Target tracking

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1. Introduction

- Tracking radar systems are used to measure the targets range, azimuth angle, elevation angle, and velocity
- Predict the future values
- Target tracking is important to military and civilian purposes as missile guidance and airport traffic control

Target tracking

Targets are divided to two types:

1- Single target
2- Multiple targets

Single target

1- Angle tracking

A- Sequential lobing

B- Conical scan

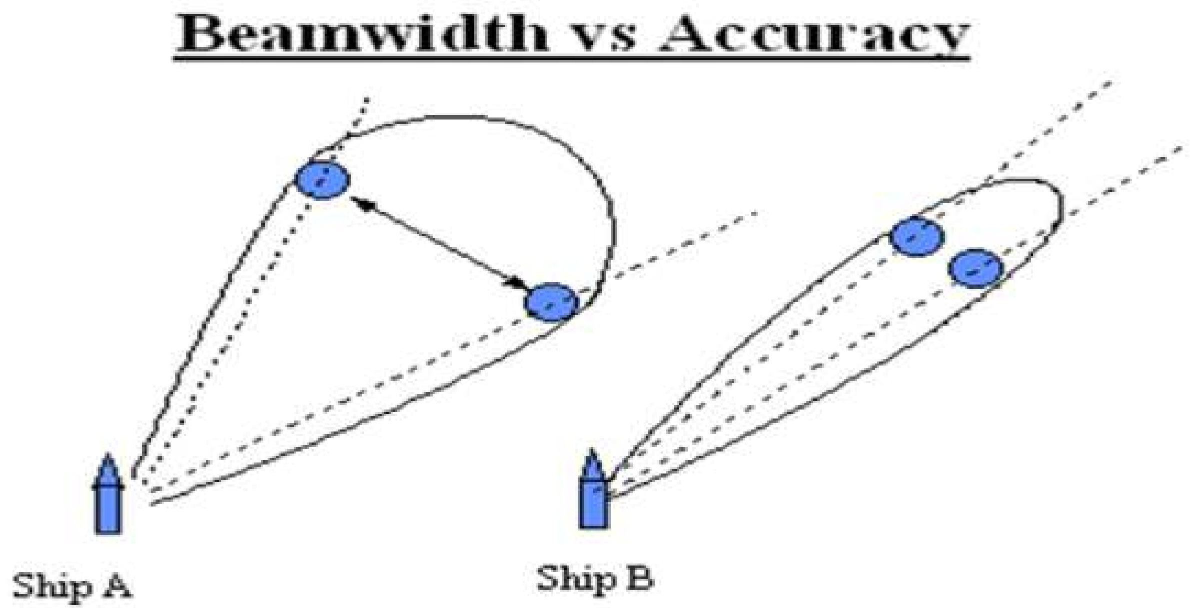
C- Amplitude compression monopulse

D- Phase compression monopulse

2- Range tracking

Relation between beamwidth and accuracy

Antennas with wide beamwidth are less accuracy than antennas with narrow beam

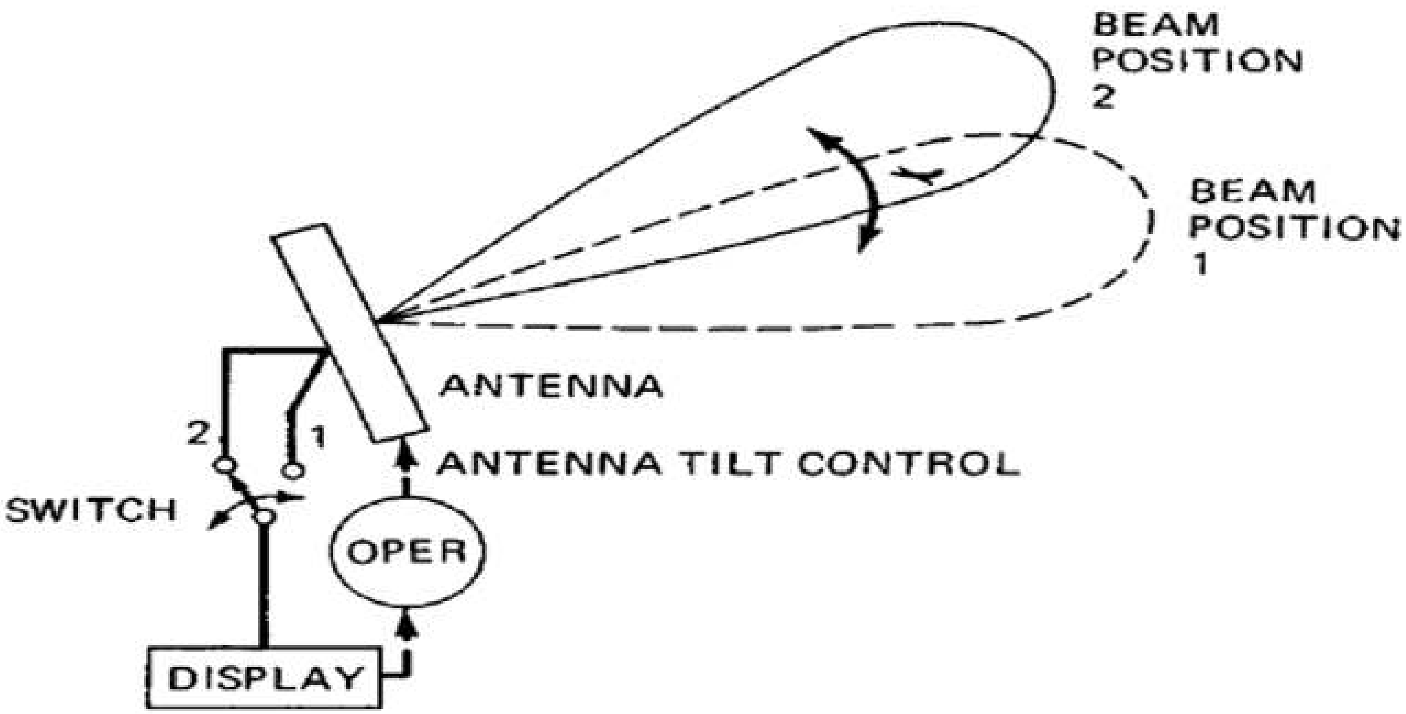


Pencil beam

In tracking processes radar used narrower beams

Line of Sight (LOS) axis

The LOS is called the radar tracking axis too



Error signal

- Describes how much the target has deviated from the beam main axis
- Radar trying to produce a zero error signal
- Azimuth and elevation error

Single target

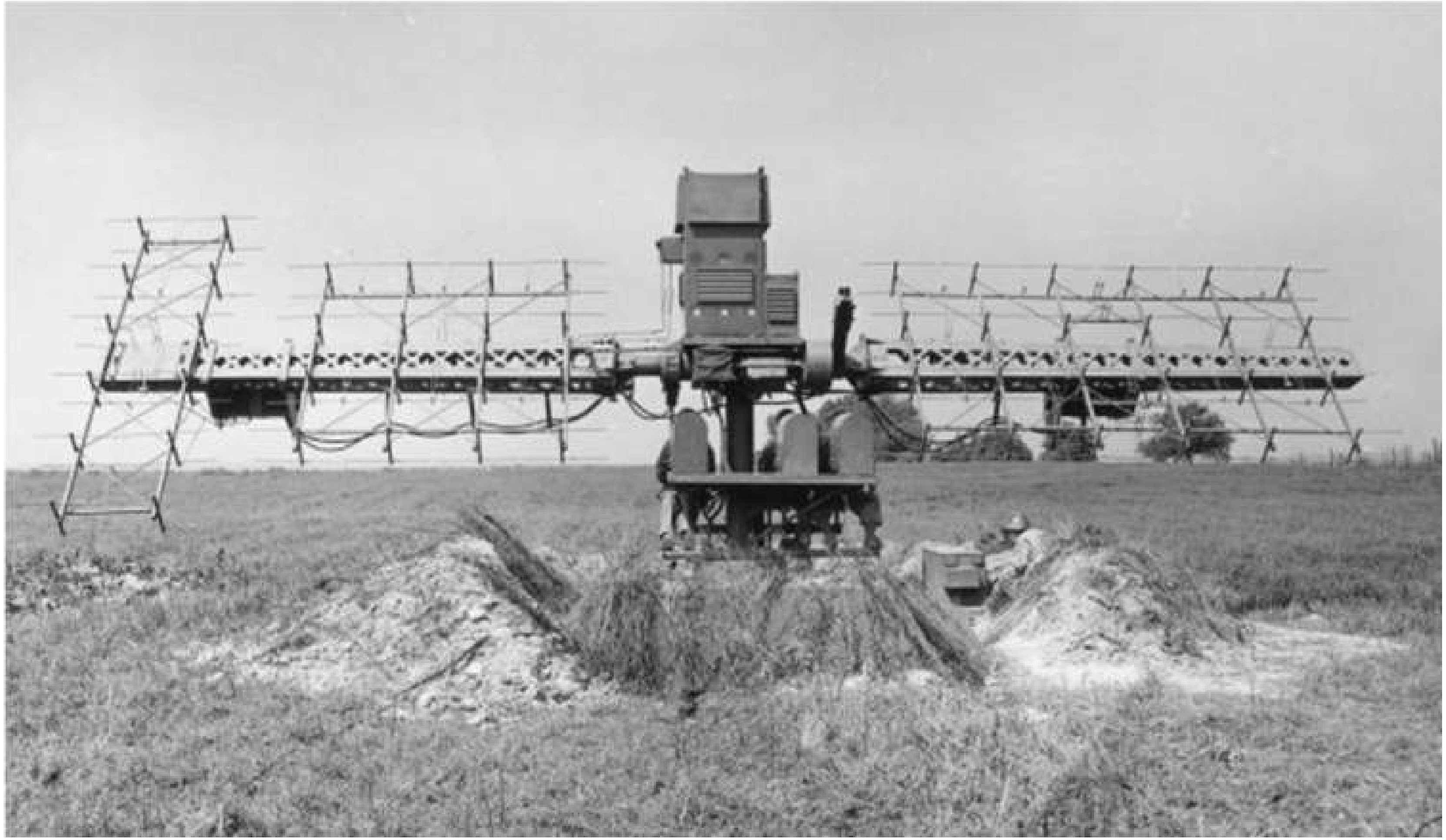
1. Sequential lobing

- Sequential lobing is often referred to as lobe switching or sequential switching

- Accuracy depends on the pencil beam width

- It is very simple to implement

SCR- 268

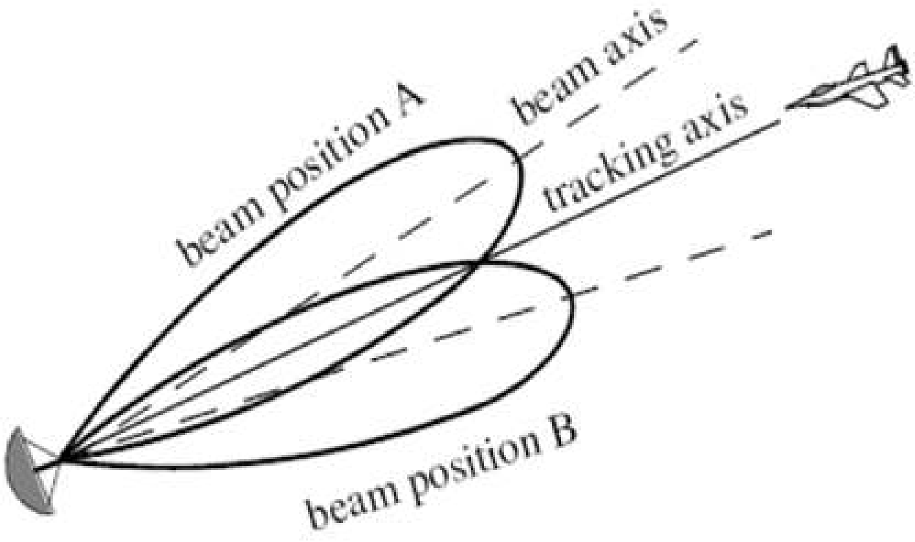


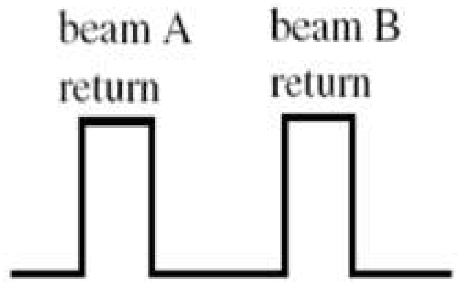
Concept of operation:

