UNIT - IV

~~Tracking~~ Radar: Tracking radar detects, determines the location and tracks the moving targets.

-> A radar which detects a target, determines its location and trajectory in future is called tracking radar.

Block diagram of tracking radar and its operation:

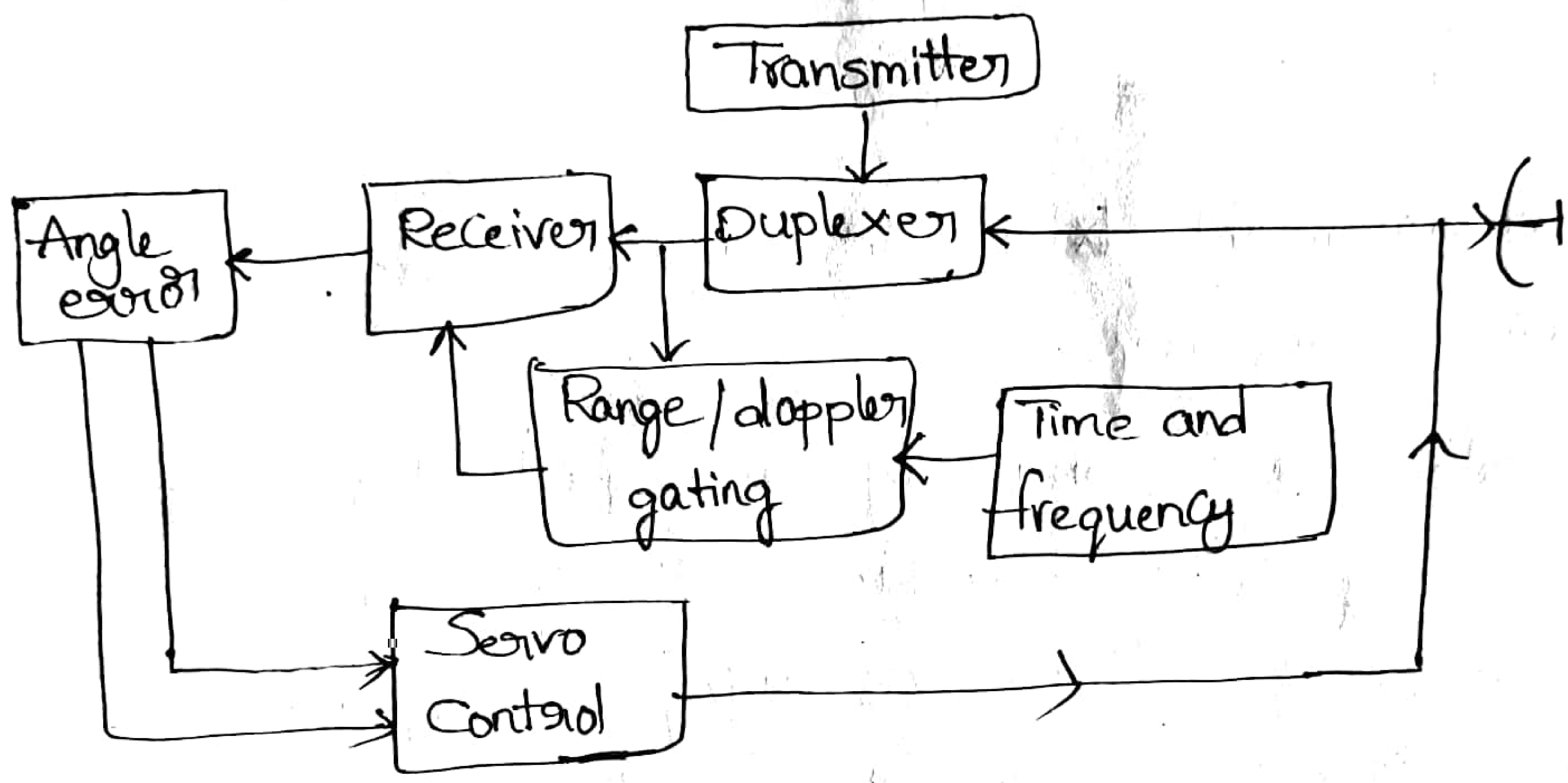


fig: Block diagram of a simple tracking radar

Operation: Its tracking operation usually depends on angular information. The antenna beam is very narrow and it tracks one target at a time. This is achieved by range gating and doppler filtering. The timing control is used for range tracking and doppler gating is used for doppler tracking. The angle error signal is fed to servo control system. This servo system steers the antenna to track the targets.

Tracking with Radar:

-> A tracking radar system measures the co-ordinates of a target and provides data which may be used to determine the target path and to predict its future position of the target.

-> By using range, elevation angle, azimuth angle and doppler frequency shift, we can also predict the future position of the target.

-> A radar might track in range, in angle, in doppler, or with any combination.

-> Generally, a continuously and fast tracking radar is necessary for tracking the fast moving target. To obtain the faster scanning rates, we have to reduce the size of the antenna and increasing the operating frequency of radar.

-> The target can be tracked by

1. Angular tracking of a target
2. Range tracking of a target
3. Doppler frequency shift tracking of a target.

-> The angular type of tracking is implemented in all types of radars. These are two types

1. Continuous tracking radar
2. Track-while-scan (TWS) radar

-> Continuously tracking radar supplies continuous [illegible] data on a particular target.

TWS radar supplies Sampled data on one or more targets.

The antenna beam in the Continuous tracking radar positioned in angle by a servomechanism actuated by an error signal.

→ The Various methods for generating the error signal may be classified as 1. sequential lobing 2. Conical scan 3. Simultaneous lobing or monopulse.

→ The range and doppler frequency shift Can also be Continuously tracked, if desired by a Servo Control loop actuated by an error signal generated in the radar receiver.

→ The information available from a tracking radar may be presented on a CRT display for action by an operator or may be ~~presented~~ supplied to an automatic Computer which determines the target Path and Calculates its probable future Course.

→ The tracking radar must first find its target before it Can track.

Differences between Search radar and Tracking radar

Search radar	Tracking radar
1. The radar is only used for detecting the target	1. This radar is used for both detecting and tracking
2. This radar is operated in Only Search or acquisition	2. This radar is operated in both Search and tracking

modes	modes.
3. It will have the knowledge of other potential targets	3. for this, in tracking it has no idea of oth potential targets.
4. In this radar, an antenna with narrow pencil beam is sufficient for finding the target	4. In this radar, an ant with narrow pencil bea is not sufficient for detecting and ranging Therfore separate radar is used for Searching
5. Search radar is mainly used in metrological, surveillance applications	5. The principal applications of tracking radar are weapon control and missile range instrumentation.

