(Jntuh)

RADAR SYSTEMS
EC 812 PE-5
(ELECTIVE V)
UNIT – 4A
B.TECH IV YEAR II SEMESTER
BY

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(Former Director DLRL Ministry of Defence)
BIET

ACKNOWLEDGEMENTS

THE CONTENTS , FIGURES , GRAPHS ETC., ARE TAKEN FROM THE FOLLOWING TEXT BOOKS & OTHERS

“ INTRODUCTION TO
RADAR SYSTEMS “
MERILL I.SKOLNIK
SECOND EDITION
TATA MCGRAW – HILL PUBLISHING COMPANY
SPECIAL INDIAN EDITION

“RADAR”
BYRON EDDE
LPE PEARSON EDUCATION

SYLLABUS
(ECE 812-PE5)
ELECTIVE-V
B.TECH IV YEAR II SEMESTER
UNIT 4

TRACKING RADAR:

Tracking with Radar, Sequential Lobing,Conical Scan, Monopulse Tracking Radar – Amplitude Comparison Monopulse(One- and two co ordinates),Phase Comparison Monopulse, Tracking in range, Acquisition and Scanning Patterns, Comparison of Trackers.

QUESTIONS THAT APPEARED IN JNTUH EXAMS R13 BATCH

SHORT QUESTIONS

1. Mention types of tracking -- 2 marks -- May 2019

2. What is meant by tracking in range --3 Marks -- May 2019

3. Define squint angle --2 Marks – April 2018

4. List the disadvantages of Sequential lobing --2 Marks –April 2018

5. Discuss the sequential lobing tracking antenna mechanism --2 Marks – May 2017

6. Briefly explain the tracking radar and search radar system --3Marks – May 2017

QUESTIONS THAT APPEARED IN JNTUH EXAMS R13 BATCH

DESCRIPTIVE QUESTIONS

1. a) Briefly explain the various tracking techniques of radar
   5 Marks -- May 2019

   b) Explain the working of one coordinate amplitude comparison monopulse radar 5 Marks -- May 2019

2. a) Explain the function of Sequential lobe tracking
   5 Marks -- May 2019

   b)Explain the working of phase comparison monopulse radar 5 Marks -- May 2019

3. a) Describe the operation of conical scan method

   5 Marks -- April 2018

   b) Draw and explain the block diagram of one coordinate comparison monopulse radar 5 Marks -- April 2018

QUESTIONS THAT APPEARED IN JNTUH EXAMS R13 BATCH (CONT)

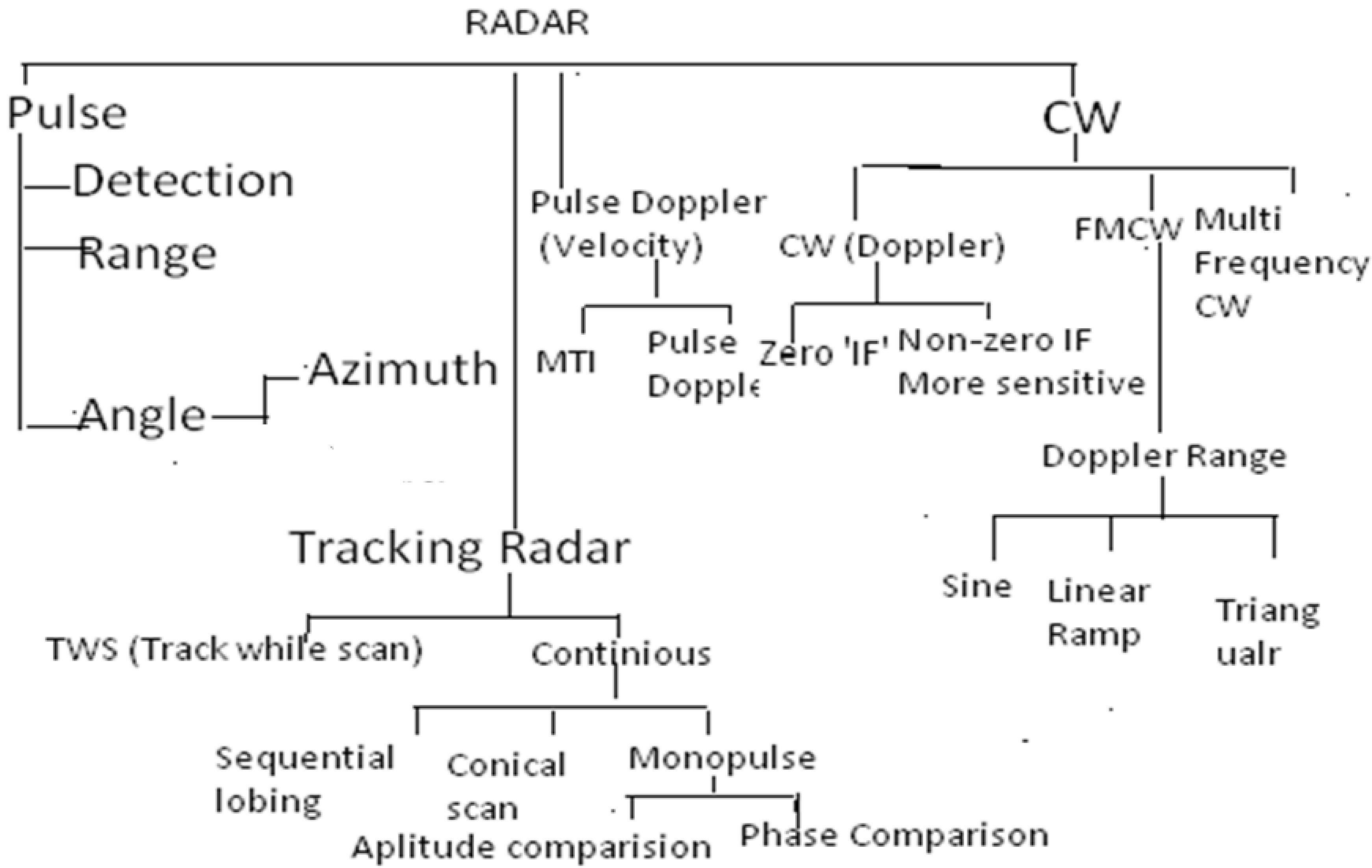
4. a) In a monopulse radar 2 antennas are used to produce a phase comparison of 25 Degrees between echo signals. It operates at 1.5 GHzs. Find the spacing between antennas if the angle is 15 Degrees - 5 Marks -- April 2018

   b) Discuss about acquisition and scanning parameters. 5 Marks -- April 2018

5. Explain with the help of a block diagram amplitude comparison monopulse radars for extracting error signals in both elevation and azimuth 10 Marks -- May 2017

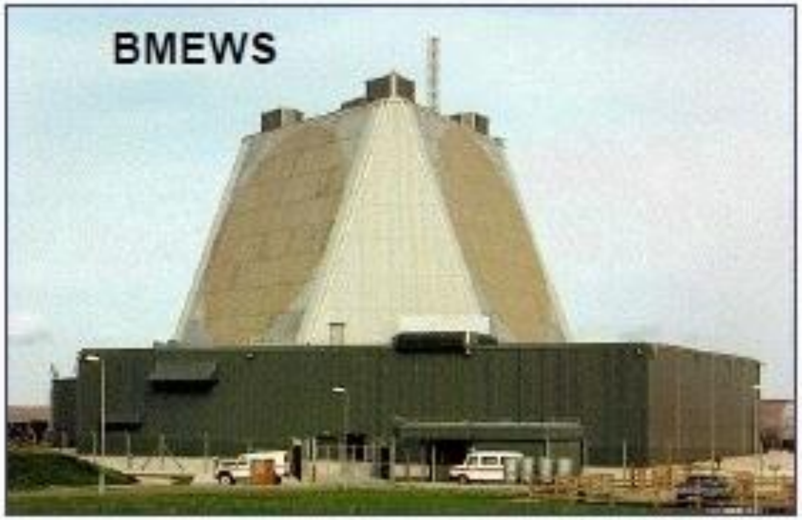
6. Define tracking in range and explain the split gate tracker method. 5 Marks -- May 2017

   b) Explain the working of a monopulse radar with the help of a block diagram 5 Marks -- May 2017


RADAR
Pulse
Detection
Range
Angle
Azimuth
Pulse Doppler
(Velocity)
MTI
Pulse
Dopple
CW
CW (Doppler)
Zero 'IF'
Non-zero IF
More sensitive
FMCW
Multi
Frequency
CW
Doppler Range
Sine
Linear
Ramp
Triang
ualr
Tracking Radar
TWS (Track while scan)
Continious
Sequential
lobing
Conical
scan
Monopulse
Aplitude comparision
Phase Comparison

A FEW TRACKING RADARS ACROSS THE WORLD

Courtesy of Lockheed Martin. Used with permission.



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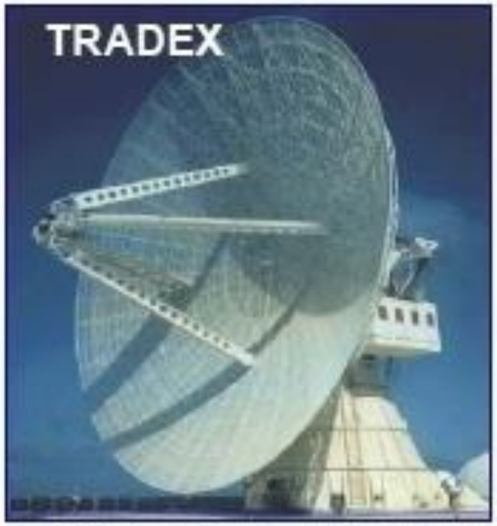
Courtesy of US Air Force

Courtesy of FAA



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TRACKING WITH RADAR

TRACKING WITH RADAR

- **Need for knowing the co-ordinates of targets accurately:**

i. To Determine and plot the target path.

ii. To Predict future position by knowing the Doppler velocity.

iii. During military operations

a) to position the Anti Aircraft guns accurately in the direction of hostile aircraft and fire

b) to use the 3 position coordinates in controlling & guiding the missile to the target.

TRACKING WITH RADAR (CONTD ..)

- Tracking Radar provide the following data accurately

  (i) Range

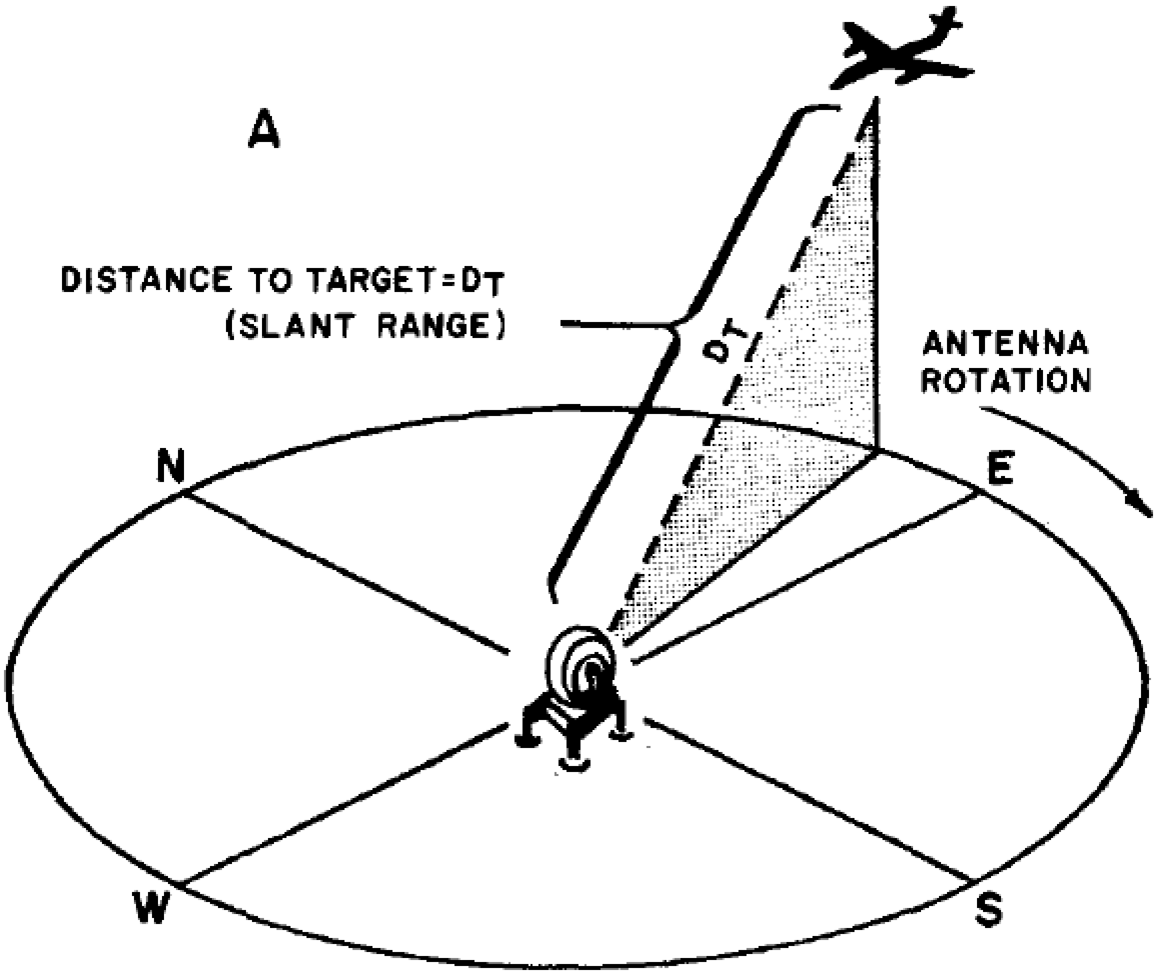
  (ii) Azimuth Angle

  (iii) Elevation Angle and

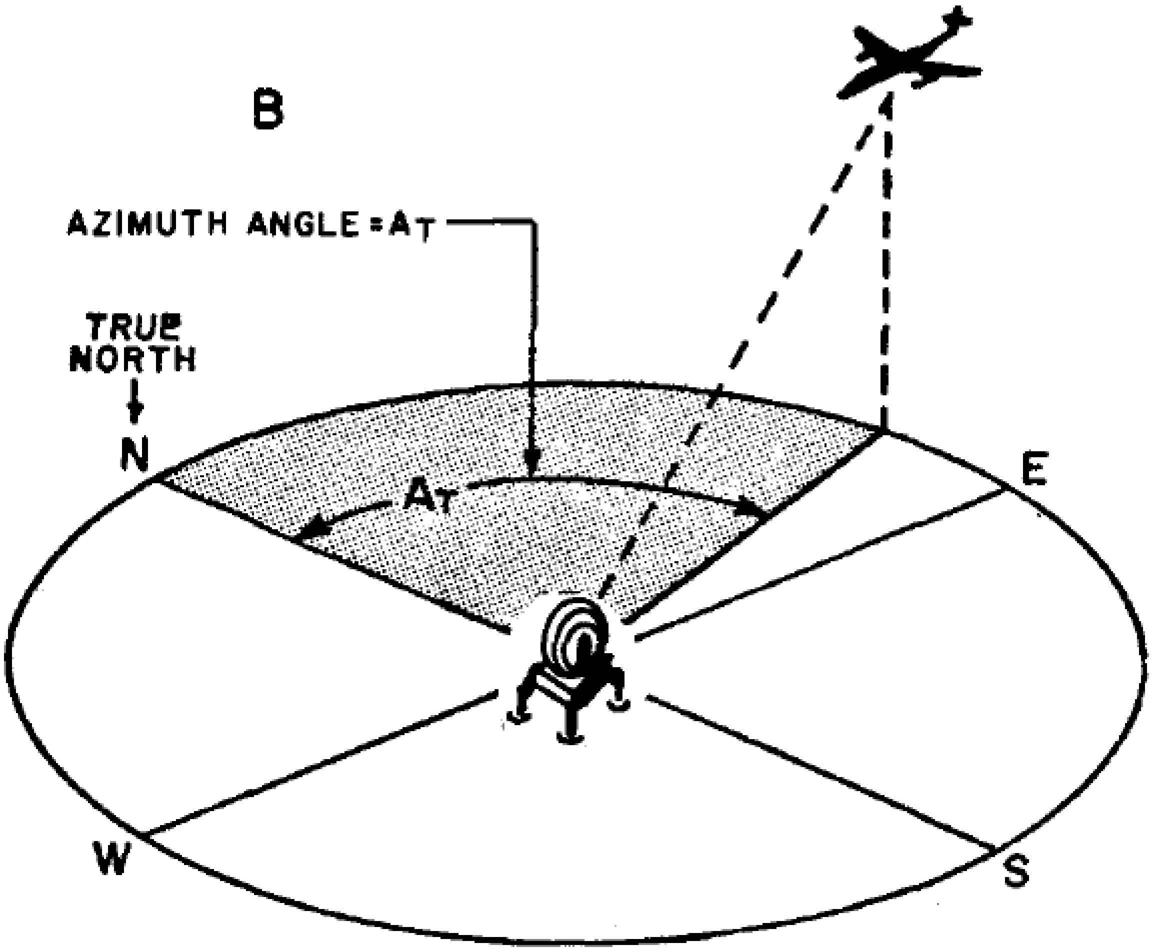
  (iv) Doppler Velocity

- The first three parameters are the 3 dimensional coordinates for the target.

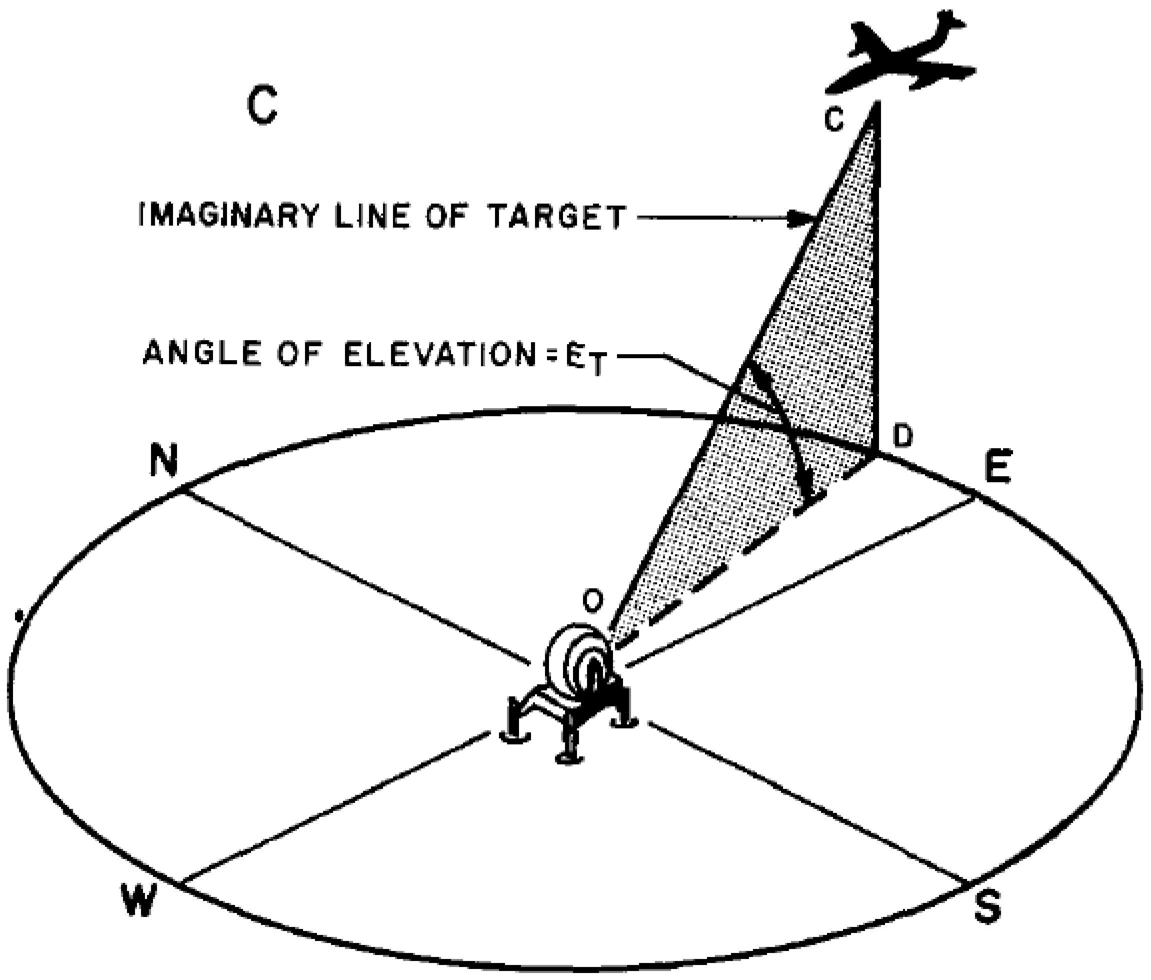
RANGE COORDINATE



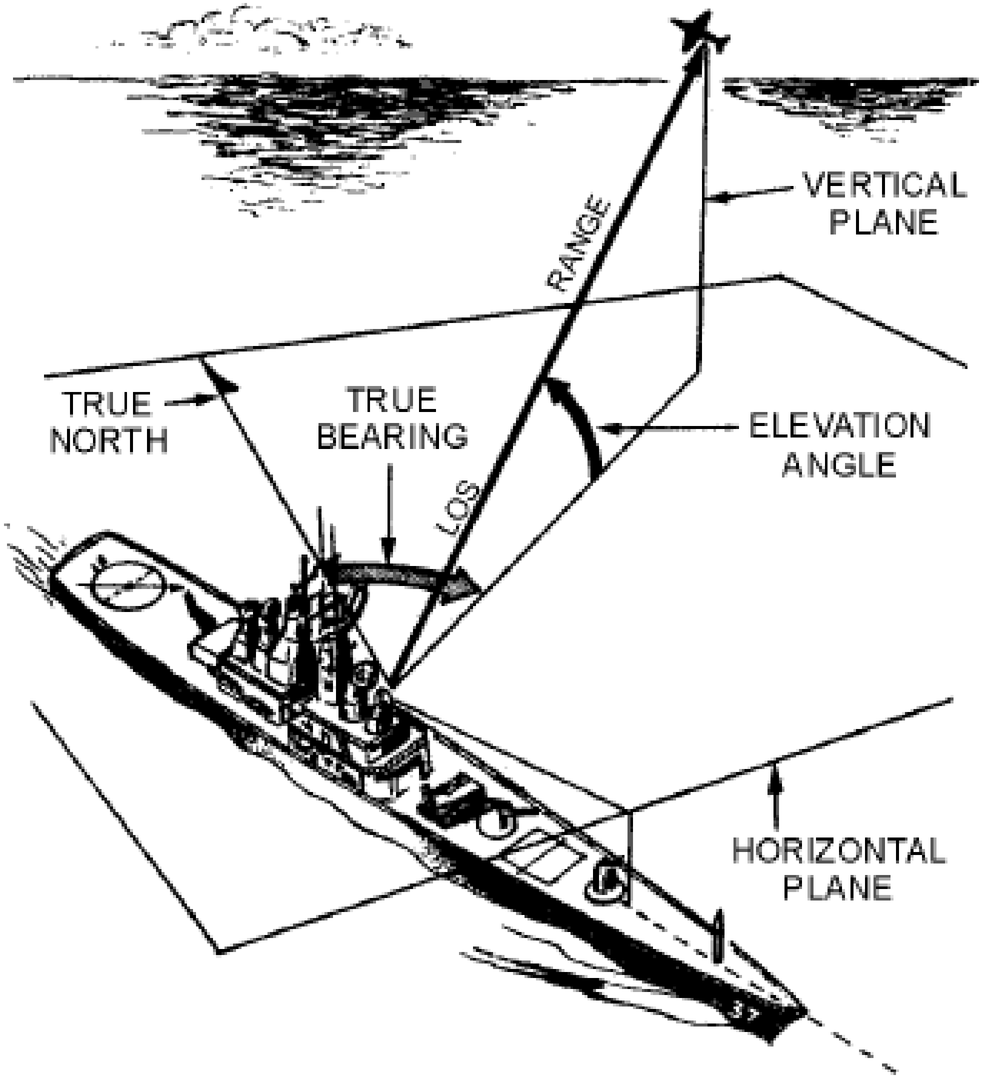
AZIMUTH ANGLE



ELEVATION ANGLE



3D COORDINATES



SEARCH & TRACK RADARS

- Based on function, Radars can be divided into
- i) Search (also called Surveillance) Radar
- ii) Tracking Radar.

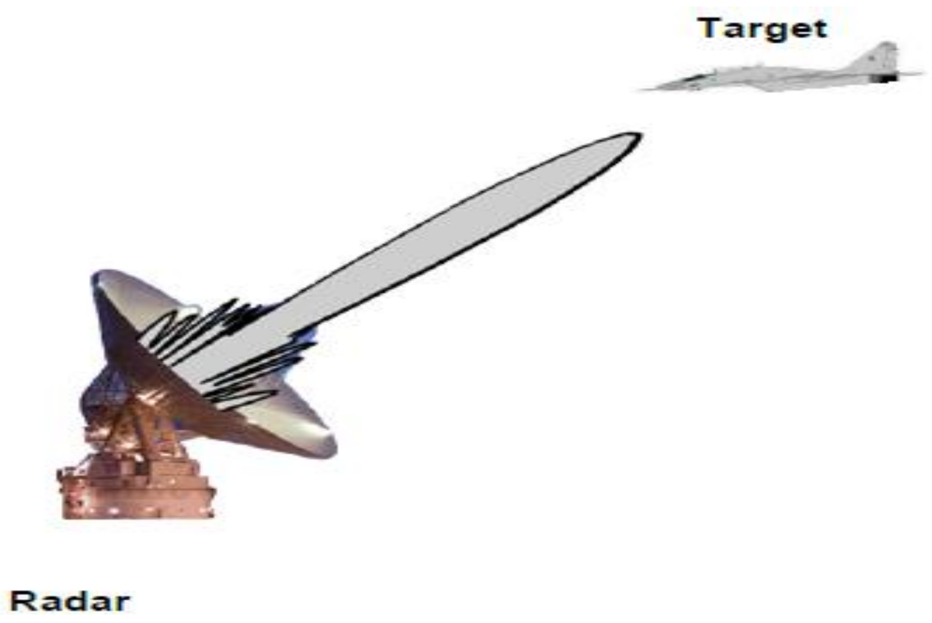
- Tracking Radar accuracies are far superior to the Search Radar.

- Basically Search Radars are 2-Dimensional where as Tracking Radars are 3-Dimentional

TRACKING RADAR (CONTD ..)

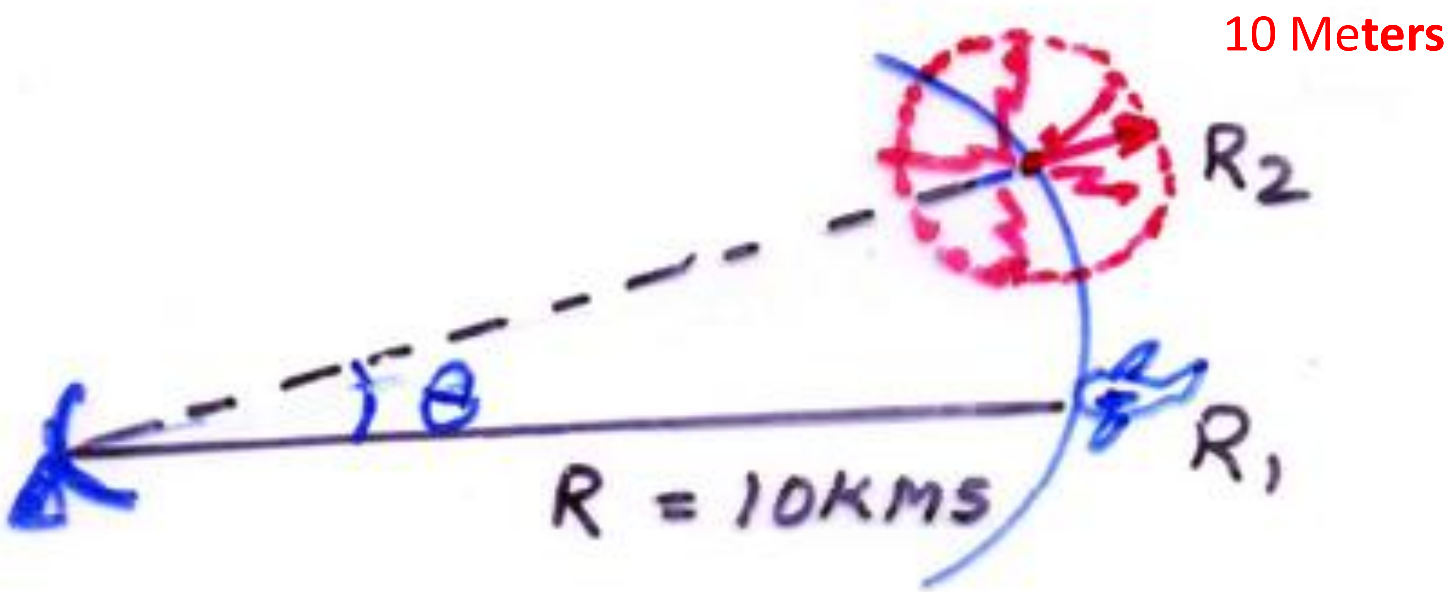
- **Need for High Accuracy :**

During military operations, in order to shoot down the hostile aircraft by (i) Anti Aircraft gun or (ii) Missile, the Coordinates of the target are required to be of high degree of accuracy.



NEED FOR HIGH TRACKING ACCURACY IN A MIISSILE SYSTEM

- **Tracking Geometry**



NEED FOR HIGH ACCURACY (CONTD ..)

Case(i): Let Range at which warhead explodes

=10 Km

Accuracy of tracking = 1^0

Miss Distance = Arc R_1R_2= $R \times \theta = 10 \times 10^3 \times 1 \times \frac{2\pi}{360}$

= 174.4 Mts.

Case (ii) : Accuracy of tracking radar = 0.1^0

Miss Distance = Arc R_1 R_2 = $R \times \theta = 10 \times 10^3 \times 0{\bullet}1 \times \frac{2\pi}{360}$

= 17.4 Mts.

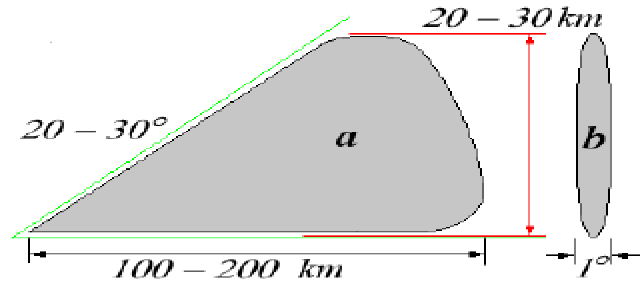
Case (iii): Accuracy of tracking = 0.1Milli Radian =$(0.00573)^0$

Miss Distance = Arc R_1 R_2 =

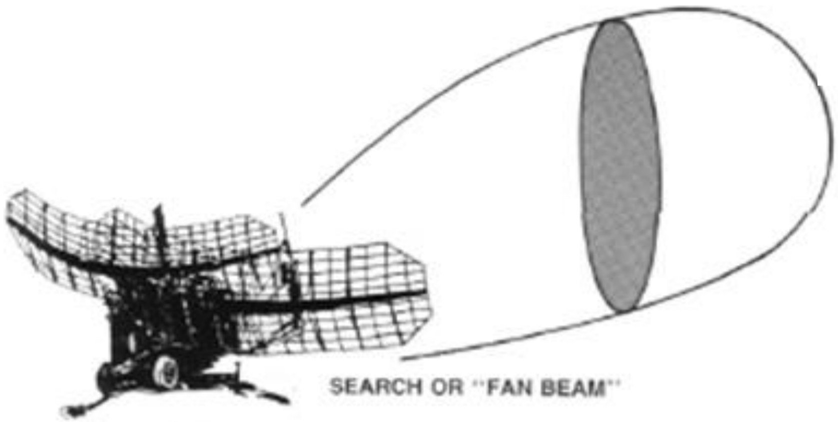
$R \times \theta = 10 \times 10^3 \times 0.1 \times 10^{-3}$= 1 Mt.