- Measuring the difference between the echo signals voltage levels

1- When the target being on the LOS

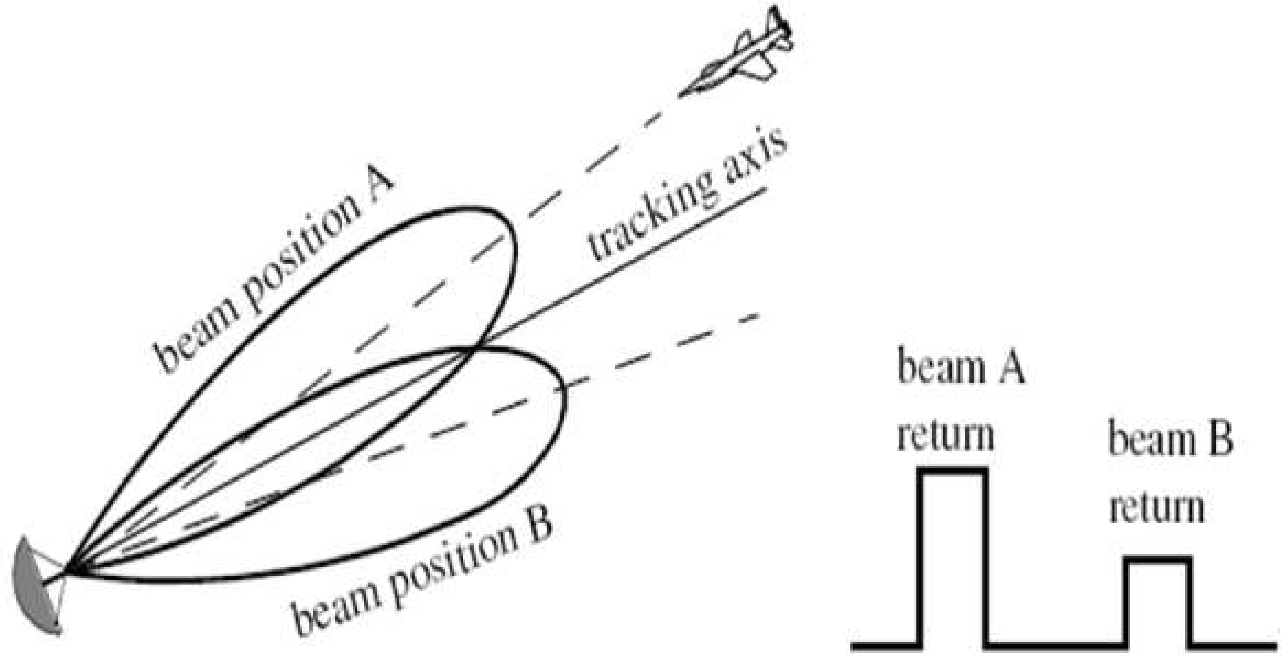
The difference between the echo signals voltage in (A) and (B) equal zero, that's mean zero error signal



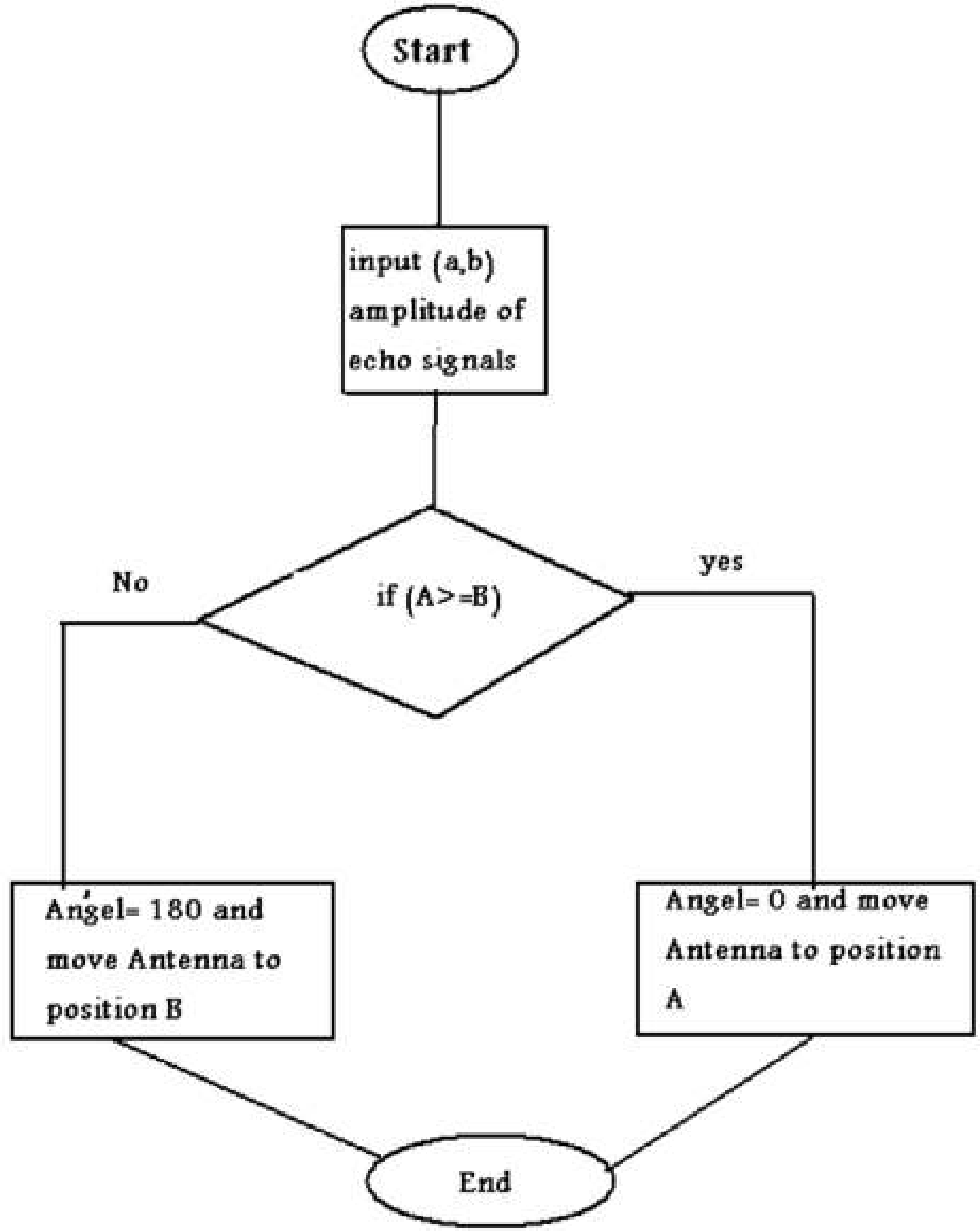


2. When the target being off the LOS

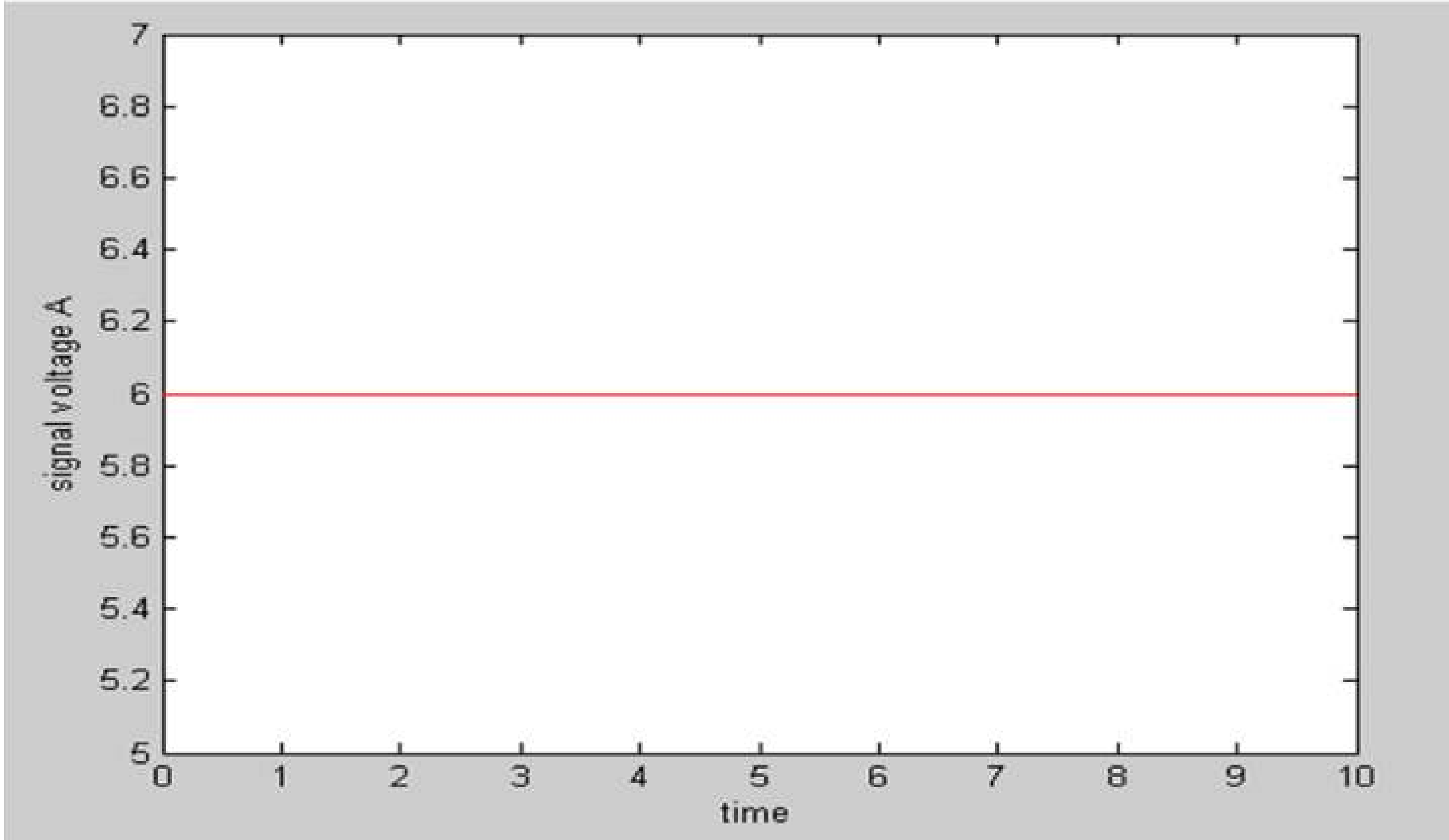
Signal in position(A) will attenuate more than signal in position(B) , that's mean a nonzero error signal



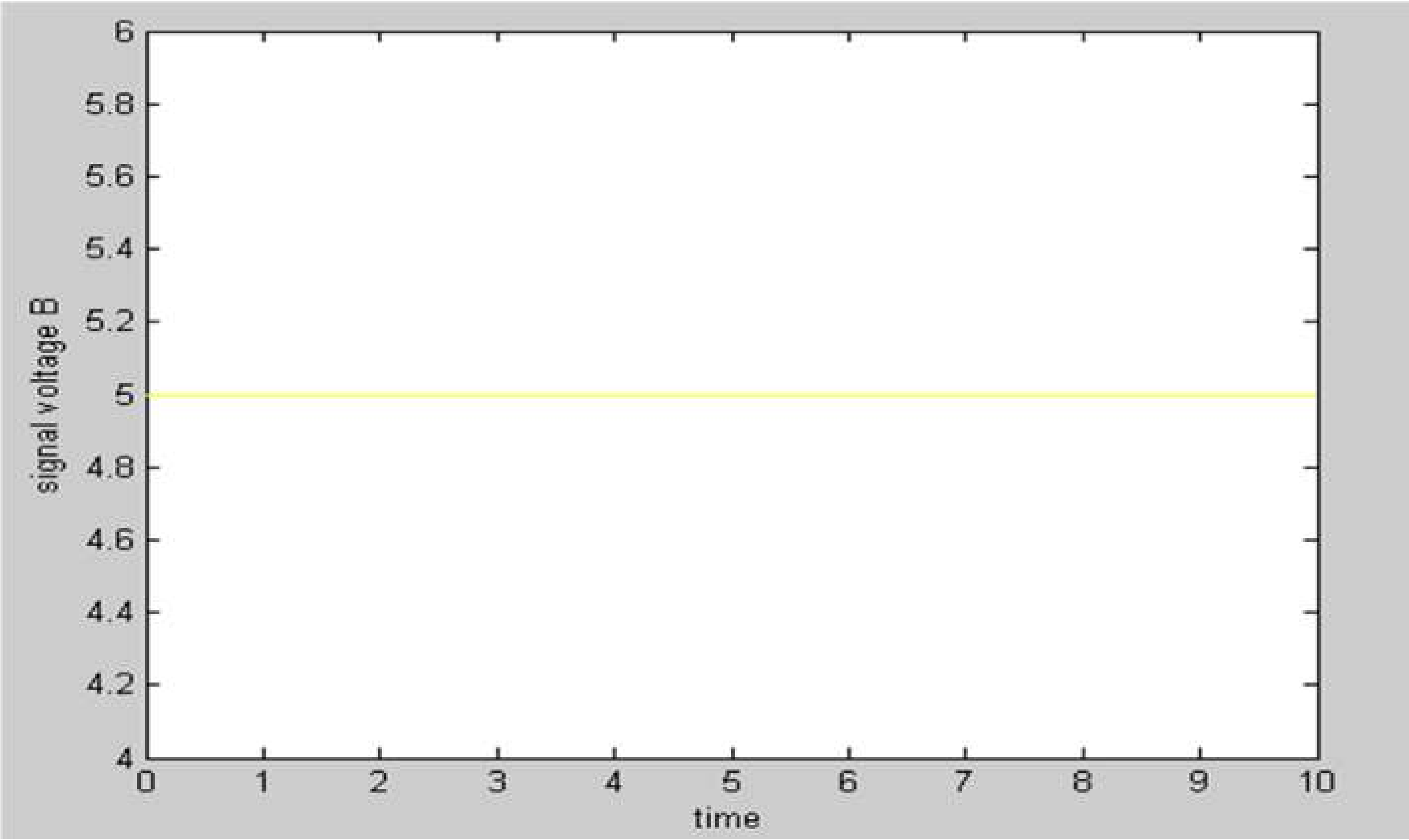
Matlab Code


Start
input (a,b) amplitude of echo signals
if (A>=B)
No
yes
Angel= 180 and move Antenna to position B
Angel= 0 and move Antenna to position A
End