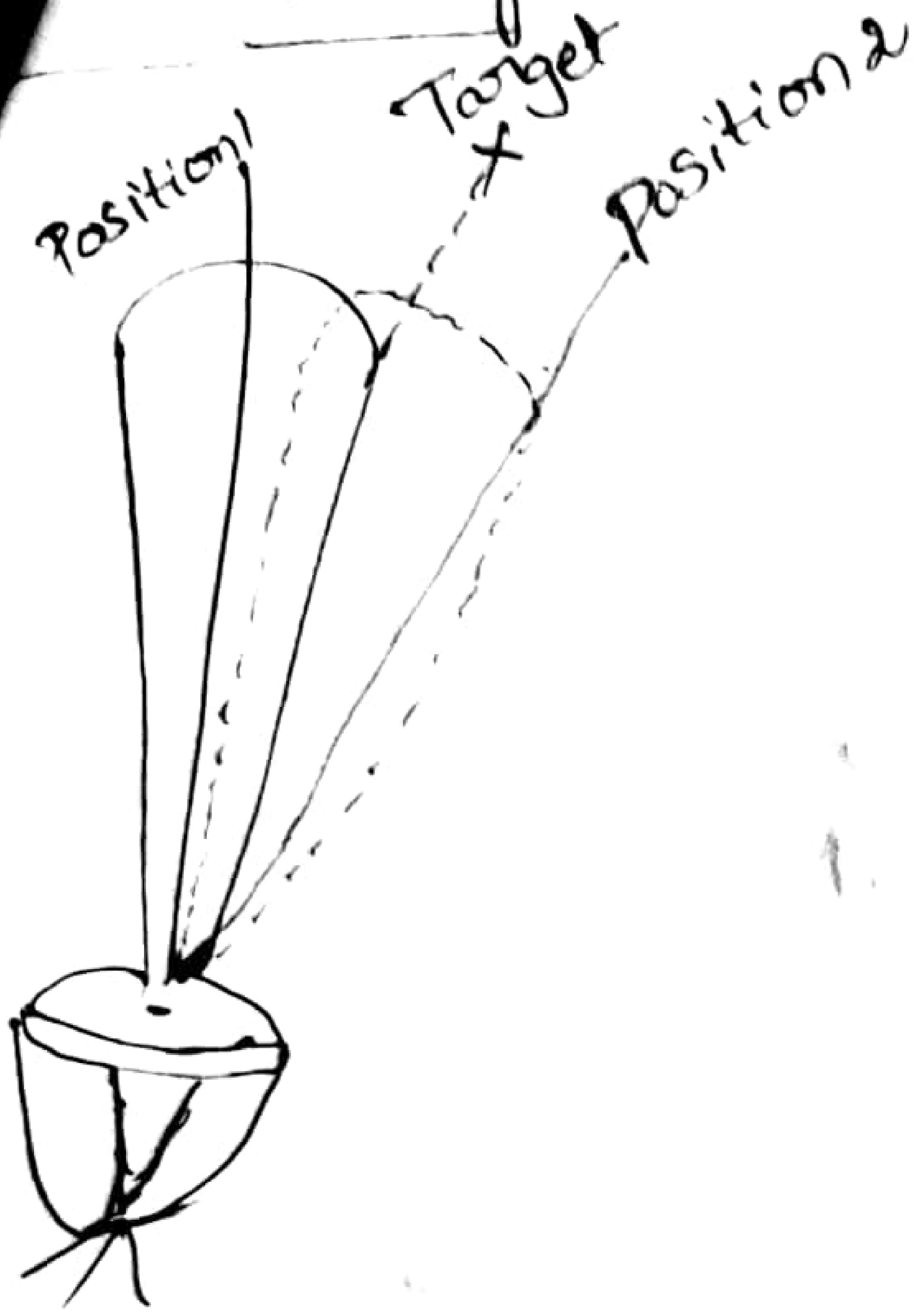
<u>Antenna</u> <u>Tracking</u>:

Need: The location of the target has to be very accurately known after it has been scanned. An antenna with narrow pencil shaped beam is useful in this regard, but this type of antenna is insufficient therfore more precise and useful method i.e tracking is employed

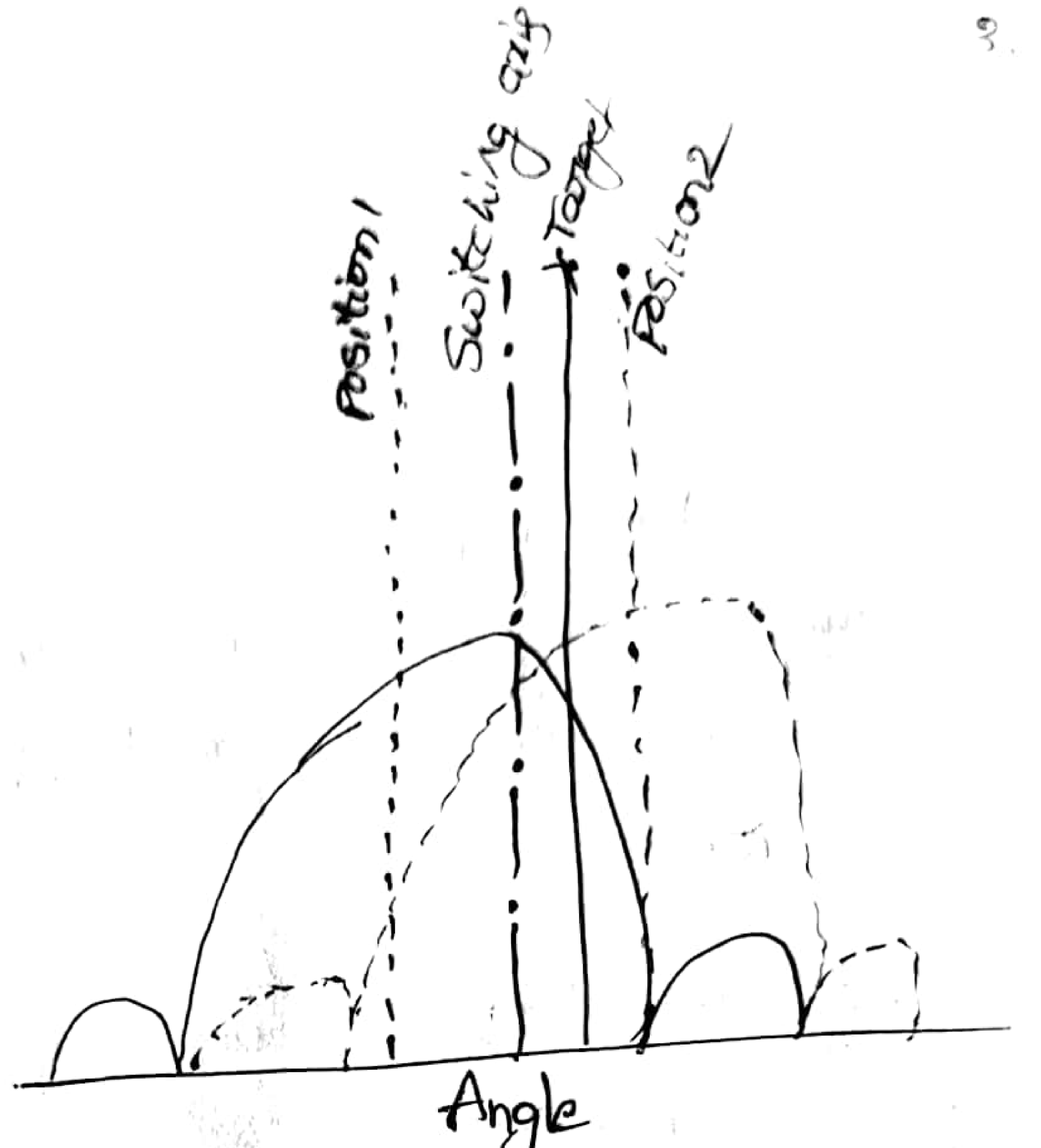
<u>Types</u>: Two most commonly used antenna tracking mechanism are