SEARCH & TRACK RADAR BEAMS

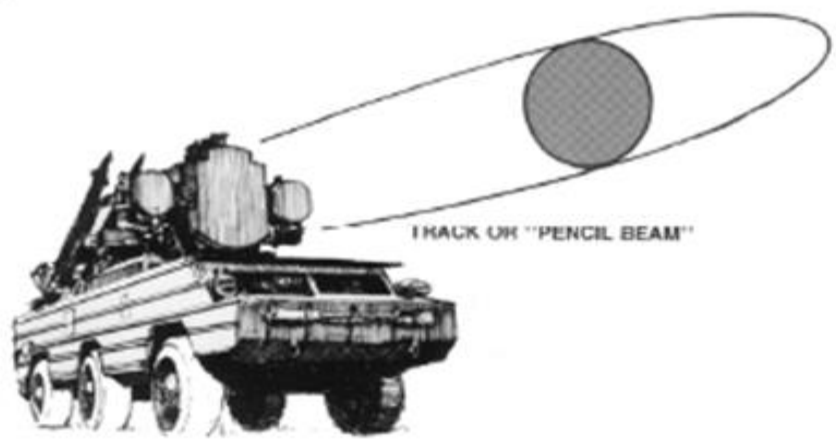
SEARCH RADAR



- Fan beam for 2-d search

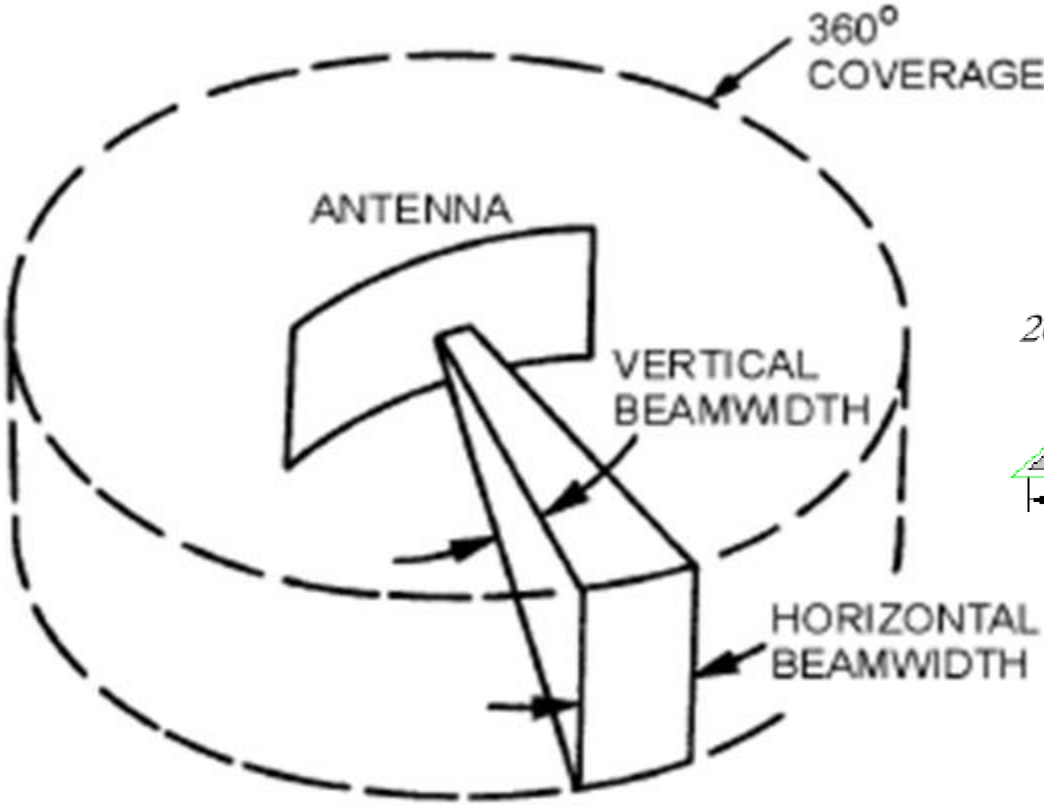


- Pencil beam for tracking for 3-d search

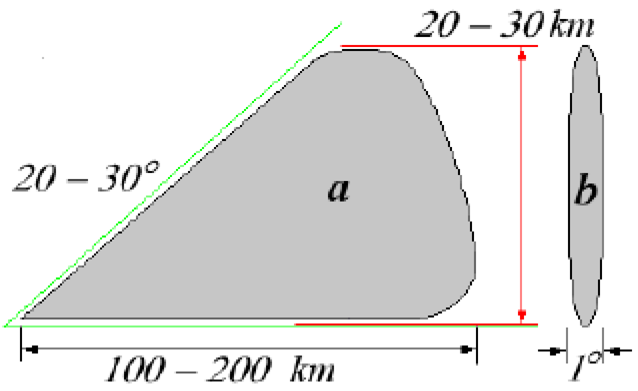


2D SEARCH RADAR

FAN BEAM

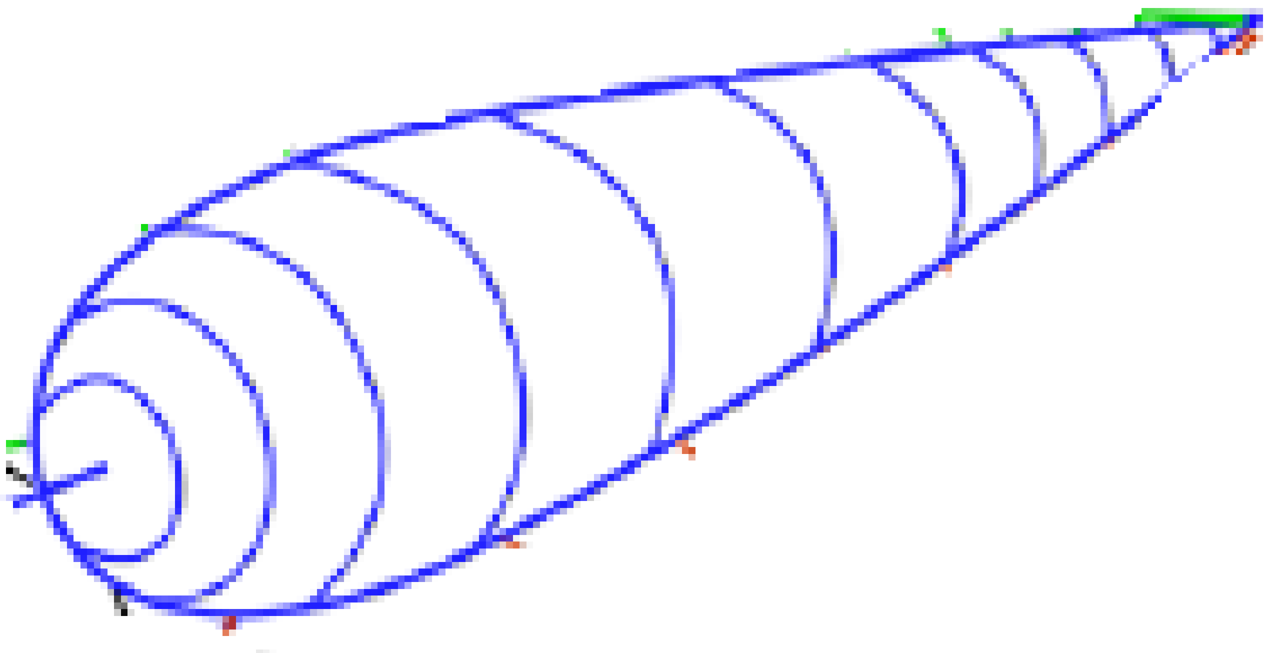


2D radar coverage pattern.



3D TRACK RADAR

PENCIL BEAM



DIFFERENCE BETWEEN ACCURACY, PRECISION & RESOLUTION

Accuracy :

The degree of conformity of measurement to the

true value

Bias Error : (True value – Average measured value)

Precision:

Repeatability of a measurement

Resolution:

Offset (angle or range) required for two targets to be recognized as separate targets

(Jntuh) Distinguish between Search Radar and Tracking Radar

COMPARISION OF SEARCH & TRACK RADARS

SEARCH RADAR	TRACKING RADAR
1. Long Range surveillance. Detects targets Hundreds of Kms away.	1. Tracks targets at medium ranges and mainly used during military operations
2. Determines parameters in 2 Dimensions Ex: (i) Range (ii) Azimuth Angle	2. Determines parameters in 3 Dimensions Ex: (i) Range (ii) Azimuth Angle (iii) Elevation Angle
3. Accuracy of parameters moderate	3. Accuracy of parameters is very high

COMPARISON OF SEARCH & TRACK RADARS (CONTD ..)

SEARCH RADAR	TRACKING RADAR
4. Uses a mechanically rotating antenna. The antenna beam scans the Azimuth 360^0 at a fixed rpm. In modern times Electronically scanned phased Array antenna is used	4. In case of single target ,servo system mechanically steers the antenna in the direction of target. In case of multiple targets an Electrically scanning beam is generated using a Phased Array Antenna
5. During the scan, Echoes are received only for a short period when the antenna looks in the direction of target.	5. Echoes are continuously received at the rate of PRI. All 3 co-ordinates are available continuously.

COMPARISON OF SEARCH & TRACK RADARS (CONTD ..)

SEARCH RADAR	TRACKING RADAR
6. For obtaining the coordinates in between scans when antenna is not looking in the direction of target, TWS(Track While Scan) method is used. Based on previous coordinates future positions are extrapolated by using prediction filters like Kalman Filter	6. The Radar Antenna continuously follows the target and looks in the direction of target . Coordinates of target are continuously available
7. Coordinates of multiple targets in 2 Dimensions possible using TWS method	7. 3 Dimensional tracking of single target possible. Using Phased Array multiple targets tracking is possible.

COMPARISON OF SEARCH & TRACK RADARS (CONTD ..)

SEARCH RADAR	TRACKING RADAR
8. Radar operates independently	8. Radar is used in conjunction with a Acquisition Radar. Initial coordinates are required before tracking.
9. Uses a single Fan beam in scanning.	9. Uses 2 pencil beams one in azimuth & other in elevation.
10. Comparatively less complex and less expensive.	10 Complex, Costly.
11.Used for civilian & military purposes.	11. Usually used for military purposes.

TRISHUL SURFACE TO AIR MISSILE

TRISHUL SURFACE AIR MISSILE

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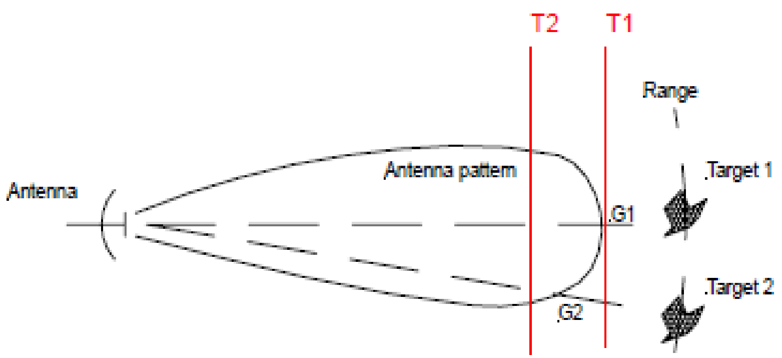
ANGULAR ACCURACY OF UNSWITCHED SINGLE BEAM

The angular accuracy of the target is equal to the Half power beam width since the target can be anywhere in the beam



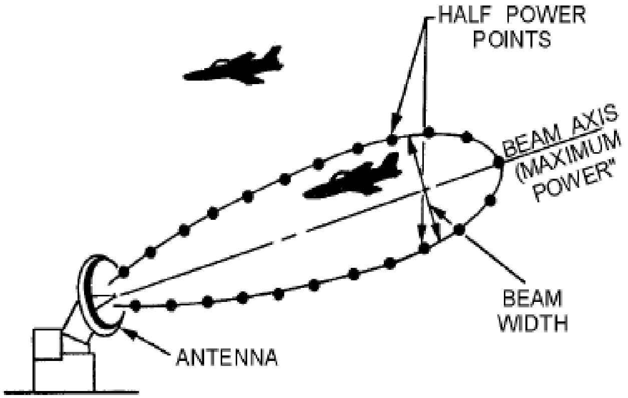
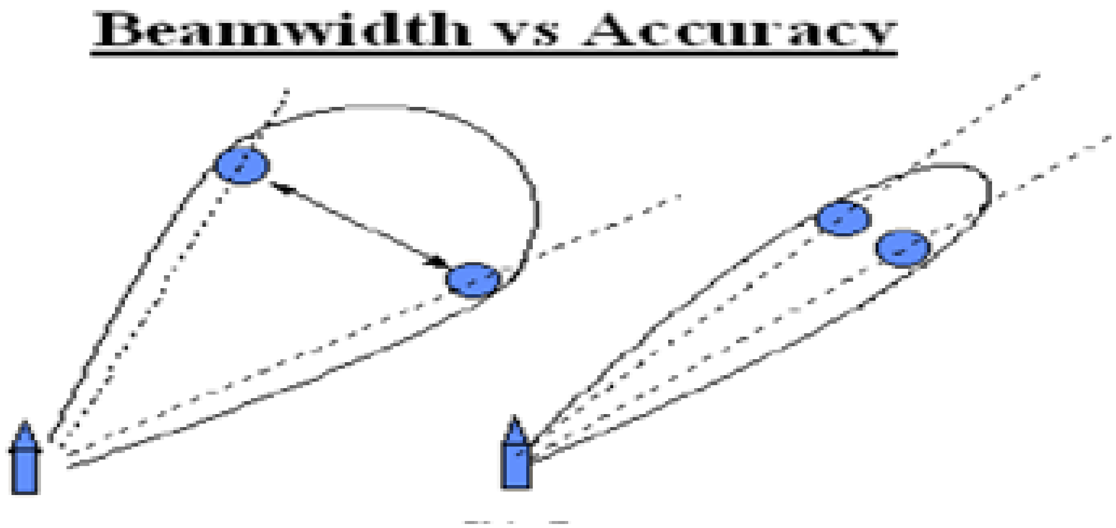


Figure 1-11.—Beam half-power points.

This gives a rough measure of target direction (with in one beam width)

ANGULAR ACCURACY OF UN-SWITCHED SINGLE BEAM

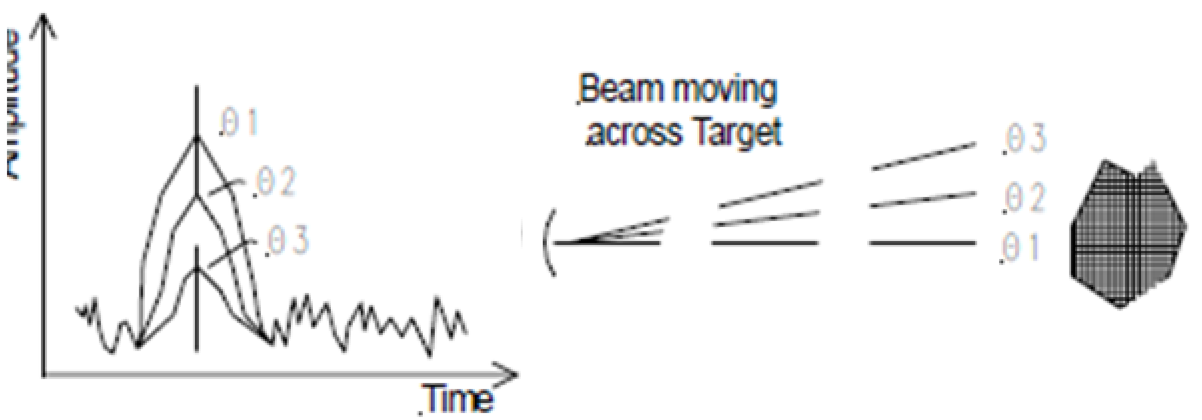
Accuracy can be improved by decreasing the beam width



ANGULAR ACCURACY OF UNSWITCHED SINGLE BEAM

It is possible to get a more accurate bearing by sweeping and noting the changes in Echo amplitude. The position of maximum amplitude gives a more accurate positional accuracy However noise limits the accuracy in determining the centroid

Accuracy obtained by single beam is not sufficient. As such Tracking Radar becomes a necessity



TRACKING RADAR

(Jntuh)

Explain the Tracking Principle

TRACKING RADAR

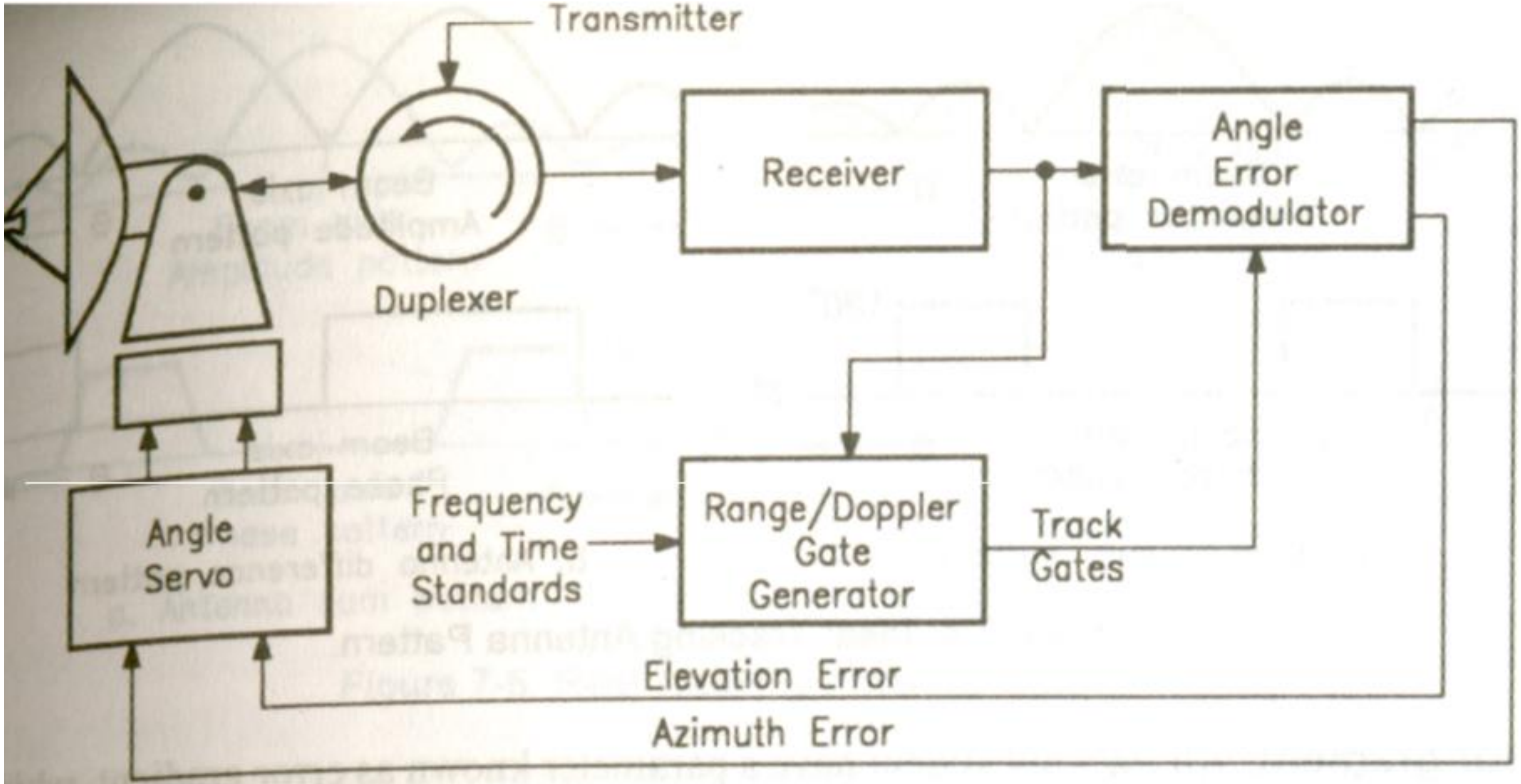
Tracking is the process where by radar antenna follows the target in space (Azimuth Ө, Elevation Ø, Range R).

Tracking radars dwell on individual targets and follow their motion in Azimuth, Elevation & Range.

Most tracking radars follow a single target.

A few modern radars can track multiple targets simultaneously. These are called Phased Array Radars which electronically steer the beam and move the position of beam instantaneously from one target to another.

Block Diagram of a Tracking System

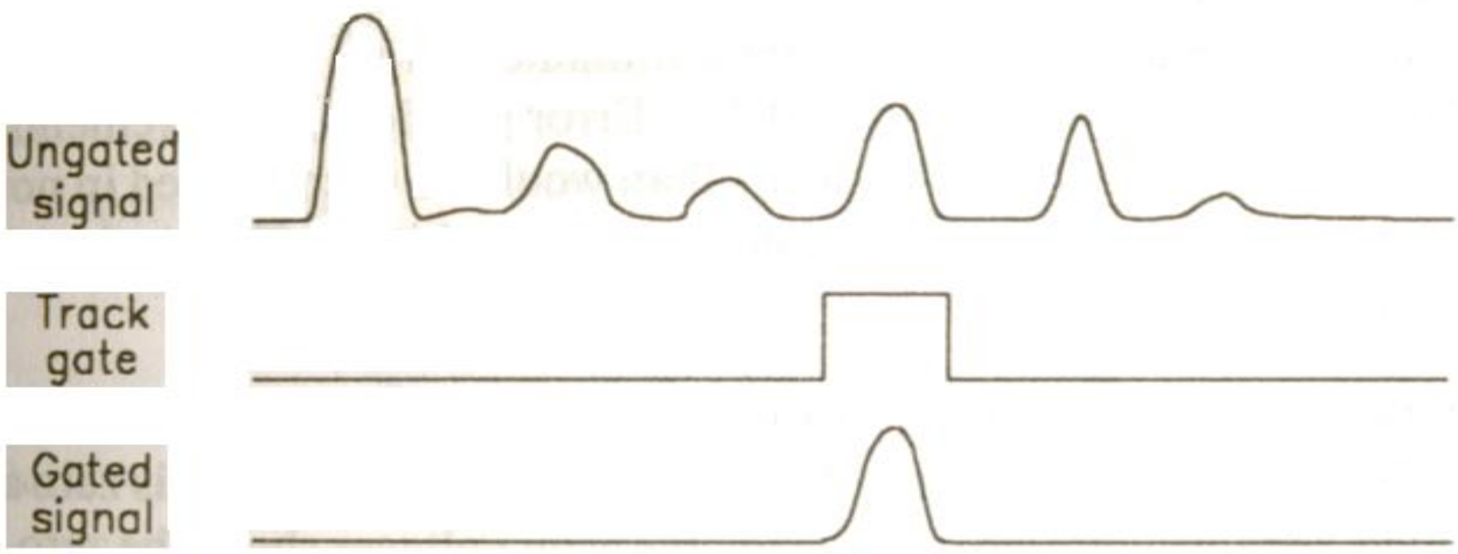


Tracking System Block Diagram.

TRACKING RADAR (CONTD ..)

- **Single target tracking:**

  Target of interest is selected by gating. This also improves S/N as noise in other range cells is stopped by gating



(Jntuh) **What factors determine the Range and angular accuracies in a Radar**

(Jntuh) **Explain in detail about limitations to tracking accuracy**

TRACKING ACCURACY

- **Factors that determine the Accuracy of Tracking:**

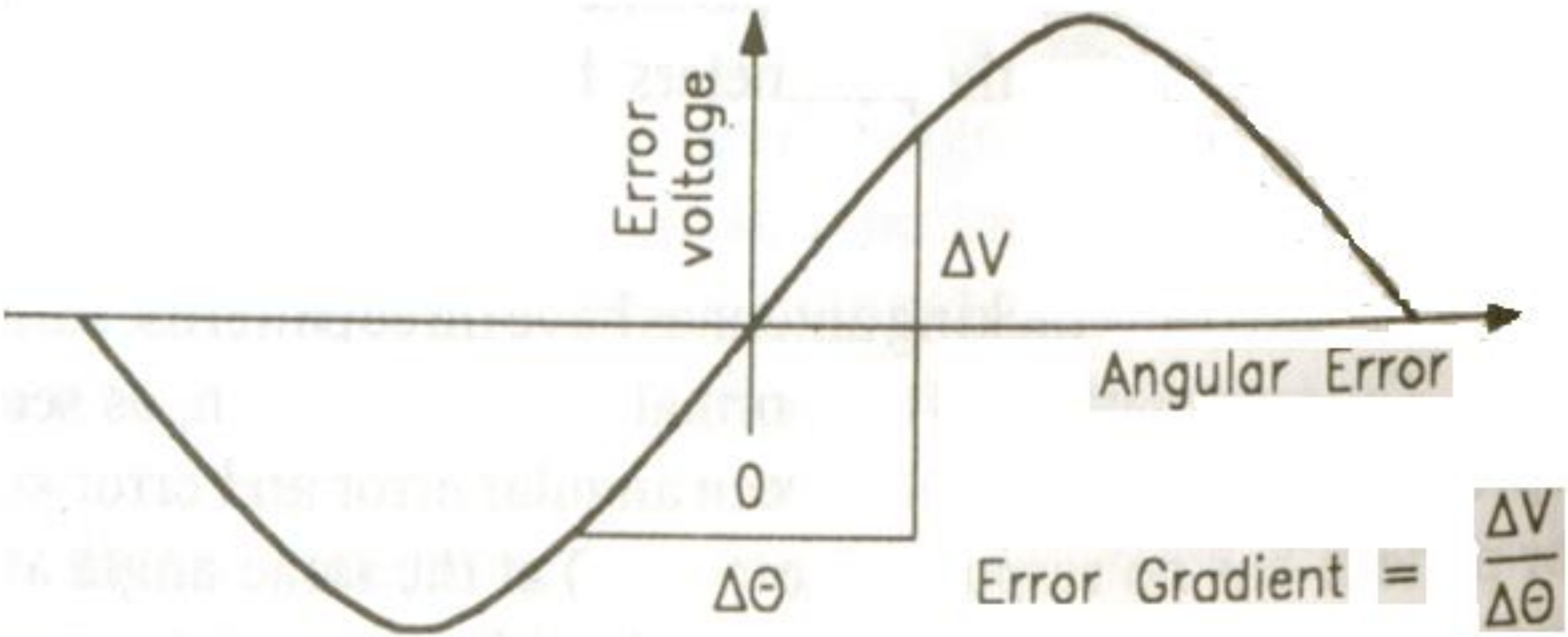
  (i) Error gradient (ii) Depth of Null

  The above 2 factors mainly determine the tracking system's ability to convert angular tracking errors into signals which can be applied to servos to move the antenna beam to the location of the target.

  They apply to (i) Angle tracking (ii) Range Tracking. and (iii) Doppler Tracking.

TRACKING ACCURACY (CONTD ..)

- **Error gradient:** Servo error voltage Vs Angular error (Volts/Degree)

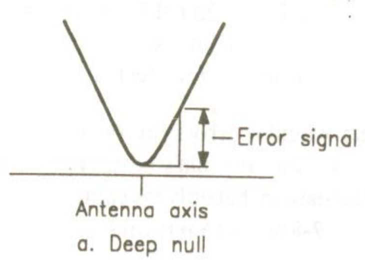


Error Gradient.

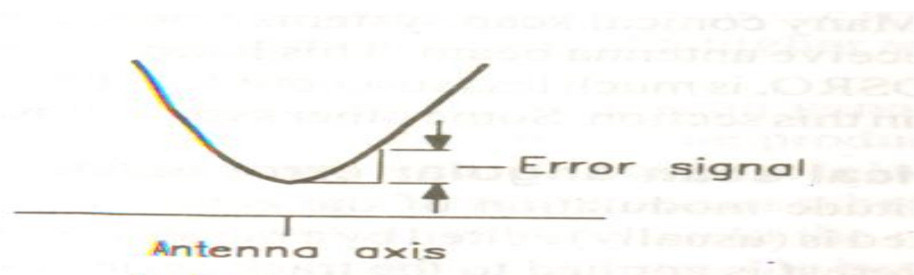
TRACKING ACCURACY (CONTD ..)

- **Depth of Null:** At zero track angular error the error voltage should be zero. At this point abrupt change of error polarity takes place from plus to minus.

  Deep Null has more gradient as such accuracy improves.



DEEP NULL



SHALLOW NULL

SEQUENTIAL LOBING

TRACKING METHODS

In search radars, the angular accuracy of a target depends on the Beam width . Smaller the beam width, higher the accuracy

However Beam width cannot be decreased beyond a value. Size of antenna increases with reduction in beam width and side lobe levels also increases

Methods are available to obtain angular accuracy far better than the Beam width.

These are called Tracking Methods

TRACKING METHODS (CONTD ..)

- The three types of methods used for improving the accuracy of angle tracking are:

i. Sequential lobing.
ii. Conical scanning.
iii. Monopulse Tracking a) Amplitude comparison
b) Phase comparison

- Tracking is associated with a servo, which steers the antenna in the direction of the target until error becomes zero.
- So the angular error has both magnitude and direction and it is the electrical equivalent to the physical difference between target direction and a reference direction.

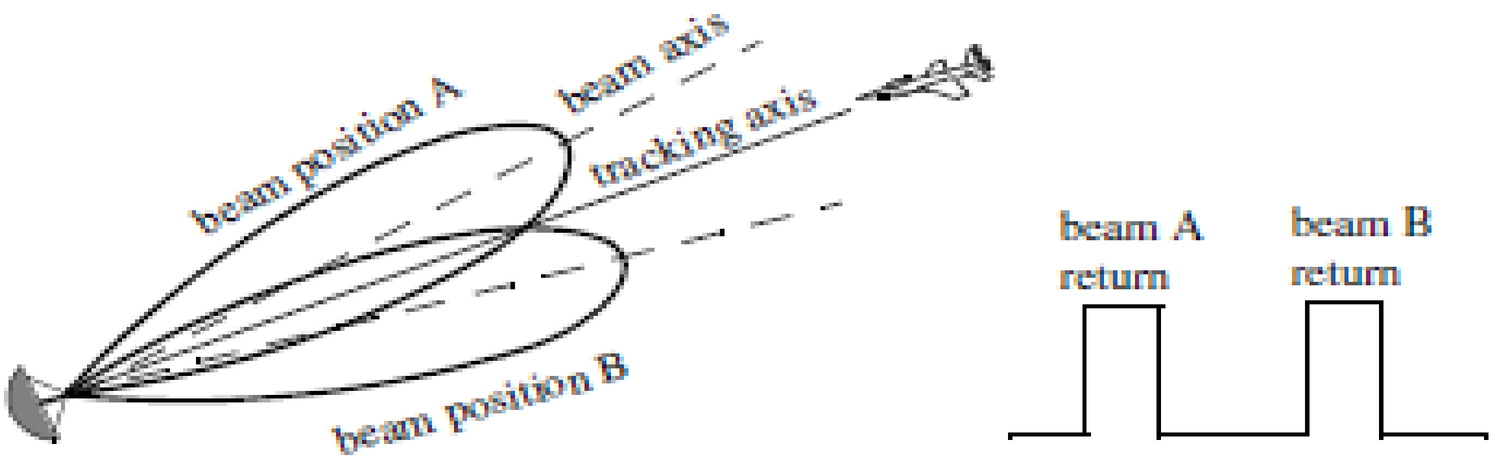
(Jntuh) **Explain about sequential lobe tracking**

SEQUENTIAL LOBING

The antenna beam is switched between 2 positions

Symmetrical pencil beam is used

Tilting the beam is obtained by offsetting the feed or the sub reflector



(a)

SEQUENTIAL LOBING (CONTD ..)

Sequential lobing is also called **Lobe Switching** or **Sequential Switching**.

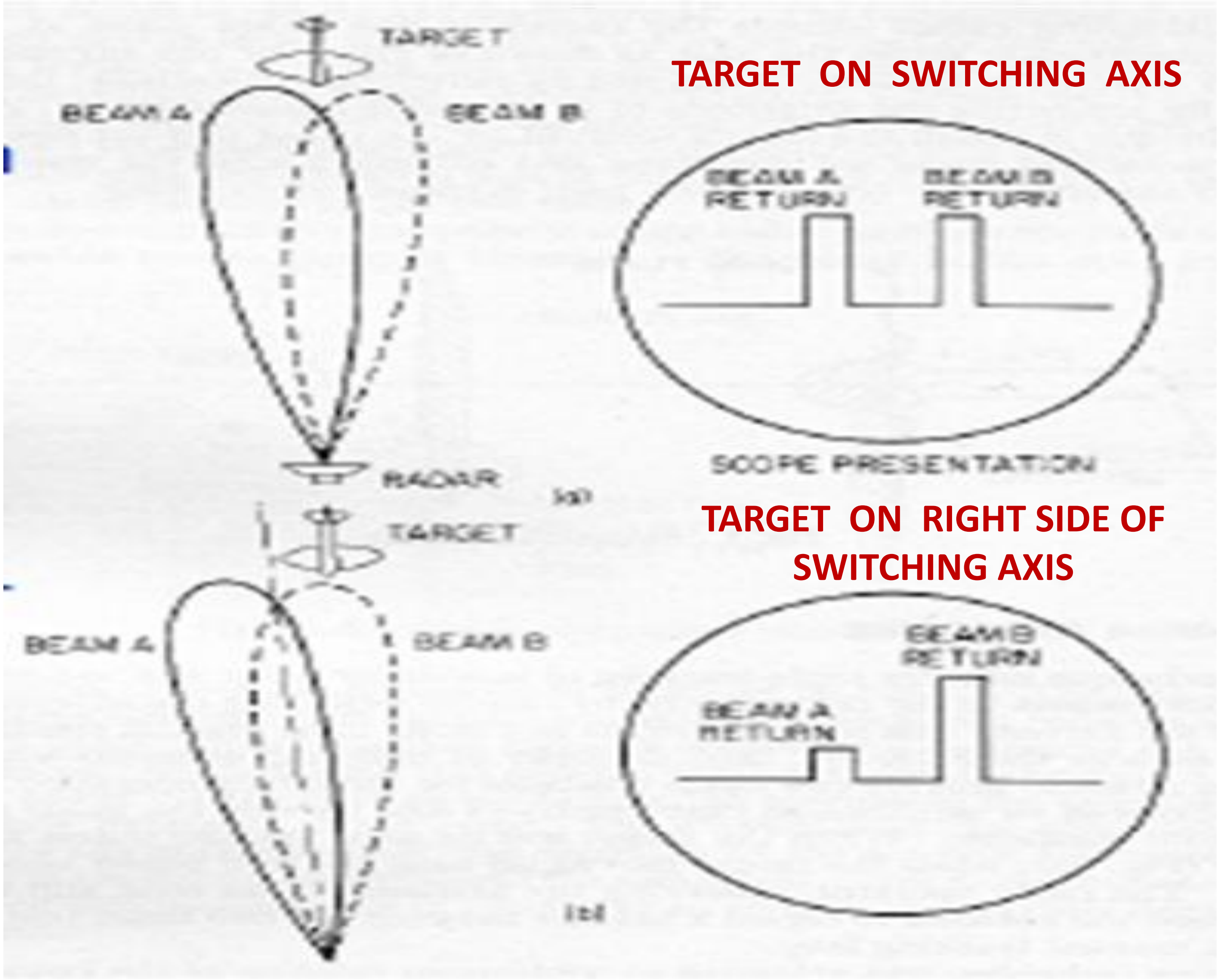
The radar beam is switched between 2 positions in order to gain improved angular information.

If the target is in the centre of the 2 beams (i.e. on switching axis), signals of equal strengths will be observed in each beam.

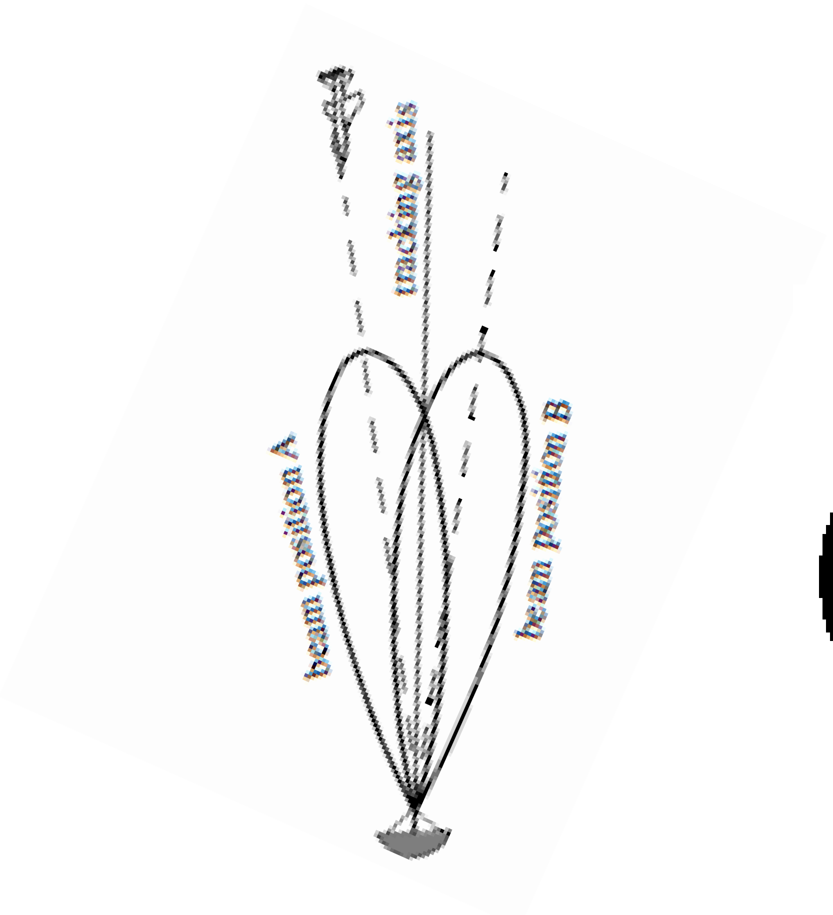
If the target is on left or right of LOS, the signal strengths are different.