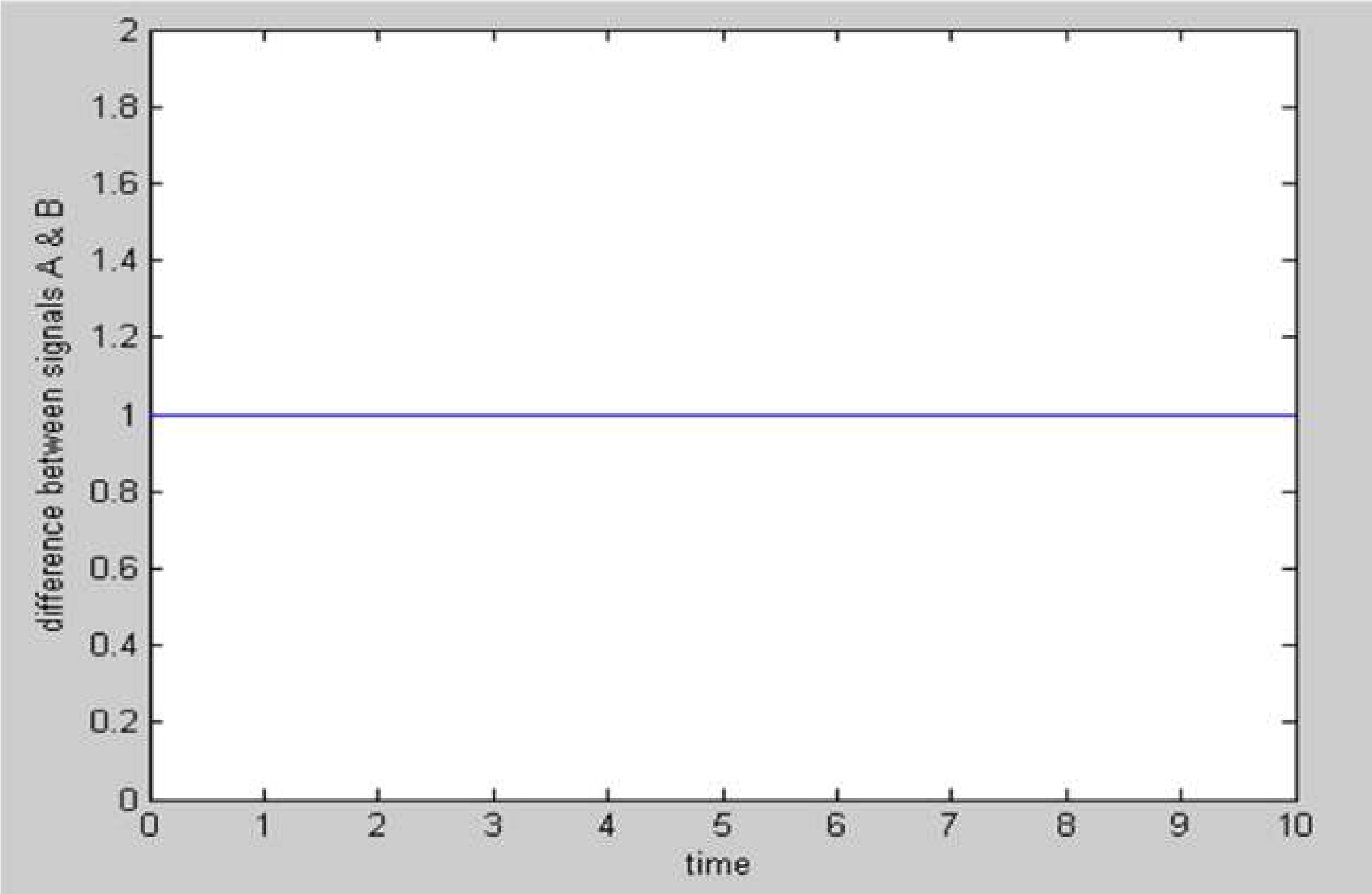
Echo Signal A



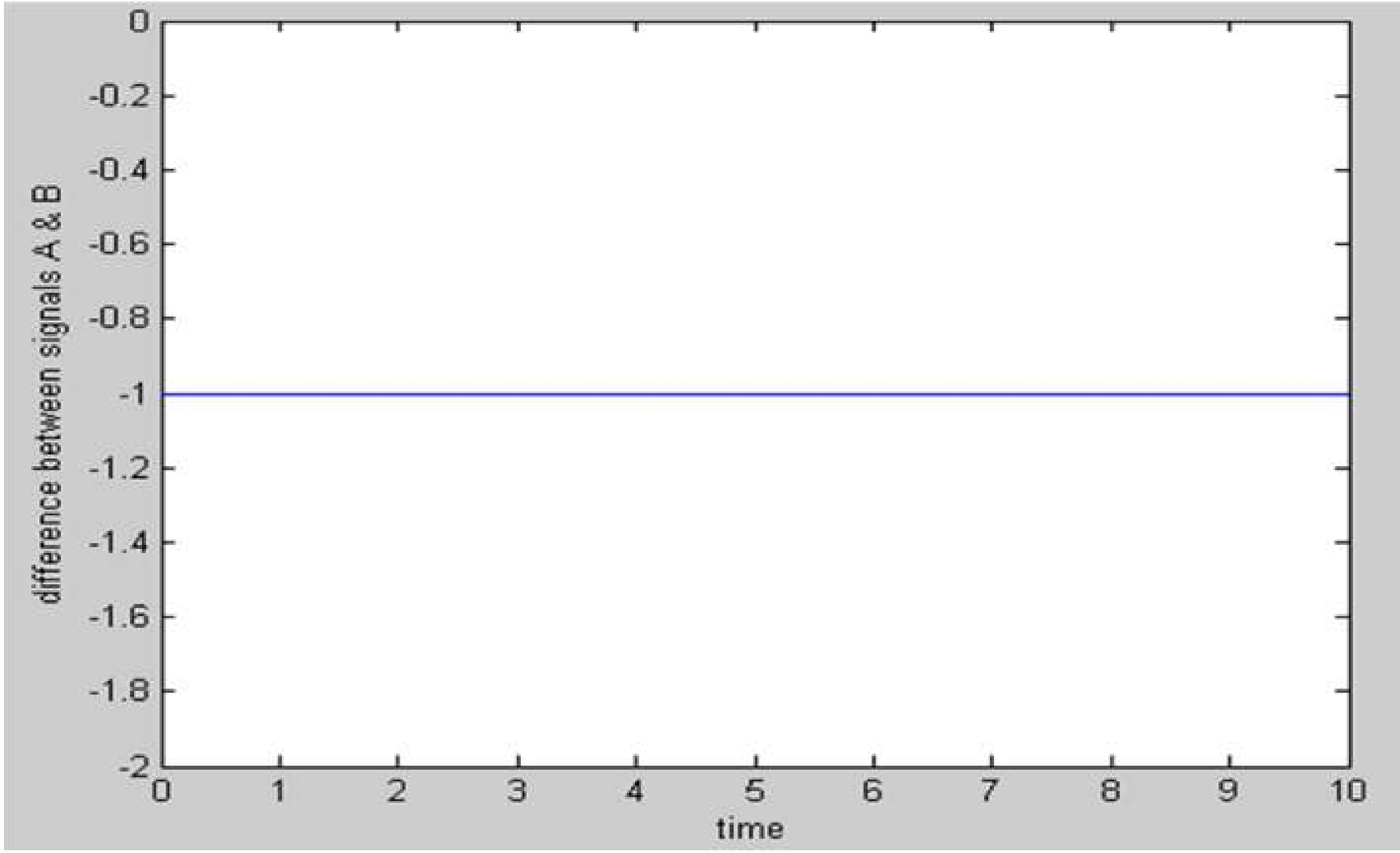
Echo Signal B



Difference between A and B:
1- A>=B, theta = 0

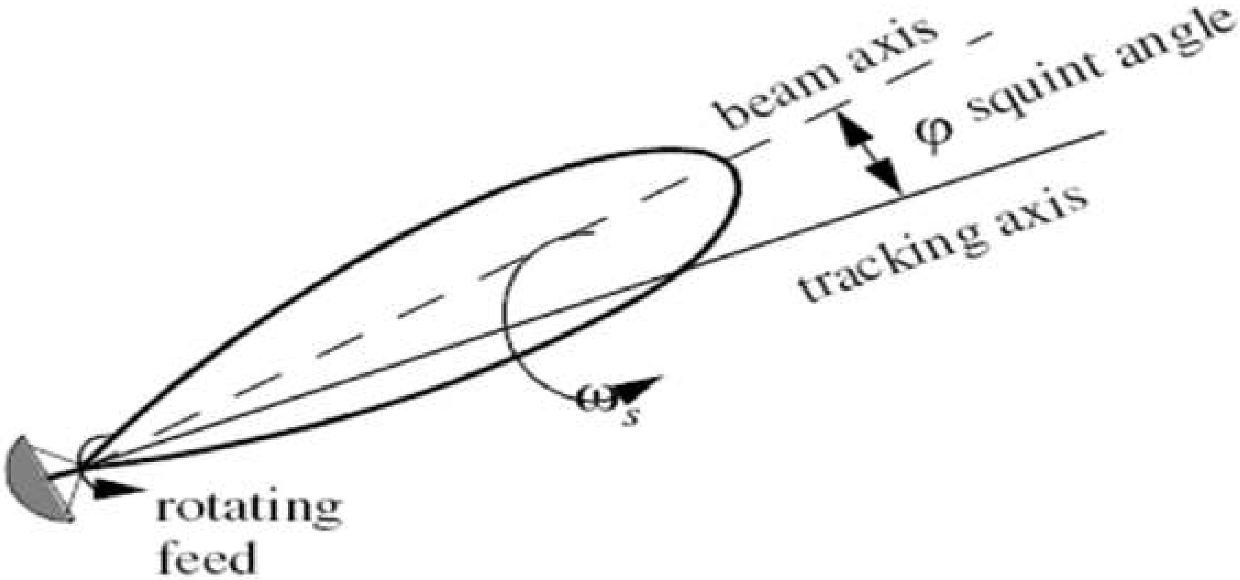


2- A<B, theta = 180



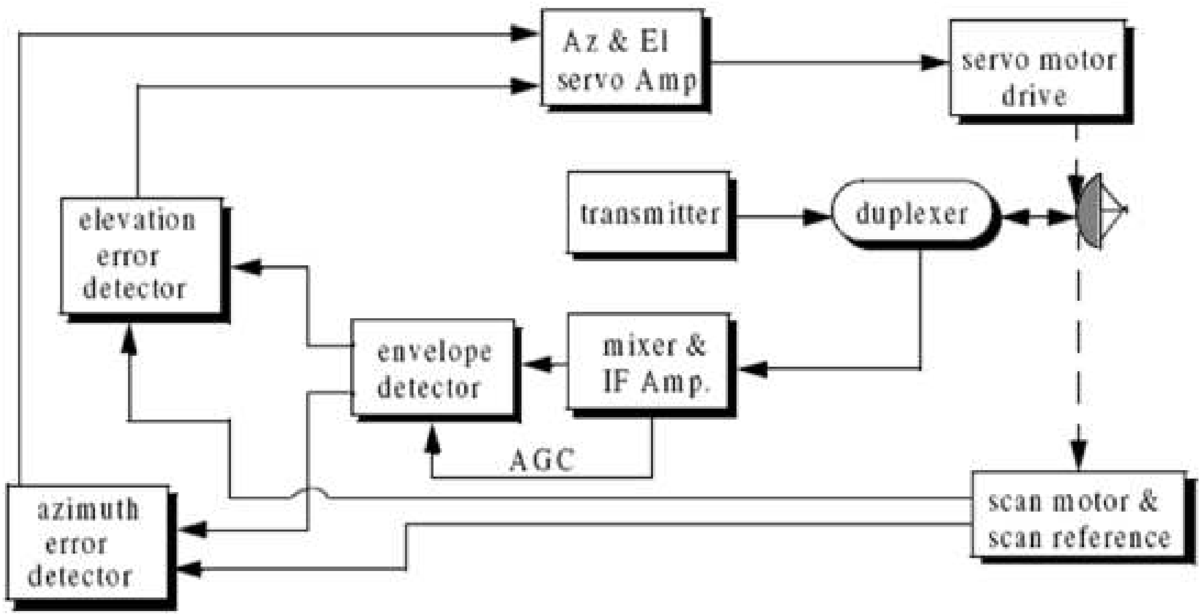
2. Conical scan

- It's an extension of sequential lobbing
- The feed of antenna is rotating around the antenna axis