1. Sequential lobing
2. Conical Scanning

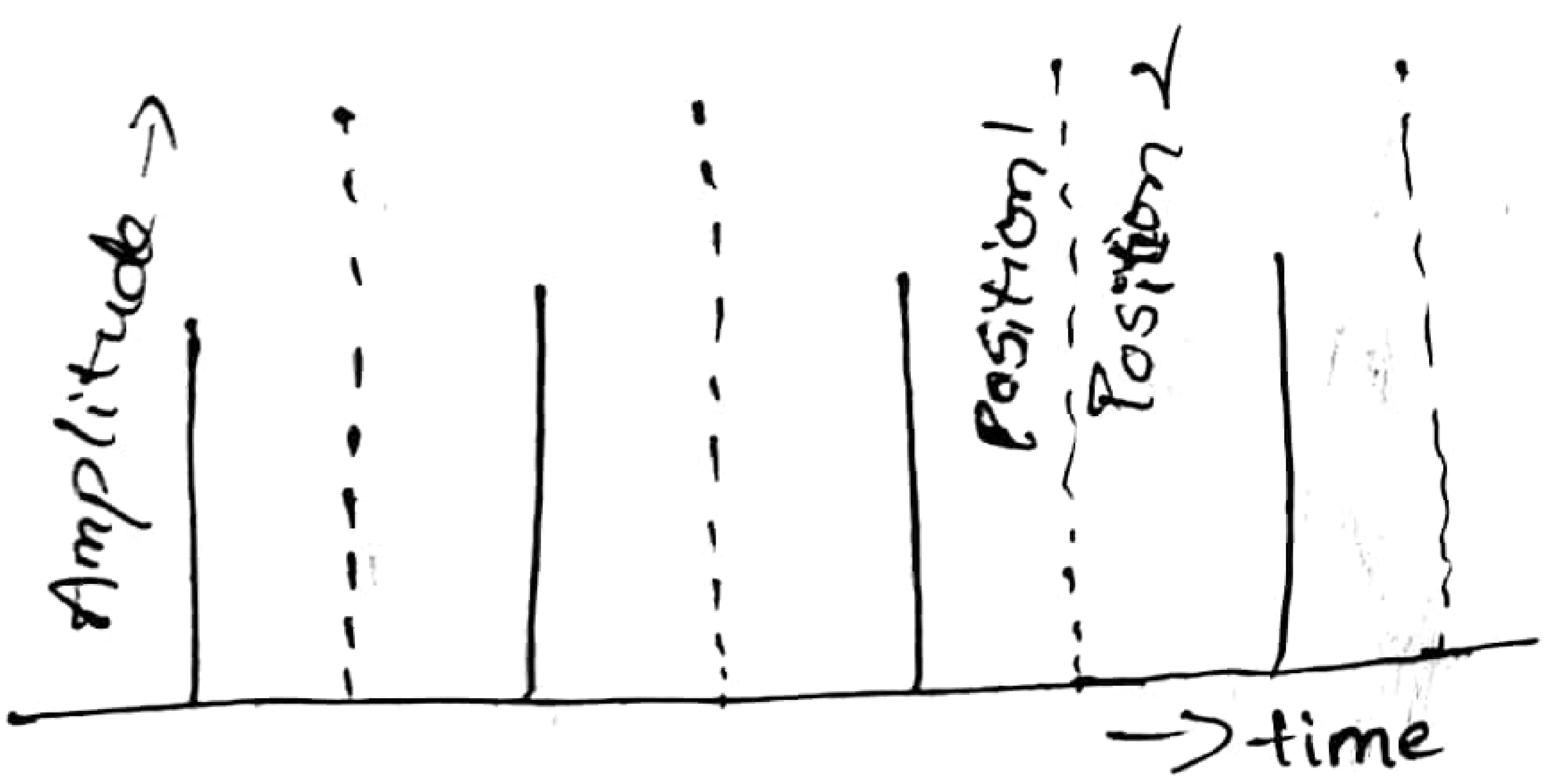
ial Lobing



(a) Polar representation of Switched antenna patterns



(b) Rectangular representation



(c) error Signal

fig(1) Lobe Switching antenna patterns and error Signal

-> In Sequential lobing the direction of antenna beam is rapidly Switched between two positions so that the strength of echo from target will fluctuate at the switching rate, unless the target is exactly midway between the two direction. The echo Strength will be the same in both antenna positions.

-> Sequential lobing is also called as lobe switching.

-> An important feature of Sequential lobing is that the target

Position accuracy can be far better than that given by the antenna beamwidth.

-> 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 co-ordinate is by alternative switching antenna beam between two position. This is called lobe switching, sequential switching or sequential lobing.

=> fig (a) is a polar representation of the antenna beam in the two switched positions. A plot in rectangular co-ordinate is shown in fig (b). and the error signal obtained from a target not on the switching axis (reference direction) is show in fig (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 may be determined from the axis direction.

additional switching positions are needed to obtain angular error in the orthogonal co-ordinate.

Thus a two-dimensional sequentially lobing radar might consist 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.

→ Sequential lobing, or lobe switching, was one of the first tracking radar techniques to be employed.

Advantages of Sequential lobing radar:

1. It requires only one antenna
2. Its operation is simple.
3. It requires less equipment.
4. It is cost effective

Disadvantages of Sequential lobing radar

1. It is not very accurate.

Conical Scan Tracking:

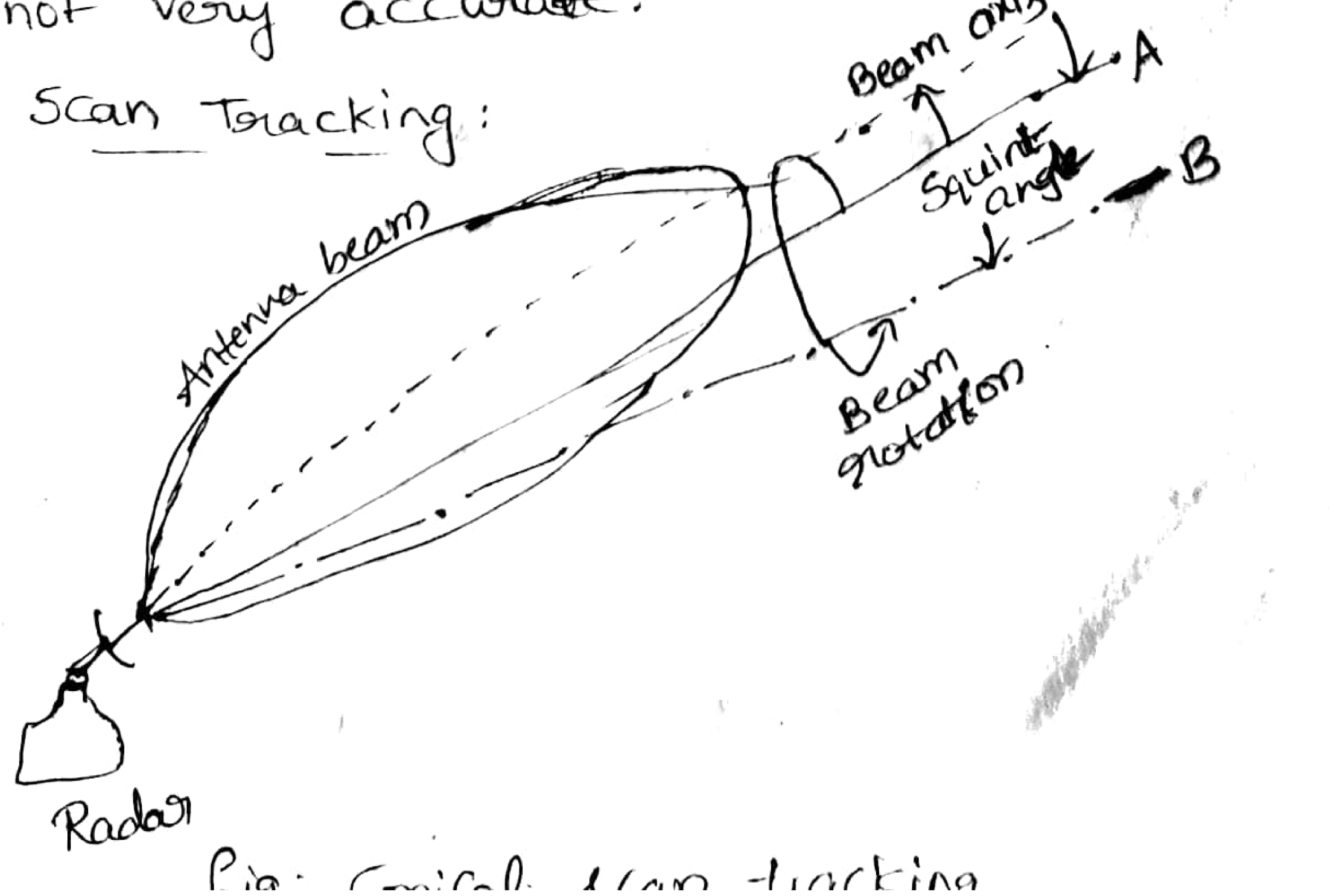


Fig: Conical scan tracking

-> A logical extension of the Simultaneous lobing ... is to rotate Continuously an offset antenna beam than discontinuously step the beam between four -ate positions. This is known as Conical Scanning.

