

Figure 9: Wave front phase relationships in phase comparison Monopulse Radar

Tracking in range:

In most tracking-radar applications the target is continuously tracked in range as well as in angle. Range tracking might be accomplished by an operator who watches an A-scope and manually positions a hand

wheel in order to maintain a marker over the desired target pip. The setting of the hand wheel is a measure of the target range and may be converted to a voltage that is supplied to a data processor.
As target speeds increase, it is increasingly difficult for an operator to manually position the hand wheel at the required speed over a sustained period of time, and automatic tracking becomes anecessity.
The technique for automatically tracking in range is based on the split range gate. Two range gates are generated as shown in Fig.10. One is the early gate, and the other is the late gate. The echo pulse is shown in Fig.10-a, the relative position of the gates at a particular instant in Fig.10-b, and the error signal in Fig.10-c.The portion of the signal energy contained in the early gate is less than that in the late gate. If the outputs of the two gates are subtracted, an error signal (Fig.10-c) will result which is used to reposition the center of the gates. The magnitude of the error signal is a measure of the difference between the center of the pulse and the center of the gates. The sign of the error signal determines the direction in which the gates must be repositioned by a feedback-control system. When the error signal is zero the range gates are centered on the pulse.

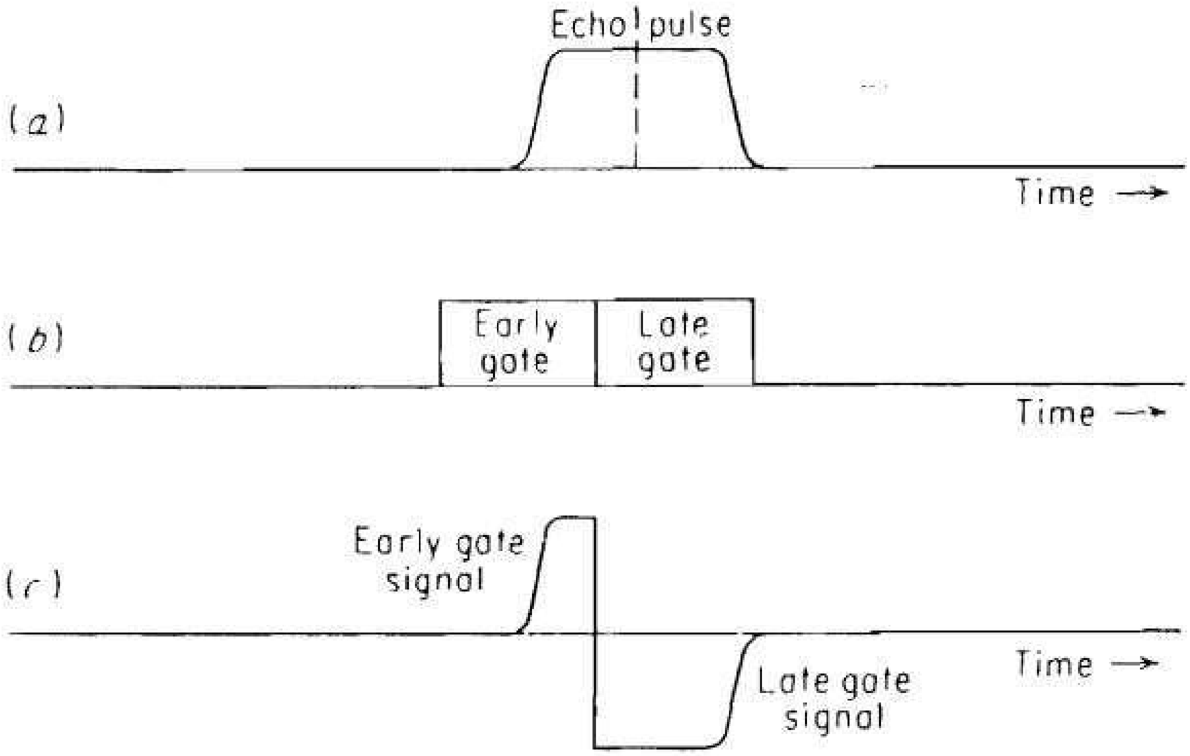

Figure 10: Split-range-gate tracking. (a)Echo pulse (b)early-late range gates(c) difference signal between early and late range gates

The range gating necessary to perform automatic tracking offers several advantages as by products. It isolates one target, excluding targets at other ranges. This permits the boxcar generator to be employed. Also, range gating improves the signal-to-noise ratio since it eliminates the noise from the other range intervals. Hence the width of the gate should be sufficiently narrow to minimize extraneous noise. On the other hand, it must not be so narrow that an appreciable fraction of the signal energy is excluded. A reasonable compromise is to make the gate width two to five times of the pulsewidth.