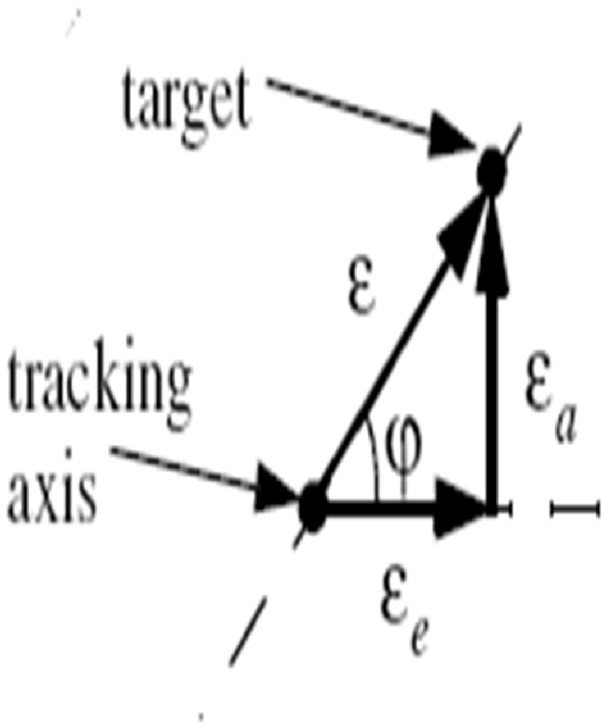


- The envelope detector is used to extract the return signal amplitude

- AGC is used to reduce the echo signal amplitude if it is strong and raises it when it is weaker



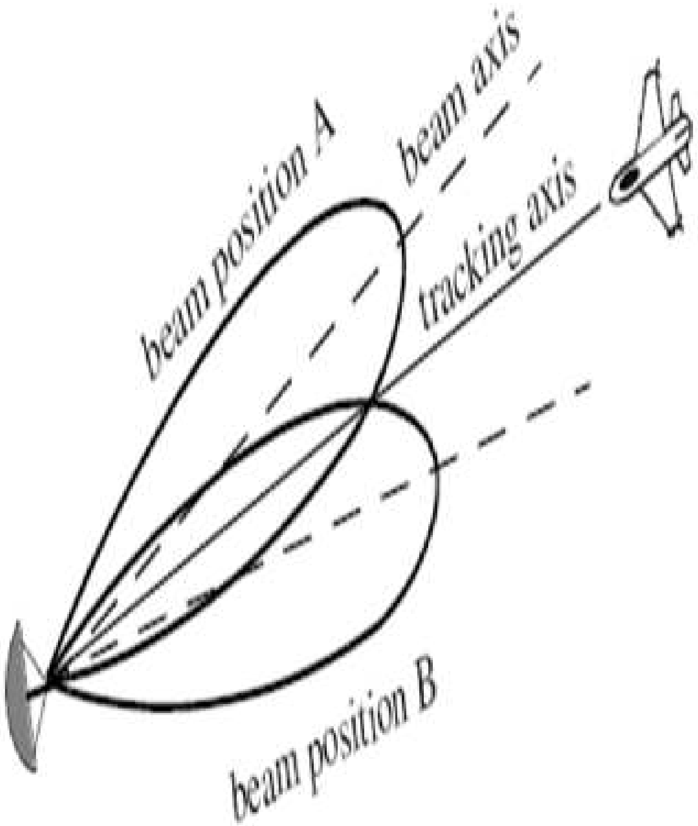
Elevation and azimuth error

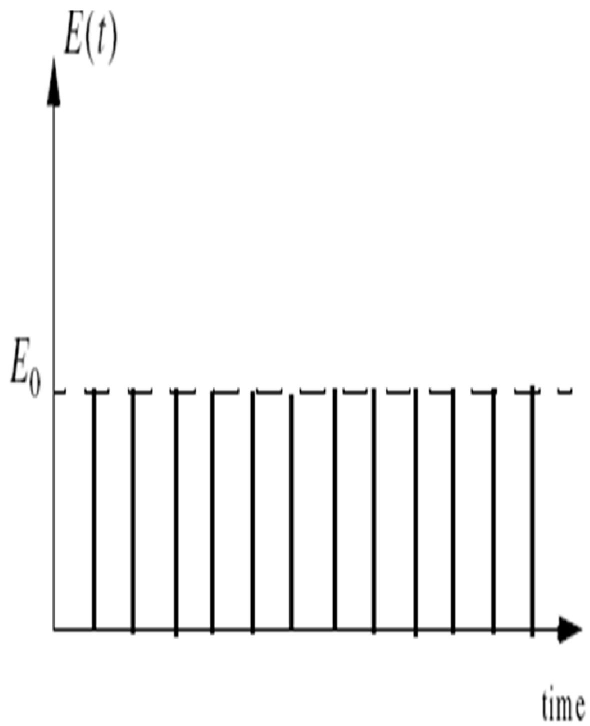


$$E_e(t) = -\frac{1}{2}E_0 \cos\varphi$$

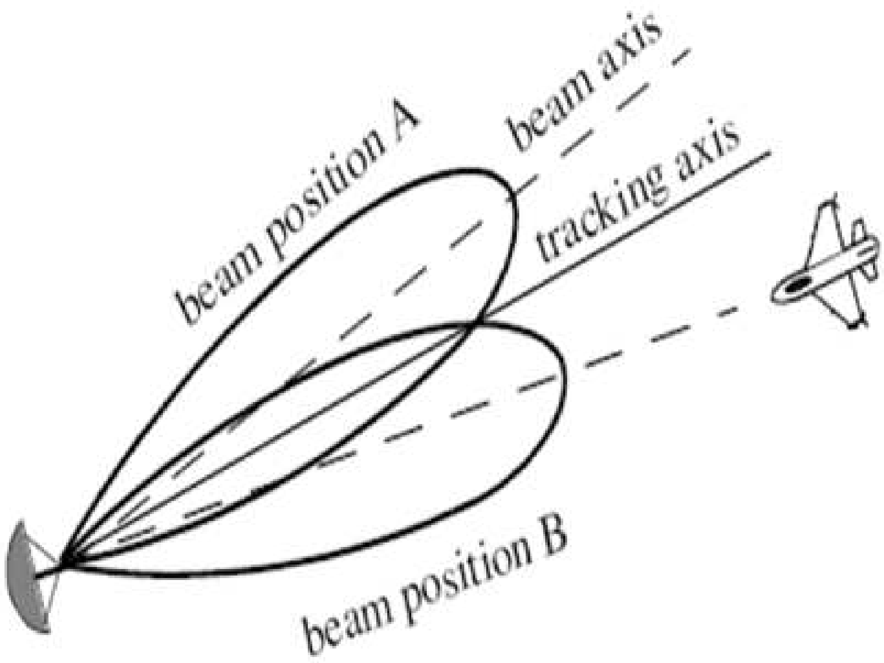
$$E_a(t) = \frac{1}{2}E_0 \sin\varphi$$

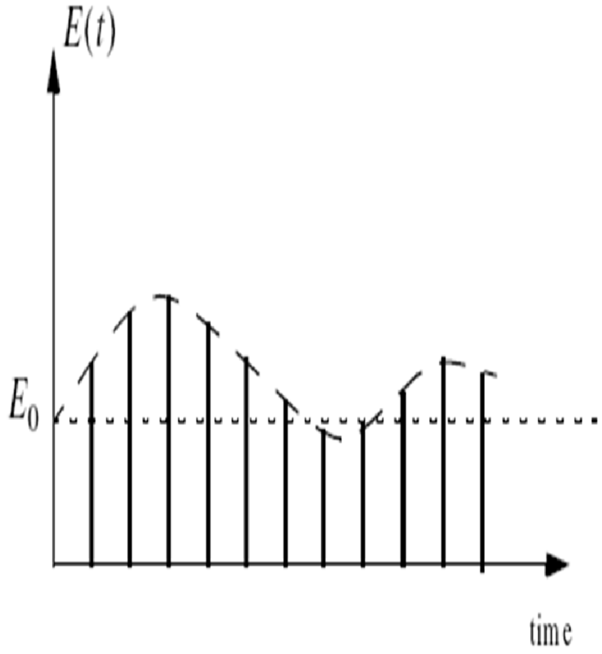
1- When the target being on the LOS





2. When the target being off the LOS



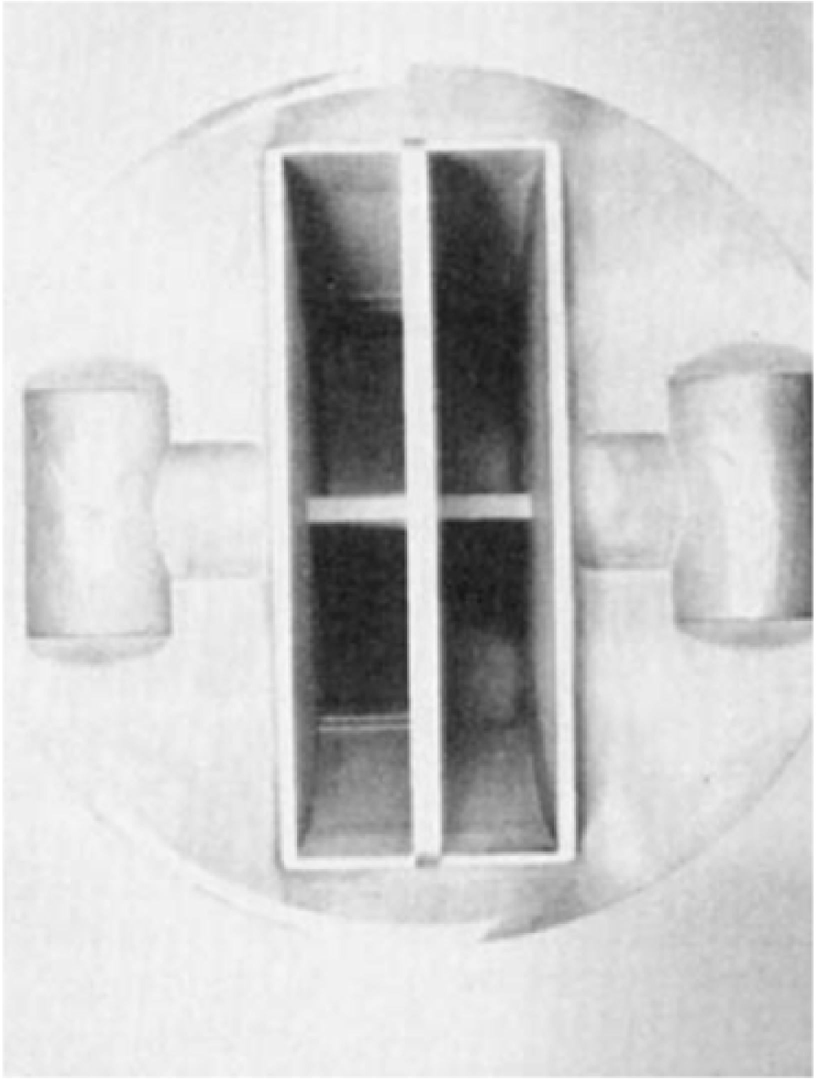


3. Amplitude compression monopulse

- This type is more accurate than sequential and conical scanning
- Feed generated four beams simultaneously with single pulse
- The four beams are inphase but have different amplitudes.