-> The angle between the axis of rotation and the a... of antenna beam is Called the Squint angle.

-> Consider a target at position A. The echo Signal 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 targe line of Sight and 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 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 problem is two dimensional. Both the rectangular and polar tracking Co-ordinates may be used.

-> When the antenna is on-target as in B fig (1) the line of Sight to the target and the rotation axis Coinside and the Conical-Scan modulation is zero.

Tracking : A monopulse tracker is defined as on which information concerning the angular location of target is obtained by comparision of signals received two or more simultaneous beams. A measurement of angle may be made on the basis of a single pulse hence the name monopulse.

(or)

-> A type of radar in which angular location of target is obtain by comparing signals received by two or more simultaneous beams is called monopulse tracker. The measurement of target angle is done on the basis of single pulse hence called Monopulse.

-> In practice, multiple pulses are usually employed to increase the probability of detection, improve the accuracy of the angle estimate, and provide resolution in doppler angle estimate, and provide resolution in doppler when neccessary.

-> By making an angle measurement based on the signals that appear simultaneously in more than one antenna beam, the accuracy is improved compared to time-shared single beam tracking systems (such as conical scan or sequential lobing) which suffer degradation when the echo signal amplitude changes with time.

-> Thus the accuracy of monopulse is not affected by amplitude fluctuations of the target echo. It is the preferred tracking technique. when accurate measurements are required.

→ The monopulse angle method may be used in a tr radar to develop an angle error signal in two -nal angle Co-ordinates that Mechanically drive the Sight of the track antenna using a closed-loop se System to keep the boresight positioned in the direction of the moving target.

→ In radars such as the phased array, angle measure-ments Can be obtained in an open-loop fashion by Calibrating the error signal voltage in terms of angle.

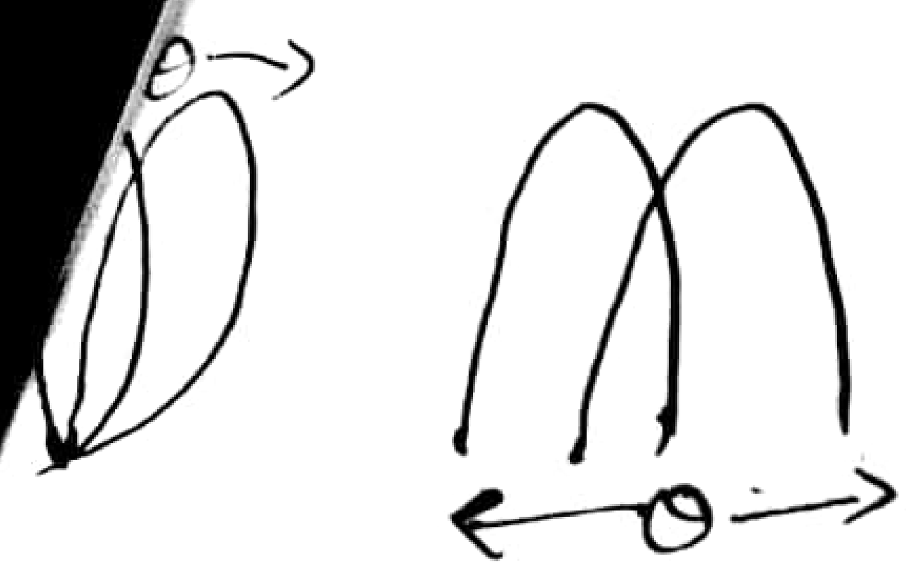
Methods of monopulse angle measurement:

There are Several methods by which a monopulse angle measurement Can be made. The most Popularly used methods are.

1. Amplitude - Comparision monopulse (or simply monopulse)
2. phase - Comparision monopulse.

→ The amplitude Comparision monopulse which Compares the amplitude of the Signals simultaneously received in multiple Squinted beam to determine the angle. While in phase Comparision monopulse the phase di-fference between two antenna beams gives the target angle.

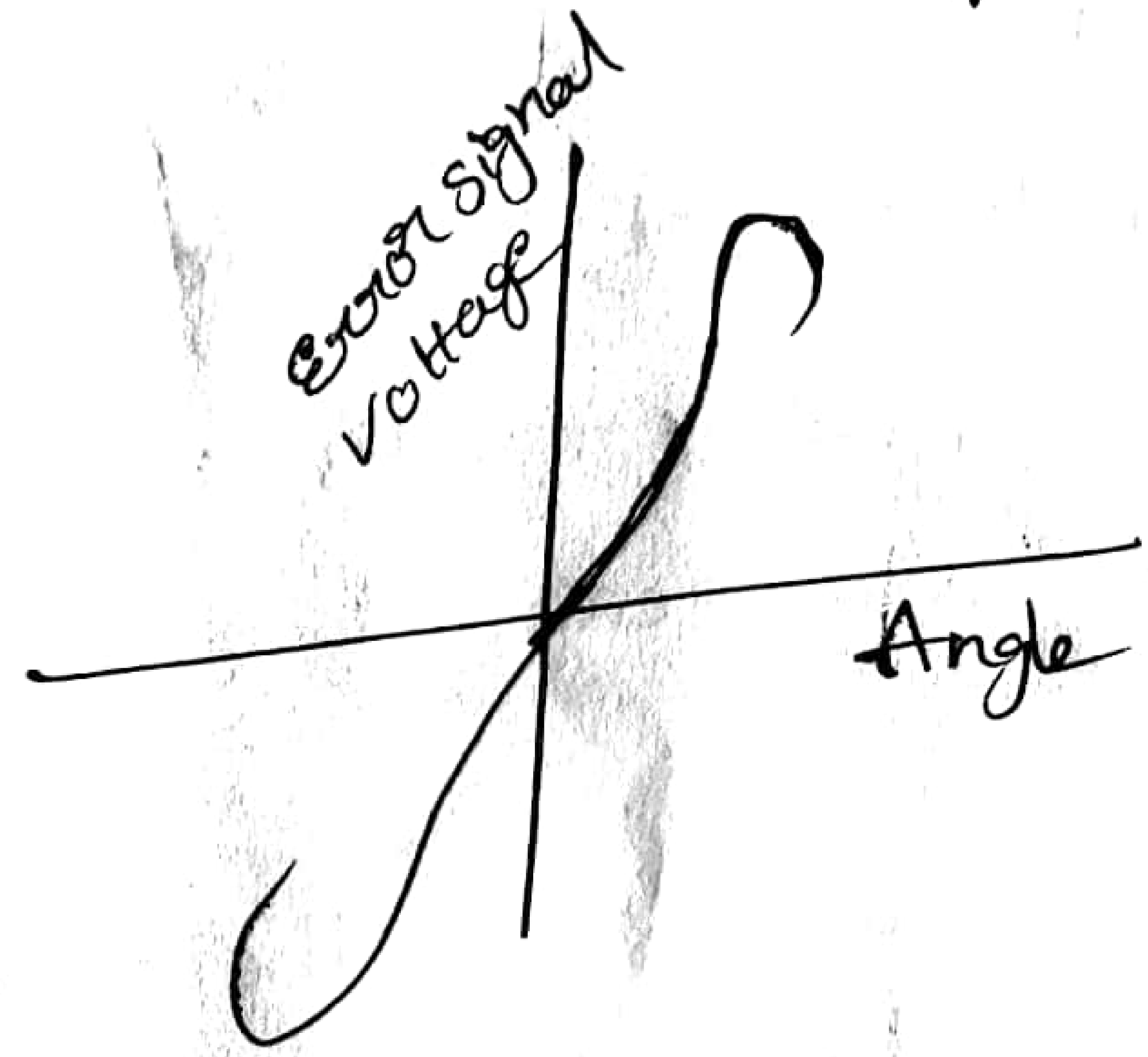
...ude - Comparision Monopulse



(a) Two Squinted antenna beams

(c) Difference pattern.