The sign of the difference determines the direction in which the antenna is required to be moved and the magnitude gives the amount of error to the servo

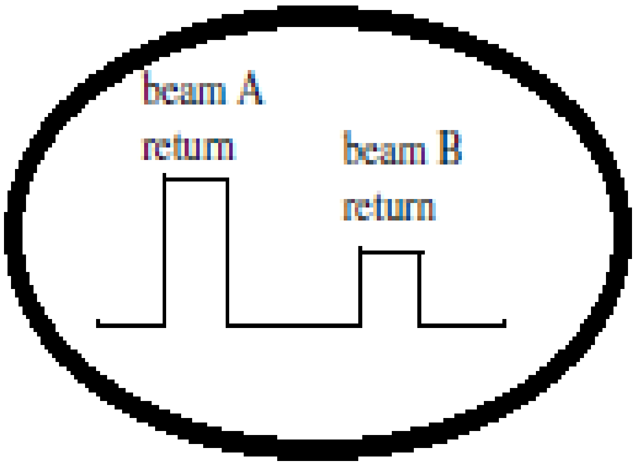
SEQUENTIAL LOBING (CONTD ..)



SEQUENTIAL LOBING (CONTD ..)

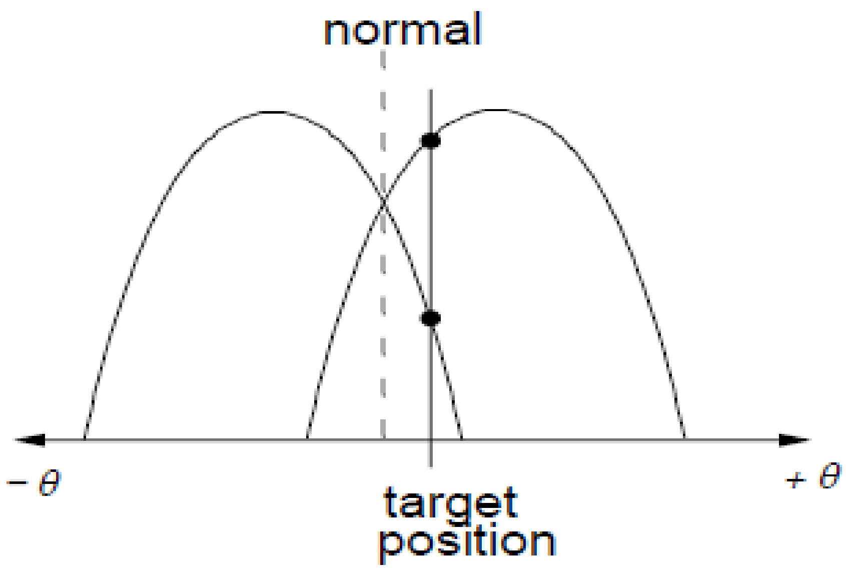


TARGET ON LEFT SIDE OF SWITHING AXIS



SEQUENTIAL LOBING (CONTD ..)

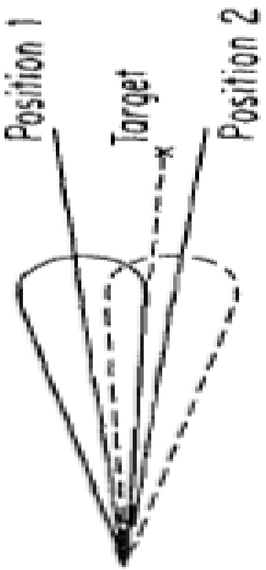
Represented in Rectangular Coordinates



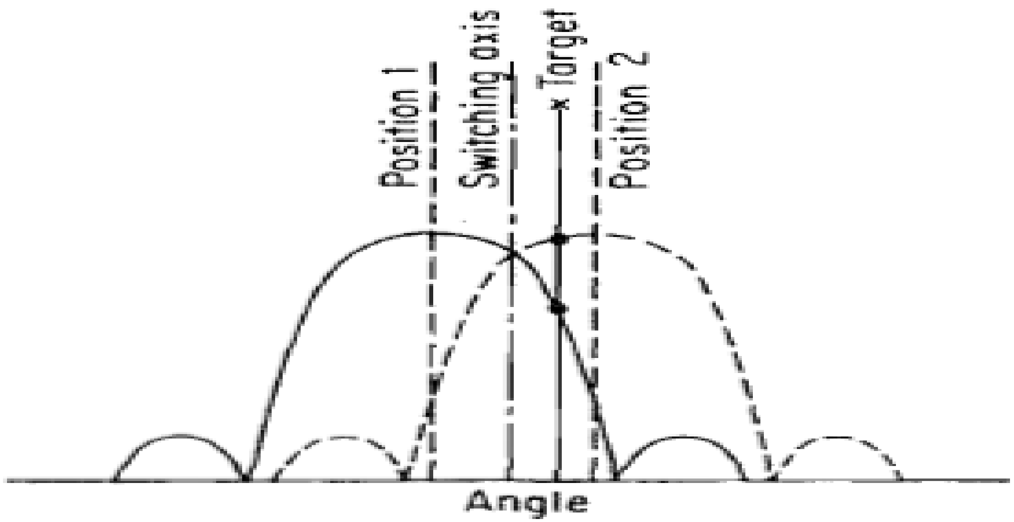
The angular accuracy can be much higher than the antenna beamwidth.

SEQUENTIAL LOBING (CONTD ..)

RECTANGULAR

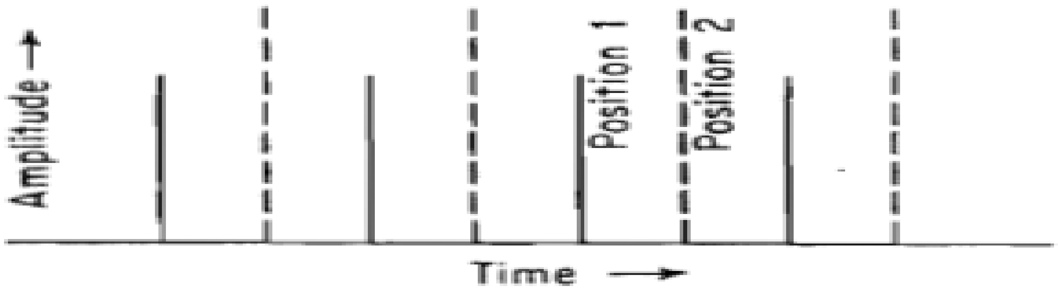


(a)



(b)

POLAR REPRESENTATION



ERROR SIGNAL

SEQUENTIAL LOBING (CONTD ..)

2 switching positions are used for Azimuth (Right & Left) and 2 more switching positions used for Elevation (Up & Down).

The 2 dimensional Sequential lobing radar consist a cluster of 4 feed horns illuminating a single target. Right- left, Up-down sectors are covered by these 4 horns

A cluster of 5 feeds also can be used . The central feed is used for transmission and the rest 4 for receiving

The angular accuracy obtained by this method will be far better than the beam width of a single beam

ADVANTAGES OF SEQUENTIAL LOBING (CONTD ..)

Advantages:

i) Uses only one Rx in switching mode

ii) Simple, less complex, less expensive, less weight. So ideally suitable for air borne applications

iii) Beacon tracking can be implemented without Tx & without range gating

LIMITATIONS OF SEQUENTIAL LOBING (CONTD ..)

Limitations: i) System noise caused by electrical and mechanical fluctuations limit the Accuracy of tracking

ii) 4 pulses are required to resolve target in 2 dimensions. Time taken more. So Bandwidth is reduced.

iii) Fluctuations in signal level from pulse to pulse reduce tracking accuracy. Fluctuations occur because of (a) Target RCS fluctuations

b) Modulation due to propeller wings etc.

iv) Antenna gain is reduced on tracking axis due to squint. This limits the operational range .

v) Servo tracking error limits the accuracy of tracking.

CONTINUED IN RADAR 4B

(Jntuh)

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(ECE 812 PE -5)
(ELECTIVE V)
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(Former Director DLRL Ministry of Defence)

BIET

Acknowledgements

The contents , figures , graphs etc., are taken from the following Text books & others

" INTRODUCTION TO RADAR SYSTEMS "

Merill I.Skolnik

Second Edition

Tata McGraw – Hill publishing company

Special Indian edition

"RADAR"

Byron Edde

LPE Pearson Education

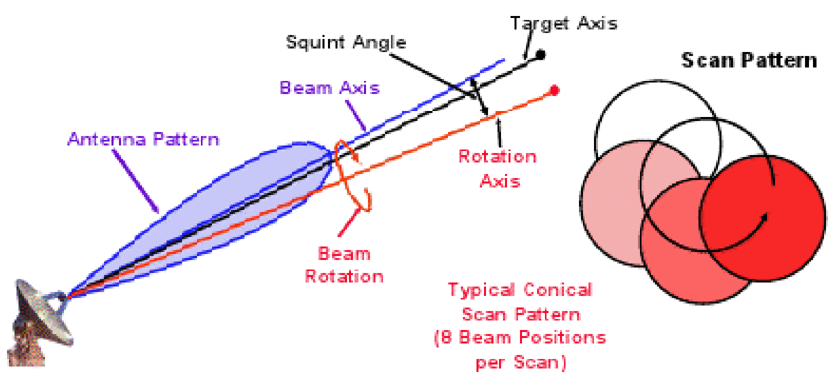
CONICAL SCAN

(Jntuh) **With a block diagram sketch explain Conical scanning method of tracking an acquired target. How is this an improvement over lobe switching?**

CONICAL SCAN

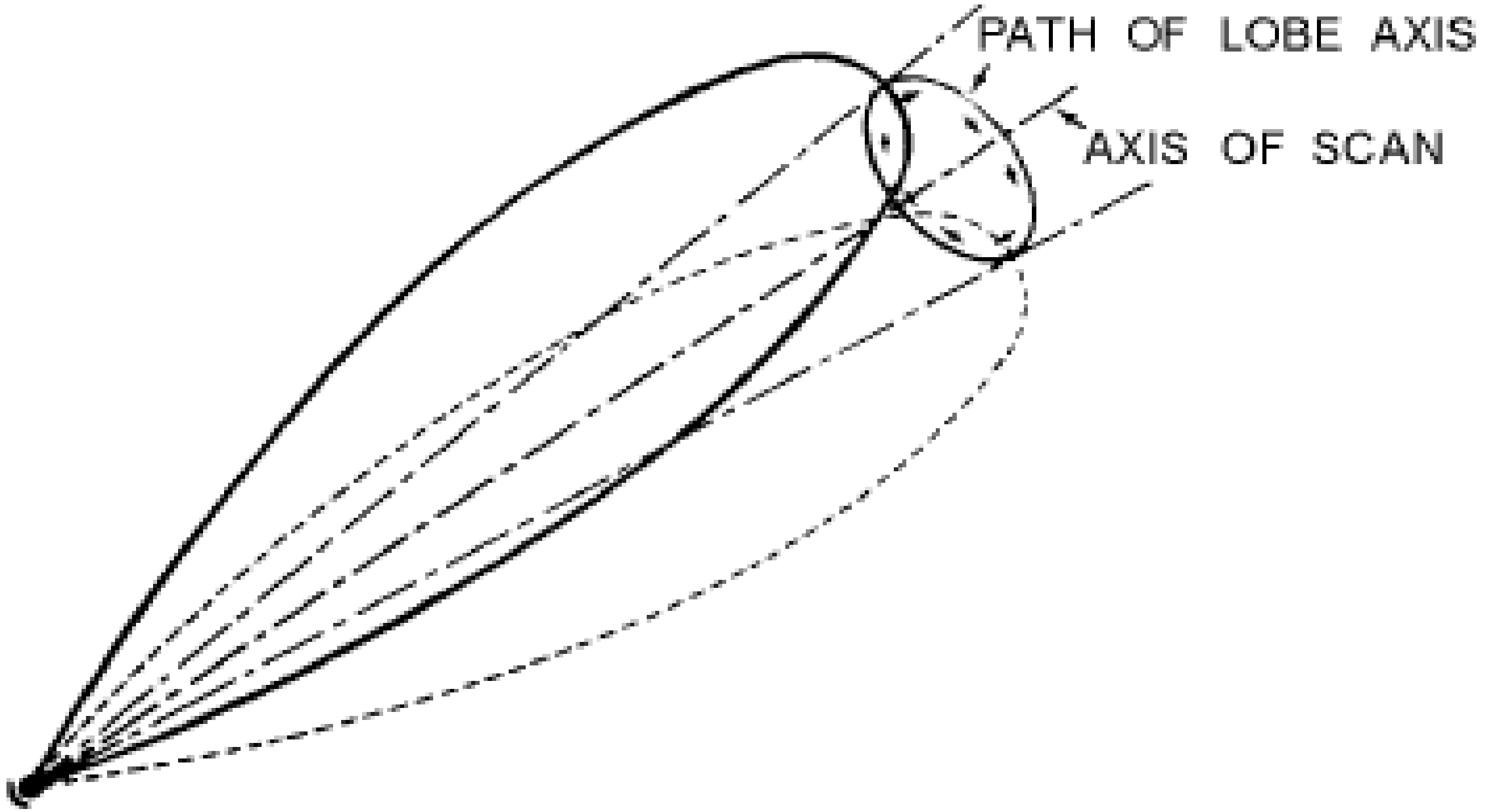
➢ Principle

- Logical extension to switched lobing is the simultaneous lobing.
- The beam is rotated continuously instead of discontinuously connecting the R_x to 4 feeds, put in 4 discrete positions (right-left , up-down)
- This method is known as Conical Scan.



- **The angle between the axis of rotation and the axis of the antenna beam is the squint angle**
- **Because of the rotation of the squinted beam and the targets offset from the rotation axis, the amplitude of the echo signal will be modulated at a frequency equal to the beam rotation**

CONICAL SCAN (CONTD ..)



CONICAL SCAN (CONTD ..)

- There are 3 Axes (i) Beam Axis (ii) Rotating Axis (iii) Target Axis

i. **Beam Axis:** Line joining the centre of antenna to the highest gain point on the beam (Lobe axis)

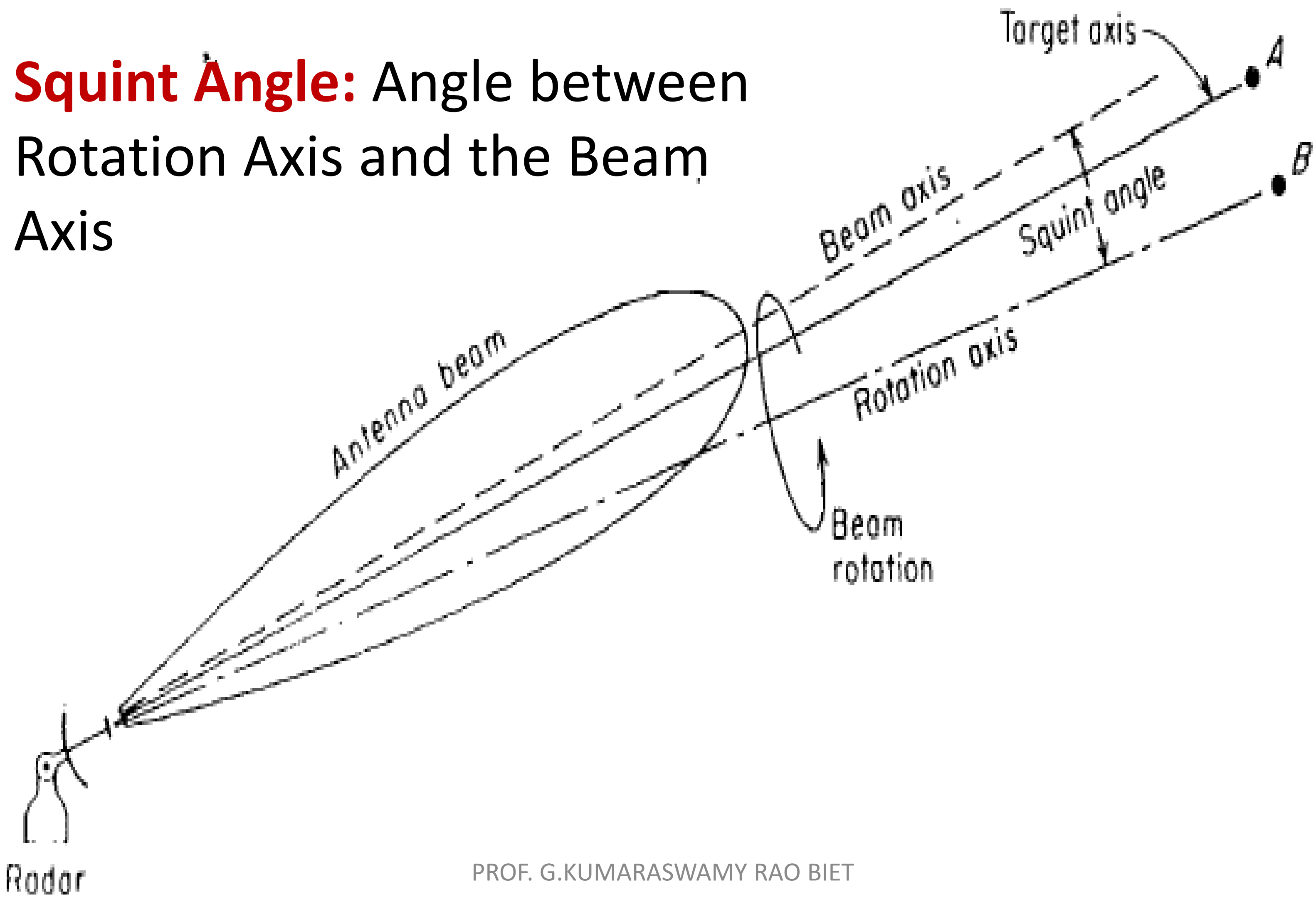
ii. **Rotation Axis:** Antenna rotated circularly along this axis. (Tracking axis) Beam Axis is offset from the Rotation axis by a squint angle. The angle between Beam axis and the Rotation axis is called Squint angle

iii. **Target Axis:** Line joining the centre of the antenna to the position of target (Direction of target)

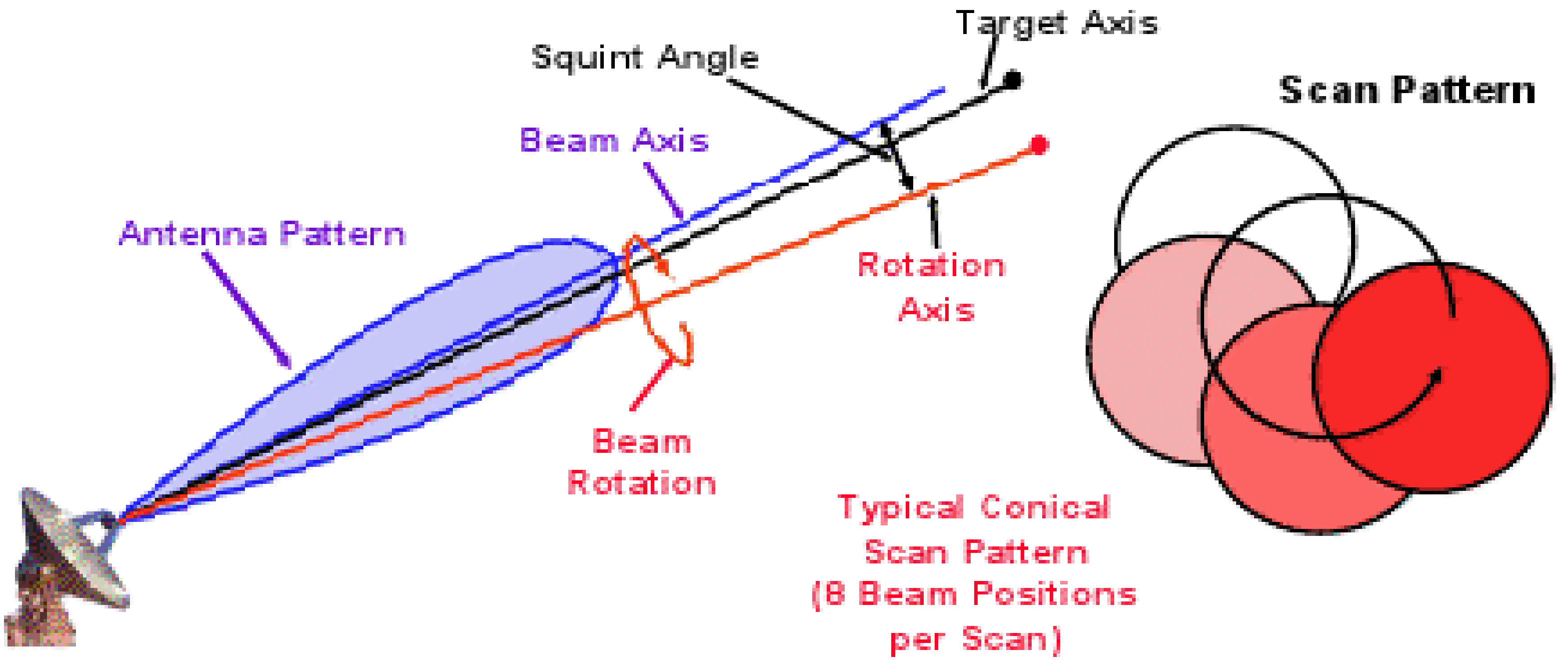
CONICAL SCAN (CONTD ..)

Orientation of the Axes

Squint Angle: Angle between Rotation Axis and the Beam Axis



CONICAL SCAN (CONTD ..)



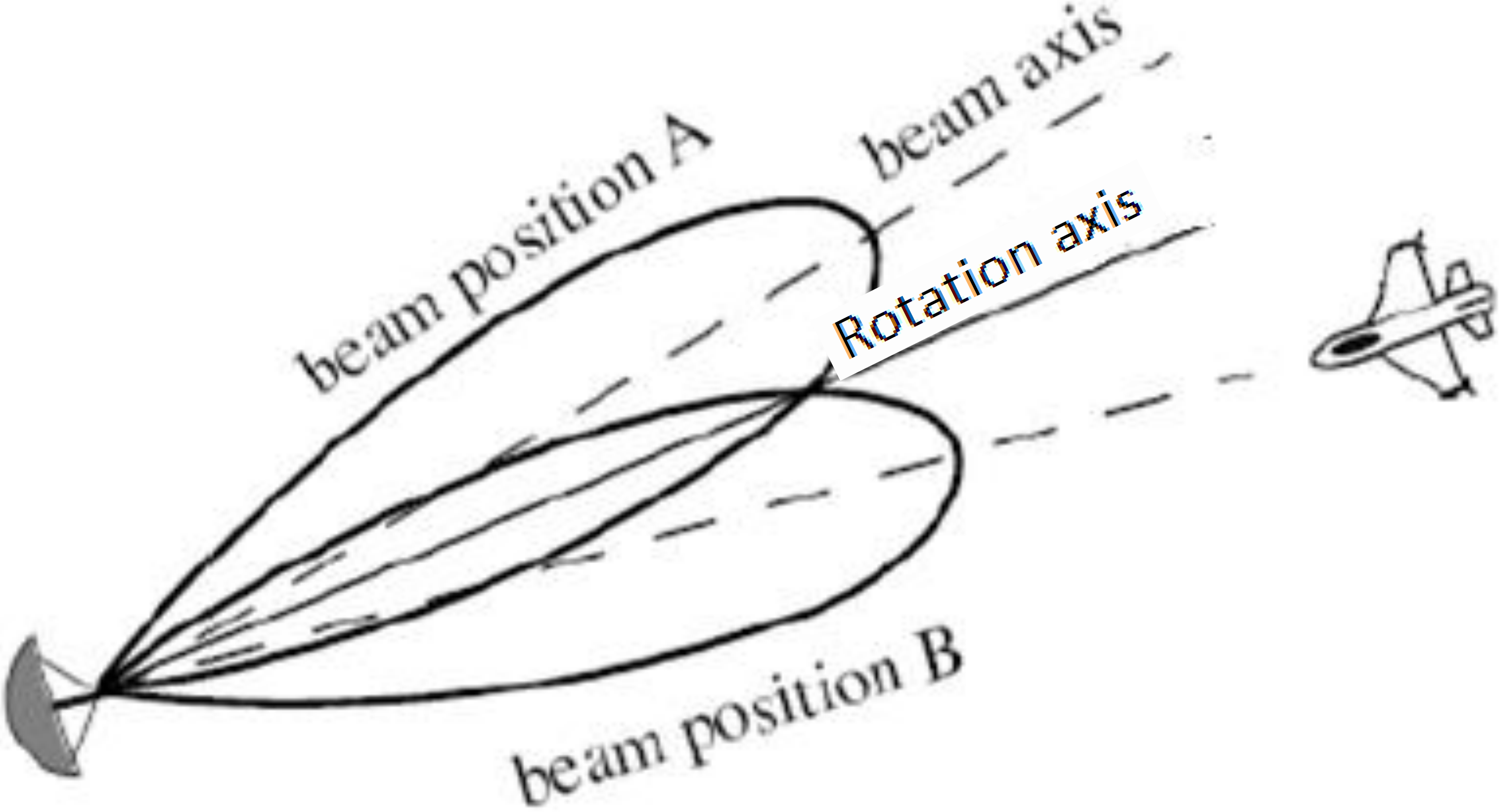
- **The angle between the axis of rotation and the axis of the antenna beam is the squint angle**
- **Because of the rotation of the squinted beam and the targets offset from the rotation axis, the amplitude of the echo signal will be modulated at a frequency equal to the beam rotation**

CONICAL SCAN MOTOR & ANTENNA

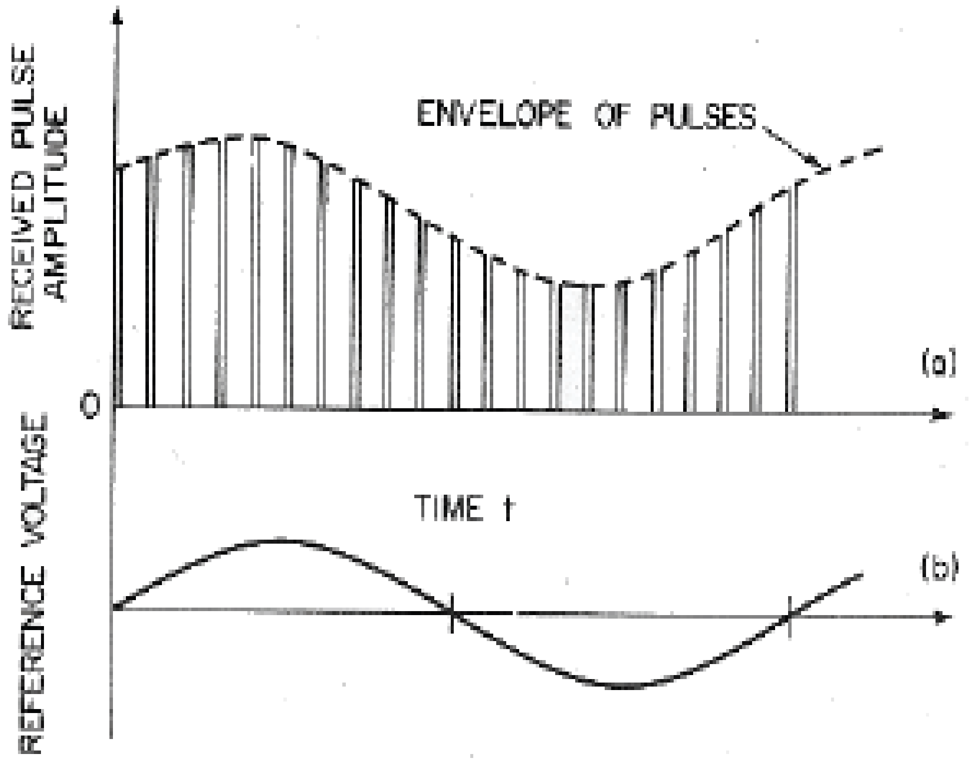
CONICAL SCAN (CONTD ..)

- Purpose of conical scan technique is to bring Rotation axis on to the Target Axis, i.e. make Rotation Axis coincides with Target Axis.
- Consider a target at position A on Target Axis.
- Echo signal from target at ‘A’ is modulated by the rotation of the beam through Rotation Axis.
- The modulated frequency of echo signal is same as the rotation frequency of the beam.

ERROR EXTRACTION



ERROR EXTRACTION



CONICAL SCAN (CONTD ..)

➢ Conical Scan Modulation (Contd ..)

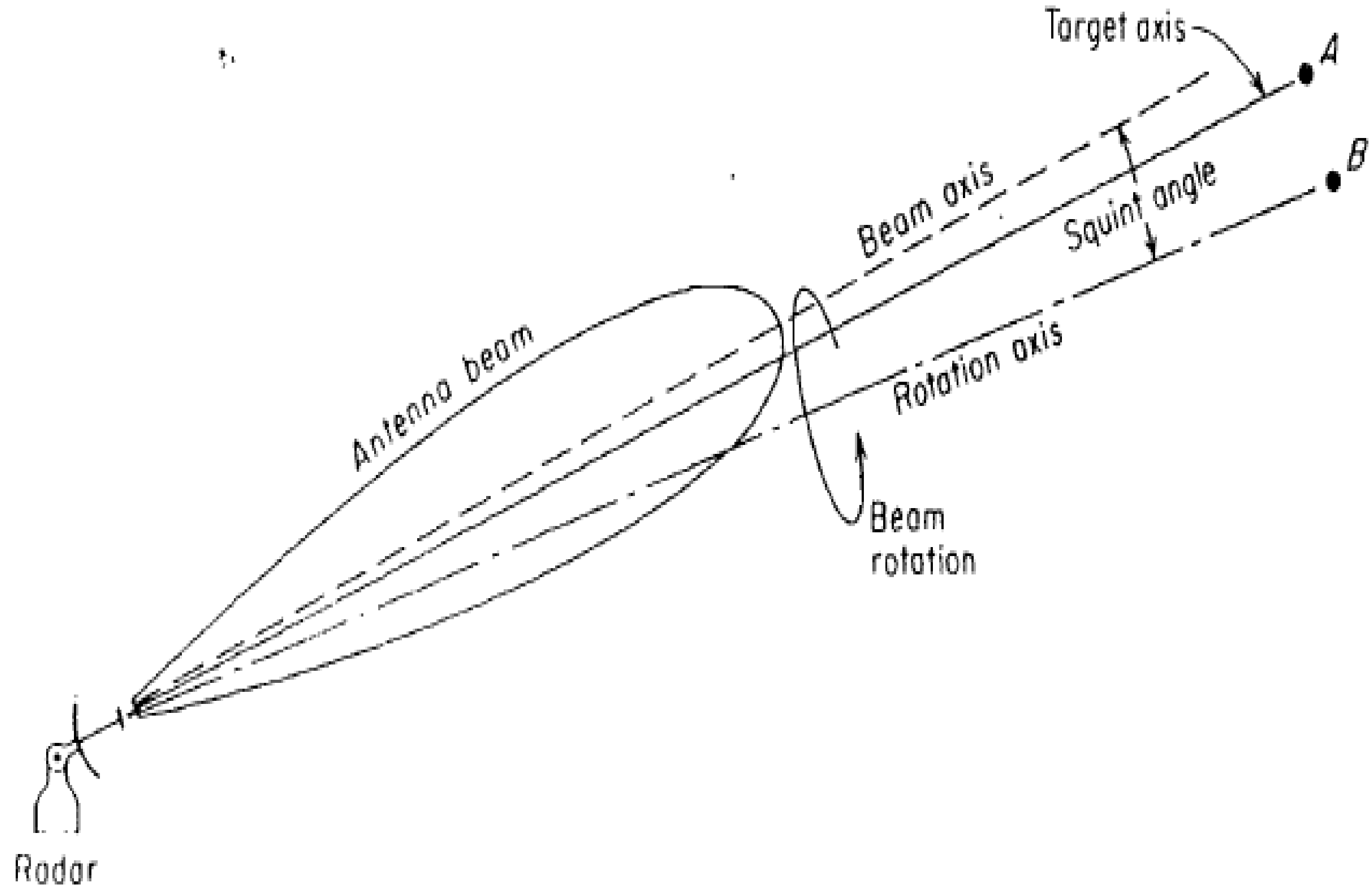
- The amplitude of the echo-signal modulation will depend on (i) Shape of antenna pattern (ii) squint angle (iii) Angle between Rotation axis and Target Axis.
- The phase depends on the position (right- left and up-down) of target axis with respect to the rotation axis
- The echo-signal modulation is called the Conical scan modulation.

CONICAL SCAN (CONTD ..)

➢ CONICAL SCAN MODULATION (CONTD ..)

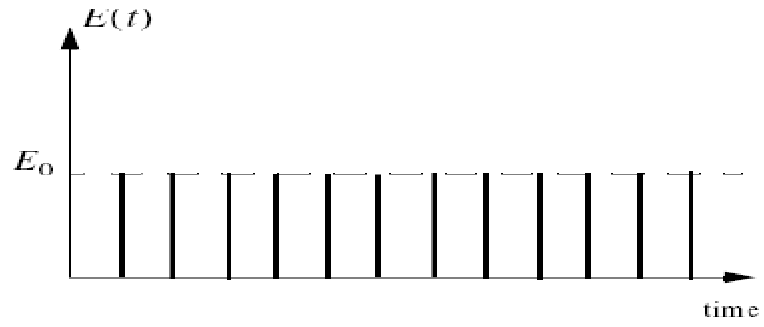
- The error in azimuth and elevation planes are extracted from the echo-signal modulation.
- The errors are applied to 2 separate servo controlled pedestals containing the antenna.
- The servo rotate the antenna configuration and bring position ‘B’ to ‘A’.
- The rotation Axis is made to coincide with target Axis.

CONICAL SCAN (CONTD ..)

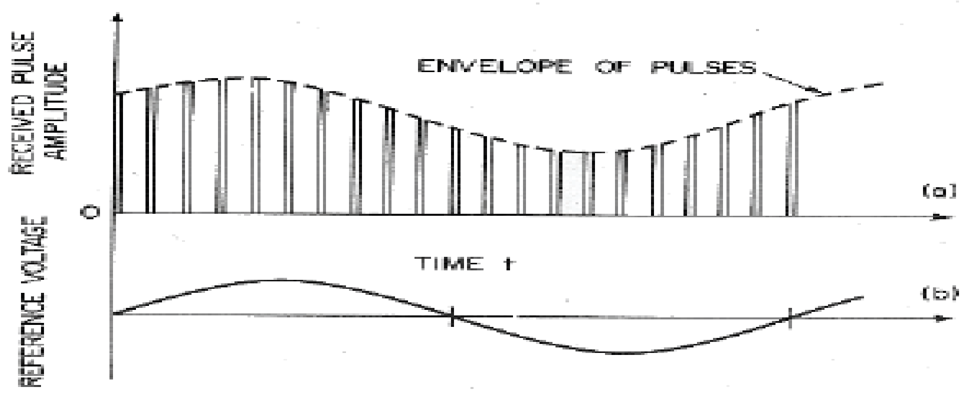


ERROR EXTRACTION (CONTD ..)