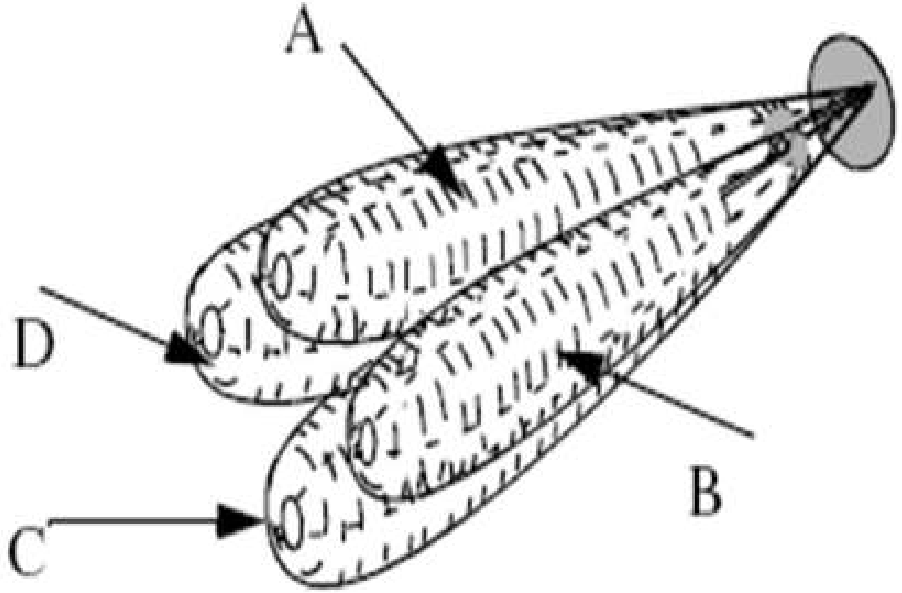
AN/FPQ-6 C-band monopulse precision tracking radar

Horn antenna generated 4 beams

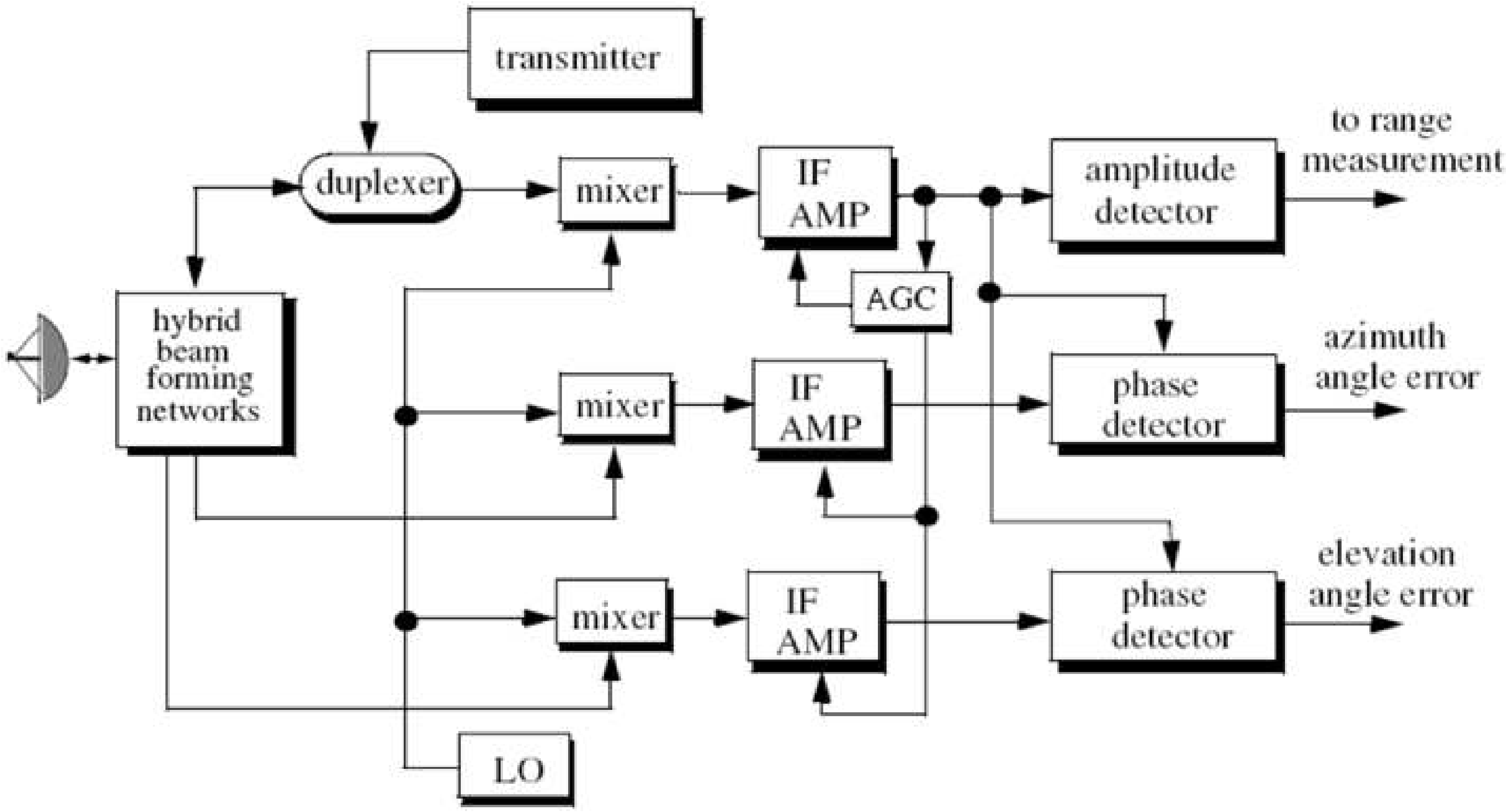


Four beams shape

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

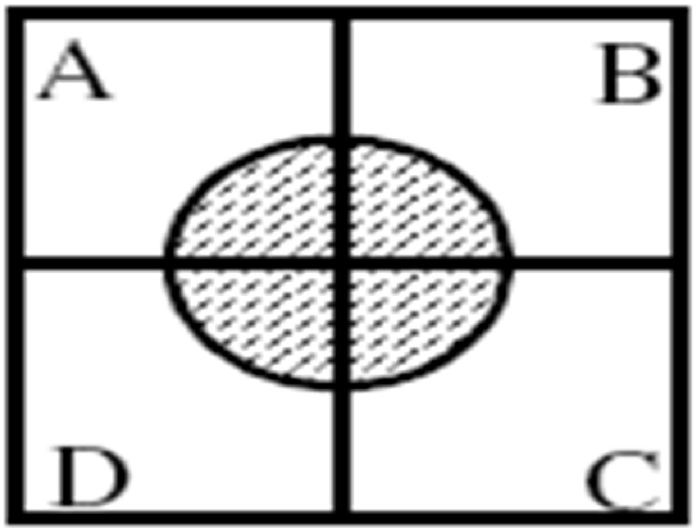


Simplified amplitude comparison monopulse radar block diagram

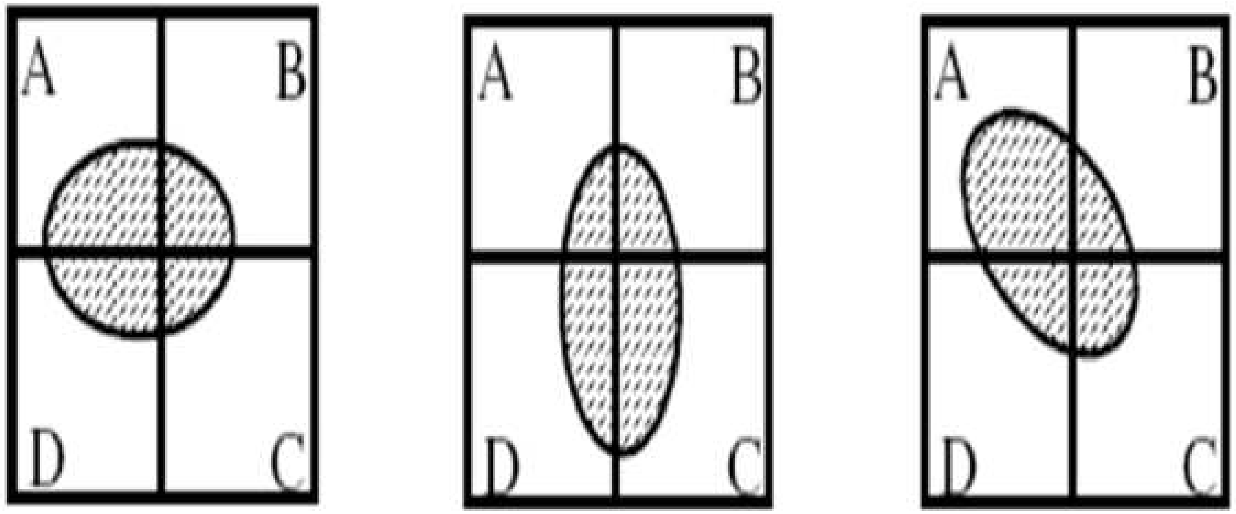


When the target being on the LOS

radar compares the amplitudes and phases of all echo signals of target



When the target being off the LOS



- To move the servosystem on the target we need to calculate Error signal output

Error signal output

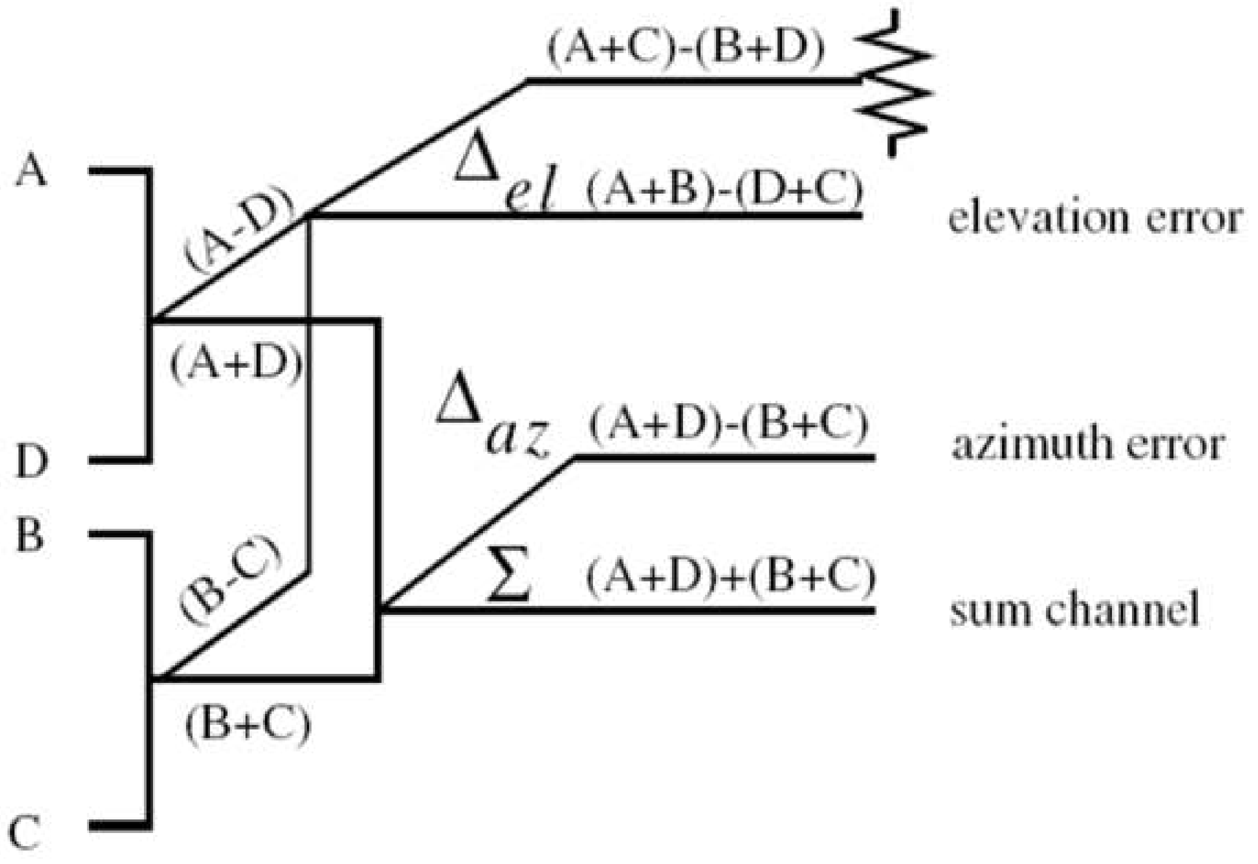
To calcualte the error signal output first we need to calculate azimuth and elevation error