(b) Sum pattern of two Squinted beams shown in (a)



(d) Error Signal

→ The amplitude-Comparision monopulse employs two overlapping antenna patterns fig (a) to obtain the angular error in one Co-ordinate.

→ Two overlapping antenna patterns with their main beams point in slightly different directions are used fig (a). The two beams in this figure are said to be Squinted or offset.

→ The two overlapping antenna beams may be generated with single reflector or with a lens antenna illuminated by two adjacent feeds.

→ A cluster of four feeds may be used if both elevation and azimuth error signals are wanted.

-> The sum of the two antenna patterns of fig. shown in fig (b) and the difference in fig (c)

-> The sum patterns is used for transmission, while sum pattern and difference pattern are used on reception

-> The signal received with the difference pattern provides the magnitude of the angle error.

-> The sum signal provides the range measurement and is also used as a refrence to extract the sign of the error signal.

-> Signals received from the sum and the difference pattern are amplified separately and combined in a phase sensitive detector to produce the error-signal characteristic shown in fig (d).

-> Amplitude comparision monopulse can have two forms.
1. one angle co-ordinate
2. Two angle co-ordinate.

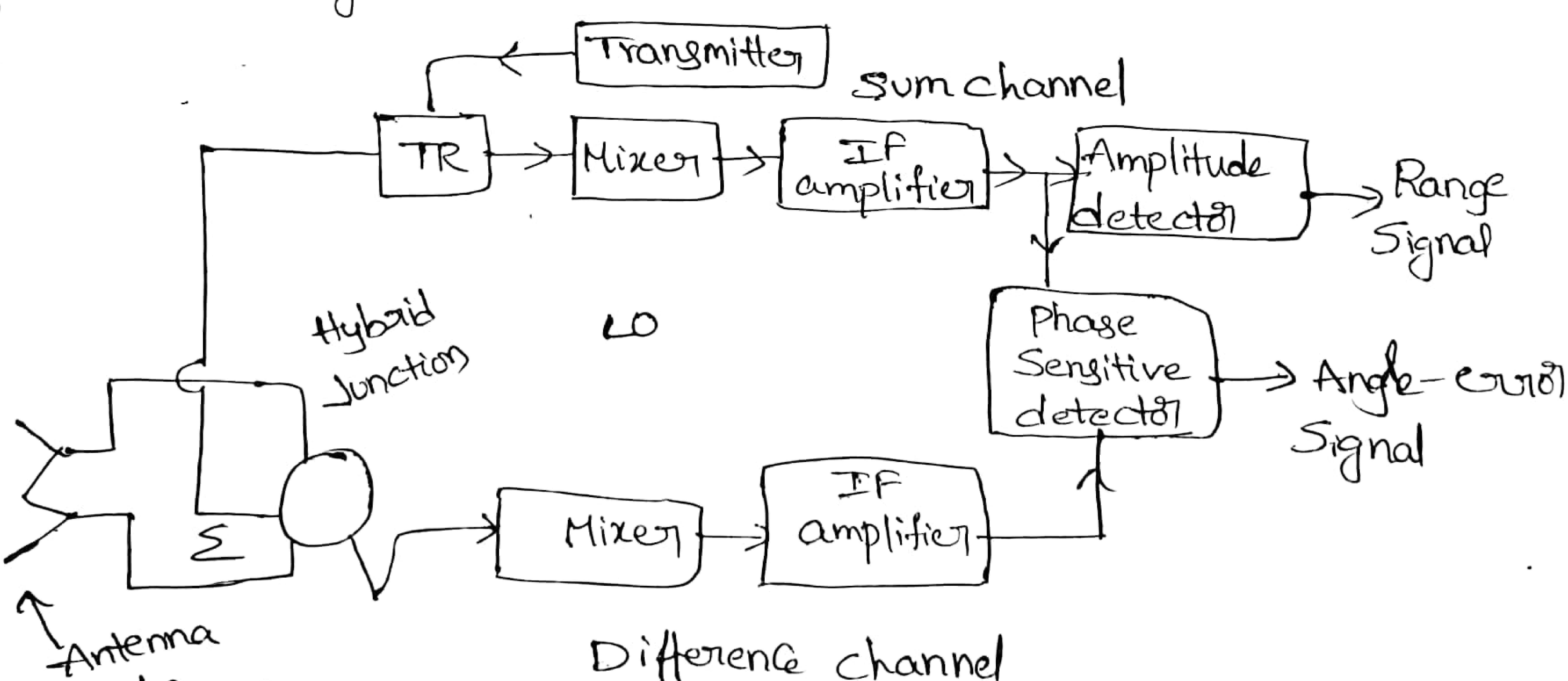


fig: Block diagram of a amplitude - comparision monopulse radar in one angle co-ordinate
Σ denotes sum channel, Δ denotes difference channel.

Block diagram of the amplitude Comparision monopulse tracking radar for a single angular Co-ordinate is shown in above fig:

-> 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 o/ps of the sum arm and the difference arm are each heterodyned to an intermediate frequency and amplified as in any Superheterodyne 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 dir... the angular error) is determined by comparing ... of the difference signal with the phase of the s...

→ If the sum signal in the IF portion of the receive... $A_s \cos \omega_{IF} t$, the difference signal would be either A_d ... $-A_d \cos \omega_{IF} t$ ($A_s > 0$, $A_d > 0$) depends on which side of cent... 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° out of phase.

→ Although a phase comparision is a part of the amplitude-comparision-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 beam is not used.

→ The purpose of the phase-sensitive detector is to conveniently furnish the sign of the error signal.

Amplitude - comparision monopulse tracking radar in two-coordinates (azimuth and elevation):

fig:- Block diagram of two-coordinate (azimuth and elevation) amplitude comparision monopulse tracking radar. Diagram in the upper left corner represents the four-horn feed

... diagram of monopulse radar for extracting angle ... in both azimuth and elevation is shown in above

... cluster of four feed horns generate four partially ...rlapping (squinted) beams.

-> The four feeds might be used to illuminate a parabolic reflector, Cassegrain reflector, or a space-fed phased array antenna.

-> The arrangement of four feeds is shown in the upper left-hand portion of the figure.

-> All four feeds are used to generate the sum pattern on transmission and reception.

-> The difference pattern in plane is formed by taking the sum of two adjacent feeds and subtracting from the sum of the other two adjacent feeds.

-> The difference pattern in the orthogonal plane is obtained similarly.

-> for example, based on the arrangement of feeds shown in above fig, the sum pattern is found from A+B+C+D; the azimuth difference pattern is obtained from (A+B)-(C+D) and the elevation difference pattern is (B+D)-(A+C)

-> Note that the upper feeds form the lower beams when radi-ated by a reflector antenna.

-> A total of four hybrid junctions are needed to obtain the Sum Pattern and the two difference Patterns

-> The three mixers for the sum, elevation difference and azimuth difference channels use a Common local oscillator to better maintain the phase relationships among the three channels.