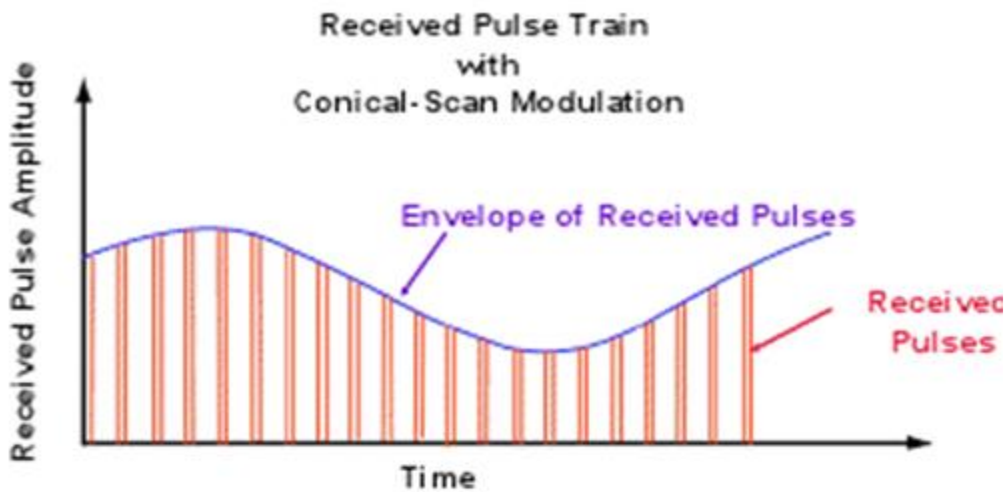
- **Target on Rotation Axis:** Zero modulation (zero error)



- **Target Away from Rotation Axis**

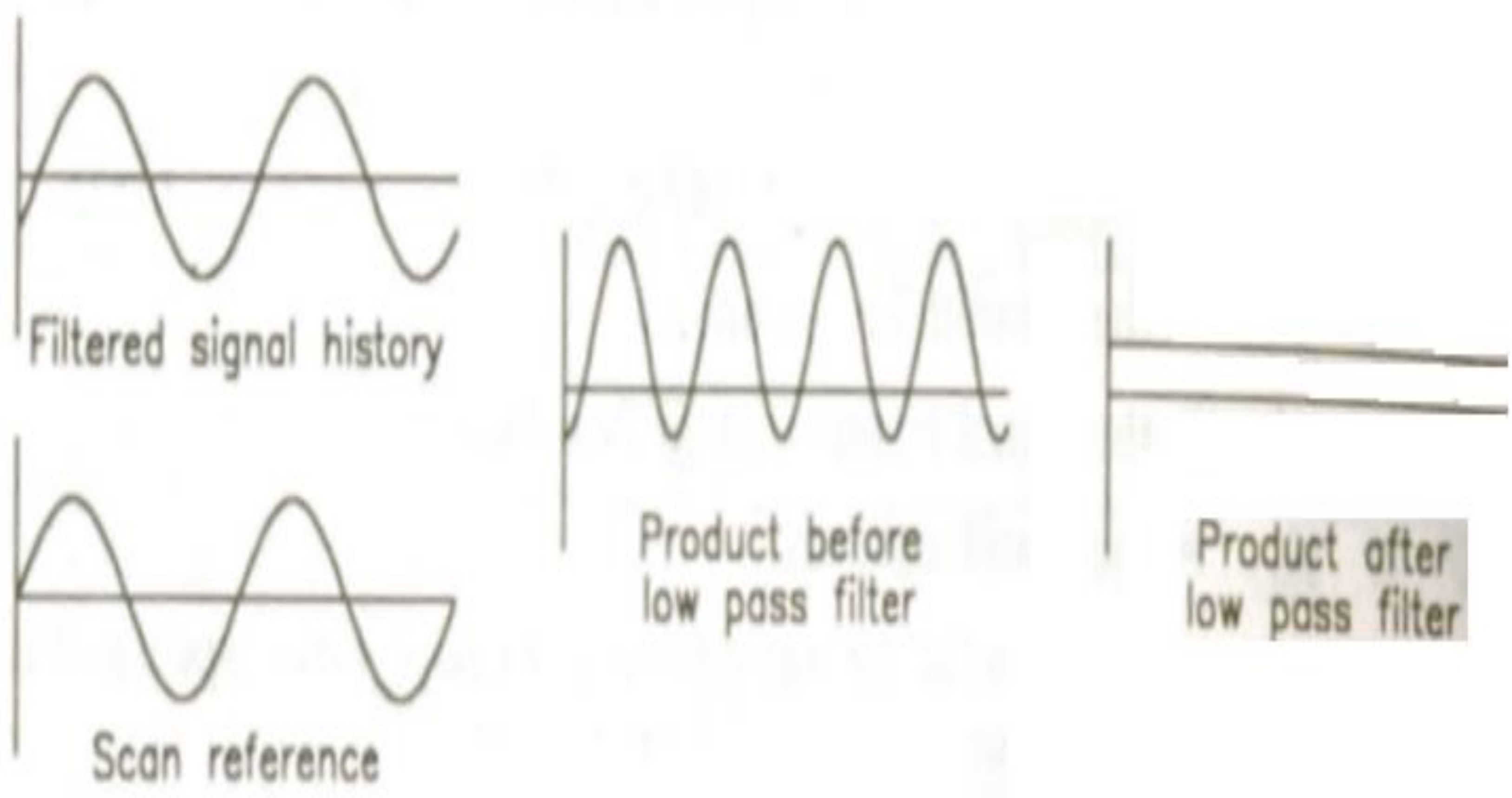


ERROR EXTRACTION (CONTD ..)



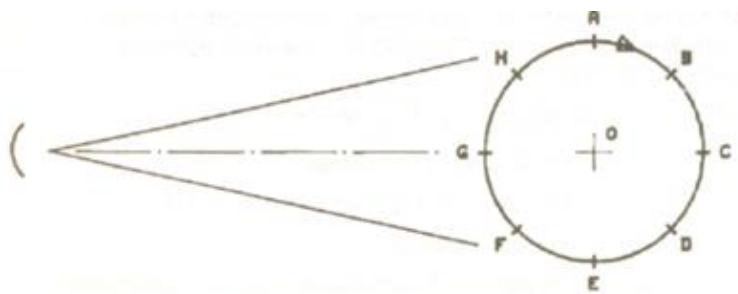
- The **amplitude of the modulation** is proportional to the angular distance between the target direction and the rotation axis
  - Beam displacement
- The **phase of the modulation** relative to the beam scanning position contains the direction information
  - Angle error

ERROR EXTRACTION (CONTD ..)



ERROR EXTRACTION (CONTD ..)

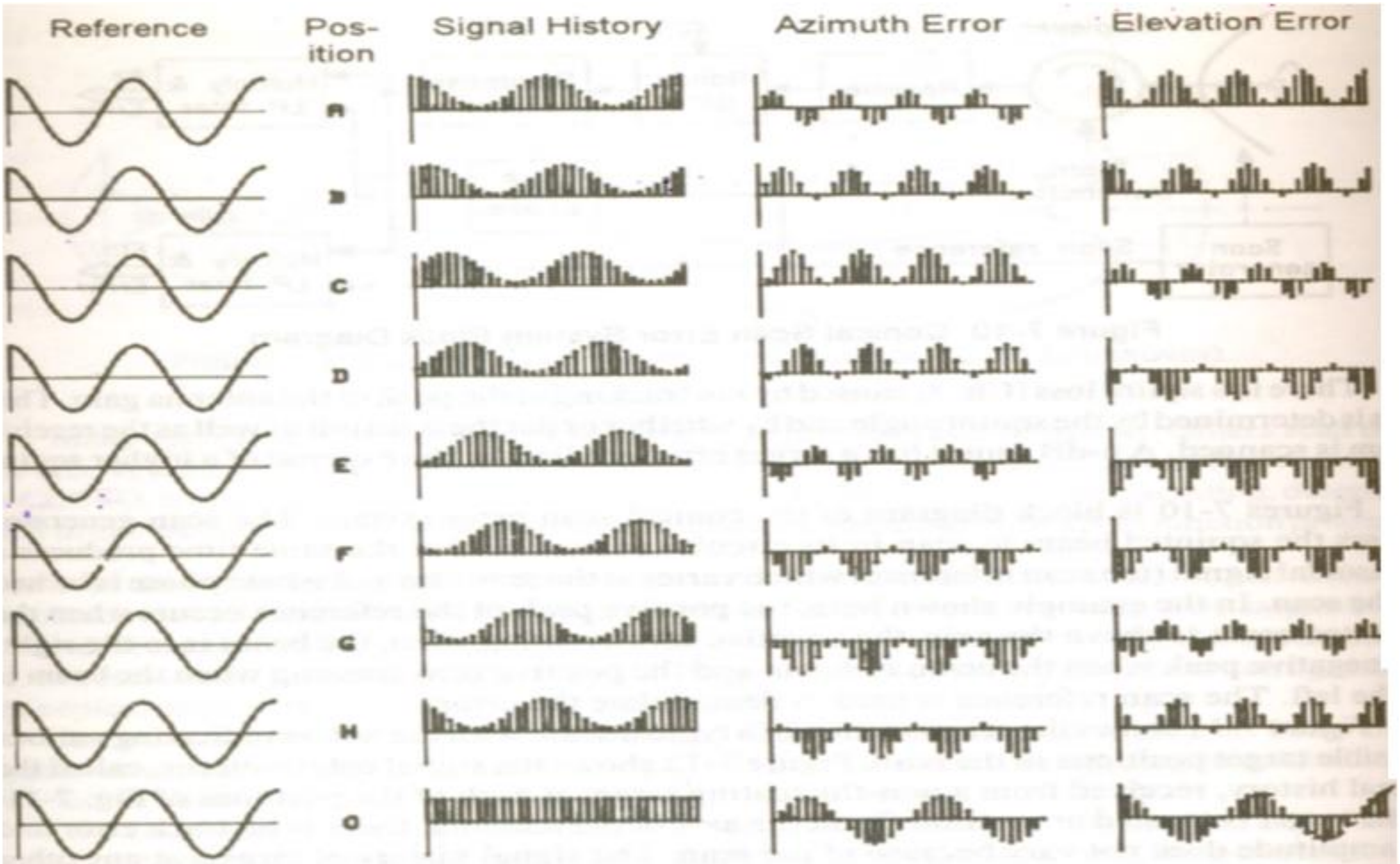
- When target and rotation axis do not coincide, the echo pulses will be modulated.
- This magnitude (depth) of modulation depends on the angle error between target axis and rotation axis.
- The modulation envelope will have the azimuth error and elevation error. This is extracted by using the reference given by the scanning motor.



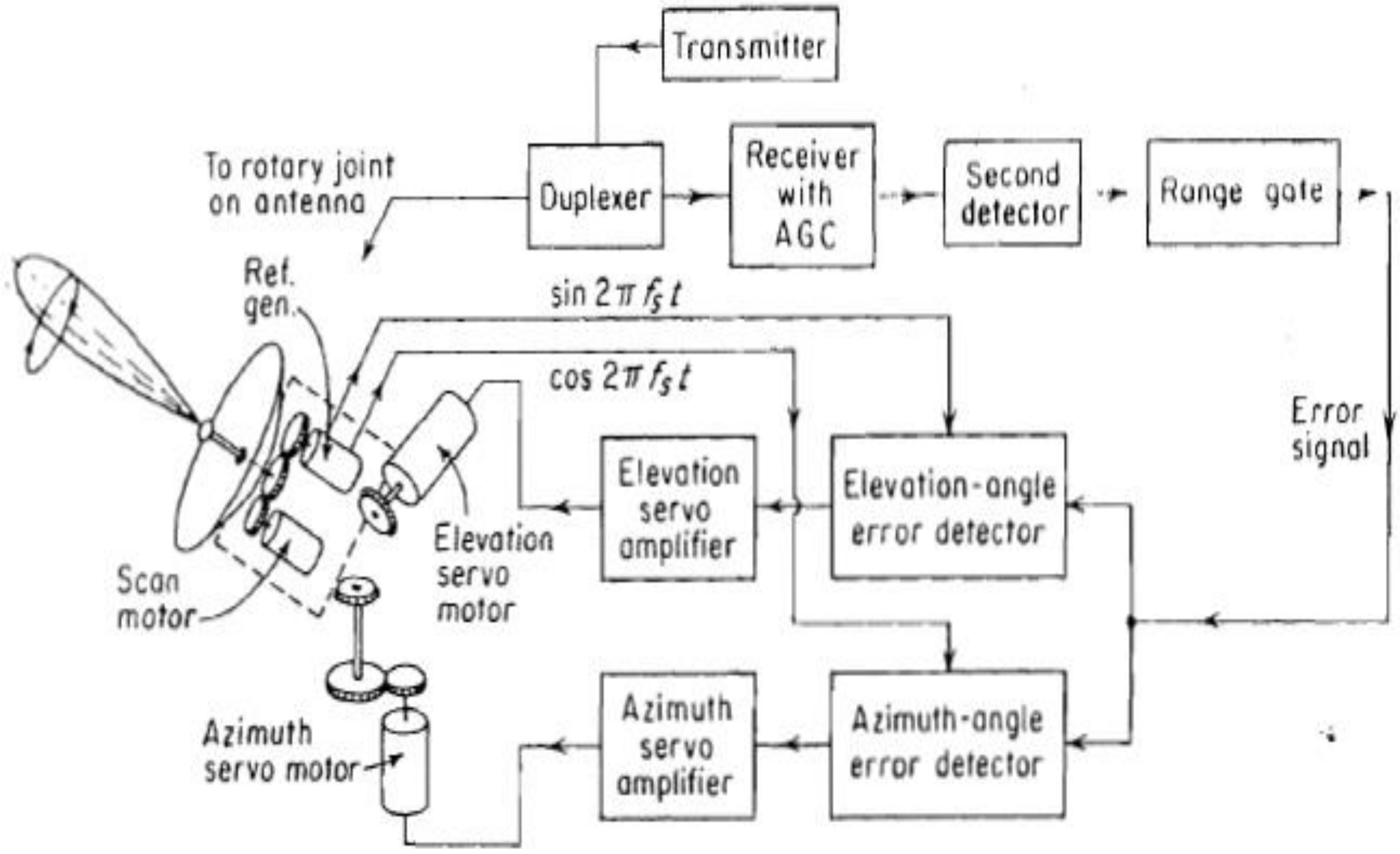
Scan Cross-Section and Target Positions.

ERROR EXTRACTION (CONTD ..)

Error Extraction Waveforms



BLOCK DIAGRAM OF CONICAL SCAN TRACKING RADAR

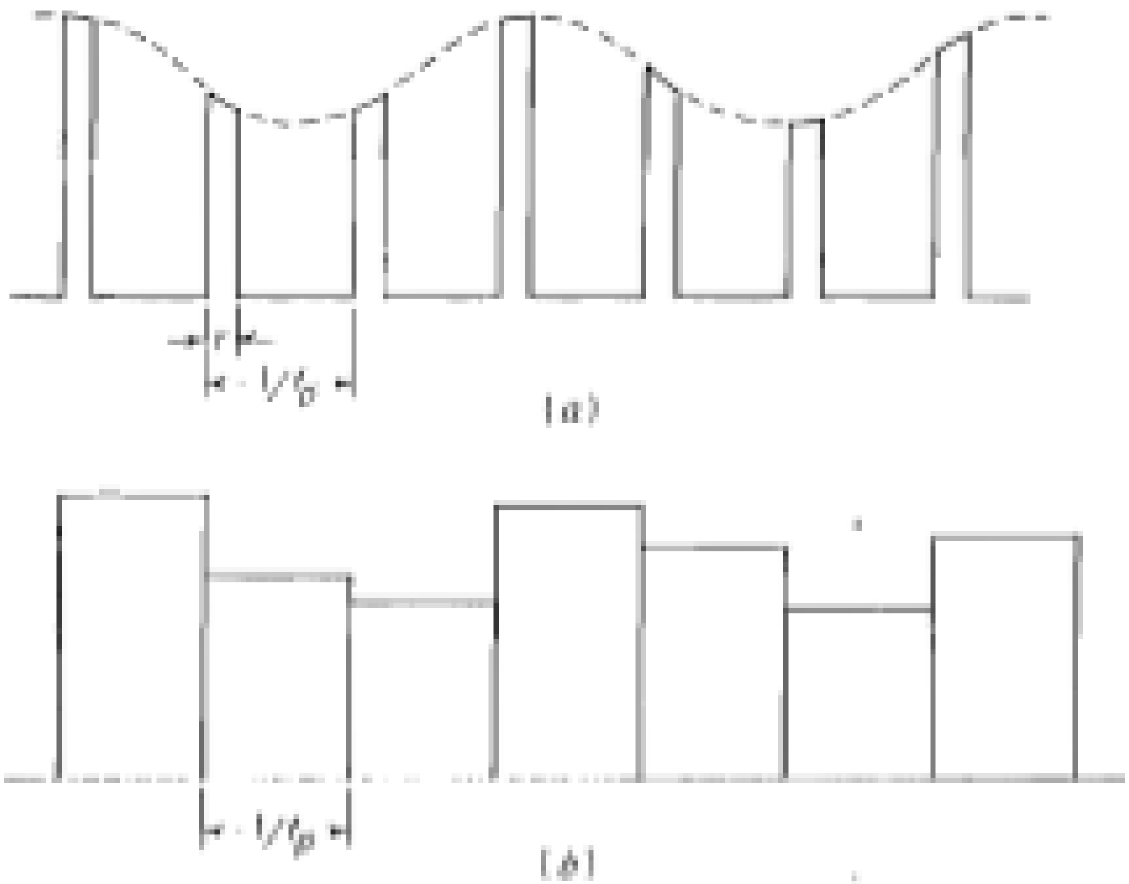


BLOCK DIAGRAM OF CONICAL SCAN (CONTD ..)

- Rx is a conventional super-heterodyne type.
- Rx is followed by an Angle error Detectors (one for Azimuth and another for Elevation)
- The envelope of the scan modulation is the video signal obtained from the output of second detector.
- Range Gate selects the particular target chosen for tracking. This reduces noise
- Scan modulation has both Azimuth & Elevation Errors in its video envelope.
- Scanned modulation signal is compared with azimuth & elevation reference signals in a Phase sensitive Detector (PSD).

BLOCK DIAGRAM OF CONICAL SCAN (CONTD ..)

- PSD extracts the azimuth and elevation error signals.
- The magnitude of the DC error signal is proportional to the angular difference between target axis and rotation axis. The polarity (positive or Negative) gives the indication whether the target axis is to the right or left of the rotation axis in case of azimuth and up or down in case of elevation.
- The angle errors are amplified and applied to the servo systems(one in Azimuth and one in Elevation).
- The accurate position of the target is obtained by measuring the values of angle transducers mounted on the pedestal (like synchros, potentiometers, angle encoders etc)

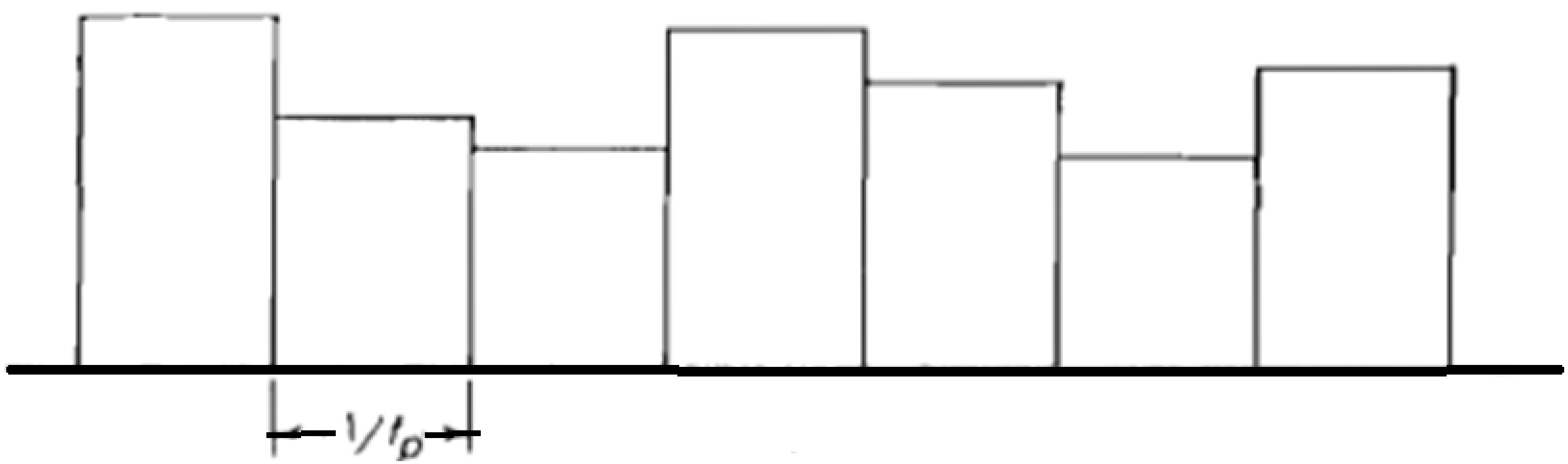


τ
1/fp
(a)
1/fp
(b)

BLOCK DIAGRAM OF CONICAL SCAN (CONTD ..)

➢ Box-Car Generator:

- Before extracting modulation of the train of narrow echo pulses, it is stretched (sample & Hold) before low pass filtering.



BLOCK DIAGRAM OF CONICAL SCAN (CONTD ..)

Box car circuit:

- Box-Car eliminates the Pulse repetition frequency and reduces its harmonics.
- Pulse stretching done by the Box car. It puts more energy between pulses and this amounts to amplification and result in increase of S/N ratio
- To satisfy the Nyquist criterion the PRF should be sufficiently more than the conical scan frequency (>2 scanning frequency)

BLOCK DIAGRAM OF CONICAL SCAN (CONTD ..)

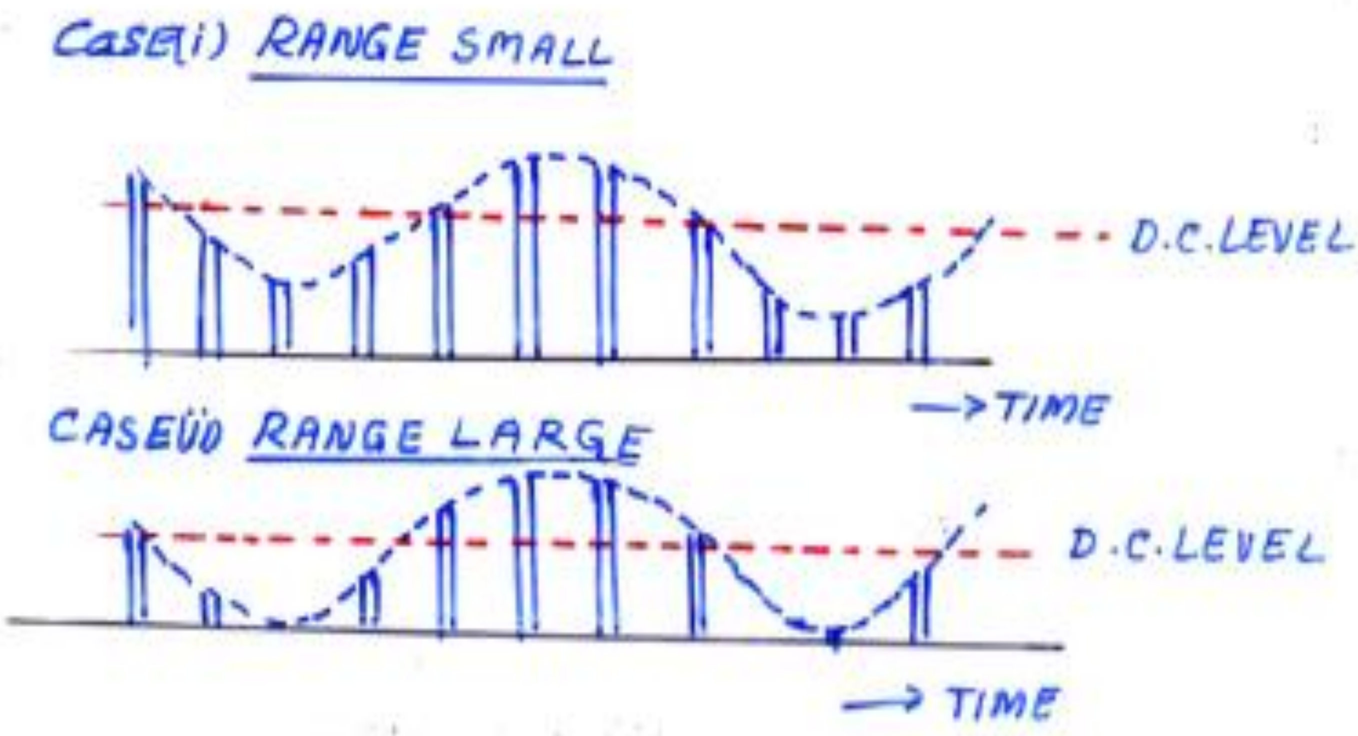
➢ Automatic Gain Control (AGC):

- The amplitude of Echo varies because of
  i. Target is moving in range (Echo signal $\propto \frac{1}{R^4}$)
  ii. Conical scan modulation (used for error extraction) of error signal
  iii. Amplitude fluctuations in RCS.
- Function of AGC is to increase or decrease the gain of the Rx automatically, such that the D.C level output is maintained constant without disturbing the Conical scan modulation at Sl.no.2 above

AGC

- **What happens when AGC not there**
- **(i) Target moving in range:**
  - Amplitude of echo signal vary with range.
  - $P_r = \frac{(P_t \; G \; A_e \; \sigma)}{(4\,\pi)^2} \times \frac{1}{R^4}$
  - Echo power varies in inverse proportion to R^4
  - Though the physical angular error is same, the DC level (servo error) is different. AGC acts to overcome this variation

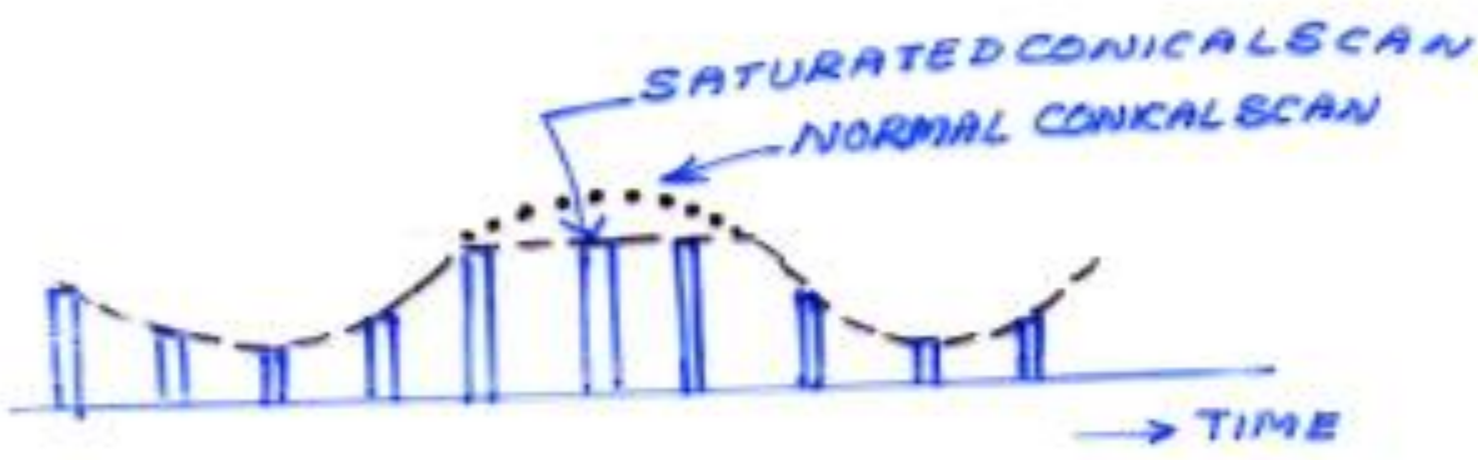
TARGET MOVING IN RANGE (CONTD..)



- Though the physical angular error is same, the DC level (servo error) is different. AGC acts to overcome this variation

AGC (CONTD ..)

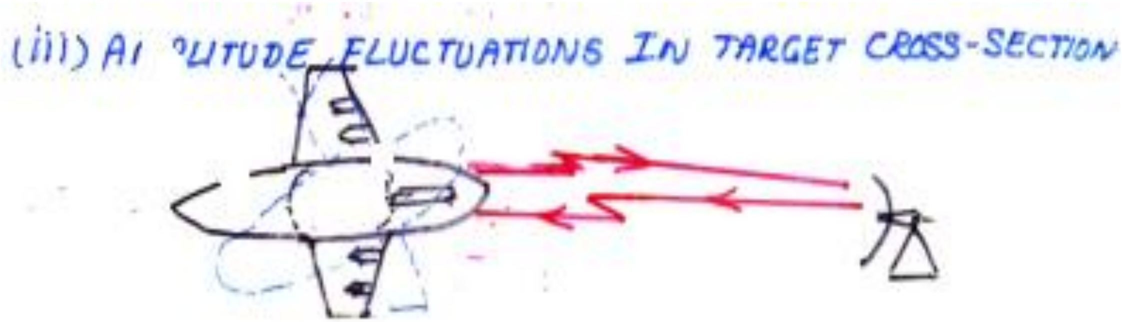
➢ (ii) Conical Scan Modulation:



- If output video saturates, modulation envelop is lost. Error extraction becomes faulty.

AGC (CONTD ..)

- **Amplitude fluctuations due to RCS**



- **Functions of AGC:**

i. Remove variations in DC voltage due to Conical modulation

ii. Remove variations in DC voltage because of inverse fourth power relationship.

iii. Prevent saturation because of large echo power

If saturation is not prevented Conical modulation is lost, thereby error extraction not possible.

☞ (Jntuh) **Explain the block diagram of AGC portion of tracking radar receiver**

AGC FILTER

- **Functions of AGC Filter:**

i. Pass all frequencies from DC to just below Conical scan modulation frequency.

ii. Blocks Conical modulation.

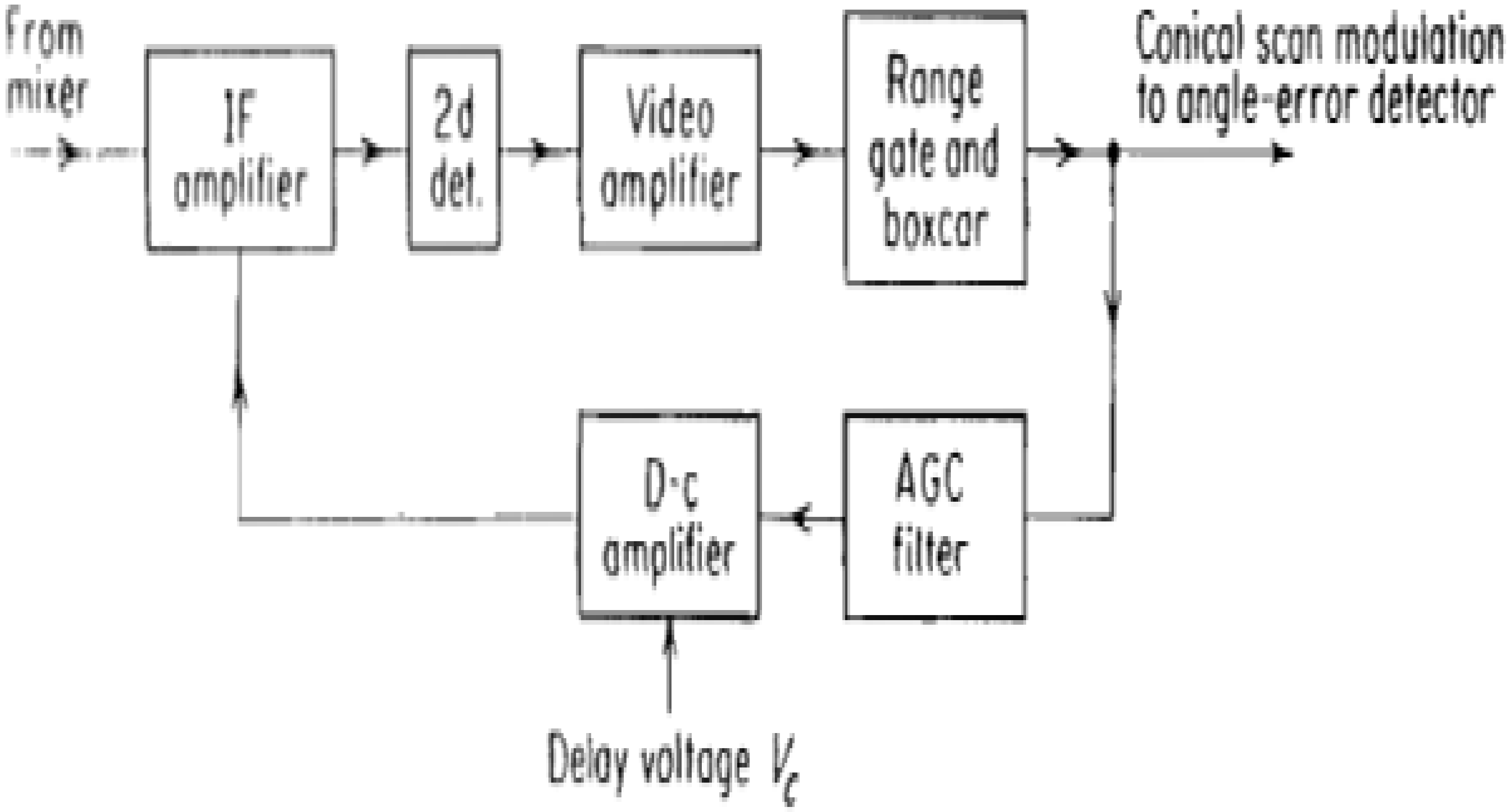
iii. Should not introduce excessive phase shift (10^0 maximum). Beyond this cross talk occurs.

- **CROSS TALK**: Azimuth & elevation planes are independent. But due to cross-talk variation in one plane affect the other.

iv. For weak signals loop gain is high and for strong signals, loop gain is less

BLOCK DIAGRAM OF CONICAL SCAN (CONTD ..)