$$e = \frac{|\Delta|}{|\Sigma|} \cos \theta$$

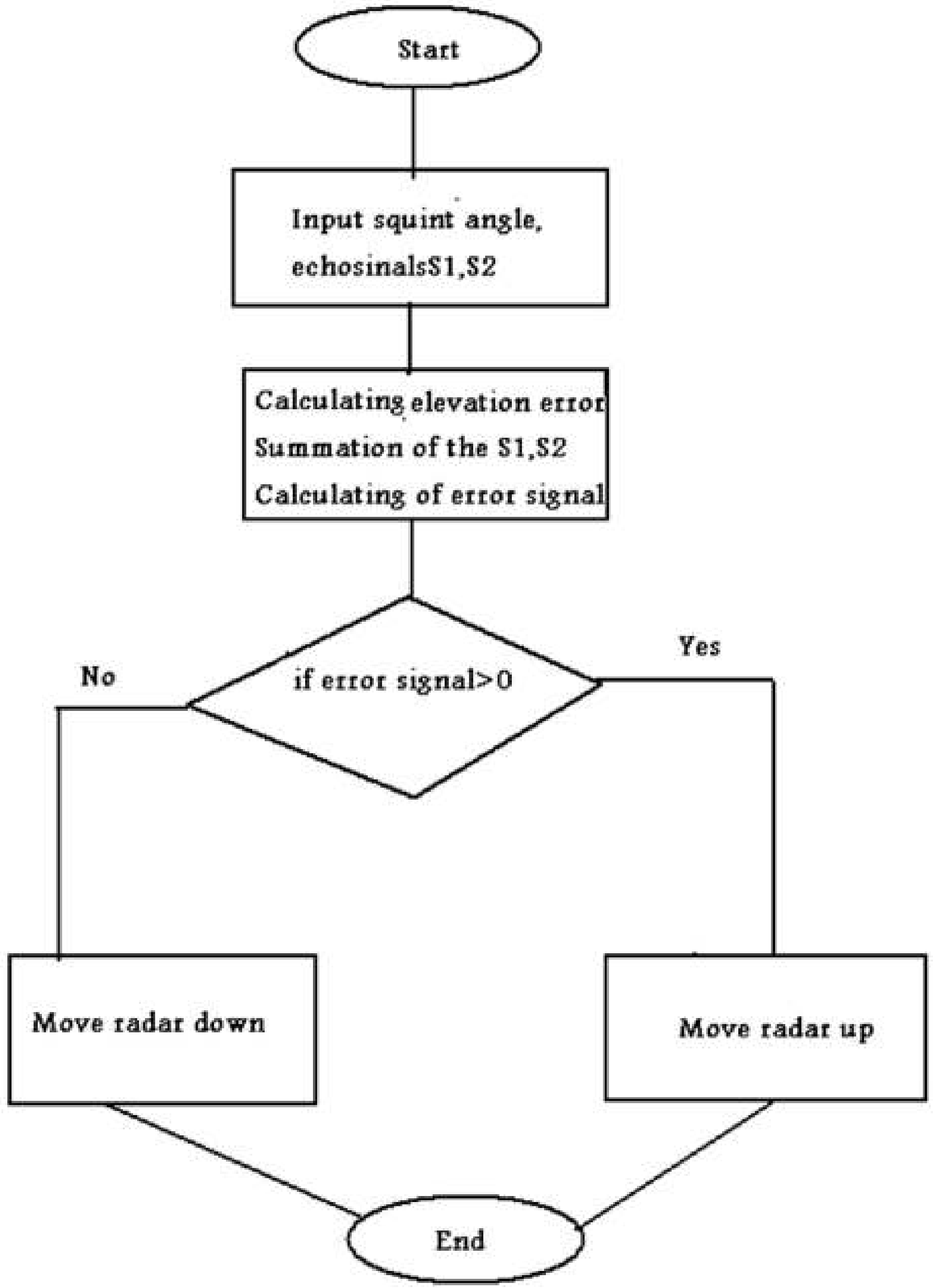
[redacted]

- Azimuth and elevation error can be calculated by using Microwave comparator circuitry

Microwave comparator circuitry

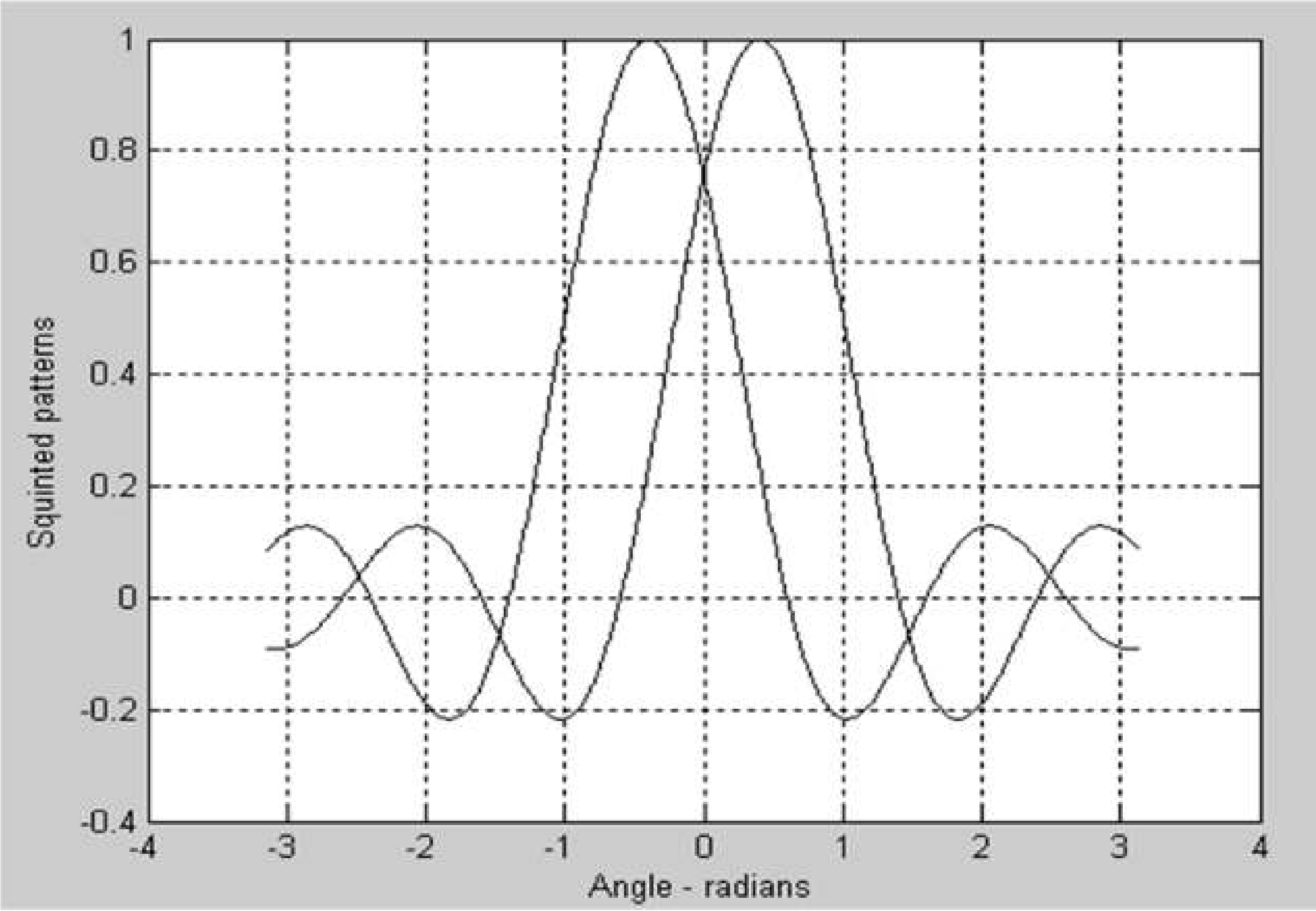


Matlab code

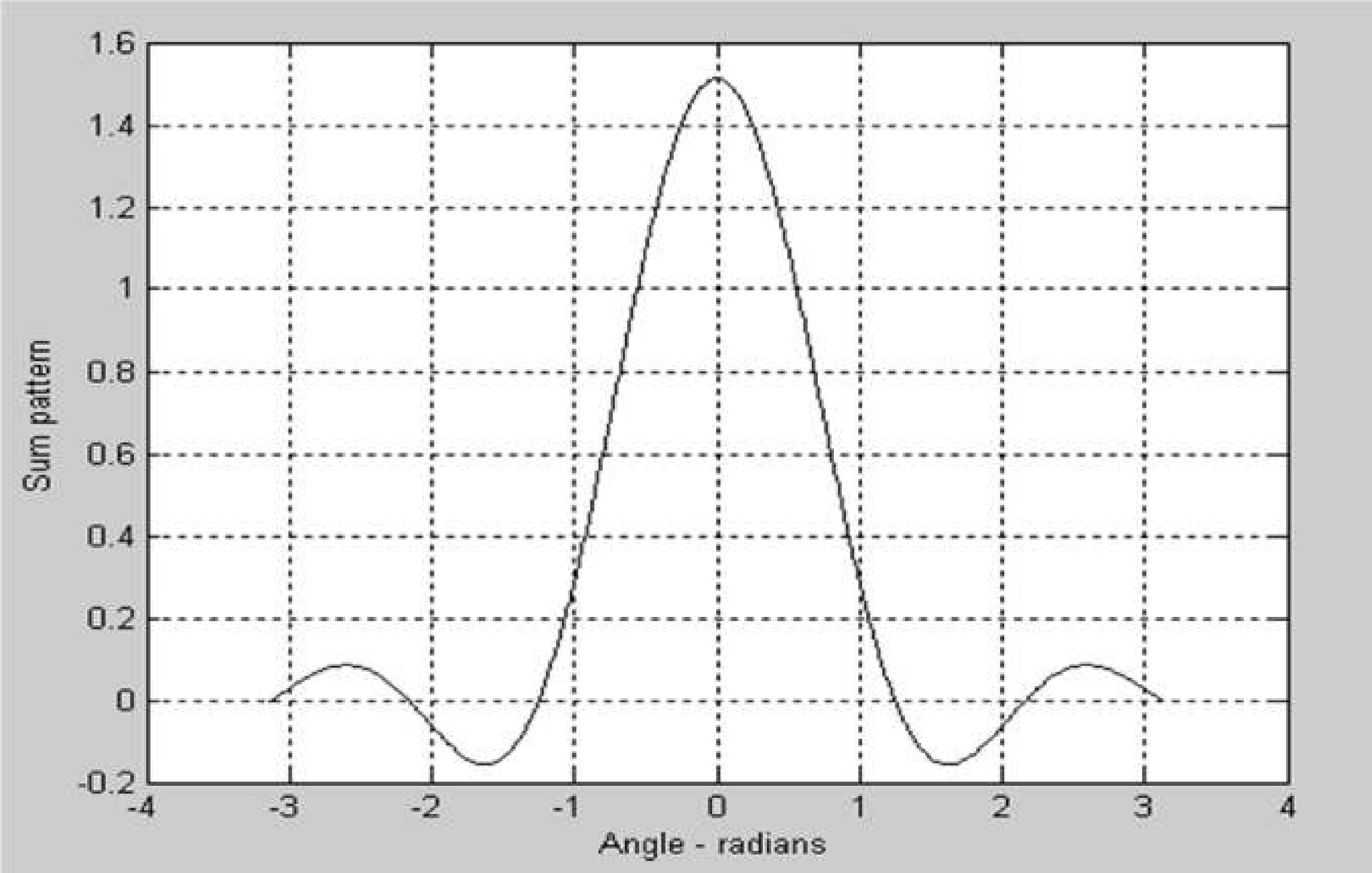


Start
Input squint angle,
echosinalsS1,S2
Calculating elevation error
Summation of the S1,S2
Calculating of error signal
if error signal>0
No
Yes
Move radar down
Move radar up
End