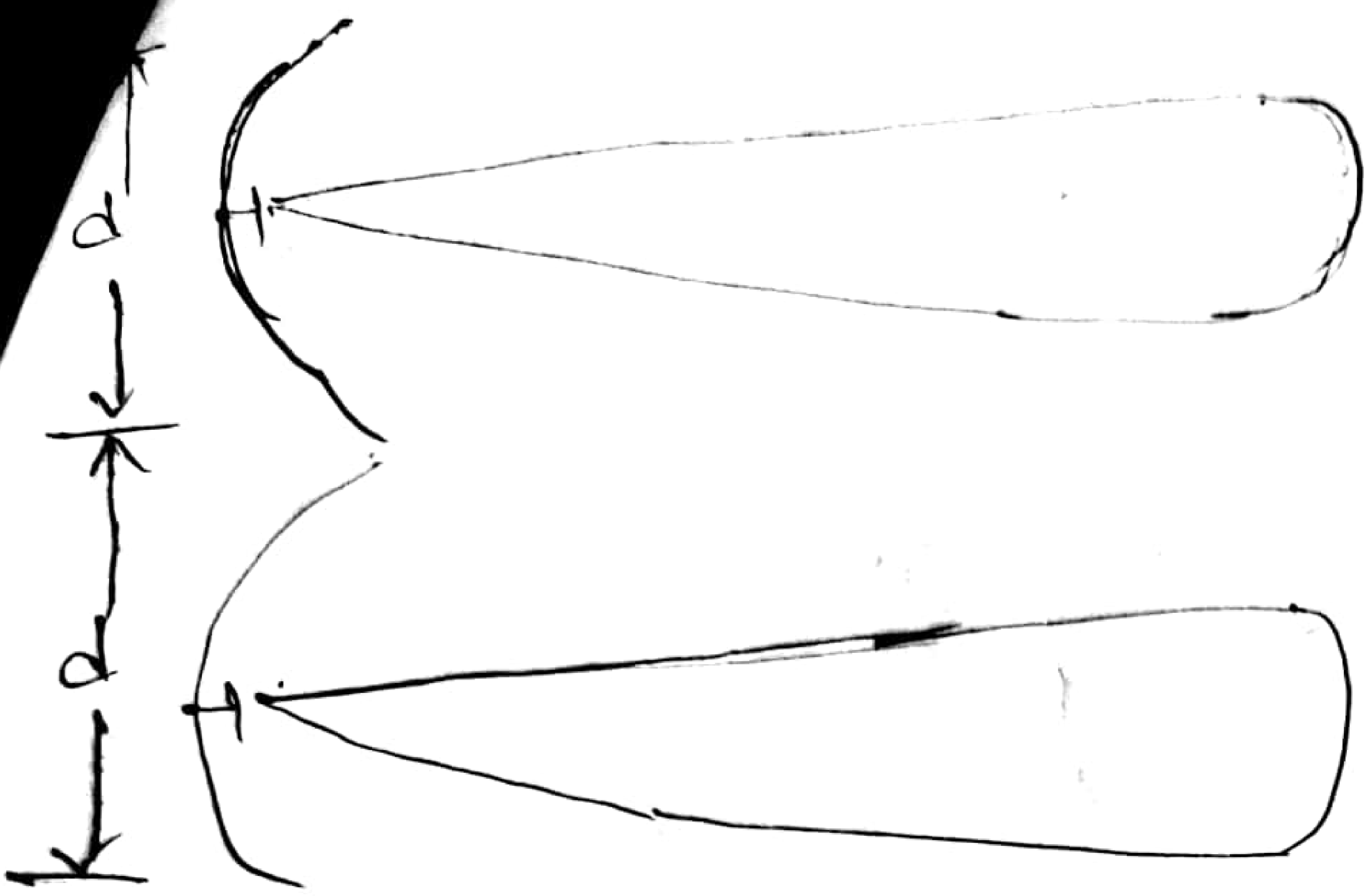
-> Two phase-sensitive detectors extract the angle e...
information; one for azimuth and the other for elevat...
information is extracted from the output of the...
channel after envelope detection.

-> Since phase comparision is made between the output... the sum channel and each of the difference channel, it is important that large relative phase difference bet-n channels should be mainted to within 25° or better for reasonably proper performance.

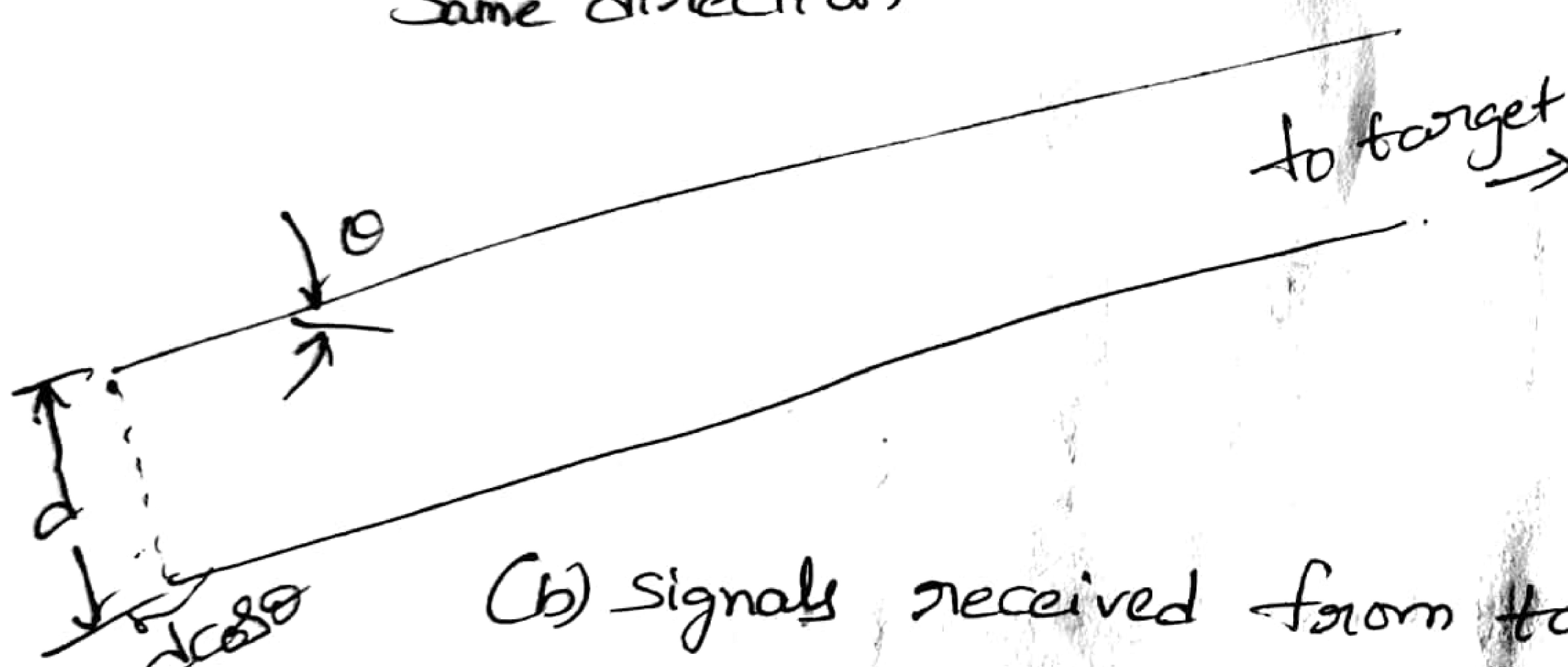
Automatic gain Control (AGC): AGC is required in the recei-ving system in order to maintain a stable. closed-loop servo system for angle tracking and to ensure that the angle error signal is not affected by changes in the received signal amplitude. As indicated in the above block diagram. the AGC signal is obtained from the peak voltage of the sum channel and generates a negative dc voltage proportional to the peak signal voltage.

-> The AGC signal from the sum channel is fed back to control the gain of all three channels so as to provide a constant angle sensitivity independent of changes in target cross-section fluctuations or changes in range.

Comparision Monopulse



(a) Two antennas radiating identical beams is Same direction



(b) signals received from target.

→ In a phase-Comparision monopulse, two antenna beams are used to obtain an angle measurement in one Co-ordinate.

→ The two beams look in the same direction and Covers the Same region of Space rather than be Squinted to look in two slightly different directions.

→ The phase Comparision monopulse is also known as interfero-meter radar.

→ The amplitudes of the signals are same, but their Phases are different.