- **AGC (Contd ..)**

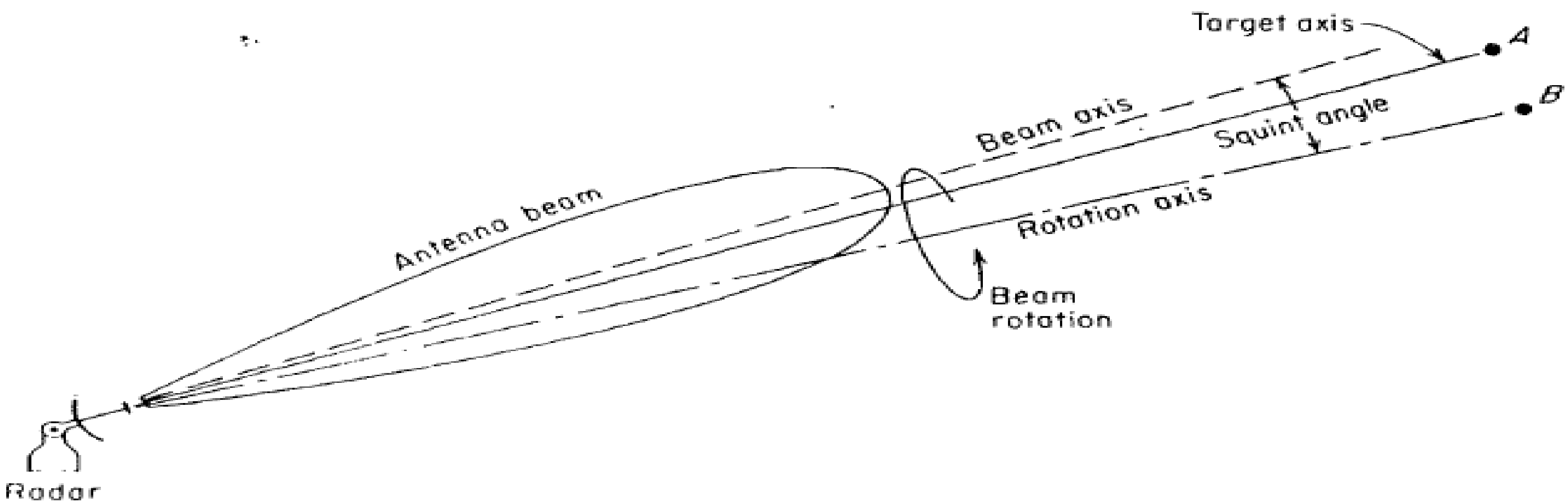


AGC (CONTD ..)

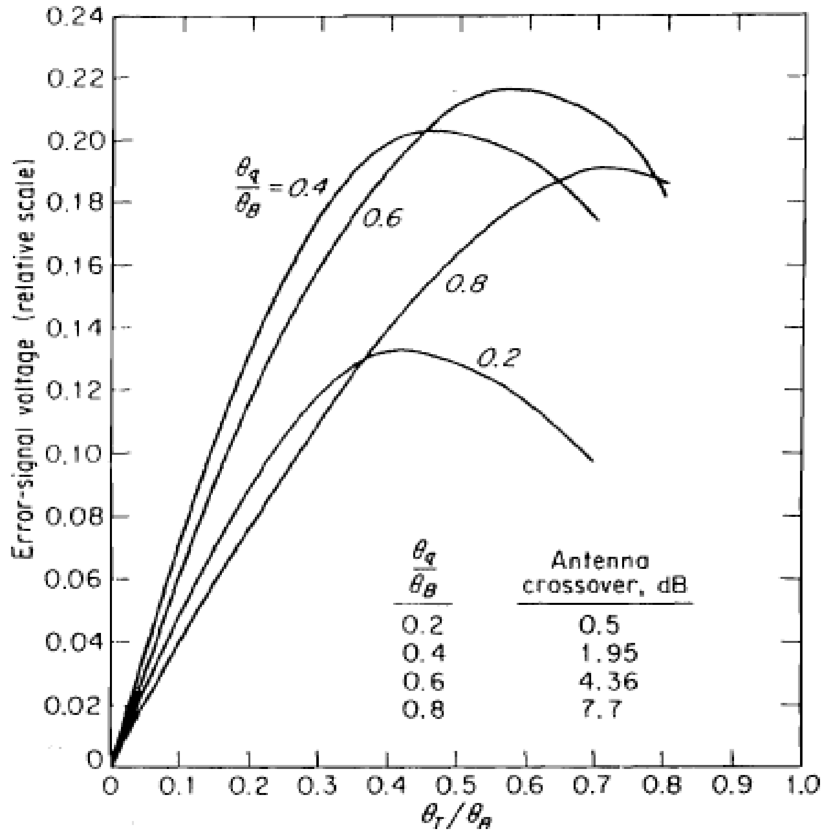
- The video envelope obtained from range gate and Boxcar is fed to a low pass(smoothening) filter.
- The DC output of filter is amplified in a D.C Amplifier.
- The Amplifier output is used to control the gain of IF Amplifier.
- If the video o/p voltage is high, the IF Amplifier gain is reduced, if it is less gain is increased. This keeps the amplitude of error signal constant.
- The filter should not disturb the conical scan modulation frequency which contains the error. The filter should pass all frequencies from DC to just below the scan modulation.

DETERMINATION OF SQUINT ANGLE

- Squint angle is the angle between the Beam axis and Rotation Axis = θ_q
- Angle between Target axis (direction of target) and Rotation Axis (tracking axis)= θ_T
- Half power Beam width = θ_B



DETERMINATION OF SQUINT ANGLE (CONTD ..)



Plot of the relative angle-error signal from the conical-scan radar as a function of target angle (θ_T/θ_B) and squint angle (θ_q/θ_B). θ_B = half-power beamwidth.

$\frac{\theta_q}{\theta_B}$	Antenna crossover, dB
0.2	0.5
0.4	1.95
0.6	4.36
0.8	7.7

- Plot shows the error voltage Vs Angle Error $\frac{\theta_T}{\theta_B}$ (normalized to Beam width θ_B)

DETERMINATION OF SQUINT ANGLE (CONTD ..)

- One of the requirement for high accuracy in angle is that slope of the error curve should be large.
- Maximum slope occurs at $\frac{\theta_q}{\theta_B}$ slightly higher than 0.4. This corresponds to 1.95 dB (say 2dB) loss in power.
- Loss in power at the crossover point affects the Range tracking accuracy.(because S/N reduces)
- As a compromise between requirement for an accurate angle and range , a value for $\frac{\theta_q}{\theta_B}$ is chosen corresponding to a loss of 1.0 dB (a point on the antenna pattern about 1.0 dB below the peak)

CONTINUED IN RADAR 4C

(Jntuh)

RADAR SYSTEMS
(ECE 812 PE -5)
(ELECTIVE V)
UNIT – 4C
B.TECH IV YEAR II SEMESTER
BY

Prof.G.KUMARASWAMY RAO
(Former Director DLRL Ministry of Defence)
BIET

Acknowledgements

The contents , figures , graphs etc., are taken from the following Text books & others

" INTRODUCTION TO RADAR SYSTEMS "

Merill I.Skolnik

Second Edition

Tata McGraw – Hill publishing company

Special Indian edition

"RADAR"

Byron Edde

LPE Pearson Education

MONO PULSE TRACKING RADAR

AN/FPQ-6 C-band monopulse precision tracking radar

(Jntuh) **What are the advantages of mono-pulse radar over the conical scan radar**

MONO PULSE TRACKING RADAR

➢ Advantage of Monopulse over Conical Scanning & Sequential lobing

- Conical scan and sequential lobing require a minimum number of pulses to extract angular error.
- Ideally the train of echo pulses must not contain any amplitude modulation other than the scanning modulation.
- But in reality due to fluctuation in RCS of the target, the echo pulse train contains additional modulation which may be near to the conical frequency.
- This degrades the tracking accuracy in case of conical scan and sequential lobing.

MONO PULSE (CONTD ..)

Advantage of Monopulse (Contd ..)

- The tracking accuracy will be superior if the extraction of error is done based on a single pulse instead of a number of pulses.
- Mono pulse (means single pulse) method of tracking computes error based on a single pulse. As such a mono pulse tracking radar has higher accuracy to conical scanning and sequential lobing.

MONO PULSE (CONTD ..)

- **Principle of Monopulse**
- Mono pulse uses more than one antenna beam simultaneously. It is also called simultaneous lobing.
- Where as conical scanning or sequential lobing uses only one antenna beam on a time shared basis.
- Mono pulse derives the angle error on the basis of a single pulse but uses simultaneous beams.
- There are two ways to derive angular errors

i. Using the relative amplitudes of echo pulses received in different beams due to single pulse transmitted.

ii. Using the relative phases of echo pulses received in different beams due to single pulse transmitted.

AMPITUDE COMPARISON MONO PULSE

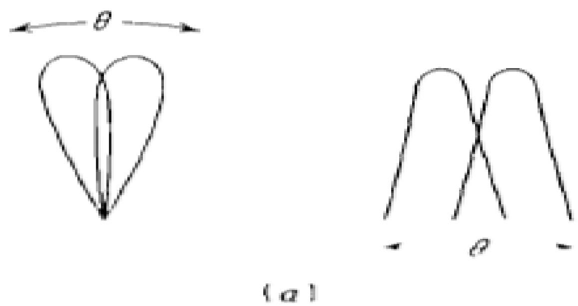
- **Methods in Mono Pulse tracking**

  i. Amplitude Comparison Monopulse.

  ii. Phase Comparison Monopulse.

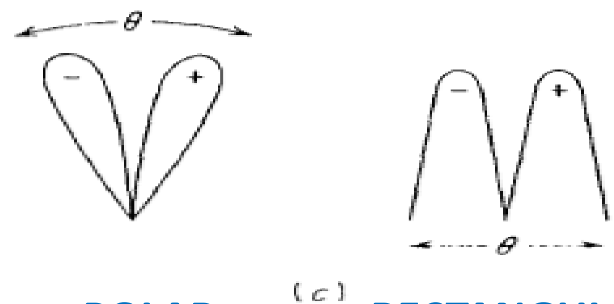
- **Amplitude Comparison Monopulse**

OVERLAPPING ANTENNA PATTERNS

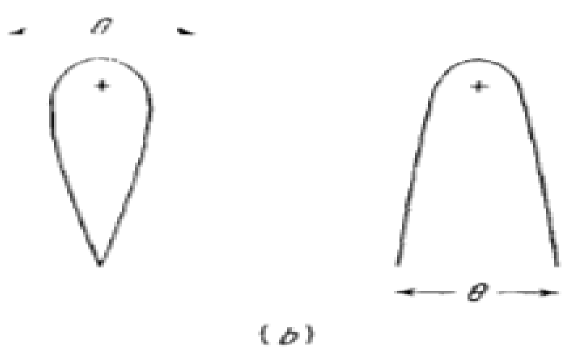


POLAR **RECTANGULAR**

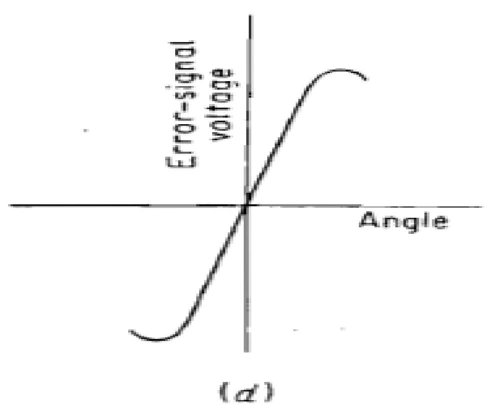
DIFFERENCE PATTERN



POLAR **RECTANGULAR**



SUM PATTERN



ERROR (product) SIGNAL

AMPLITUDE COMPARISON MONO-PULSE (CONTD..)

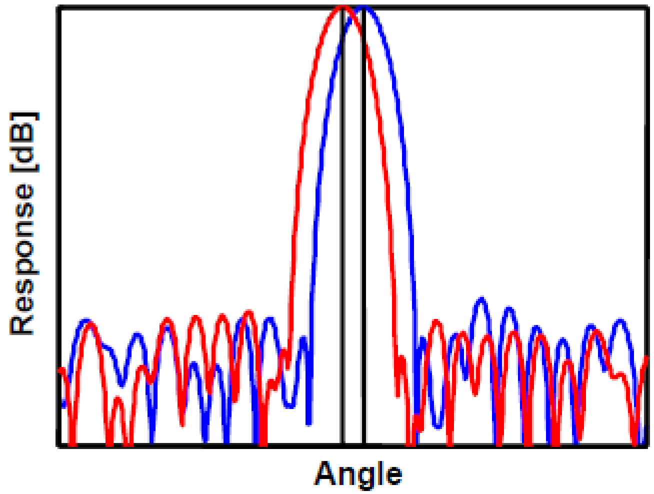
- There are 3 antenna tracking patterns

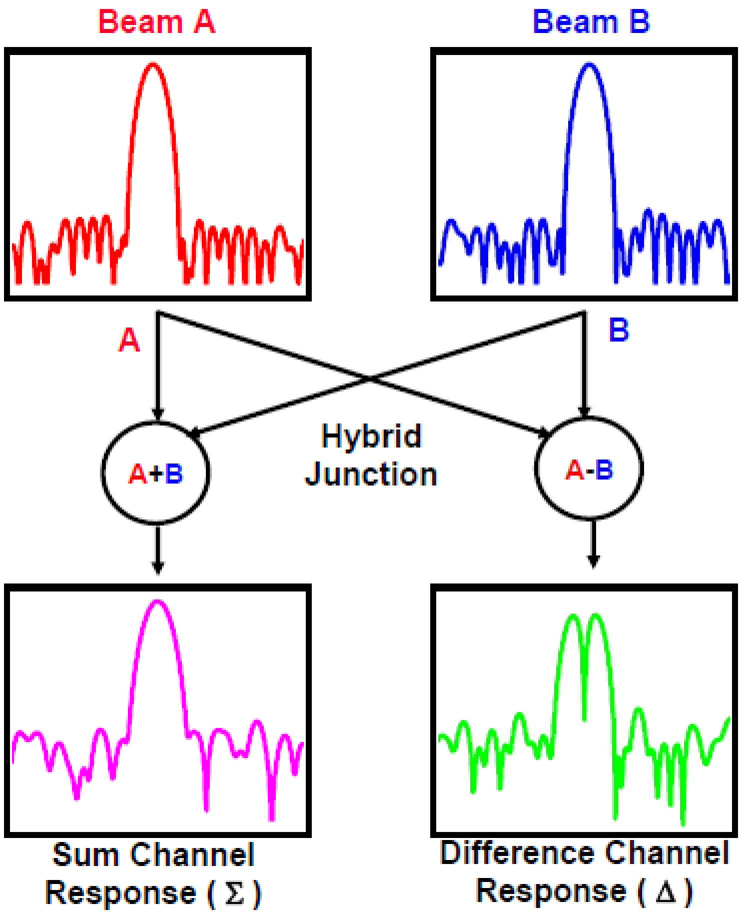
  (i) Sum

  (ii) Azimuth Error

  (iii) Elevation Error
- Error pattern is the signal Amplitude Vs Angular error (in azimuth or elevation)
- At Null, the error pattern has zero gain and sum pattern has maximum gain.

AMPLITUDE COMPARISON MONOPULSE (CONTD..)

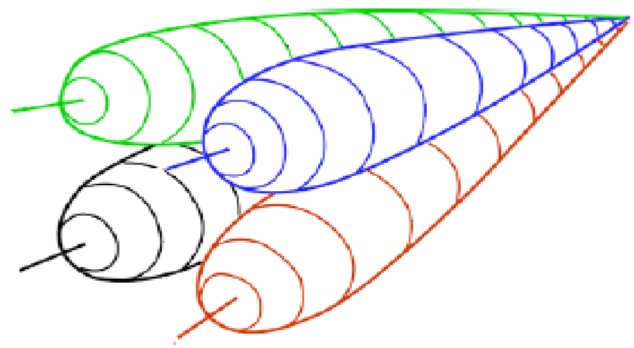




- Receive two beams directed at slightly different angles
  - Typical offset 0.3 x beamwidth
- Generate Sum and Difference Signals
  - Sum = Σ = A + B
  - Difference = Δ = A - B

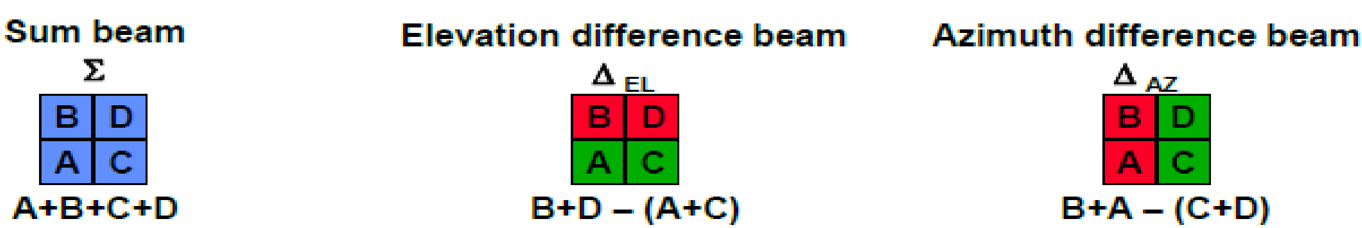
AMPLITUDE COMPARISON MONOPULSE

Two Dimensional- Four Horn Monopulse



- Σ = Sum channel signal
  Δ = Difference channel signal
  ϕ = phase difference between Σ and Δ
- Error signal $e = \dfrac{|\Delta| \cos\phi}{|\Sigma|}$

Note that the lower feeds generate the upper beams

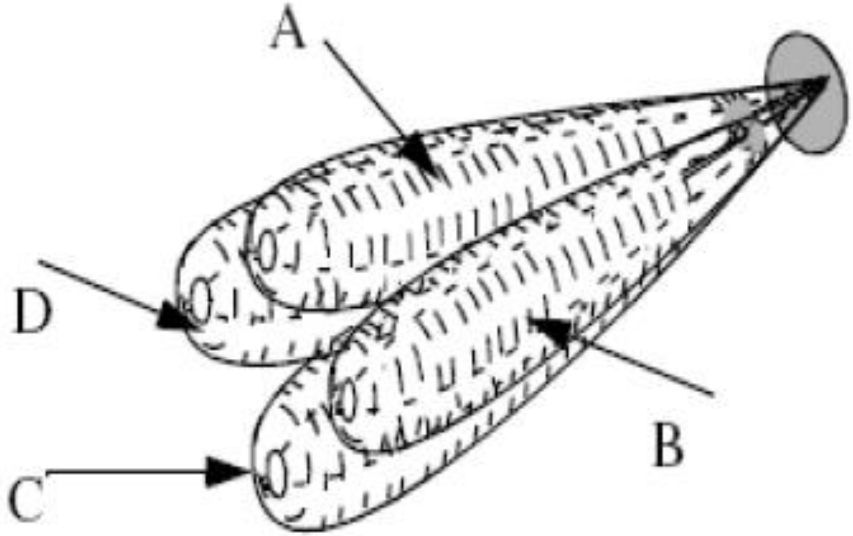


AMPLITUDE COMPARISON (CONTD ..)

- Employs 2 overlapping antenna patterns in one coordinate
- Generates 2 overlapping antenna patterns either (i) With a single reflector or (ii) With a lens antenna illuminated by 2 adjacent feeds
- Sum pattern is used for transmission. For reception both sum and difference pattern are used.
- For Range measurement Sum pattern is used.
- Difference pattern is used for deriving the angular error.
- Sign of error is obtained by using the sum pattern as a reference signal.

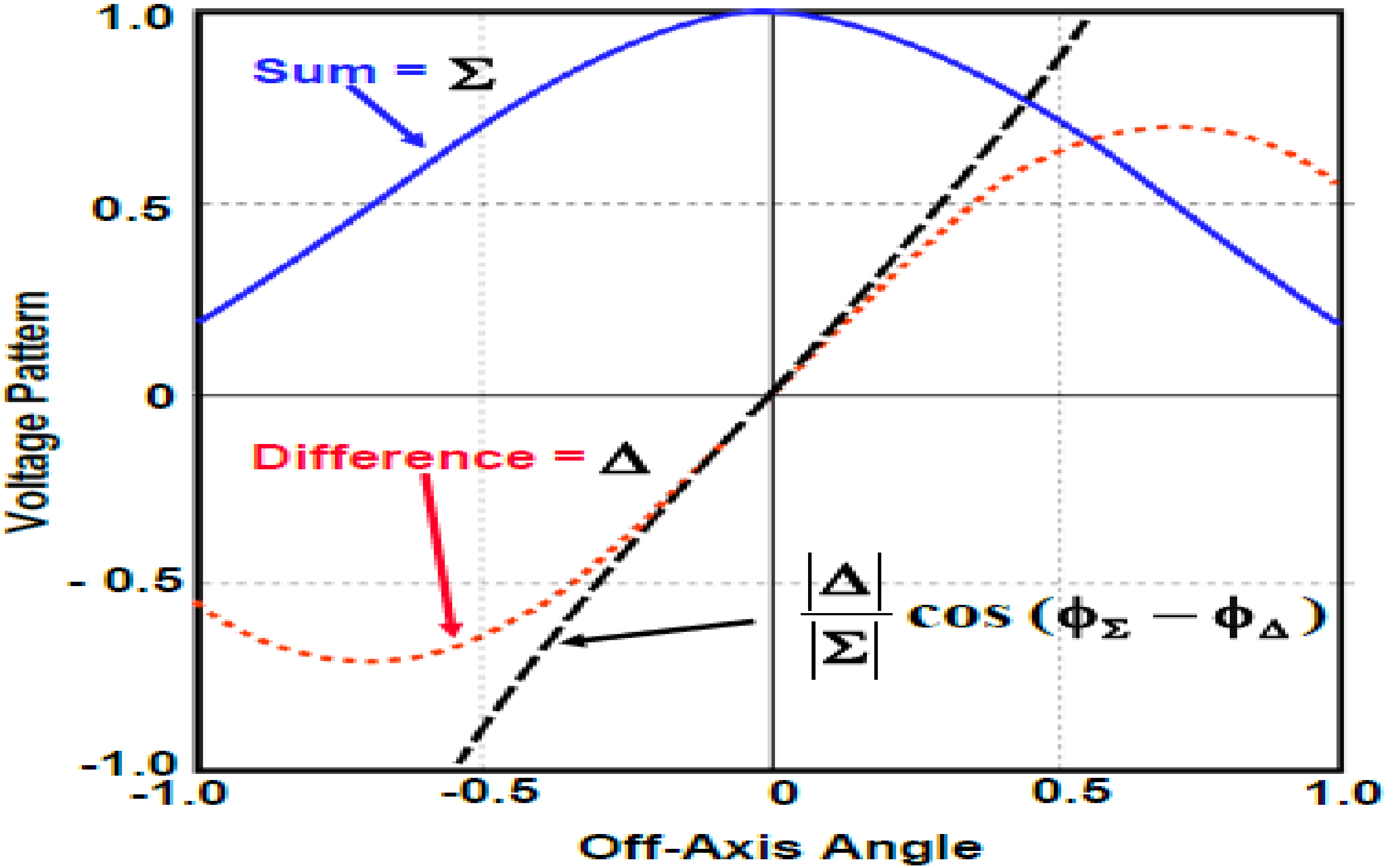
MONOPULSE CONCEPT(CONTD..)

Four feeds mainly horns are used to produce the monopulse antenna pattern



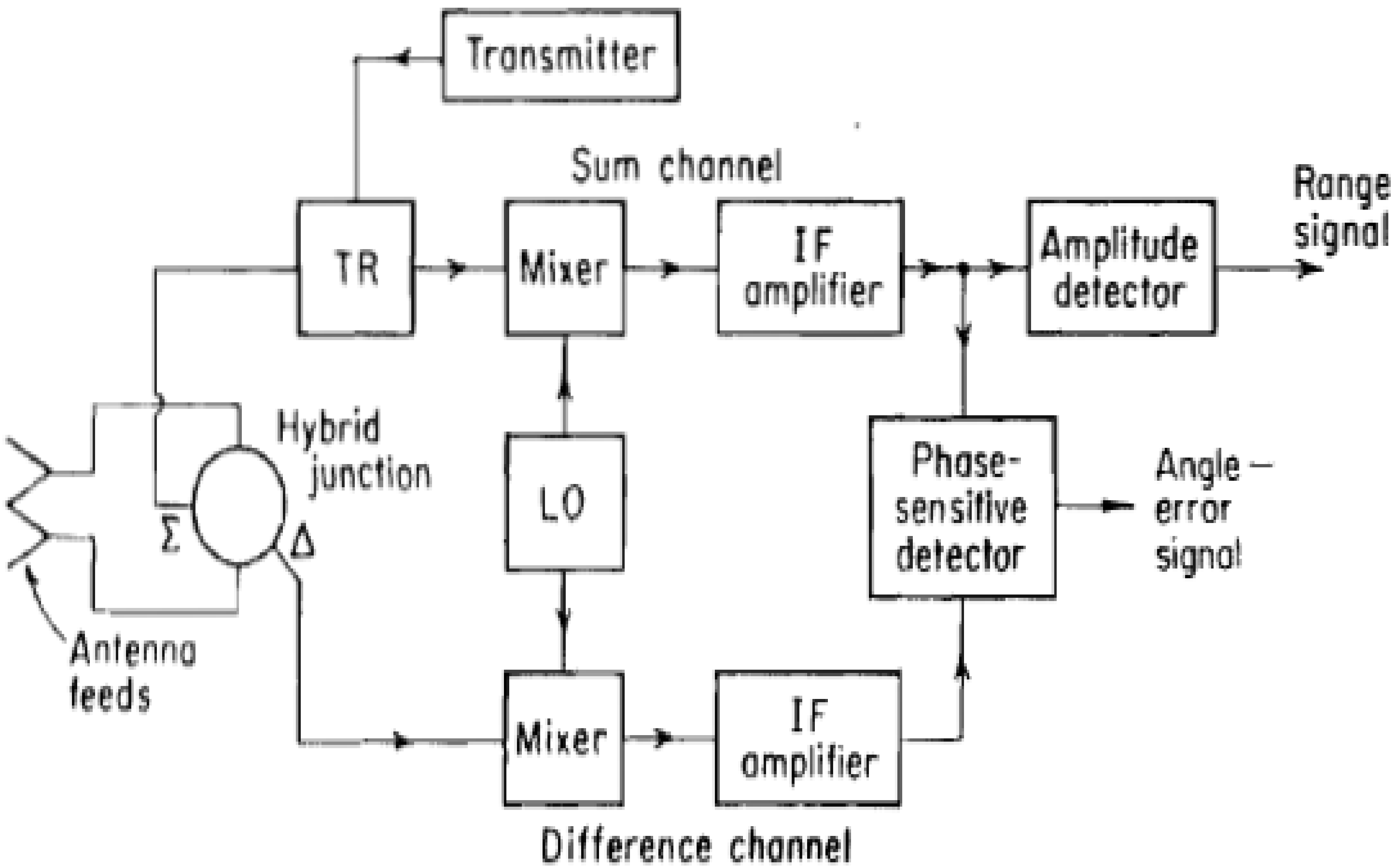
ERROR PATTERN

Monopulse Error Pattern



(Jntuh) **Explain the block diagram of amplitude comparison mono-pulse radar for single angular co-ordinate and explain its operation**

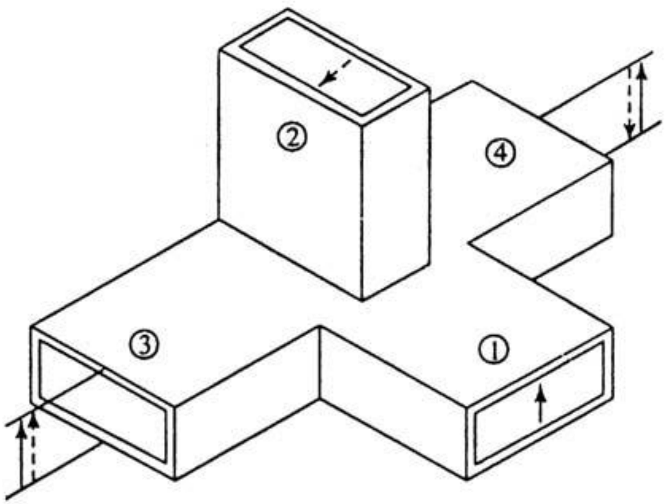
BLOCK DIAGRAM OF ONE COORDINATE SYSTEM

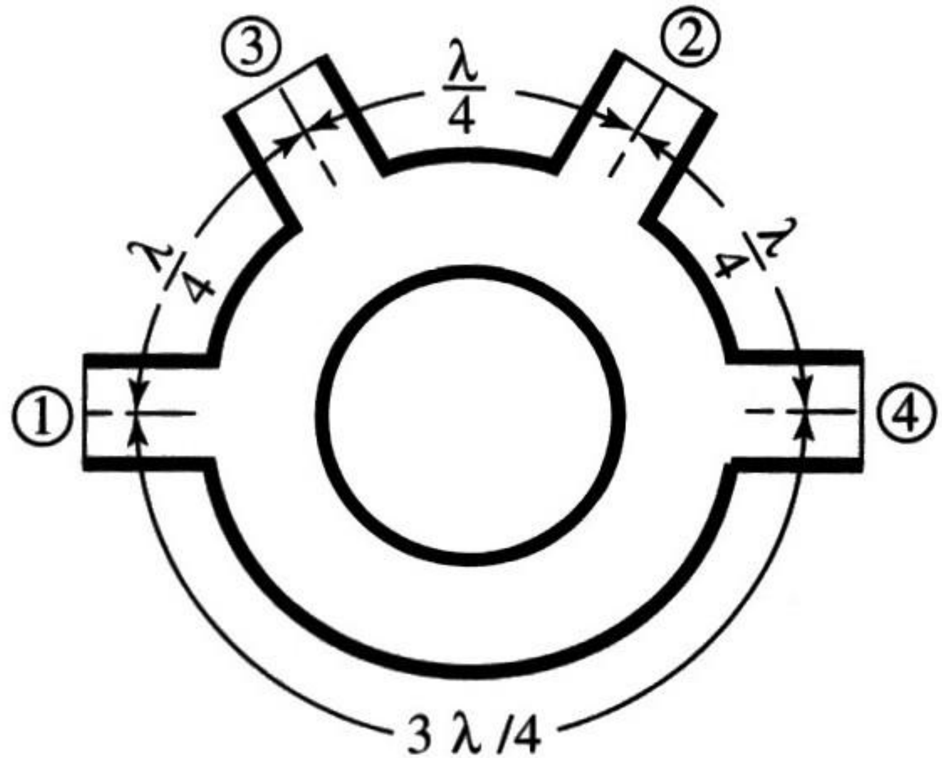


MAGIC T

- .

Magic - T





Hybrid
Ring Junction
or “Rat-Race”

BLOCK DIAGRAM OF ONE COORDINATE SYSTEM (CONTD)

- Magic T is used as a hybrid junction.
- $\sum$ (sum) channel used for transmission. Duplexer introduced in this channel for protection of R_x.
- Δ (Difference) channel is used for receiving the Echo.
- $\sum$ and Δ are converted to IF frequencies using the principle of super heterodyning.
- Phase sensitive Detector (PSD) extracts the amplitude and polarity of the error signal. The two inputs to PSD are the $\sum$ and Δ IF signals.

BLOCK DIAGRAM (CONTD ..)