Acquisition and Scanning patterns:

A tracking radar must first find and acquire its target before it can operate as a tracker. Therefore it is usually necessary for the radar to scan an angular sector in which the presence of the target is expected. Most tracking radars employ a narrow pencil-beam antenna. Searching a volume in space for an aircraft target with a narrow pencil beam would be somewhat analogous to searching for a fly in a dark auditorium with a flashlight. It must be done systematically in a fixed pattern if the entire volume is to be covered uniformly and quickly. Examples of the common types of scanning patterns employed with pencil-beam antennas are illustrated in Fig.11 below.

- In the ***helical scan***, the antenna is continuously rotated in azimuth while it is simultaneously raised or lowered in elevation. It traces a helix in space.
- The ***Palmer*** scan consists of a rapid circular scan (conical scan) about the axis of the antenna, combined with a linear movement of the axis of rotation. When the axis of rotation is held stationary the Palmer scan reduces to the ***conical*** scan.

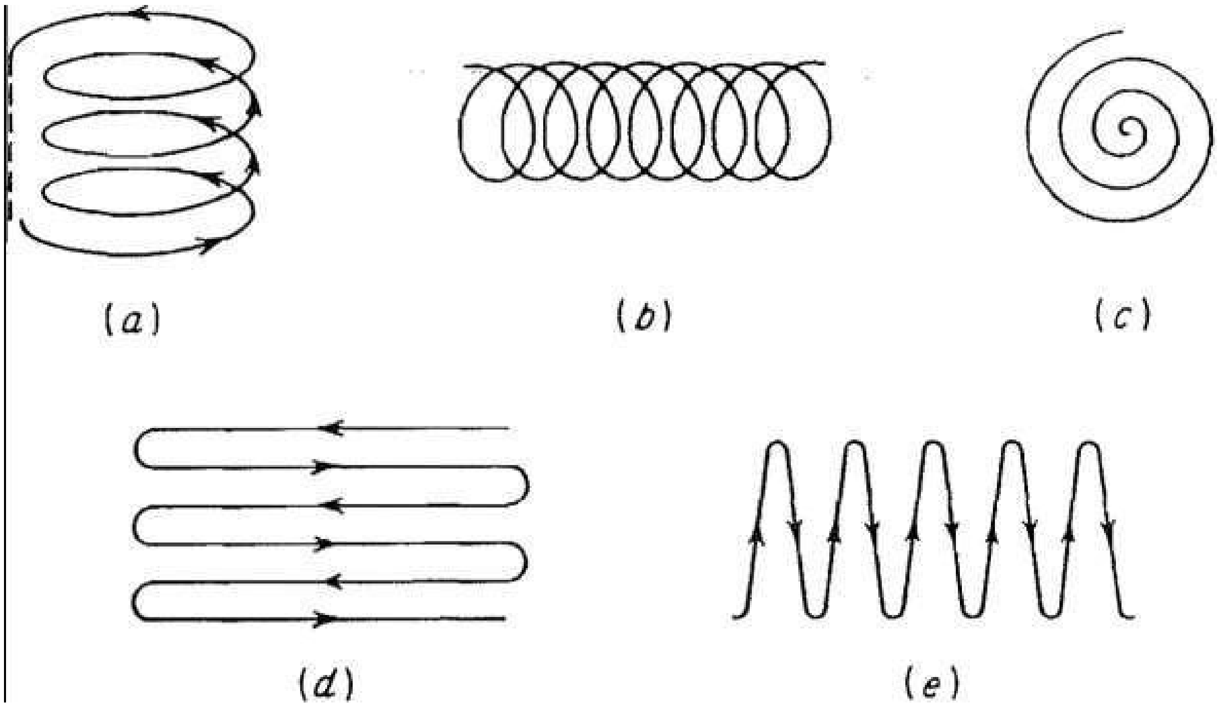

Figure 11 : Examples of acquisition search patterns:(a) Trace of helical scanning beam(b)Palmer scan (c) spiral scan(d)raster, or TV, scan (e) nodding scan. The raster scan is sometimes called an n-bar scan, where *n* is the number of horizontal rows.

- The spiral scan covers an angular search volume with circular symmetry. Both the spiral scan and the Palmer scan suffer from the disadvantage that all parts of the scan volume do not receive the same energy unless the scanning speed is varied during the scan cycle. As a consequence, the number of hits returned from a target when searching with a constant scanning rate depends upon the position of the target within the search area.