→ Consider two antennas Spaced a distance 'd' a part as in fig (b). If the Signal arrives from a direction θ with respect to the normal to the base line, the

Phase difference in the signals received in the two a...

$$\Delta\alpha = 2\pi \frac{d}{\lambda} \sin\theta$$

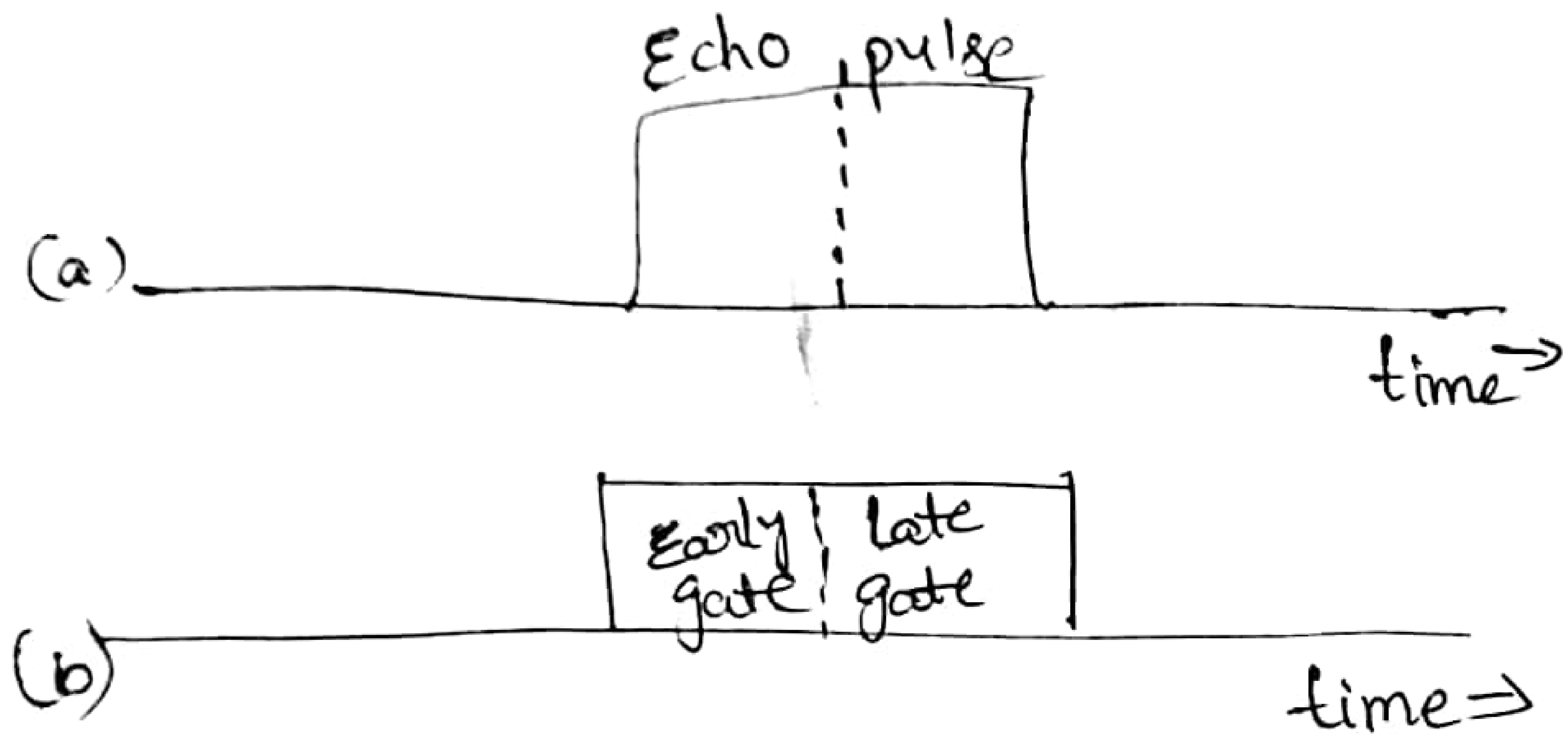
where

θ is signal arriving from a direction θ ... normal to baseline.

λ is wave length

d is the distance between two antennas.

Tracking in Range:



(c) fig: Difference Signal between early and late range gates.

fig(1) Split-range-gate tracking (a) echo pulse (b) Early gate range gates.

→ The technique for automatically tracking in range is base on the split range gate.

→ Two range gates are generated as shown in fig(1) one is in the early gate, and the other is the late gate.

→ The echo pulse is shown in fig(a) the relative position of the gates at a particular instant in fig(b) and the error signal in fig(c).

→ In this example the portion of the signal in the early gate is less than that of the late gate.

signals in the two gates are integrated and subtracted
produce the difference error signal.

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 feed back control
system. When the error signal is zero, the range gates
are centered on the pulse.

→ The position of the two gates indicates the target's range
If there exists deviation of the pair of the gates from
the center, then the echo pulse increases the signal.
energy in one of the gates and decreases in the other
gate. This produces an error signal that causes
the other pulses to be moved so as to reestablish
equilibrium.

Advantages of range gating:

1. It allows to isolate a single target.
2. The gate rejects the unwanted signals.
3. It improves SNR
4. It eliminates the noise.

Acquisition and Scanning patterns:

-> A tracking radar must first find and acquire its t... before it can operate as a tracker. Therefore it is usu... necessary for the radar to scan an angular in which the presence of the target is suspected.

-> Most tracking radars employ a narrow pencil-beam antenna for accurate tracking in angle; but it can be difficult to search a large volume for targets when use a narrow antenna beamwidth.

-> Some other radar must first find its target to be track and then designate the targets coordinates to the tracker. These radars have been called acquisition radars or designation radars and are surveillance radars that search a large volume.

-> The various scanning patterns which are employed with pencil-beam antenna are.

1. Helical Scanning 2. Palmer Scanning 3. Spiral Scanning 4. Raster or TV Scanning 5. Nodding Scanning.

Helical Scanning:

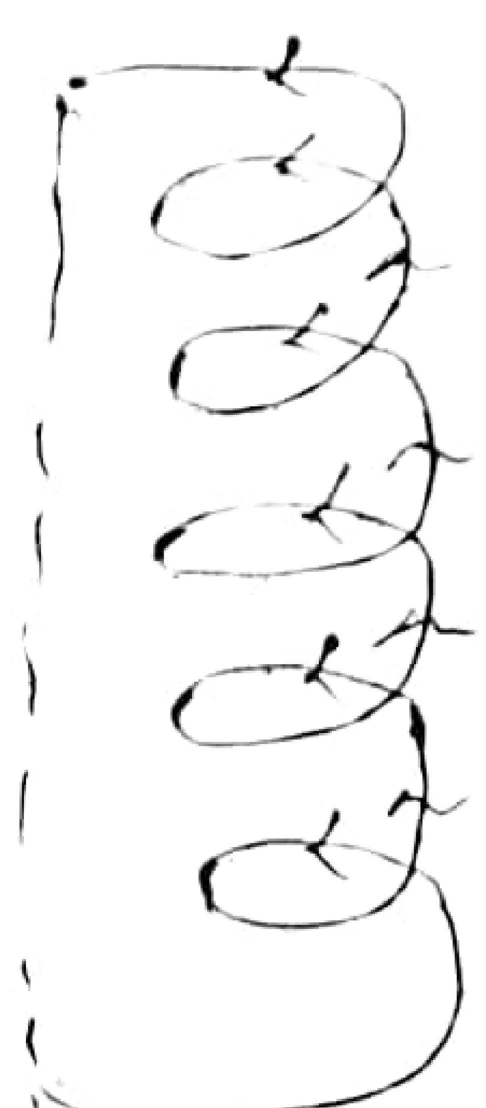


fig: Trace of helical scanning beam.

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helical Scan is used to obtain hemispheric cover as with
pencil beam.

helical Scan, the antenna is Continuously rotated in azimuth
while it is simultaneously raised or lowered in elevation
it traces a helix in Space.

-> Here, the tracking is basically helical.