- Angular error signal actuates the servo to position the antenna in the direction of target.
- Sign or polarity of error signal is obtained by comparing the phase of difference signal with phase of sum signal.
- Sum signal = $A_s \cos \omega_{IF} t$
- Difference signal = $A_d \cos \omega_{IF} t$ (In phase)

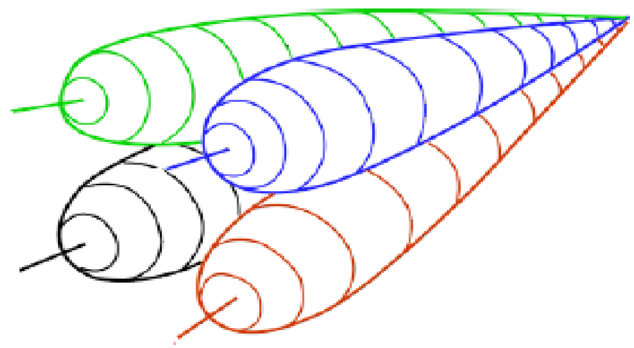
or

= $A_d \cos \omega_{IF} (t + \pi)$ (180^0 Phase)

AMPLITUDE COMPARISON MONO-PULSE

Two Dimensional- Four Horn Monopulse

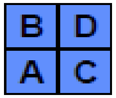
- Σ = Sum channel signal
  Δ = Difference channel signal
  ϕ = phase difference between Σ and Δ
- Error signal $e = \dfrac{|\Delta| \cos \phi}{|\Sigma|}$



Note that the lower feeds generate the upper beams

Sum beam

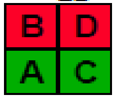
Σ



A+B+C+D

Elevation difference beam

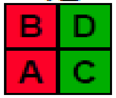
Δ_{EL}



B+D – (A+C)

Azimuth difference beam

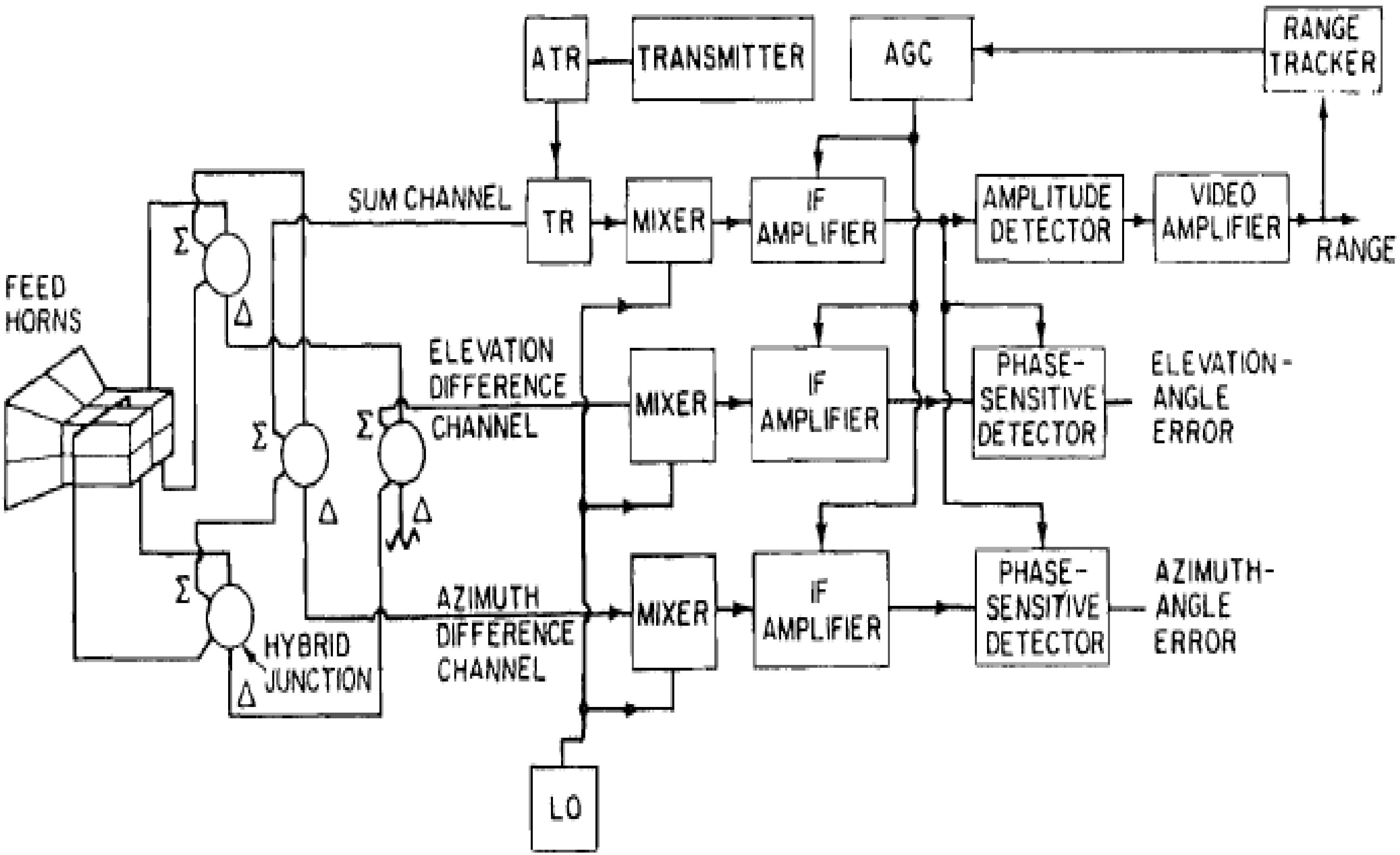
Δ_{AZ}



B+A – (C+D)

(Jntuh) **Explain the block diagram of amplitude comparison mono-pulse radar for extracting errors in both elevation and azimuth**

BLOCK DIAGRAM OF 2 COORDINATE SYSTEM



BLOCK DIAGRAM OF 2 COORDINATE SYSTEM

- The cluster of 4 feeds is called the monopulse comparator. The feeds are used with a parabolic reflector
- All the 4 feeds generate sum pattern
- Difference pattern in Azimuth plane is

  = sum of 2 adjacent feeds – sum of the other 2 adjacent feeds (B+D) — (A+C)
- Difference pattern in Elevation plane is

  = Difference of 2 adjacent feeds + Difference of other 2 adjacent feeds (B — D) + (A — C)

  (B+A) — (C+D)

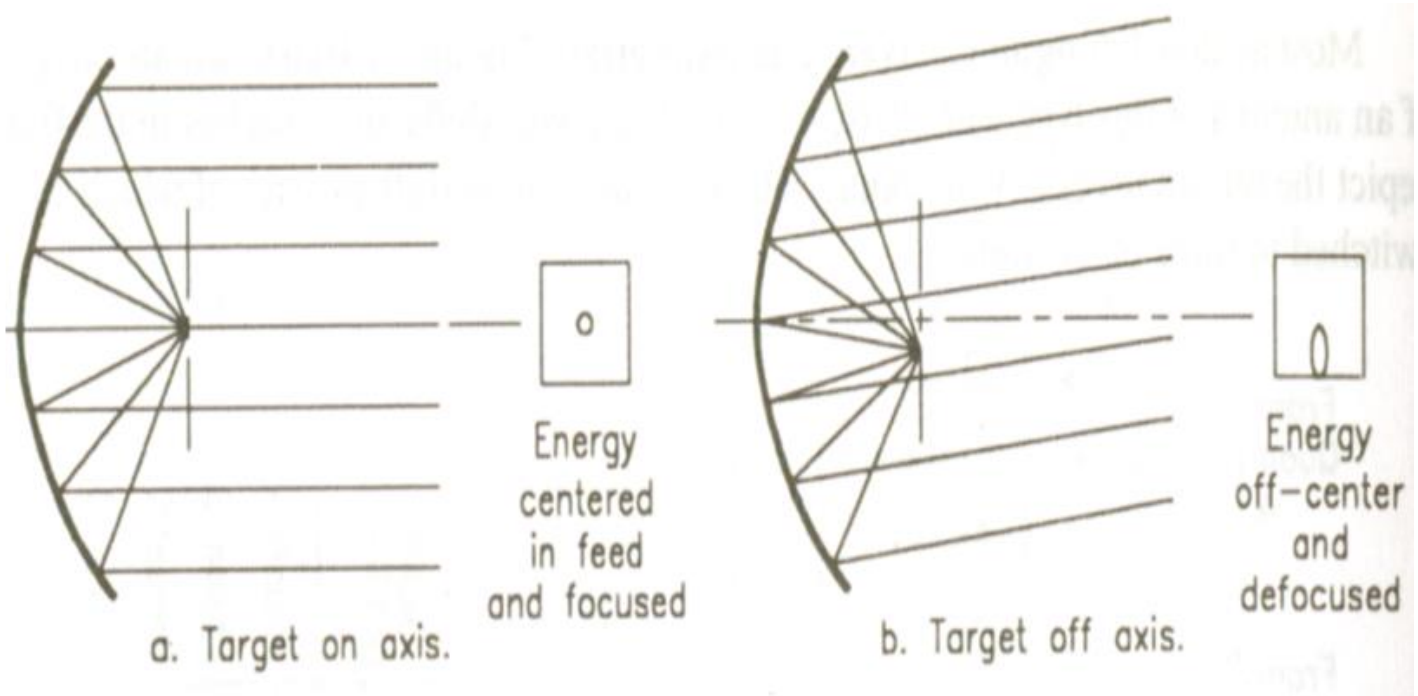
BLOCK DIAGRAM OF 2 COORDINATE SYSTEM (CONTD..)

- All 3 mixers operate from a single Local Oscillator to maintain same phase relationship between the 3 channels

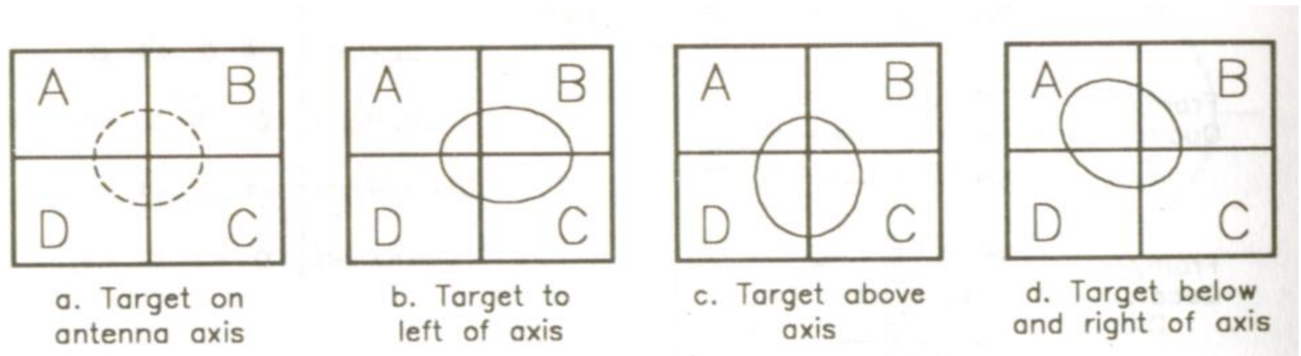
- 2 PSDs extract the angle error information one for Azimuth and the other for Elevation

- Range information is obtained from Sum channel

MONO-PULSE COMPARATOR



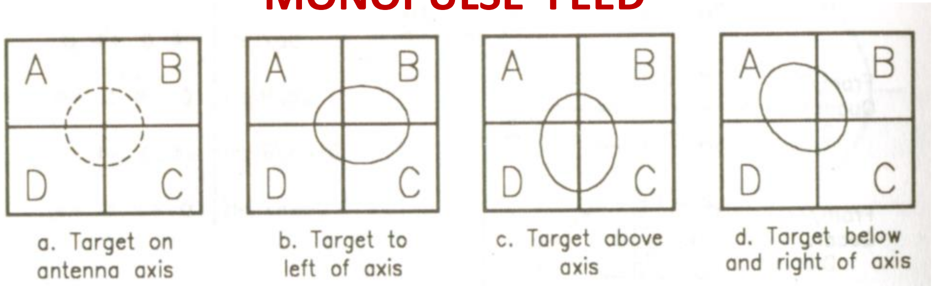
MONOPULSE CONCEPT

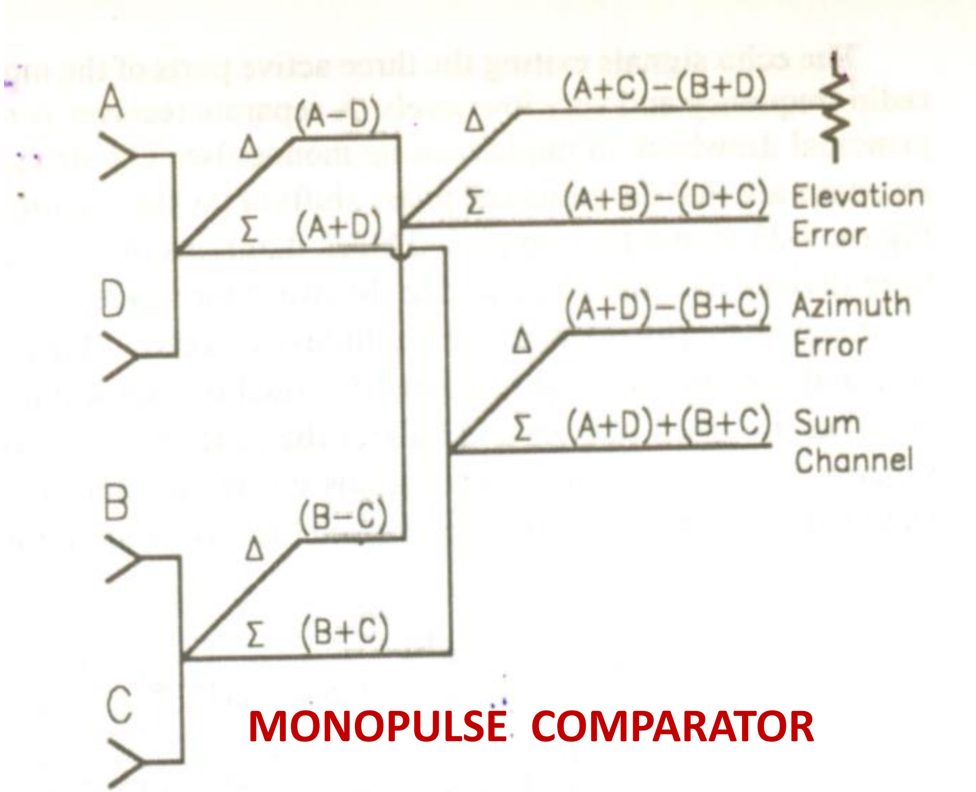


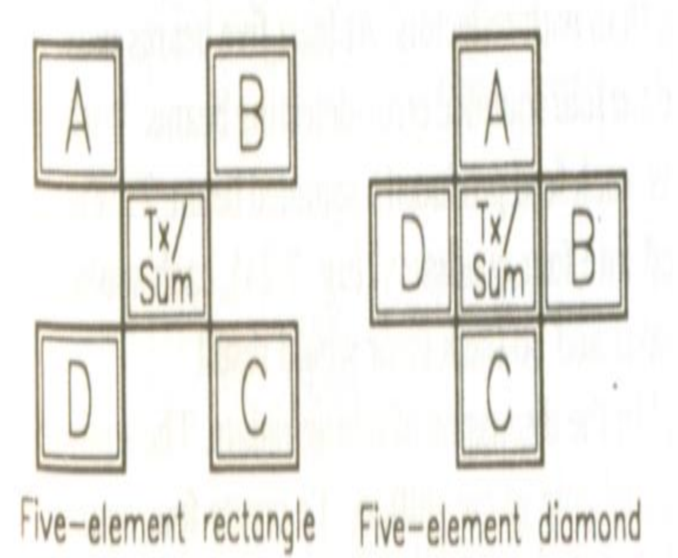
MONOPULSE FEED

MONO-PULSE COMPARATOR

MONOPULSE FEED







MONOPULSE COMPARATOR

FEED CONFIGURATION

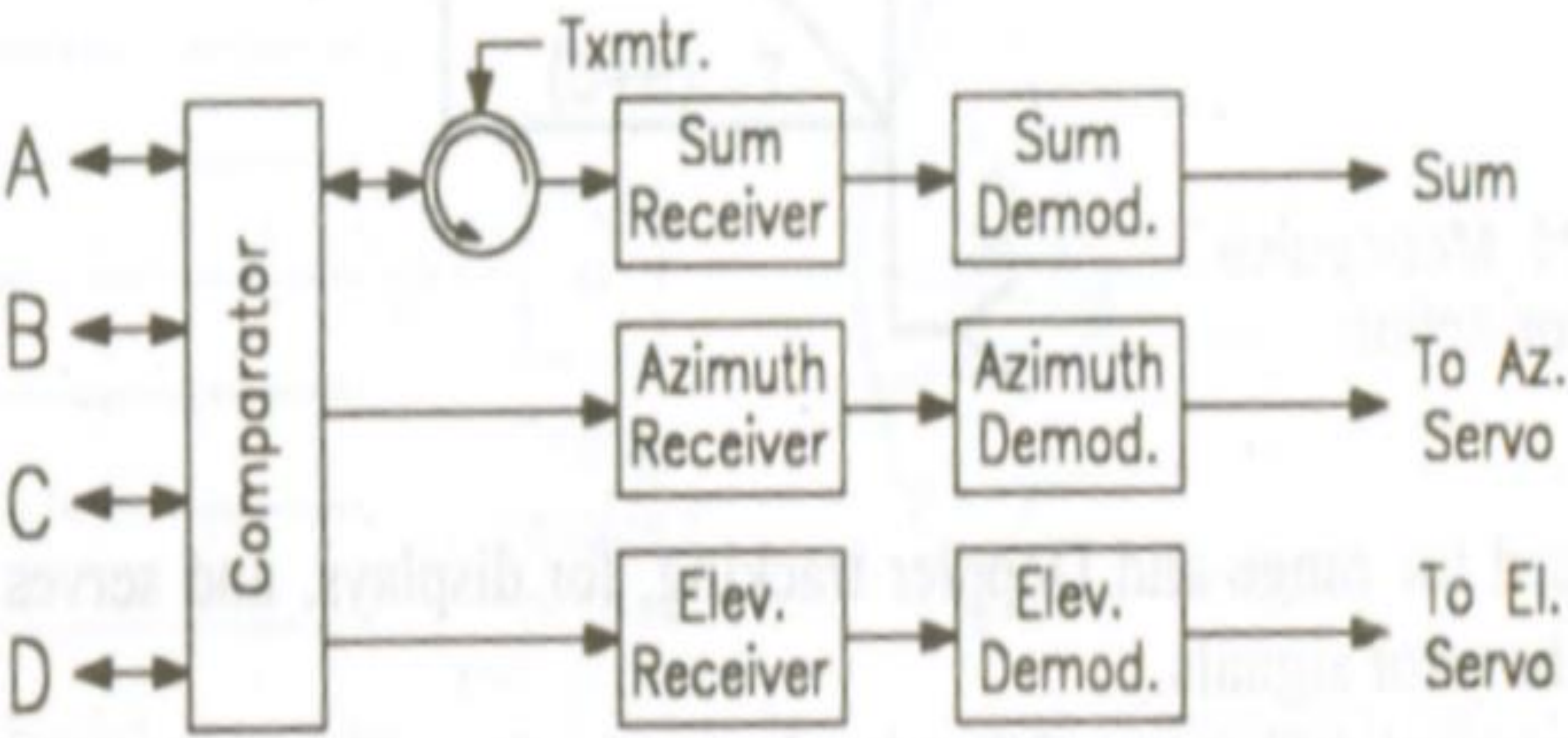
MONO-PULSE COMPARATOR

- If target is on antenna axis all the energy is focused at parabola's focal point
- A comparator antenna with 4 feeds is placed at the focus of parabolic dish
- If target is on antenna axis all feeds receive the same amount energy A=B=C=D
- If target is on left of antenna A=D, B=C, and A<B
- If target is above axis A=B, D=C and A < D
- If target is below and right of axis A>D and B>C

MONOPULSE CONCEPT (CONTD ..)

- Feeds are connected in pairs, A and D is a pair and B and C is another pair.
- Signals from the 2 feeds are combined so that their sum and difference are formed.
- Azimuth error = (A+D) – (B+C) .
- Elevation error (A+B) – (D+C).
- Sum channel (A+D) + (B+C).
- Magic T can be used for obtaining sum and difference.

3-CHANNEL MONO-PULSE RECEIVER

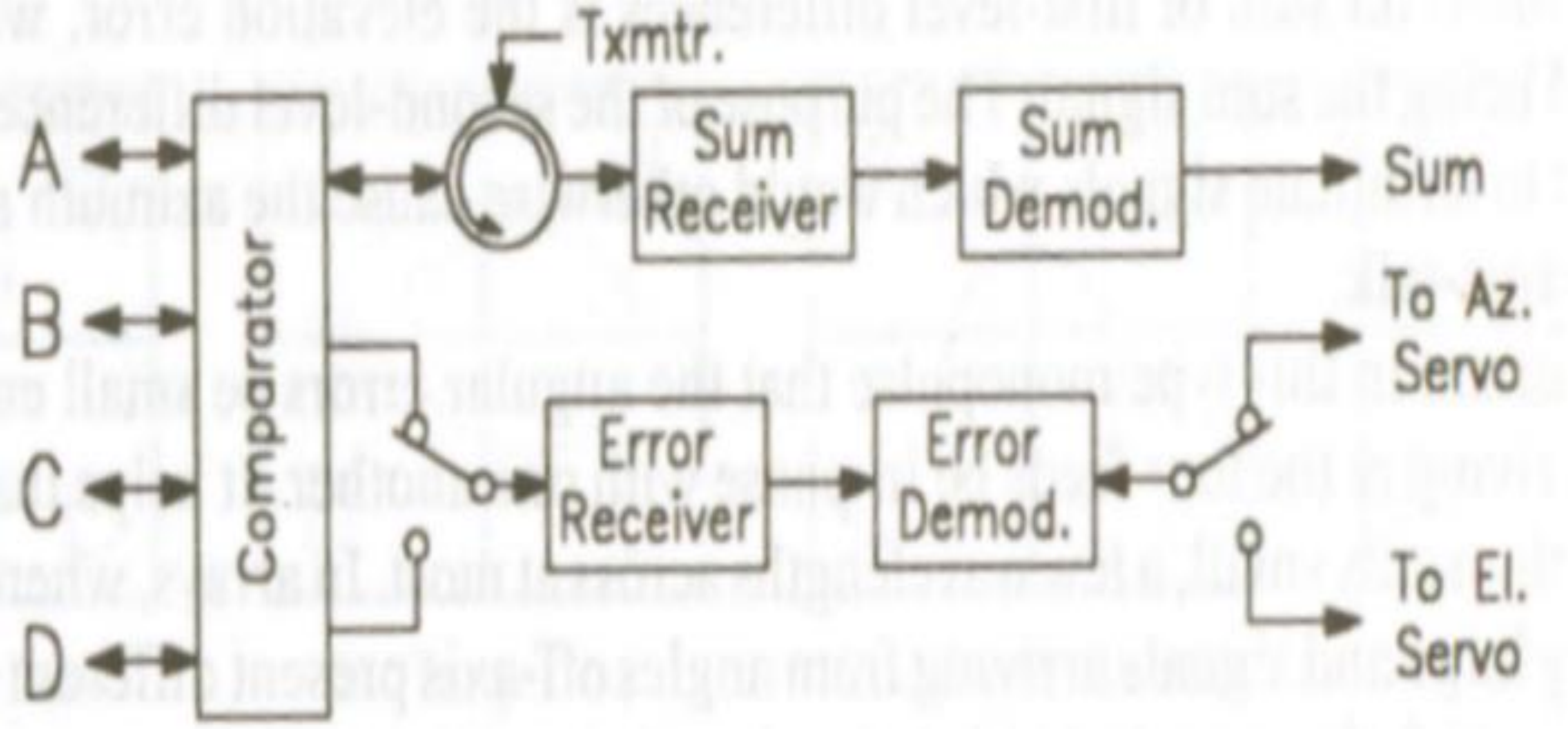


a. Three-channel monopulse receiver

3 CHANNEL MONO-PULSE R_X

- Phase comparison is made between sum channel and each of the difference channels to obtain errors.
- So the phase shifts introduced by each of the channels should be identical. They should not differ by more than 25^0 for proper performance.
- The gains of the channels also should be identical.

2-CHANNEL MONOPULSE RECEIVER



b. Two–channel monopulse receiver

2 CHANNEL MONOPULSE R_X

- Because of stringest requirement of identical gain and phase matching an alternative to 3 phase Monopulse $R_x$is the 2 channel Monopulse R_x.
- This uses time – division multiplexing, so that the error channels share one R_x.
- Half the signal energy is lost in the multiplexed R_x. S/N deteriorates and accuracy suffers.
- Used only when the requirement is for smaller weight and size.

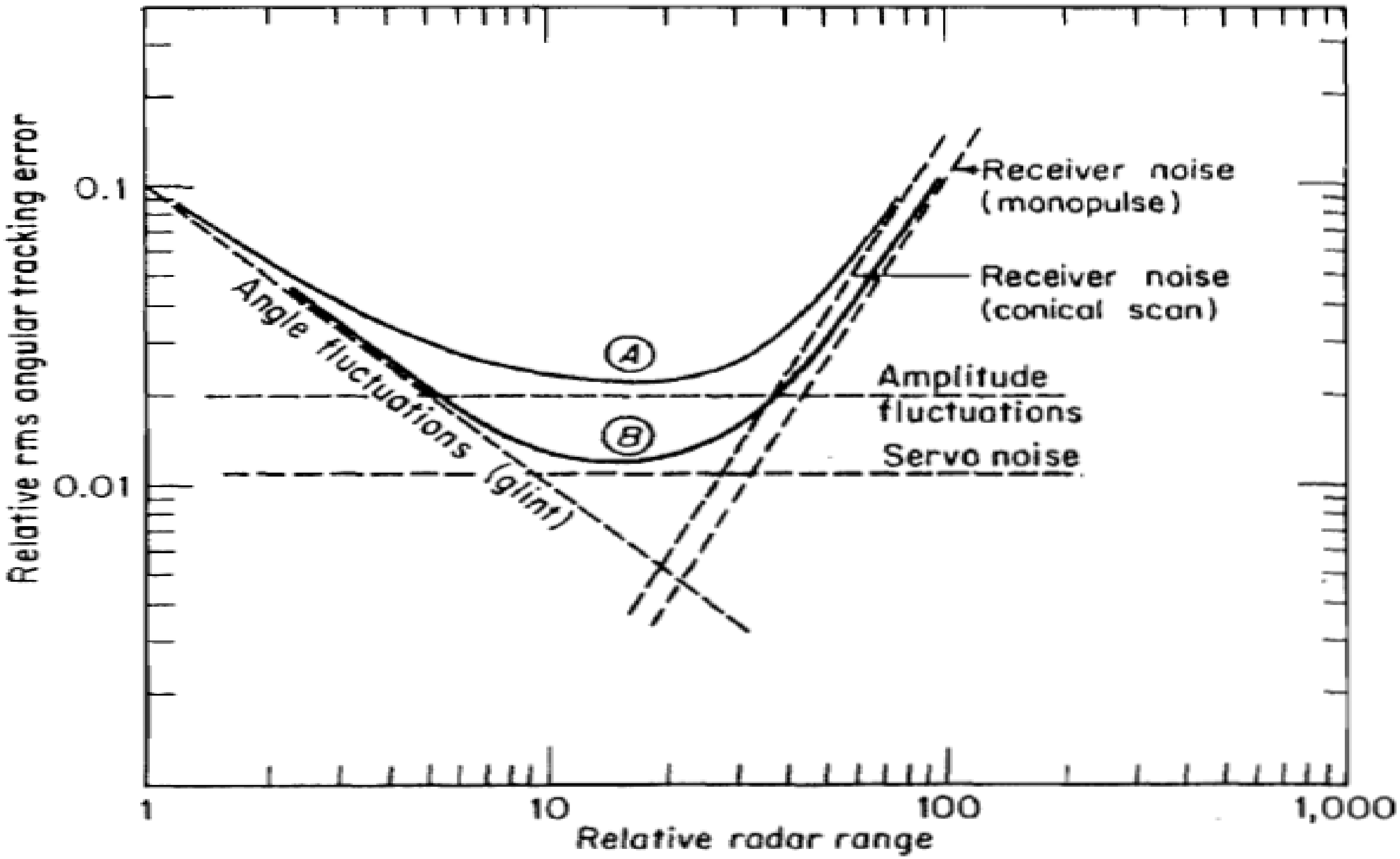
SINGLE CHANNEL MONOPULSE R_X

- Single IF channel is used on time shared basis.
- Sum and difference channels use the same IF channel in time shared basis.
- The sum signal is passed through the single IF amplifier followed by the 2 difference signals (Azimuth & Elevation).
- After amplification suitable compensating delays introduced to bring them in time coincidence.
- The requirement of identical gain & phase is met in this configuration.
- However S/N degrades since only a portion of pulse is used.

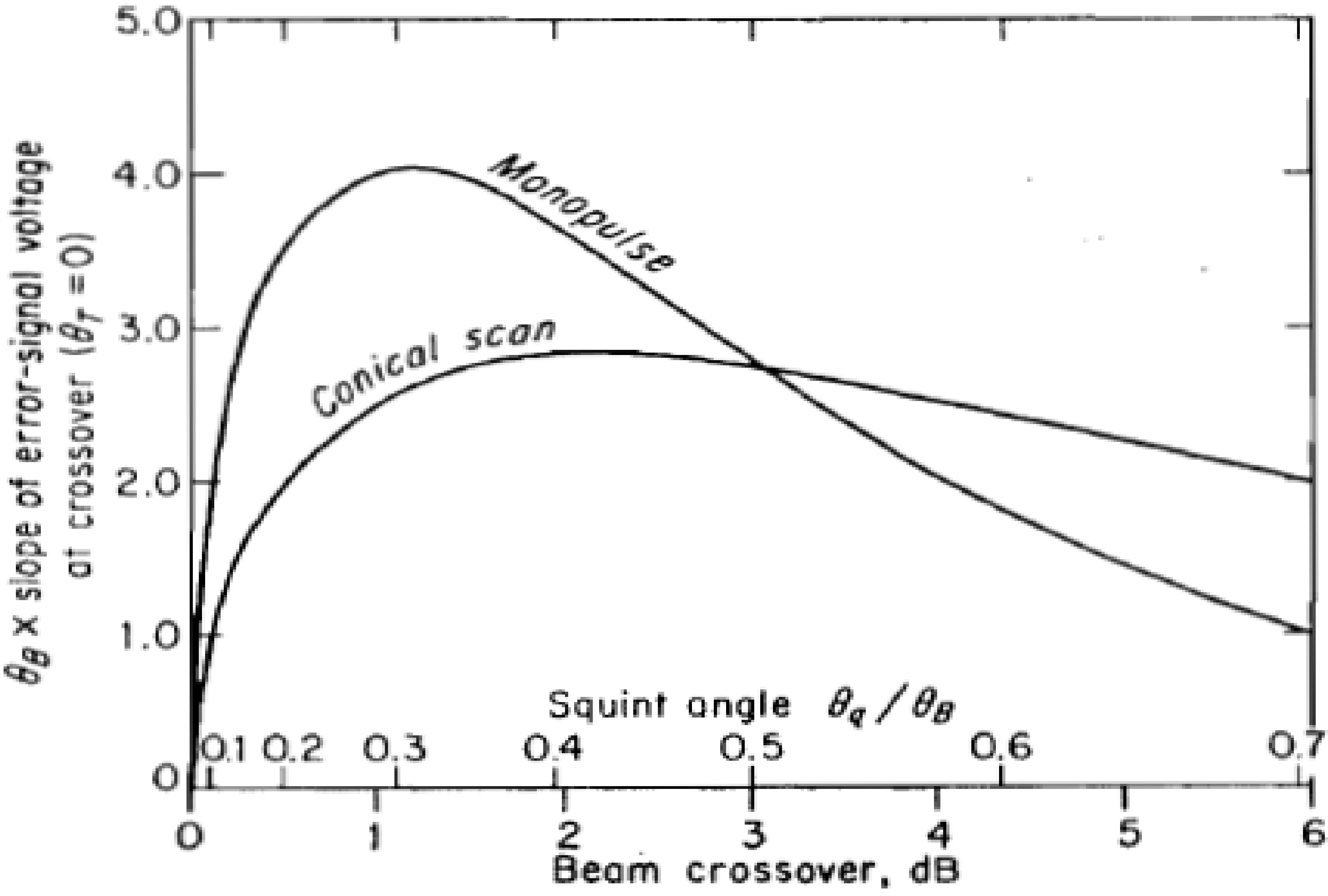
COMPARISON OF ACCURACIES OF MONOPULSE WITH CONICAL SCAN

- For high accuracy the Monopulse R_x should have
  i. Maximum bore sight gain in sum pattern.
  ii. Large value of slope for difference pattern at cross over of offset beams.
  iii. Side lobe of sum and difference must be low.
  iv. Antenna should have the desired band width and polarization characteristics.
- Error signal slope is a function of squint angle or beam cross over. Maximum slope occurs at beam cross over of about 1.1 dB (Graph)

COMPARISION MONOPULSE & CONICAL SCAN



COMPARISON MONOPULSE & CONICAL SCAN



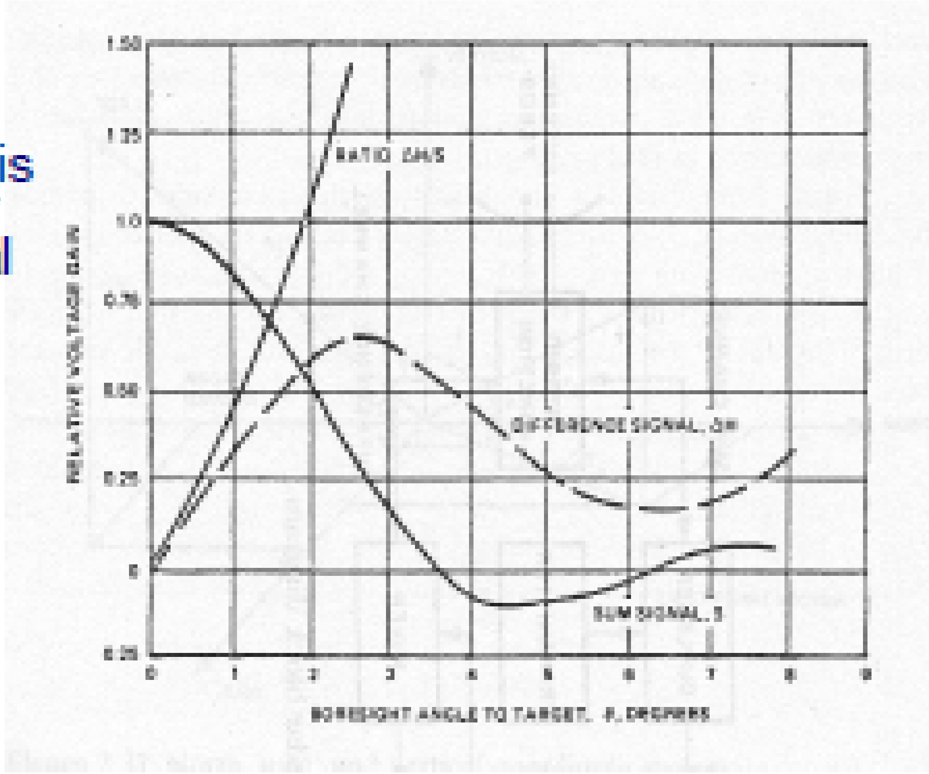
AGC IN MONO PULSE R_X

- AGC is used for normalization
- AGC is required in order to maintain a stable closed loop angle tracking.
- Voltage obtained from sum channel IF, is used to control the gain of 3 receiver channels.
- AGC required to maintain constant output due to changes in range and target size.
- The error signal is now normalized to
- $\frac{\Delta \ A_Z}{\Sigma}$ and $\frac{\Delta \ E_l}{\Sigma}$

REQUIREMENT FOR NORMALIZATION

Monopulse Normalisation

- Difference channel IF signals are normalised with respect to the sum channel to produce an error signal that is independent of the echo amplitude
- This ratio can be obtained using an AGC circuit that operates on the two difference channels and is driven by the sum channel, or by division after detection in a digital tracker .
- An envelope detector generates the sum channel voltage signal from the sum channel IF
- To obtain angular error signals that include sign and magnitude, phase sensitive detectors demodulate the azimuth and elevation error signals using the sum channel IF signal as a reference to produce the two error voltages.

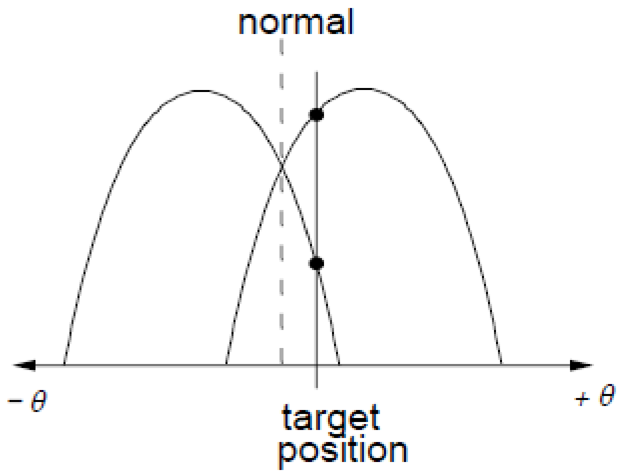


NORMALIZATION

➢ Necessity for Normalisation:

- Why Δ/Σ is used to determine the angular error why not only Δ ?