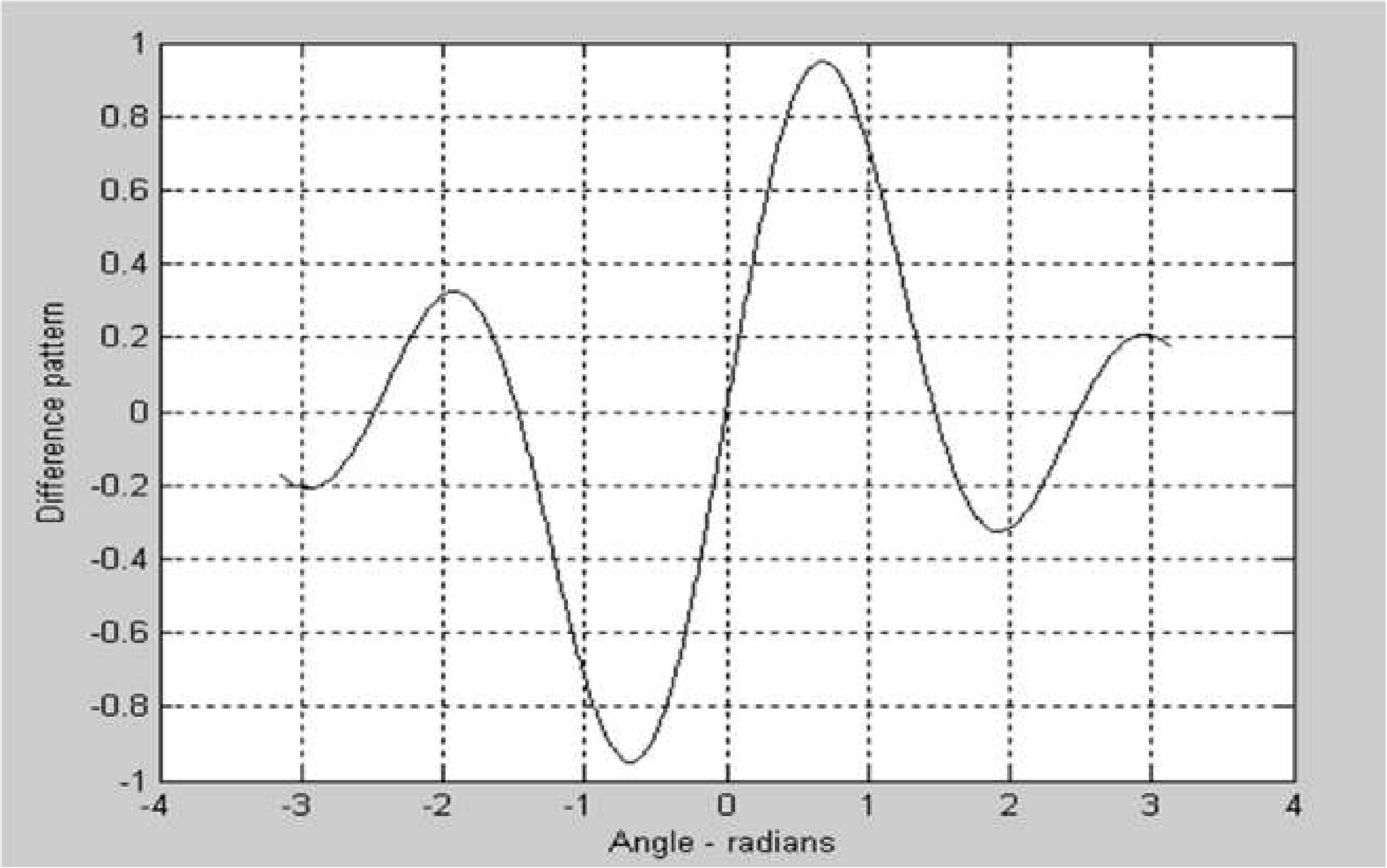
Two echo signals at squint angle (phi=0.4 rad)



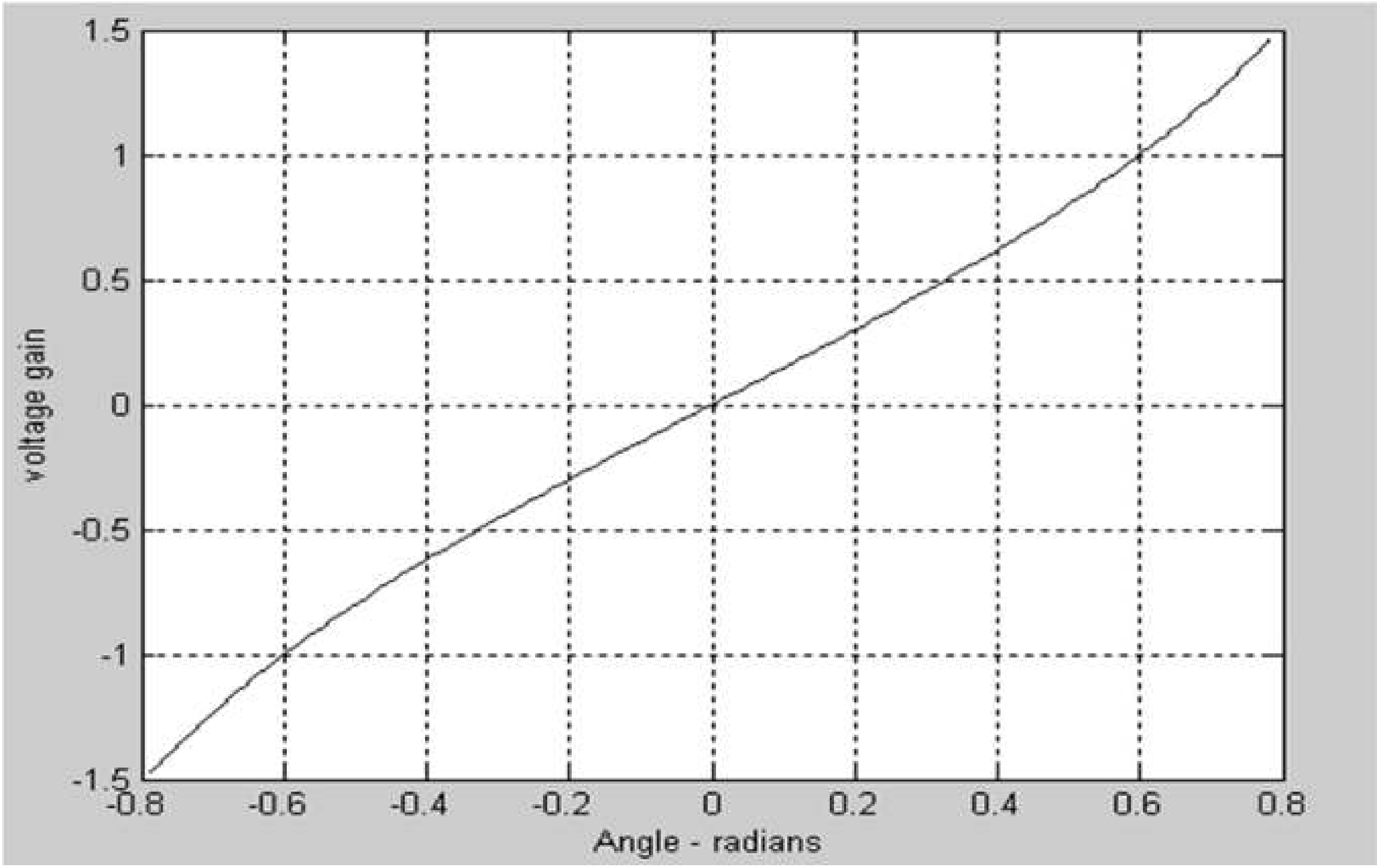
Sum of the two signals S1,S2



Difference between S1,S2



Elevation Error signal

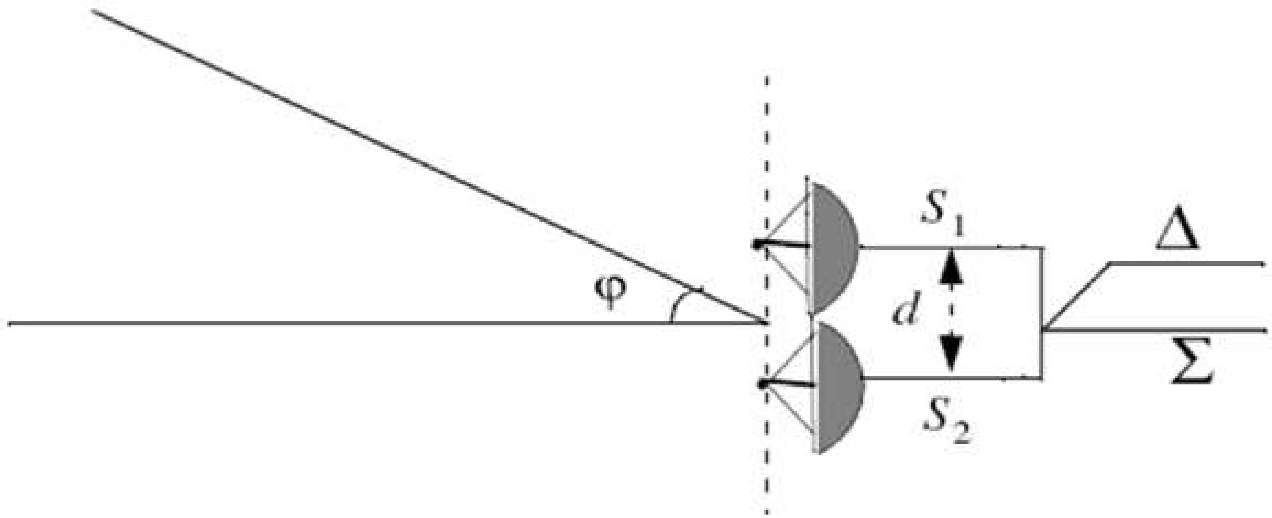


4- Phased compression monopulse

- It's the same as the last type but the amplitude here is equal for the four beams with different phases

- Phase comparison monopulse tracking radars use a minimum of a two-element array antenna

Single coordinate phase monopulse antenna



$$\frac{|\Delta|}{|\Sigma|} = \tan\left(\frac{\phi}{2}\right)$$

Range tracking

- Target range is measured by estimating the round-trip delay

$$R = \frac{cT_R}{2}$$

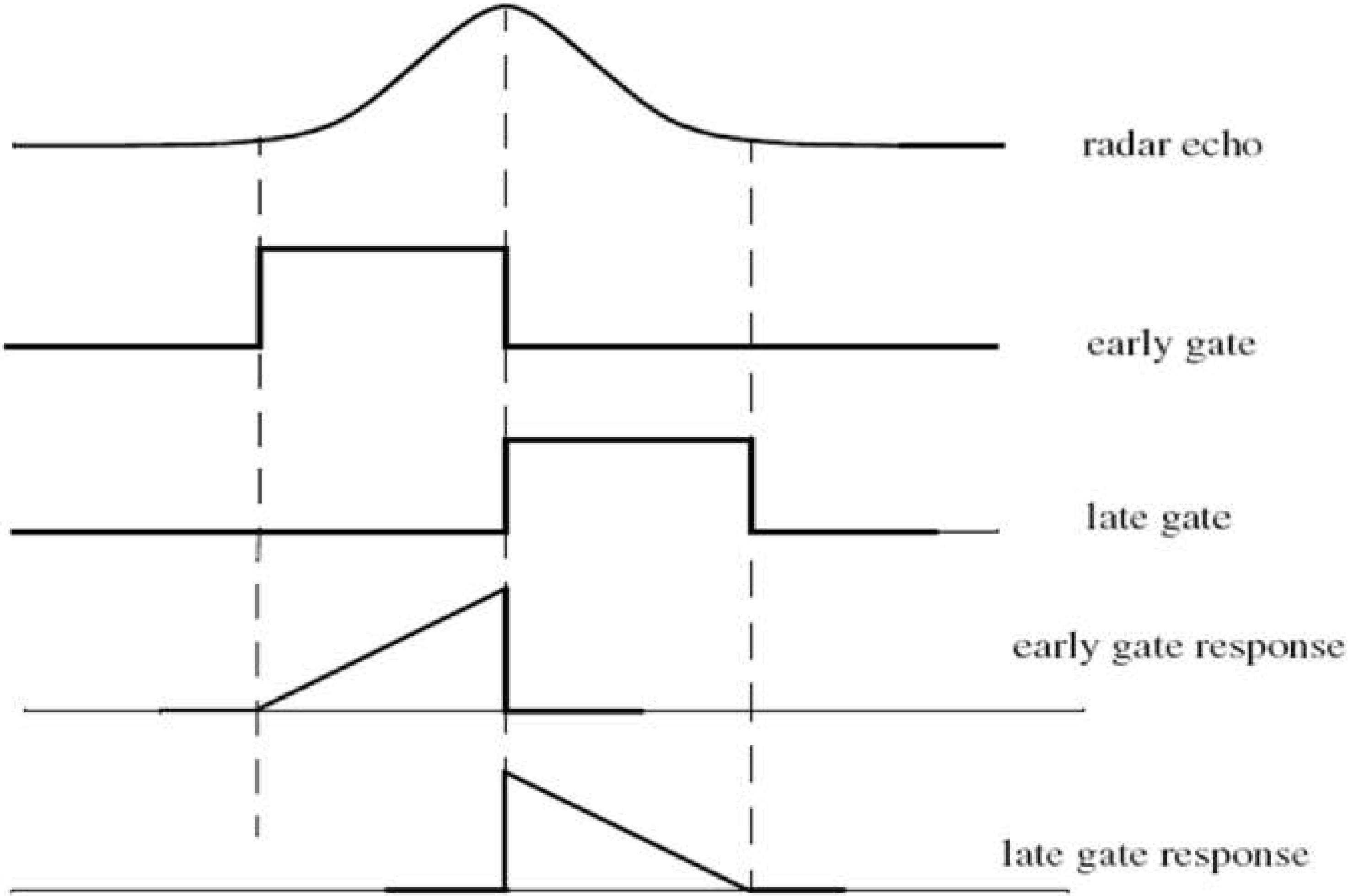
$$where \quad c = 3x10^8, \; m/s$$

$$T_R = round-trip\,time, \sec$$

Split Gate System

- It consist of two gates:
  1-Early gate
  2- Late gate
- The early gate produces positive voltage output but the late gate produces negative voltage output.
- Subtracting & integration
- Output is: zero, negative or positive