-> Helical Scanning was employed for the Search mode of the SCR-584 fire-control radar, during world war-II for the aiming of antiaircraft - gun batteries.

-> The SCR-584 antenna was rotated at the rate of 6Pm and Covered a 20° elevation angle in 1 min.

Palmer Scan:

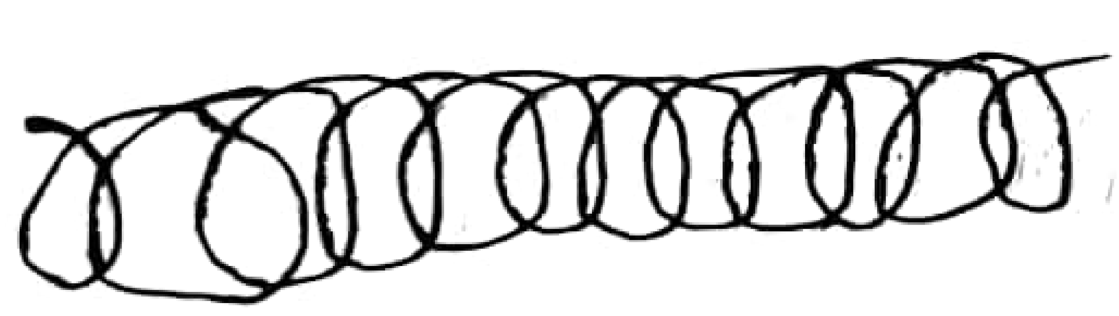


fig: Palmer Scan.

-> 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. Because of this property the palmer scan is sometimes used with Conical Scan tracking radar

-> which must operate in both search and track mode.

-> The mechanisms used to produce Conical Scanning Can also be used for palmer scanning. This type of Scanning is

Suited to a Search area which is larger in one than the other.

Spiral Scan:

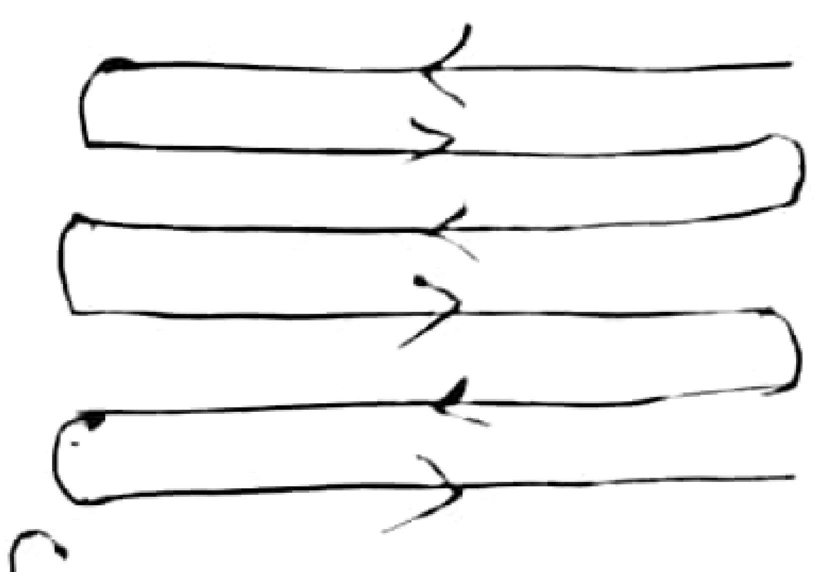
fig: Spiral Scan

-> If a limited area of circular shape is to be covered Spiral Scan may be used.

-> Spiral Scanning covers an angular Search volume with circular symmetry.

-> Spiral Scanning covering a circular area as shown in above fig.

Raster or TV Scan:



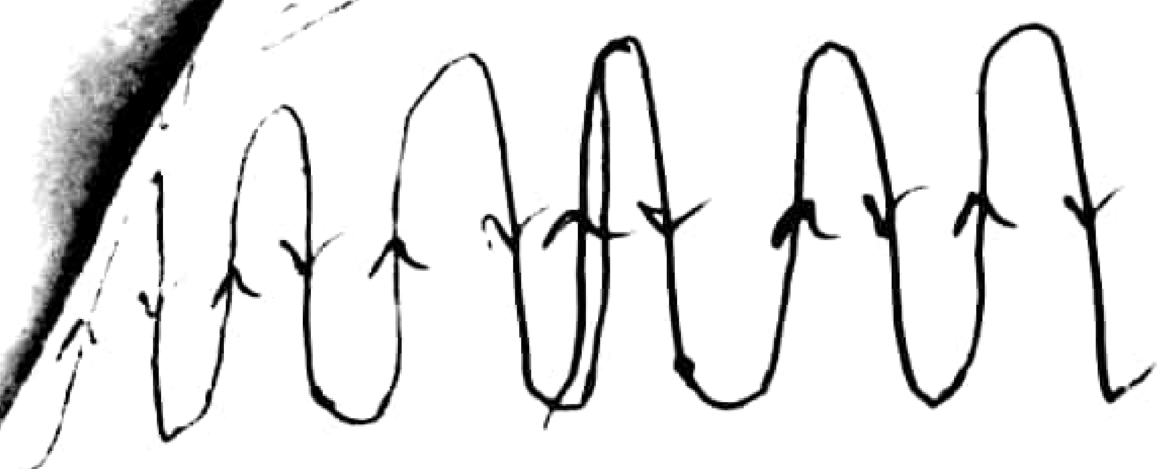
fig, Raster a TV Scan.

-> In raster Scan, the antenna Scans the area in a uniform manner.

-> The raster Scan is a simple and convenient means for Searching a limited area, usually rectangular shaped

-> It is also called as TV Scan.

Scan :



Figi Nodding Scan

The noding Scan produced by oscillating the antenna beam rapidly in elevation and slowly in azimuth.

-> Nodding Scan may also be used to obtain hemisphere Coverage that is elevation angle extending to 90° and the azimuth Scan angle to 360°

-> The nodding Scan is also used with height finding radars.

Comparision of Trackers :

Monopulse Tracking	Conical Scan Tracking
1. Multiple beams are used to determine the angle of arrived of echo signal Single pulse is required to derive the angle error information.	1. A single antenna beam on a time shared basis is used.
	2. Multiple pulses are required to derive the angle error information.
2. High SNR	3. Low SNR
3. More accurate tracking	4. Less accurate tracking
4. High Cost	5. Low Cost
5. Complex design.	6. Simple design
6. Cassegrain antenna is used	7. Horn antenna is used.
7. This radar first makes angle measurement and the integrate's a number of pulses to obtain required SNR	8. This radar first Integrates number of pulses then extractes the angle measurement.

Monopulse Tracking Radar:-	Conical Scan tracking radar:-
1. It is a simultaneous scanning system	1. It is a sequential scanning system
2. Signal-to-Noise ratio is large	2. Signal-to noise ratio is small
3 Angle accuracy is better	3. Angle accuracy is inferior to that of monopulse radar
4. Range accuracy is better	4. Range accuracy is inferior to that of monopulse radar.
5. Angle accuracy is not affected by fluctuation in the echo amplitude	5. Angle accuracy is also not affected by the fluctuation in echo amplitude.
6. System performance is degraded by glint	6. system performance is degrade by glint.
7. It is more complex	7. It is not complex.
8. Monopulse system come into existence first	8. Conical scan come later.
9. It has two receiving channels	9. It has only one receiving channel
10. It has two feeds	10. It has single feed.
11. Rotation of antenna beam is done at a relatively low speed.	11. Rotation of antenna beam is done at a relatively high speed.
12. It requires a single pulse	12. It requires a minimum of four pulses.
13. Angle measurement is made in two co-ordinates	13 Angle measurements is made in two coordinates.
14. In this, angle measurement is made first and then are integrated.	14. In this the number of pulses are integrated first and then angle measurement is made.
15. Its cost is relatively high	15. Its cost is relatively low.