➢ Example:



Power received $P_r \; \alpha \; \dfrac{1}{(\text{Range})^4} \; \alpha \; \dfrac{1}{R^4}$

NORMALISATION (CONTD ..)

i. Without Normalisation (1 V = 1 Deg)

Range	Signal A	Signal B	Δ = A-B	Angular Error
R	2 V	1 V	2-1 = 1 V	1^0
0.840 R	4 V	2 V	4-2 = 2 V	2^0
0.707 R	8 V	4 V	8-4 = 4 V	4^0

ii. With Normalisation (1V =1 Deg)

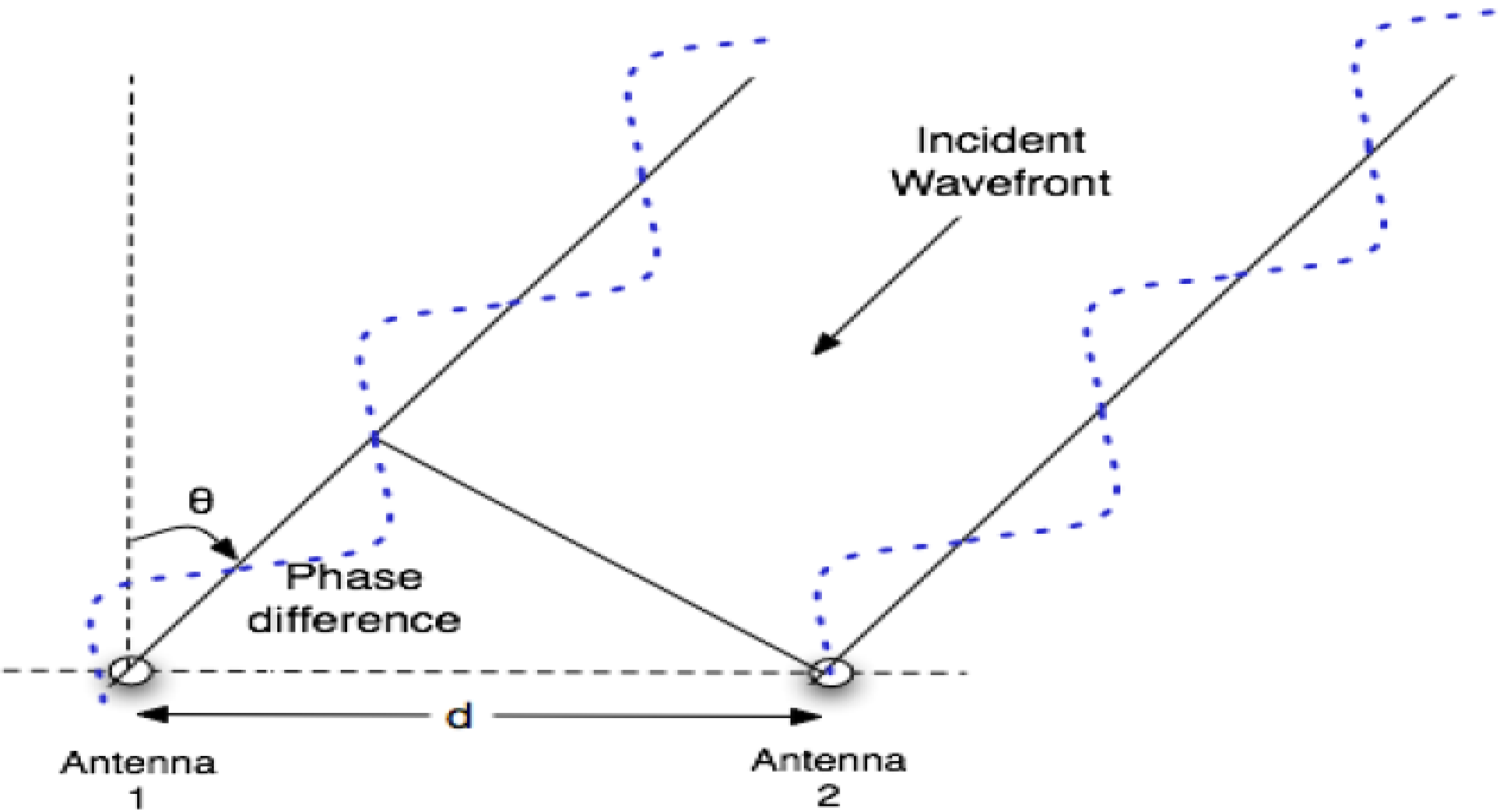
Range	Signal A	Signal B	$3 \times \frac{\Delta}{\Sigma} = 3 \times \frac{A - B}{A + B}$	Angular Error
R	2 V	1 V	1 V	1^0
0.840 R	4 V	2 V	1 V	1^0
0.707 R	8 V	4 V	1 V	1^0

- The above shows normalisation has helped in obtaining same angular error for different ranges.

PHASE COMPARISON MONOPULSE

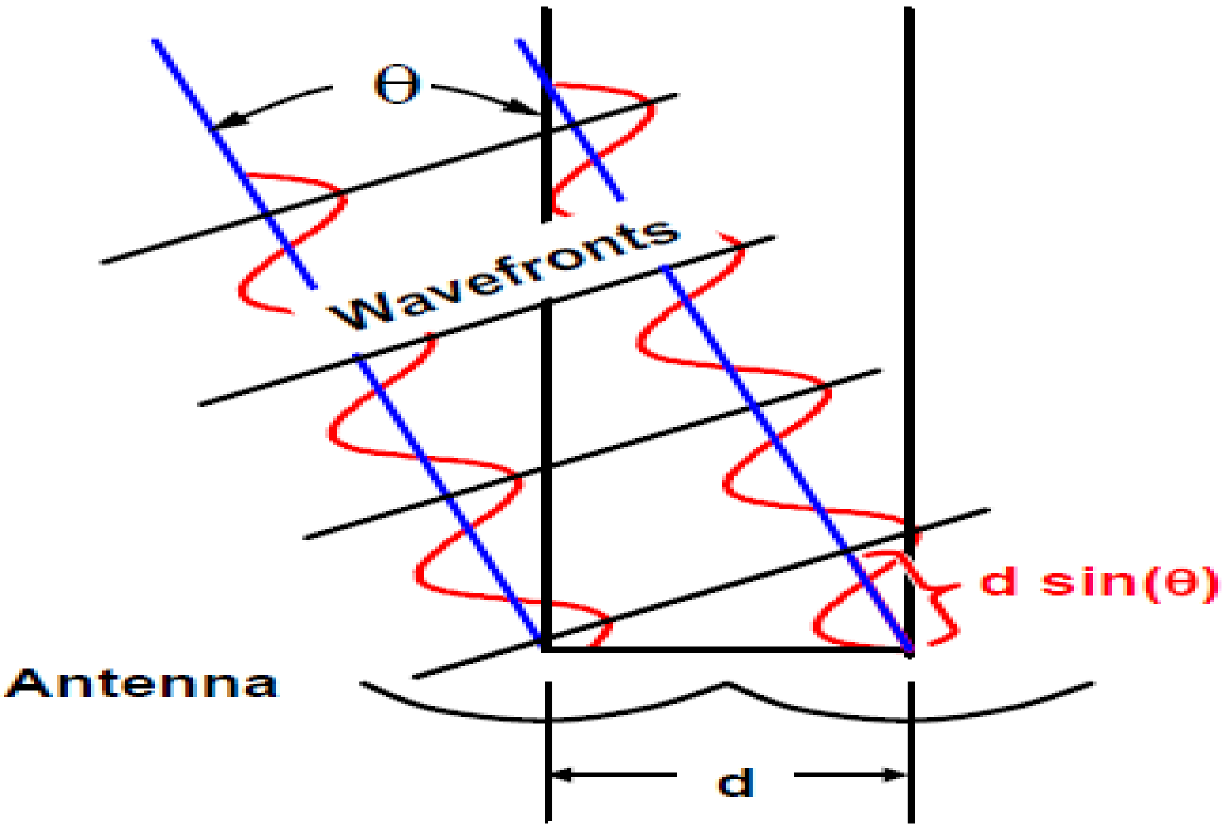
(Jntuh) **Explain phase comparison mono-pulse tracking technique**

Phase-Comparison Monopulse Radar



PHASE COMPARISON MONOPULSE

- .

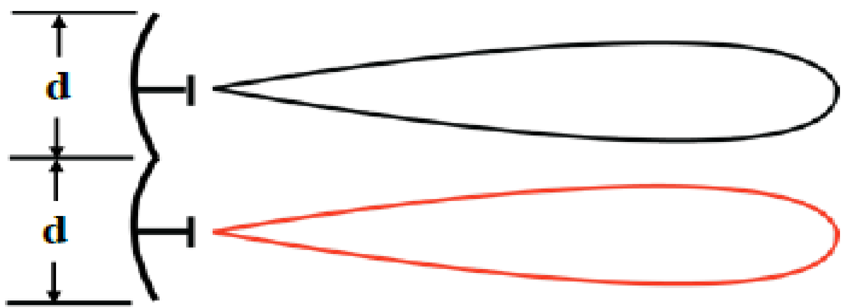


PHASE COMPARISON MONOPULSE

- Angle of Error is determined by comparing the phase difference between signals from two separate antennas.
- For phase comparison antennas are not offset from the axis (unlike in amplitude comparison).
- The individual antenna bore sight are made parallel.
- This makes far-field radiation illuminate the same volume in space.
- Amplitudes of Echoes received in the antennas are same. But their phases are different.

PHASE COMPARISON MONOPULSE (CONTD ..)

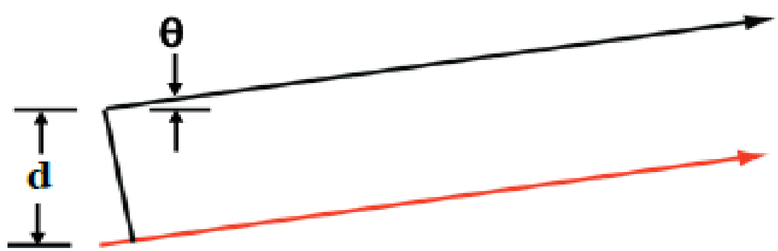
- A tracking radar working on phase information is also called Interferometer Radar.



Two antennas radiating identical beams in the same direction

Also known as "interferometer radar"

Geometry of the signals at the two antennas when received from a target at an angle θ

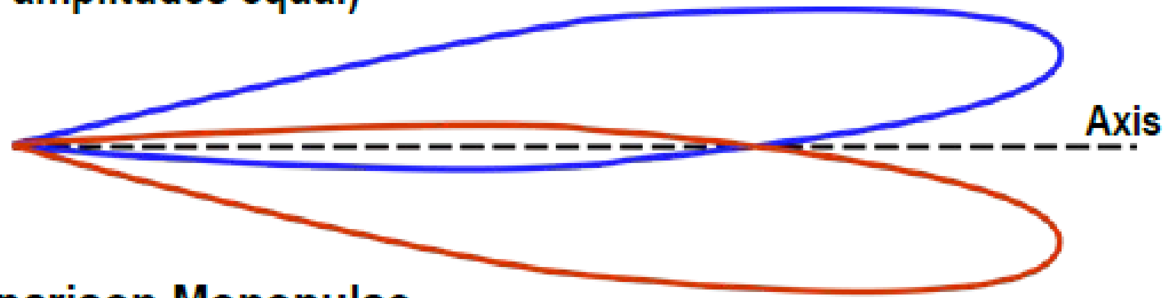


The phase difference of the signals received from the two antennas is :

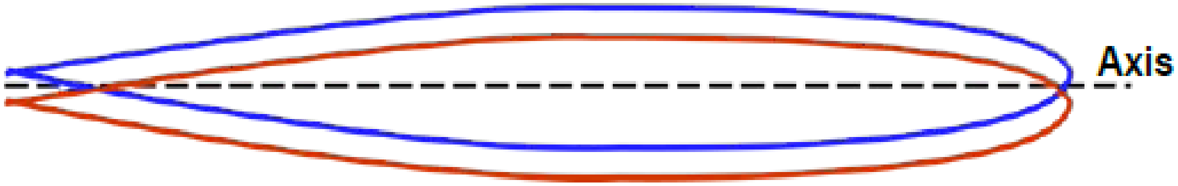
$$\Delta\phi = 2\pi \frac{d}{\lambda} \sin\theta$$

AMPLITUDE VS PHASE COMPARISON

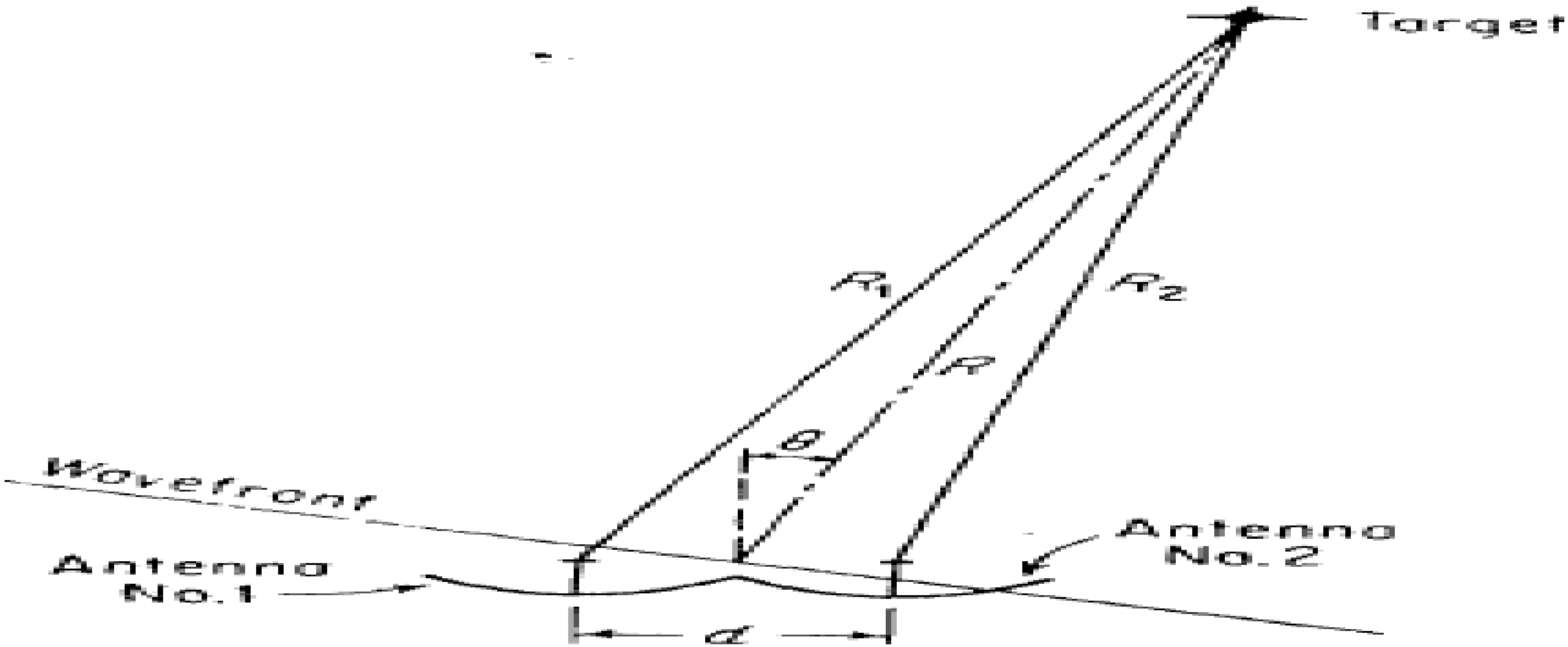
- Amplitude Comparison Monopulse
  - Common phase center, beams squinted away from axis
  - Target produces signal with same phase but different amplitudes (On axis amplitudes equal)



- Phase Comparison Monopulse
  - Beams parallel and identical
  - Lateral displacement of phase center much greater than λ
  - Target produces signal with same amplitude but different phase (On axis phases equal)
  - Grating lobes and high sidelobes a problem

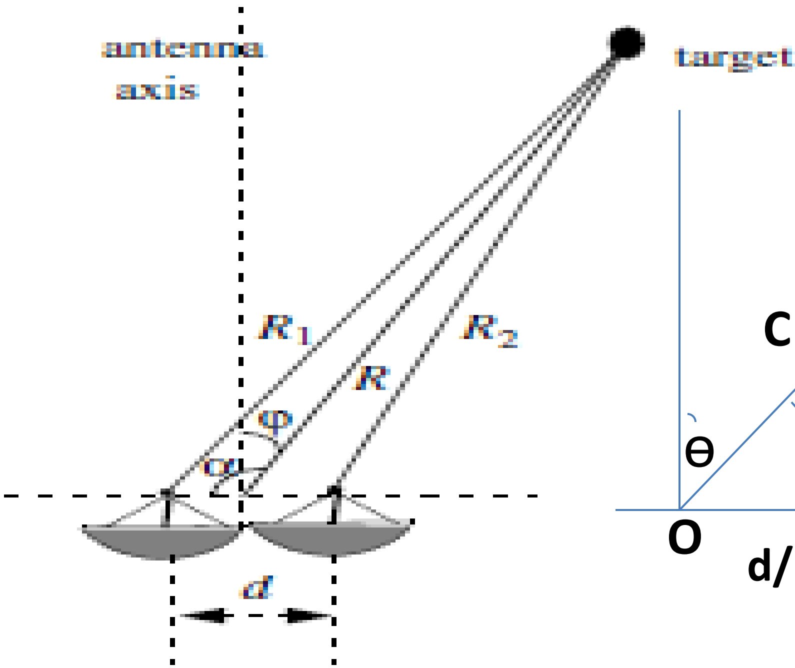


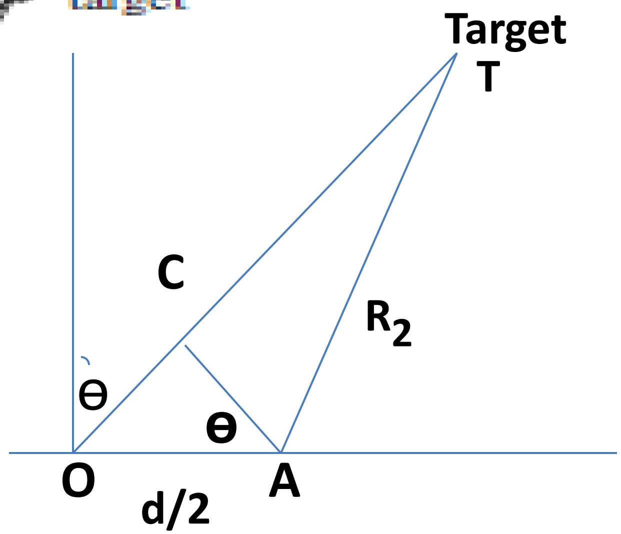
PHASE VS ANGLE ERROR



- 2 Antennas are located by a separation distance ‘d’
- Distance to target R is very large compared to ‘d’.
- θ = Angle between target line (LOS) to perpendicular bisector of line joining the 2 antennas

PHASE VS ANGLE ERROR





- $R_2 = R - \frac{d}{2}\ \text{Sin}\ \theta$
- $R_1 = R + \frac{d}{2}\ \text{Sin}\ \theta$

SIN ϴ = OC / OA

OC = OA × SIN ϴ

OC = d/2 × SIN ϴ

AT = R_2 = CT

OT = R = OC + CT

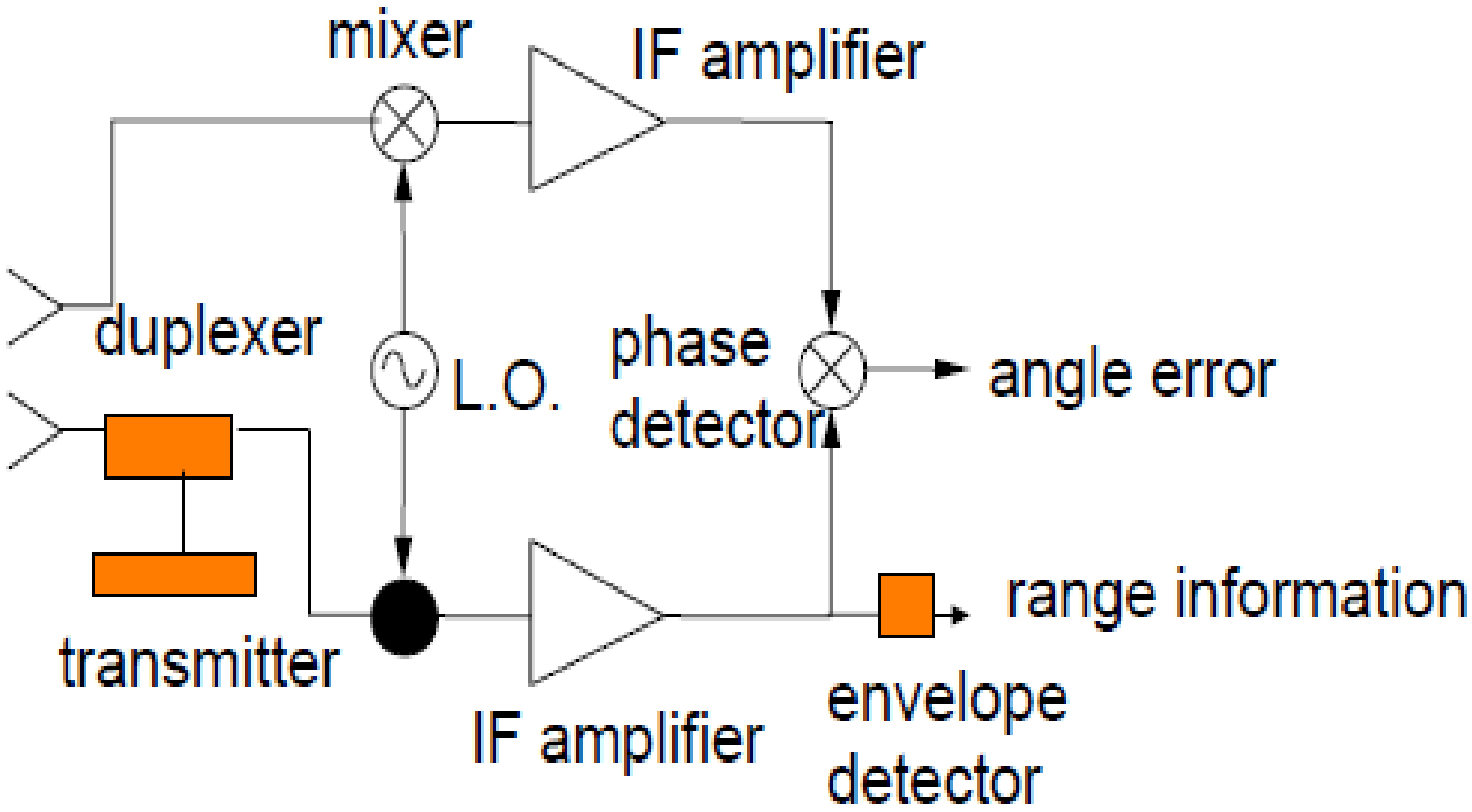
R_2 = CT = R – OC

R_2 = R – d/2 × SIN ϴ

PHASE VS ANGLE ERROR (CONTD ..)

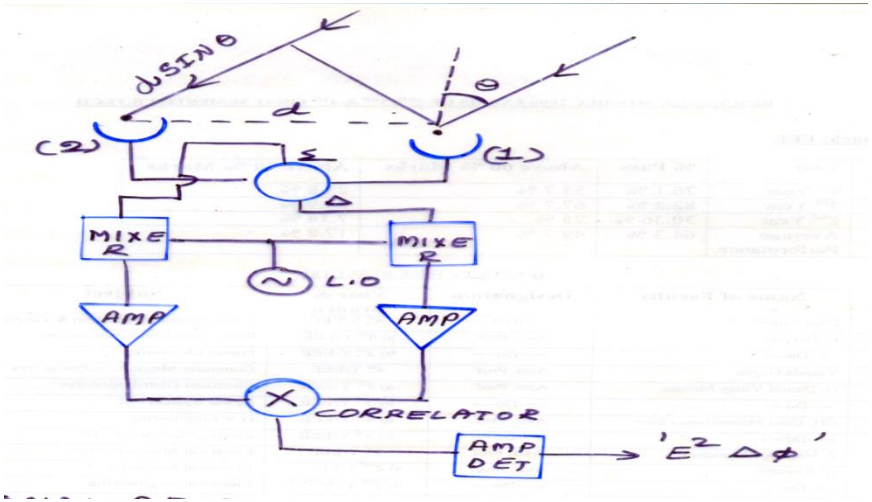
- Difference in distance travelled by the wave front to reach Antenna 2 after reaching Antenna 1.
- $R_1 - R_2 = d \sin \theta$
- But λ distance corresponds to 2π phase.
- $d \sin \theta$ distance corresponds to phase angle $\Delta \emptyset$
- $\Delta \emptyset = \frac{2\pi}{\lambda} d \operatorname{Sin} \theta = K \operatorname{Sin} \theta$
- $\Delta \emptyset = K\theta$ (Since $\sin \theta = \theta$ for small angles)
- So $\Delta \emptyset$ is used as the error to position the antenna by servo system

BLOCK DIAGRAM OF PHASE MONOPULSE



BLOCK DIAGRAM OF PHASE MONO-PULSE (CONTD ..)

- Signal received at Antenna 1 = E1 = E cos ω_it
- Signal received at Antenna 2 = E2 = E[cos ω_it + $\Delta\emptyset$]
- Sum $\sum$ = E1 +E2 = E cos W_ct + E[cos ω_it + $\Delta\emptyset$]
- Difference D = E1−E2 = E cos ω_it – E [cos ω_it + $\Delta\emptyset$]



- Cos A + Cos B = 2 Cos $\frac{A+B}{2}$ Cos $\frac{A-B}{2}$
- Cos A − Cos B = −2 Sin $\frac{A+B}{2}$ Sin $\frac{A-B}{2}$

BLOCK DIAGRAM OF PHASE MONO-PULSE (CONTD ..)

- Output of correlator = $\sum$ x Δ
- $\sum = 2\ \mathrm{E\ Cos}\ \frac{[\omega_i\ t + \omega_i\ t + \Delta\phi]}{2} \times \mathrm{Cos}\ \frac{[\omega_i\ t - \omega_i\ t + \Delta\phi]}{2}$
- $\sum = 2\ \mathrm{E\ Cos}\ \left[\omega_i\ t + \frac{\Delta\phi}{2}\right] \times \mathrm{Cos}\left[-\frac{\Delta\phi}{2}\right]$
- $\Delta = 2\ \mathrm{E\ Sin}\ \frac{[\omega_i\ t + \omega_i\ t + \Delta\phi]}{2} \times \mathrm{Sin}\ \frac{[\omega_i\ t - \omega_i\ t + \Delta\phi]}{2}$
- $\Delta = 2\ \mathrm{E\ Sine}\ \left[\omega_i\ t + \frac{\Delta\phi}{2}\right] \times \mathrm{Sine}\left[-\frac{\Delta\phi}{2}\right]$

BLOCK DIAGRAM OF PHASE MONOPULSE (CONTD ..)

- $\Sigma \times \Delta = 2\,\mathrm{E}\,\mathrm{Cos}\left[\omega_\mathrm{i}\,\mathrm{t} + \frac{\Delta\varnothing}{2}\right]\,\mathrm{Cos}\left[-\frac{\Delta\varnothing}{2}\right] \times$

  $- 2\,\mathrm{E}\,\mathrm{Sin}\left[\omega_\mathrm{i}\,\mathrm{t} + \frac{\Delta\varnothing}{2}\right]\,\mathrm{Sin}\left[-\frac{\Delta\varnothing}{2}\right]$
- $\left[\omega_\mathrm{i}\,\mathrm{t} + \frac{\Delta\varnothing}{2}\right] = \omega_\mathrm{i}\,\mathrm{t}$ since $\frac{\Delta\varnothing}{2}$ is small
- $\Sigma \times \Delta = 2\,\mathrm{E}\,\mathrm{Cos}\,(\omega_i\,t)\mathrm{Cos}\left[\frac{\Delta\varnothing}{2}\right] \times 2\,\mathrm{E}\,\mathrm{Sin}\,(\omega_i\,t)\,\mathrm{Sin}\left[\frac{\Delta\varnothing}{2}\right]$

But Sin 2 A = 2 Sin A . Cos A

-
-

BLOCK DIAGRAM OF PHASE MONOPULSE (CONTD ..)

- $\Sigma \times \Delta = \mathrm{E}^2 \,\mathrm{Sin}\left[2 \;\omega_\mathrm{i}\, \mathrm{t}\right] \,\mathrm{Sin}\,\Delta\emptyset$
- $\Sigma \;\times\; \Delta \;= \mathrm{Sin}\,\Delta\emptyset \;\; E^2\, Sin\, [2 \;\omega_i\, t]$

- Output of Amplitude Detector

  $\mathrm{Ed} = \mathrm{E}^2 \sin\,(\Delta\emptyset) = \mathrm{E}^2\, \Delta\emptyset$ (For small values of $\Delta\phi$)

- Ed is applied to servo system for making $\Delta\emptyset$ zero

LIMITATIONS OF PHASE MONOPULSE

- **Limitations :**

i) High side lobe levels – give rise to large inaccuracies

ii) 4 Antennas are mounted to point the beams in same direction. Awkwardness of arrangement of antennas

CONTINUED IN RADAR 4D

(Jntuh)

RADAR SYSTEMS
(ECE 812 PE -5)
(ELECTIVE V)
UNIT – 4D
B.TECH IV YEAR II SEMESTER
BY
Prof.G.KUMARASWAMY RAO
(Former Director DLRL Ministry of Defence)
BIET

Acknowledgements

The contents , figures , graphs etc., are taken from the following Text books & others

" INTRODUCTION TO RADAR SYSTEMS "

Merill I.Skolnik

Second Edition

Tata McGraw – Hill publishing company

Special Indian edition

"RADAR"

Byron Edde

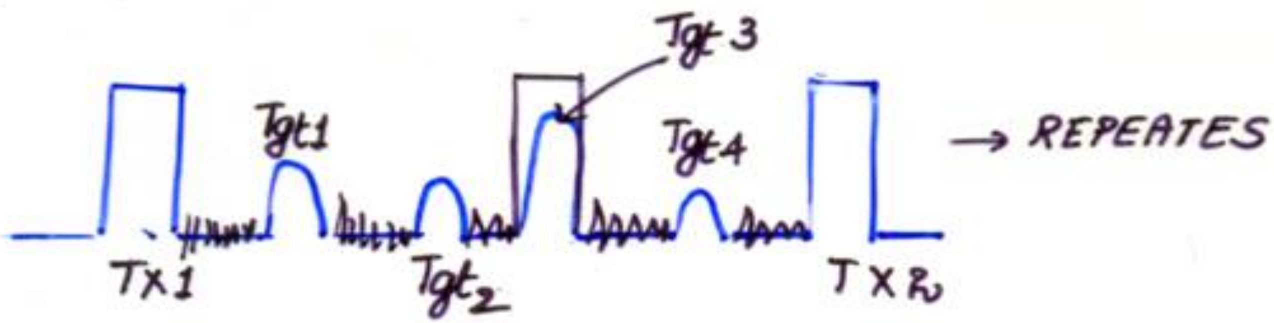
LPE Pearson Education

TRACKING IN RANGE

(Jntuh) **Explain how tracking in range is achieved using split range gates**

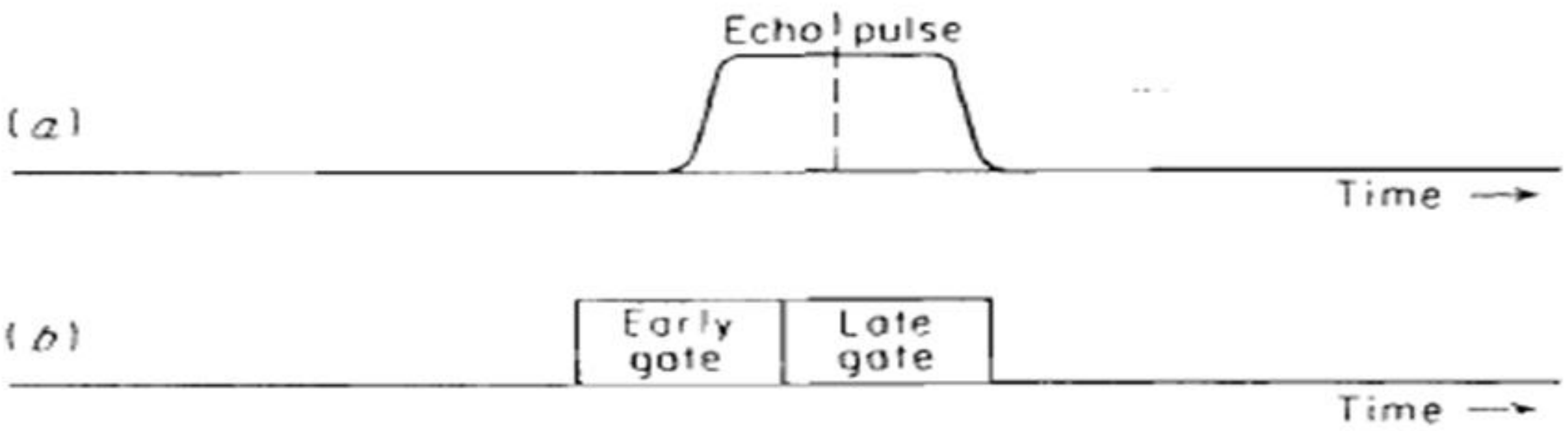
TRACKING IN RANGE

- Tracking radars track the target in angle as well as in Range.
- Range can be tracked by an operator by positioning the range gate by a hand wheel while looking in 'A' or 'J' scope.
- It becomes difficult to continuously move the hand wheel if the target is moving fast .
- So Automatic range tracking becomes a necessity.