- The raster or TV, scan, unlike the Palmer or the spiral scan, scans the search area in a uniform manner. The raster scan is a simple and convenient means for searching a limited sector, rectangular in shape.
- Similar to the raster scan is the nodding scan produced by oscillating the antenna beam rapidly in elevation and slowly in azimuth. Although it may be employed to cover a limited sector-as does the raster scan-nodding scan may also be used to obtain hemispherical coverage, that is, elevation angle extending to **90^0** and the azimuth scan angle to **360^0**

Comparison of trackers:

General comparison of all types of Trackers:

- Of the four continuous-tracking-radar techniques that have been discussed (sequential lobing, conical scan, amplitude-comparison monopulse, and phase-comparison monopulse), conical scan and amplitude-comparison monopulse have seen more application than the other two.
- The phase-comparison monopulse has not been too popular because of the relative awkwardness of its antenna (four separate antennas mounted to point their individual beams in the same direction), and because the side lobe level might be higher than desired.
- Although sequential lobing is similar to conical scan, the latter is preferred in most applications, since it suffers less loss and the antenna and feed systems are usually less complex.

Comparision of conical-scan radar and the amplitude-comparison monopulse:

- When the target is being tracked, the signal-to-noise ratio available from the monopulse radar is greater than that of **a conical scan** radar, all other things being equal, since the monopulse radar views the target at the peak of its sum pattern while the conical-scan radar views the target at an angle off the peak of the antenna beam. The difference in signal-to-noise ratio might be from 2 to 4 dB. For the same size aperture, the beam width of a conical-scan radar will be slightly greater than that of the monopulse because its feed is offset from the focus.

- The tracking accuracy of a monopulse radar is superior to that of the conical-scan radar because of the absence of target amplitude-fluctuations and because of its greater signal-to noise ratio. It is the preferred technique for precision tracking. However, both monopulse and conical-scan radars are degraded equally by the wandering of the apparent position of the target (glint).

- The monopulse radar is the more complex of the two. Three separate receivers are necessary to derive the error signal in two orthogonal angular coordinates. Only one receiver is needed in the conical-scan radar. Since the monopulse radar compares the amplitudes of signals received in three separate channels, it is important that the gain and phase shift through these channels be identical. The RF circuitry that generates the sum and difference signals in a monopulse radar has been steadily improved, and can be realized in small size. A popular form of antenna for monopulse is the Cassegrain.

- With the monopulse tracker it is possible to obtain a measure of the angular error in two coordinates on the basis of a single pulse. **A** minimum of four pulses are usually necessary with the conical-scan radar. However, continuous-tracking radar seldom makes a measurement on a single pulse. (Phased array radars and some surveillance radars however might use the monopulse principle to extract an angle measurement on the basis of a single pulse.) In practice the two radars utilize essentially the same number of pulses to obtain an error signal if the servo tracking bandwidths and pulse repetition frequencies are the same. The monopulse radar first makes its angle measurement and then integrates a number of pulses to obtain the required signal-to-noise ratio and to smooth the error. The conical-scan radar, on the other hand, integrates a number of pulses first and then extracts the angle measurement.
- In brief, the monopulse radar is the better tracking technique; but in many applications where the ultimate in performance is not needed, the conical-scan radar is used because it is less costly and less complex.

Previous year examination questions:

1. Why is amplitude comparison mono pulse more likely to be preferred over the phase comparison mono pulse and conical scan tracker over sequential lobbing, or lobe switching tracker? Explain. [16]
2. (a) Discuss in detail about the Amplitude fluctuations and how its effects are minimized.
   (b) Explain Mono pulse tracking in two angle coordinates. [8+8]

3. (a) Draw and explain block diagram of Conical-scan tracking radar.
   (b) Why does tracking radar have poor accuracy at low elevation angles? Explain. [8+8]
4. (a) Draw and explain the following with respect to Tracking in range:
   i. Echo pulse
   ii. Early-late range gates
   iii. Difference signal between early and late range gates.
   (b) Limitation of automatic detection and tracking. [8+8]

5. (a)Explain the operation of Monopulse tracking radar with a Block Diagram.

   (b)Write the differences between a Conical scanning Radar and a Monopulse Radar.

6.(a)With a neat diagram explain the operation of a conical scan Radar. Explain the various

   factors that need to be considered for optimum squint angle.

   (b) Explain with the help of a neat block diagram Amplitude comparison Monopulse radar for

   extracting error signals in both Azimuth and Elevation

7. (a) Compare the tracking techniques.
   (b) Explain in detail about limitations to tracking accuracy. [10+6]

8. (a) Draw and explain the wave front phase relationships in phase comparison monopulse radar.

   (b) Write a brief note on acquisition and scanning patterns.