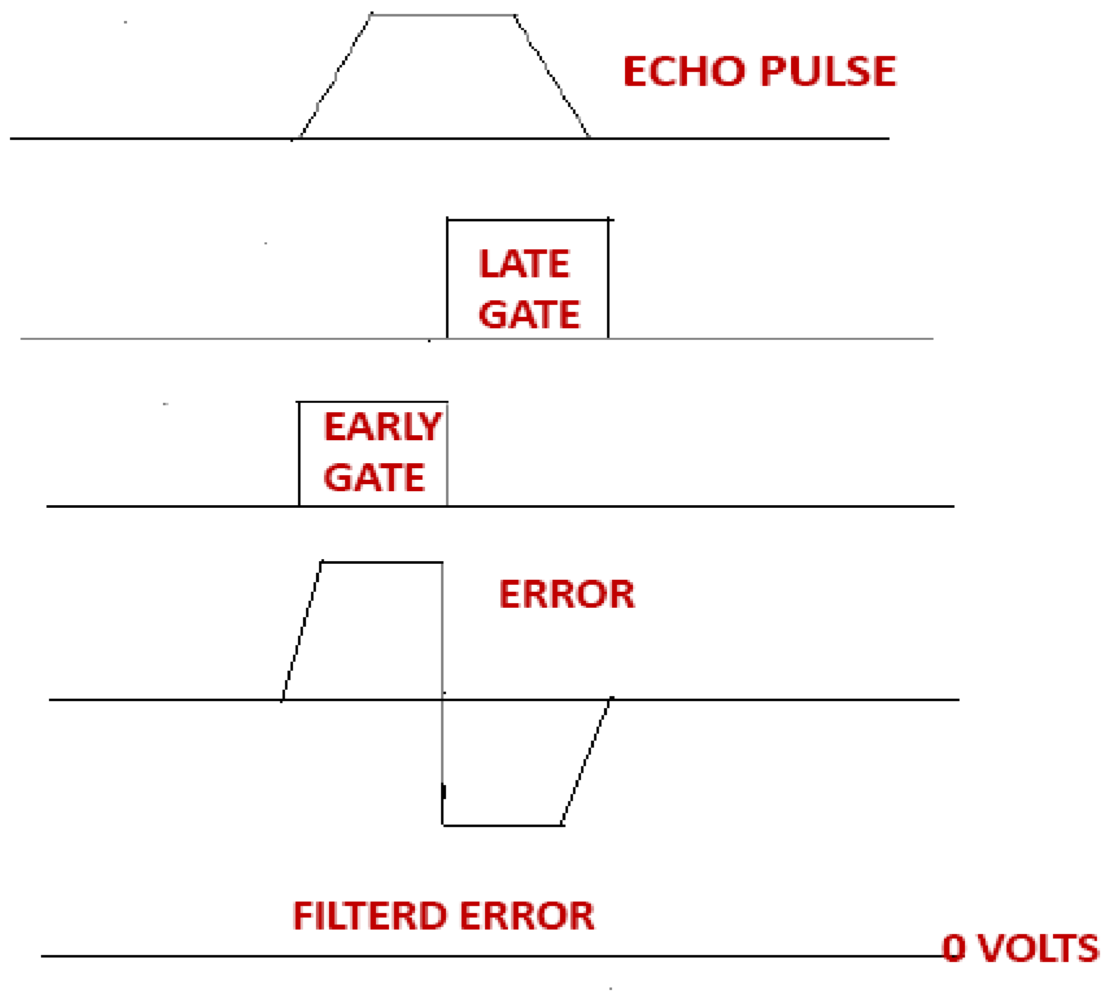


SPLIT GATE RANGE TRACKING

- **Principle :**



RANGE GATES STATIONARY



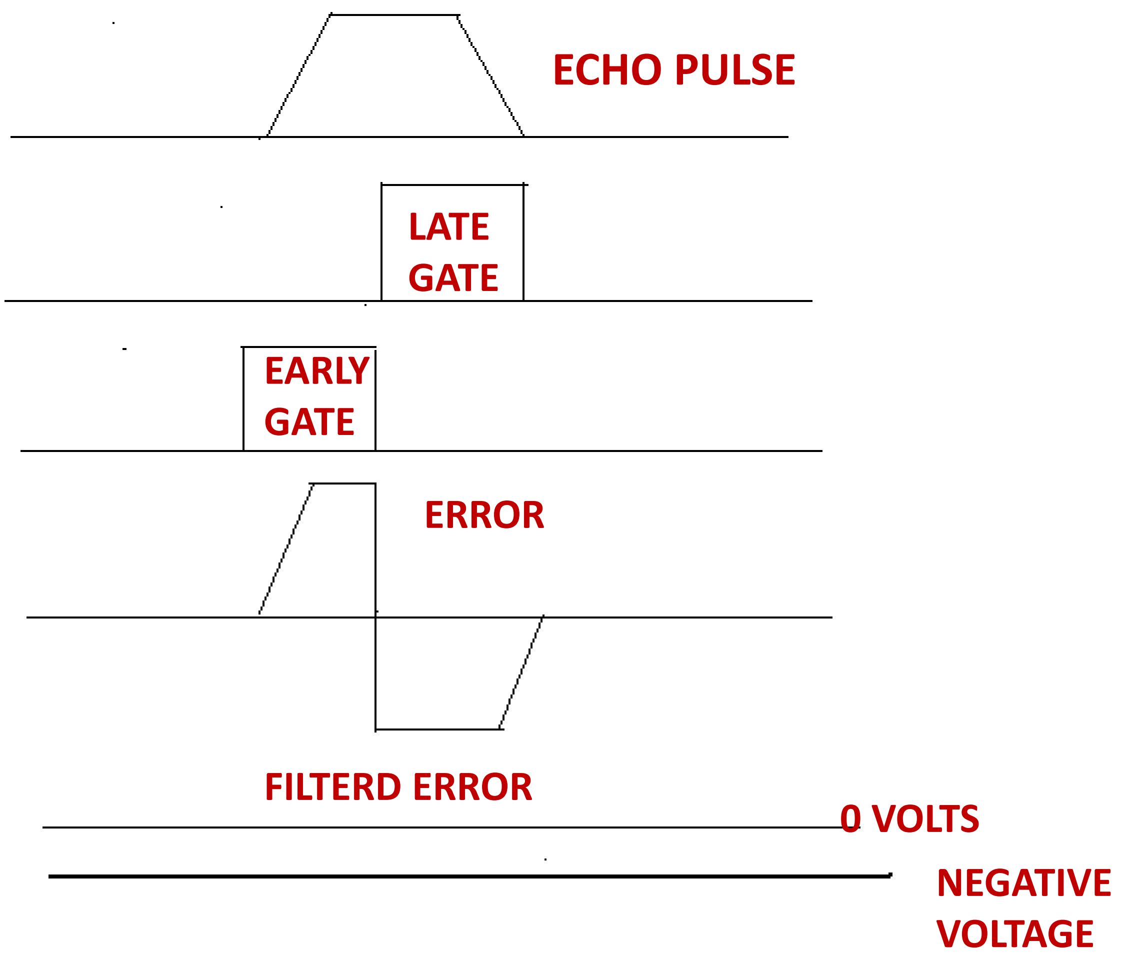
SPLIT GATE RANGE TRACKING (CONTD ..)

- 2 Range gates are generated (i) Early Gate (ii) Late Gate.
- Split range gates are placed on the Echo signal.

➢ Case(i) Range Gates Stationary

- When the centre position of the split range gates and the centre position of Echo coincides, the portion of signal energy in Early Gate is same as the portion of signal energy in Late Gate. Subtraction of these areas under these Gates gives a value Zero. In this case the Range Gates remain stationary.

TARGET MOVES TO RIGHT

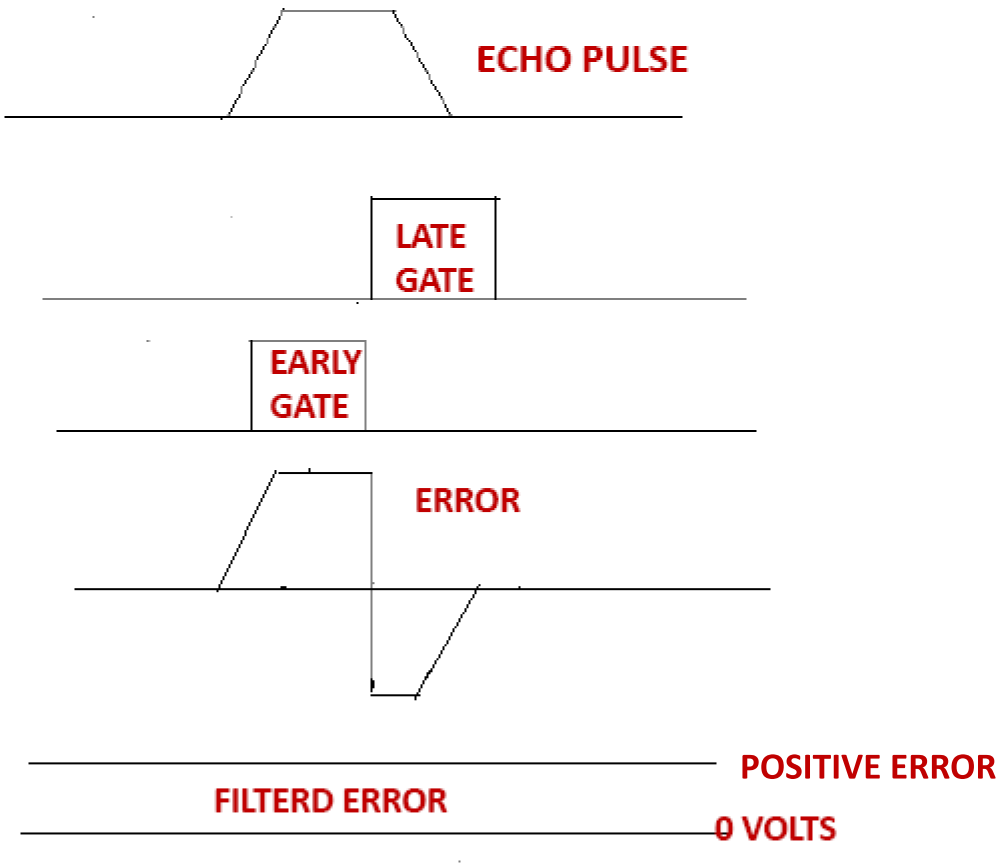


SPLIT GATE RANGE TRACKING (CONTD ..)

➢ Case(ii) TARGET MOVES TO RIGHT

- Portion of Echo energy in Early gate is less compared to portion of Echo energy in Late gate.
- Echo energies are subtracted . An error signal is produced because of subtraction.
- Error signal is the measure of the difference between centre of the Echo pulse and centre of the split gates
- Sign of Error signal (in this case negative) determines the direction of movement of split Gates.
- An Automatic feed back control system moves the split gate until the split range gates are centered on the pulse. The gates are moved until the error becomes zero.

TARGET MOVES TO LEFT



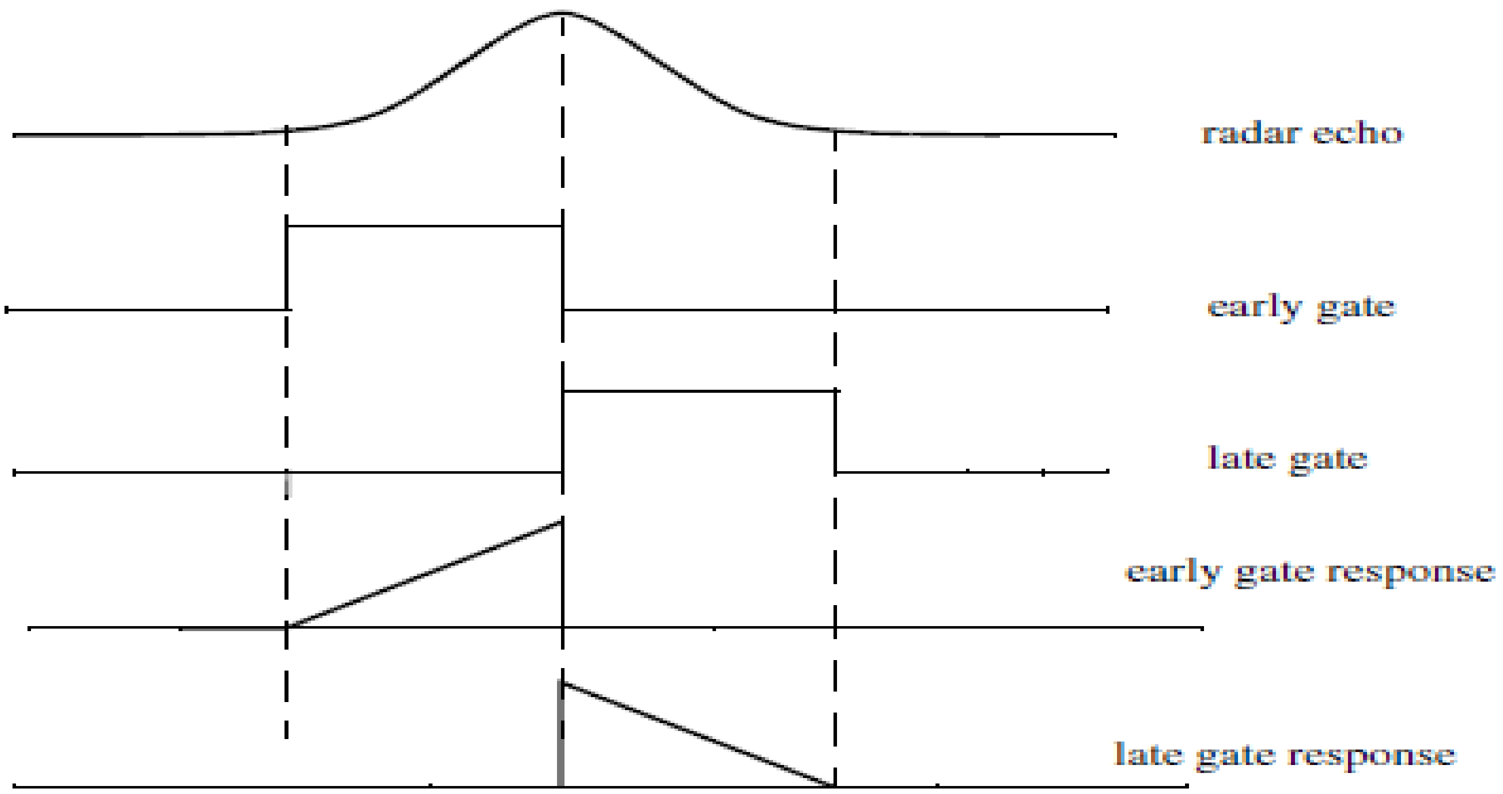
SPLIT GATE RANGE TRACKING (CONTD ..)

➢ Case(iii) TARGET Moves to Left

- Echo energy in Early gate is more than in the Late Gate.
- Subtraction of the echo energies result in Position Error.
- Feedback servo moves the position of the split range gates to the left and repositions the centre of the gates until error becomes zero
- Thus automatic tracking is established without operators interference when the target moves in range.

SPLIT GATE RANGE TRACKING

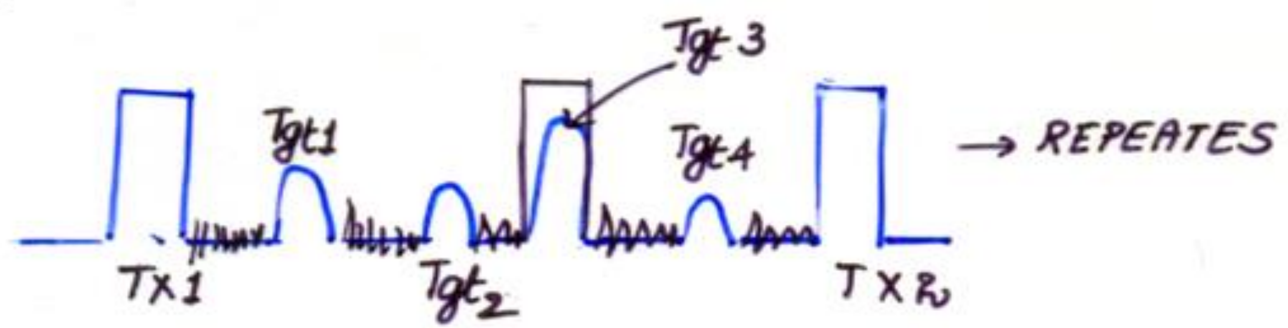
- **Practical range gate :**



SPLIT GATE RANGE TRACKING (CONTD ..)

➢ **Advantages**

1. Isolates one target from the other targets at different ranges.



2. Improves S/N Ratio since it eliminates noise from other range cells.
3. Box car generator can be used which in turn improves S/N

SPLIT GATE RANGE TRACKING (CONTD ..)

➢ Target Tracking Accuracy

i. Narrow width of gates corresponds to less noise.

ii. To capture all the signal energy in the echo, gate width need to be large.

- So width of gates is a compromise of the above two controversial requirements.
- Also accuracy depends on

i. pulse shape and width of the echo pulse

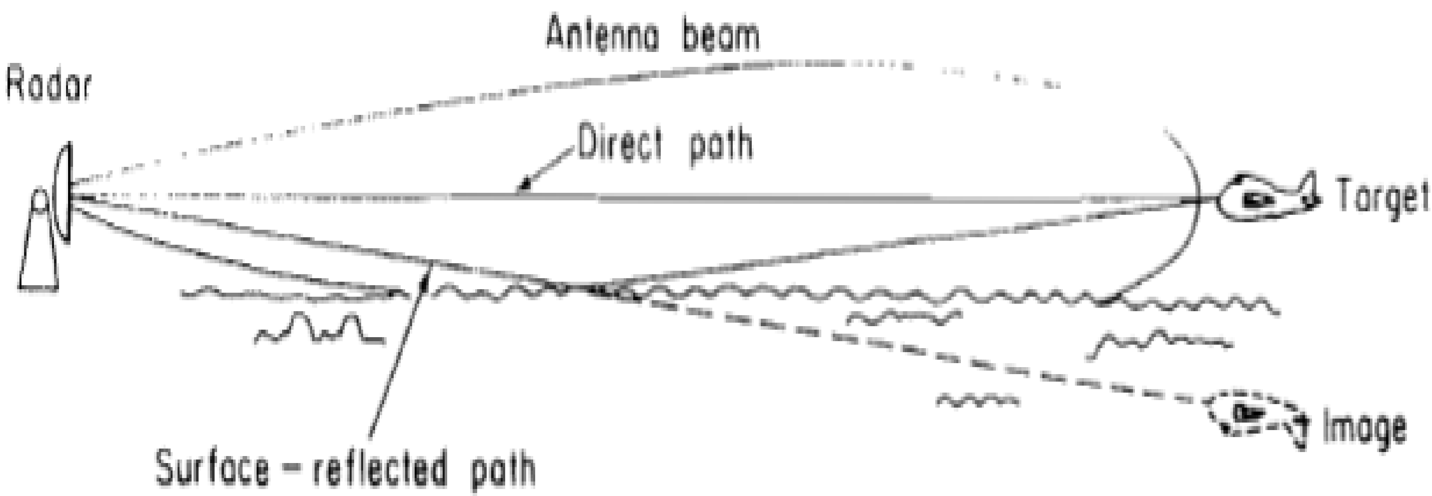
ii. band width

iii. number of pulses.

LOW ANGLE TRACKING

LOW ANGLE TRACKING

- Target flying near the surface of earth or sea requires Low Angle Tracking.
- Radar Rx gets 2 echo pulses one from direct path (reflected from target) and another indirect path (reflected from ground or sea surface)



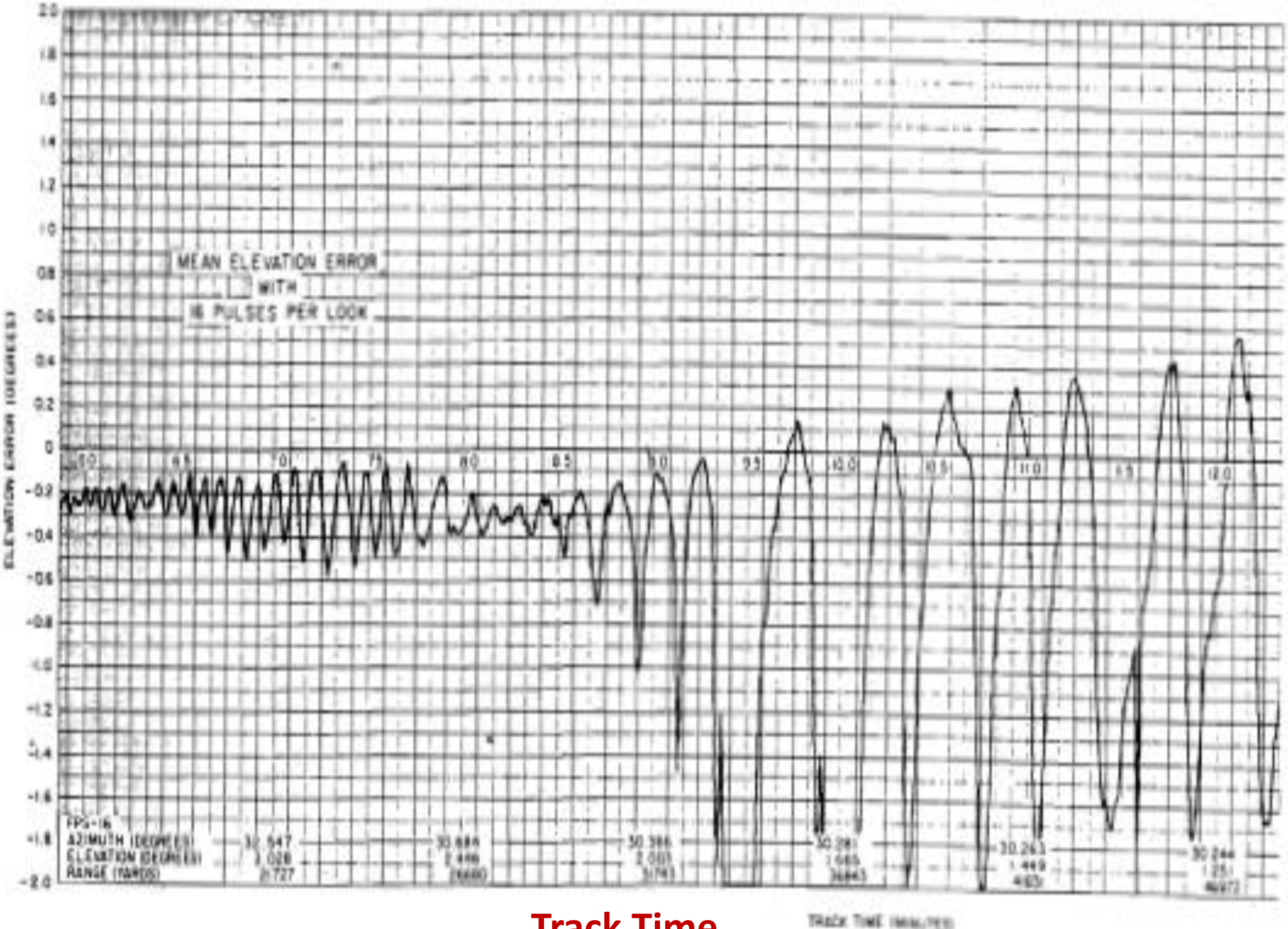
LOW ANGLE TRACKING (CONTD ..)

- Surface reflected signal is called the multipath.
- Direct signal and multipath signal combine and give rise to erroneous angle tracking of target in elevation.
- Multi path can be thought of as a signal originating from a fictitious target called the mirror target.
- The error caused due to mirror target is called glint error.

Range	Elevation Angle	Multipath effect	tracking
Small	Large	Less	Smooth
Intermediate	0.8 to 6 beam width	Enters through side lobes	Makes small oscillations
Long	Less than 0.8 Beam width	Large interface	Angular excursions Large

LOW ANGLE TRACKING (CONTD ..)

ELEVATION ANGLE



Track Time

LOW ANGLE TRACKING (CONTD ..)

➢ Avoiding Large Tracking Error in Elevation

i. Use narrow beam width so that multipath can be avoided to certain extent.

ii. Employ Off-Axis tracking or Off-Boresight tracking

- Antenna is locked in elevation at some small positive angle while tracking in Azimuth is continued
- The elevation angle could be 0.7 to 0.8 Beam width.
- Elevation error can be assumed to be half way between the horizon and antenna bore sight.

iii. Use heavy smoothing

ACQUISITION

ACQUISITION

- Track radar must find and acquire the target before it can operate as a tracker.
- Tracking radars employ a narrow pencil beam antenna.
- Searching the hemisphere in space for an aircraft target would take long time using a narrow beam

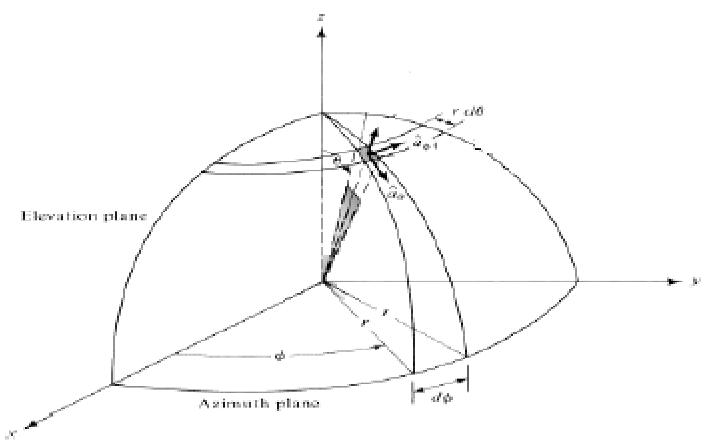


Figure indicates azimuth and elevation plane

ACQUISITION (CONTD ..)

➢ Necessity for Acquisition

- Let us say the Beam width of a Track Radar is 0.1^o.
- In 360^o space number of Beams $\frac{360}{0.1}$ =3600
- 10 pulses with 500 μ sec pulse interval are used from each individual beam to determine the presence or absence of a target.
- Time taken for searching the hemisphere of space

= $10 \times 500 \times 10^{-6} \times 3600 = 18.0$ sec

- If target speed is 300 Mt/sec (1 Mach), the target would have moved by 300 x 18.0 = 5400 Mts before next scan beam is on the target.
- This shows the necessity of acquisition before tracking

(Jntuh) **What are the various methods of acquisition before tracking a target with a radar? Explain**

(Jntuh) **Explain scanning pattern employed with pencil beam antenna**

SCANNING PATTERNS

- Various common types of scanning patterns employed are

(i) Helical scan

(ii) Palmer scan

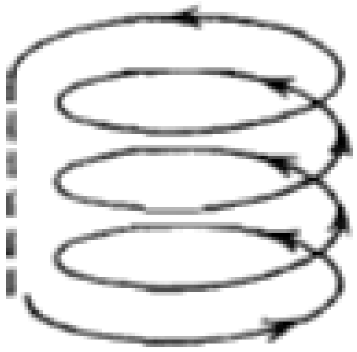
(iii) Spiral scan

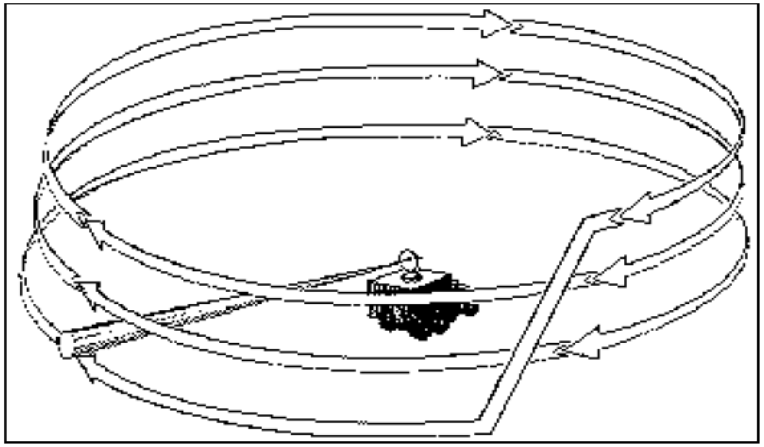
(iv) Raster scan

(v) Nodding scan

SCANNING PATTERN (CONTD ..)

➢ **(i) Helical Scan**





- Antenna is continuously rotated in azimuth while it is simultaneously raised or lowered in elevation.

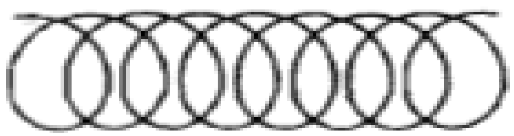
SCANNING PATTERN (CONTD ..)

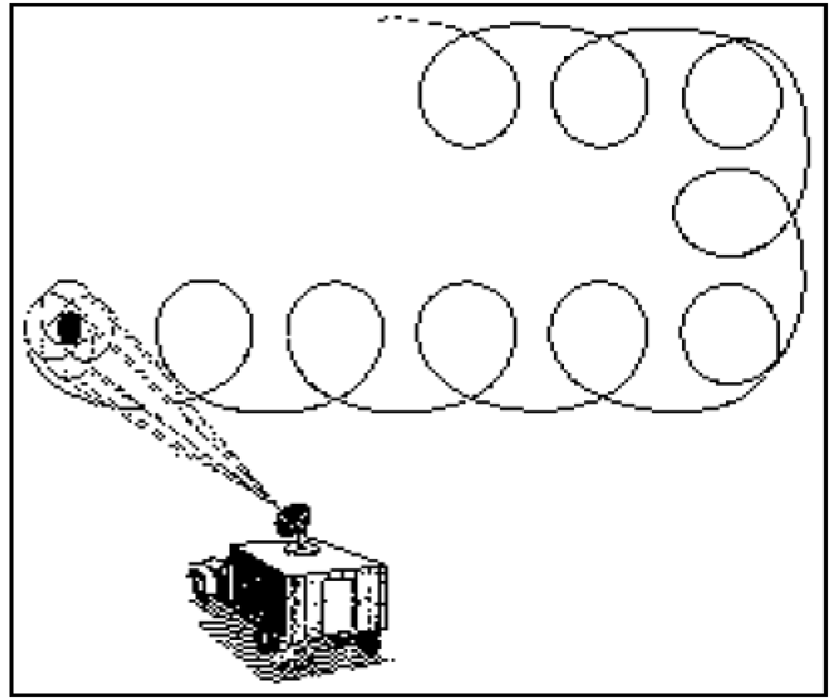
➢ Helical Scan (Contd ..)

- Movement of beam is like a helix in space.
- Helical scan was employed in search mode of SCR-584 fire control radar.
- SCR-584 rotated at 6 rpm and covered 20^{o} elevation angle in 1 min.

SCANNING PATTERN (CONTD ..)

➤ **(ii) Palmer Scan**





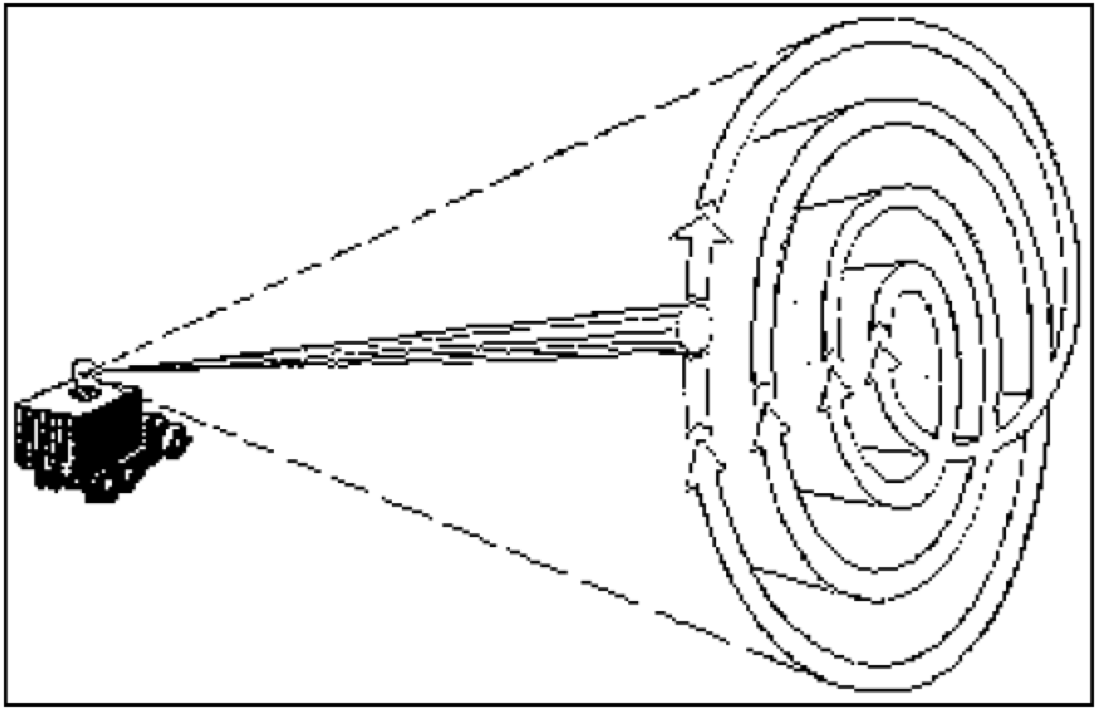
- Rapid circular scan(conical scan) about the axis of antenna, combined with a linear movement of the axis of rotation is called Palmer scan.

PALMER SCAN (CONTD ..)

- When aim of rotation is held stationary, the palmer scan reduces to the Conical scan.
- Palmer scan is used with conical scan tracking radars
- Track radar with conical scan will operate with a acquisition as well as track mode.
- During acquisition, squint angle is increased to reduce the time required to scan a given volume.

SCANNING PATTERN (CONTD ..)

- **(iii) Spiral scan**



- Spiral scan covers an angular search volume with circular symmetry.

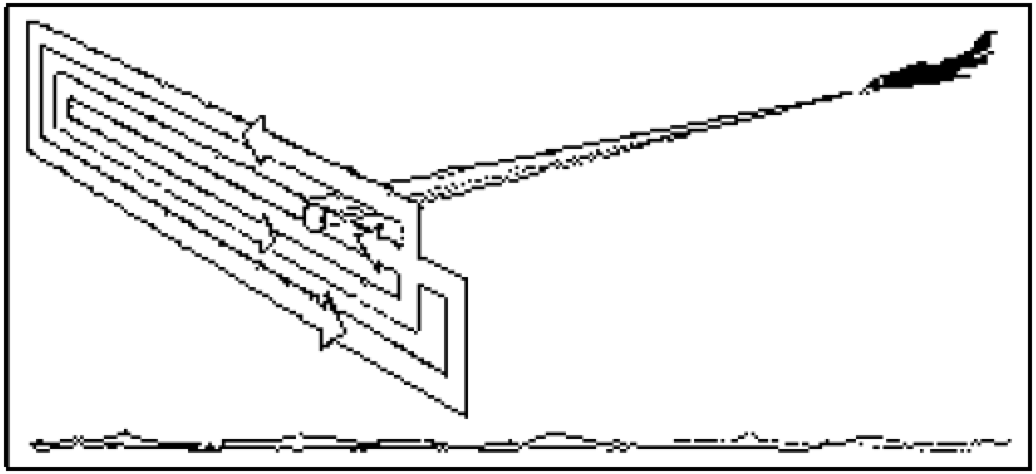
SCANNING PATTERN (CONTD ..)

➢ Disadvantage of palmer and spiral scan

- All parts of the scan volume do not receive the same energy unless the scanning speed is varied during the scan cycle.
- Number of echoes from a target, when searching with constant rate depends upon the position of the target with in the search area.

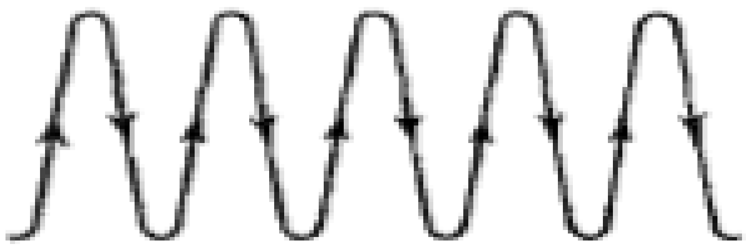
SCANNING PATTERN (CONTD ..)

- **(iv) Raster or TV Scan**



SCANNING PATTERN (CONTD ..)

➢ **(v) Nodding scan**



- Produced by oscillating the antenna beam rapidly in elevation and slowly in azimuth.

(Jntuh) **Compare the tracking techniques**

COMPARISION OF TRACKERS

COMPARISON OF TRACKERS

- **Disadvantages of sequential lobe switching:**

i. 4 pulses required to determine the position in 2 Dimensions. Time taken is more. So reduced Bandwidth.

ii. Fluctuations in signal level from pulse to pulse reduce tracking accuracy. Fluctuations are caused because of a) target RCS aspect ratio b) Modulation due to propeller blades (in helicopter)

iii. Antenna Gain at Boresight is less than Antenna peak Gain. So operational range reduces

iv. Reduction in S/N Ratio.

- **Advantage:** simple, light weight, single Rx

Comparison Of Monopulse Vs Conical Scan

Sl No	Characteristics	Conical Scan	Monopulse(Amplitude)
1	S/N ratio	• S/N ratio less • Tracks target away from peak of antenna beam	• S/N Ratio large • Sum pattern is used
2	Tracking accuracy	• less since S/N is less & Pulse to Pulse echo fluctuations	• Superior since S/N is large • Not affected by fluctuations from pulse to pulse
3	Minimum number of pulses required	•Requires minimum of 4 pulses per revolution of beam to extract angle in azimuth & elevation.	• 3 D extraction of positon requires only one pulse transmission

Comparison Of Monopulse Vs Conical Scan (Contd ..)

Sl No	Characteristics	Conical Scan	Monopulse(Amplitude)
4	Beam width	Beam width larger and so collects more noise.	Beam width less and so collects less noise
5	Complexity	• less complexx • Uses single feed • Requires one R_X channel	•More complex and expensive •Requires antenna comparator •Requires 3 R_X sum, Difference in Az & elevation
6	Susceptibility to Jamming	•More susceptible to jamming •Inverse conical scan jamming used.	•Less susceptible to jamming •Difference channel subtracts jamming noise.
7	Application	•Gun control Tracking Radar	•Missile Guidance Radar •Missile Homing Radars

END OF UNIT 4