Split range gate
- Its predict the target movement



Multiple target

Multiple Targets

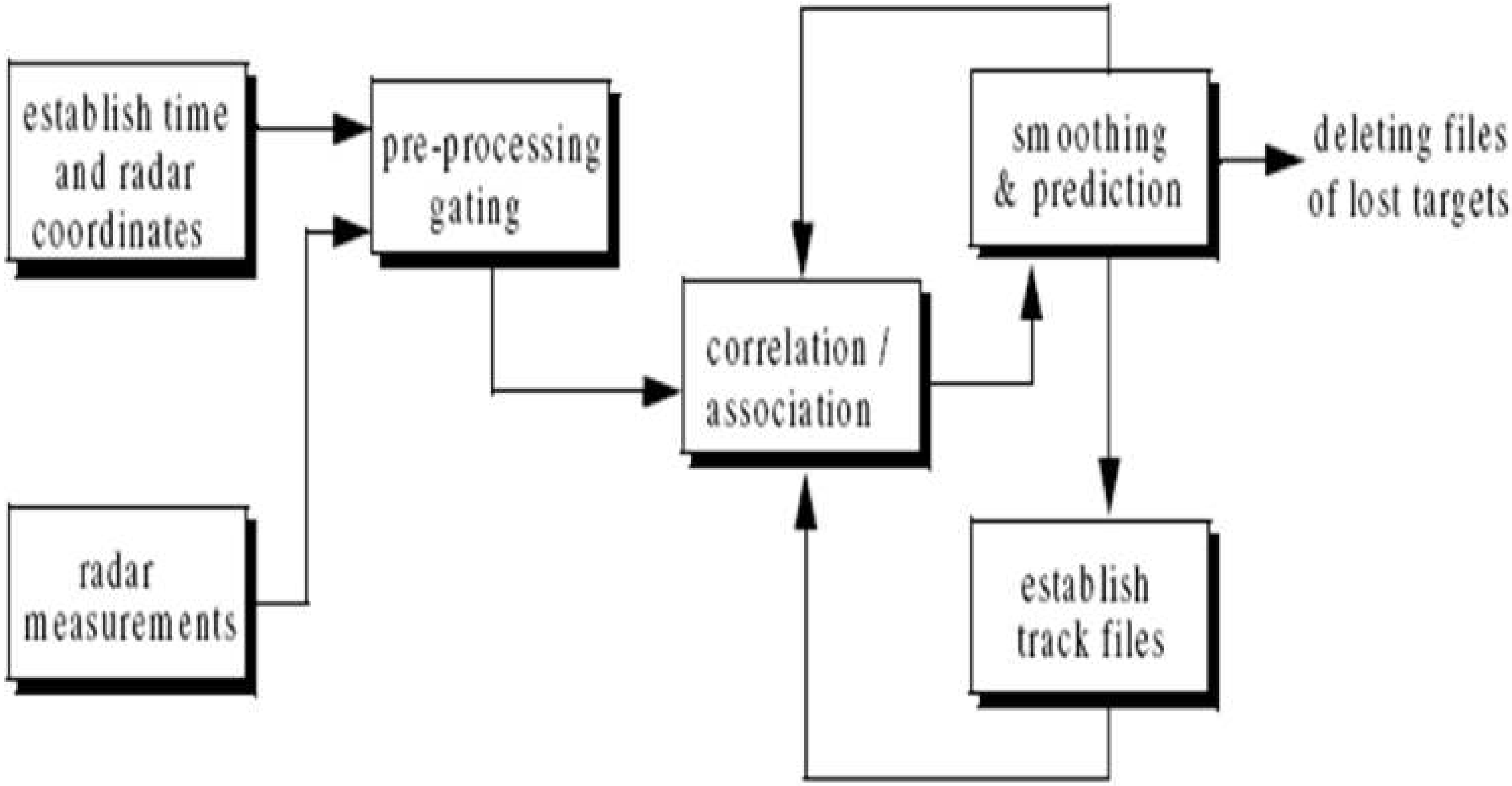
Here the system is more difficult since:

- Tracking
- Scanning
- reporting

Track while scanning (TWS)

- This type of radar is used for multiple targets
- It scans for new targets while its tracking old targets
- When TWS scan a new target it initiates a new track file

Correlation unit is correlate old tracked file with a new scanned measurements



Any Tws Radar Make

- Target detection
- Generation of tracking "Gates"
- Target track initiation and track file generation (if a new target)
- Correlation
- Track gate prediction, smoothing and positioning
- Display and future target calculations

Target Detection

This task is accomplished by two method :

- Circuit in receiver
- signal-processing equipment

Generation Gate

- Gate : small volume of space consist of many of cells

- Function : monitoring of each scan of the target information

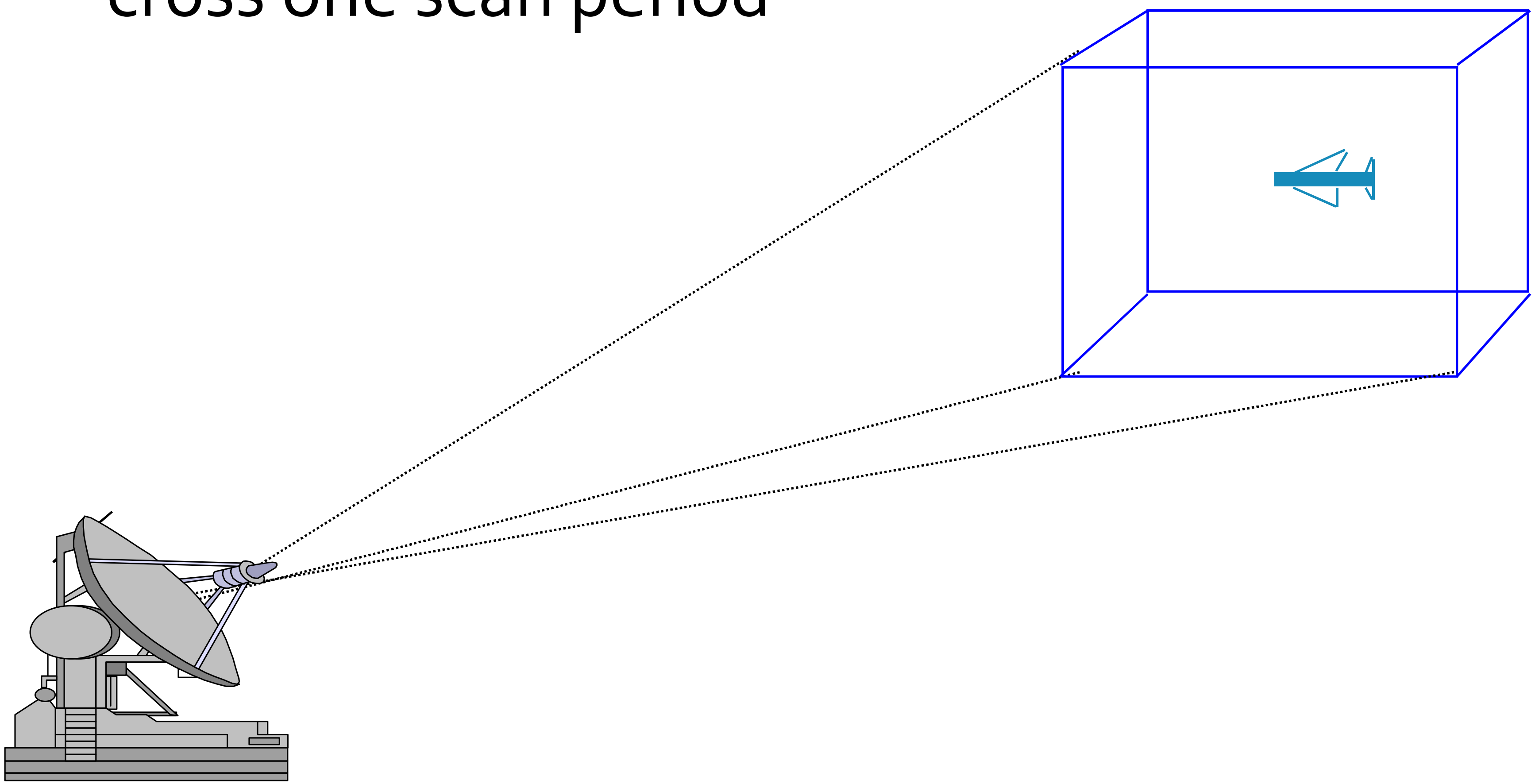
- Gating has responsibility for knowing if new/exist target

Gate Types

- Acquisition gate
- Tracking gate
- Turning gate

Acquisition Gate

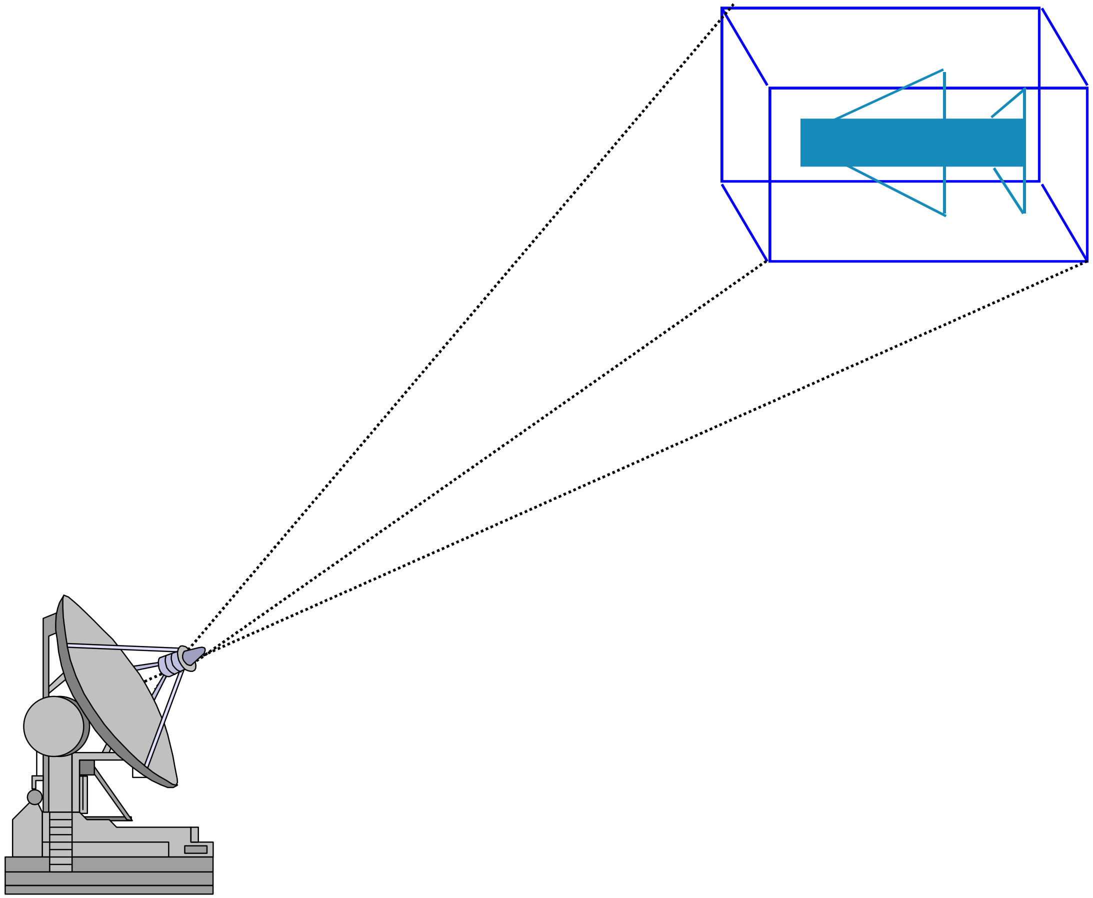
- This gate is large to facilitate target motion cross one scan period



Tracking Gate

- This gate is generated when the target is within the acquisition gate on the next scan
- It is very small gate
- It is moving to the new expected target position

Tracking Gate



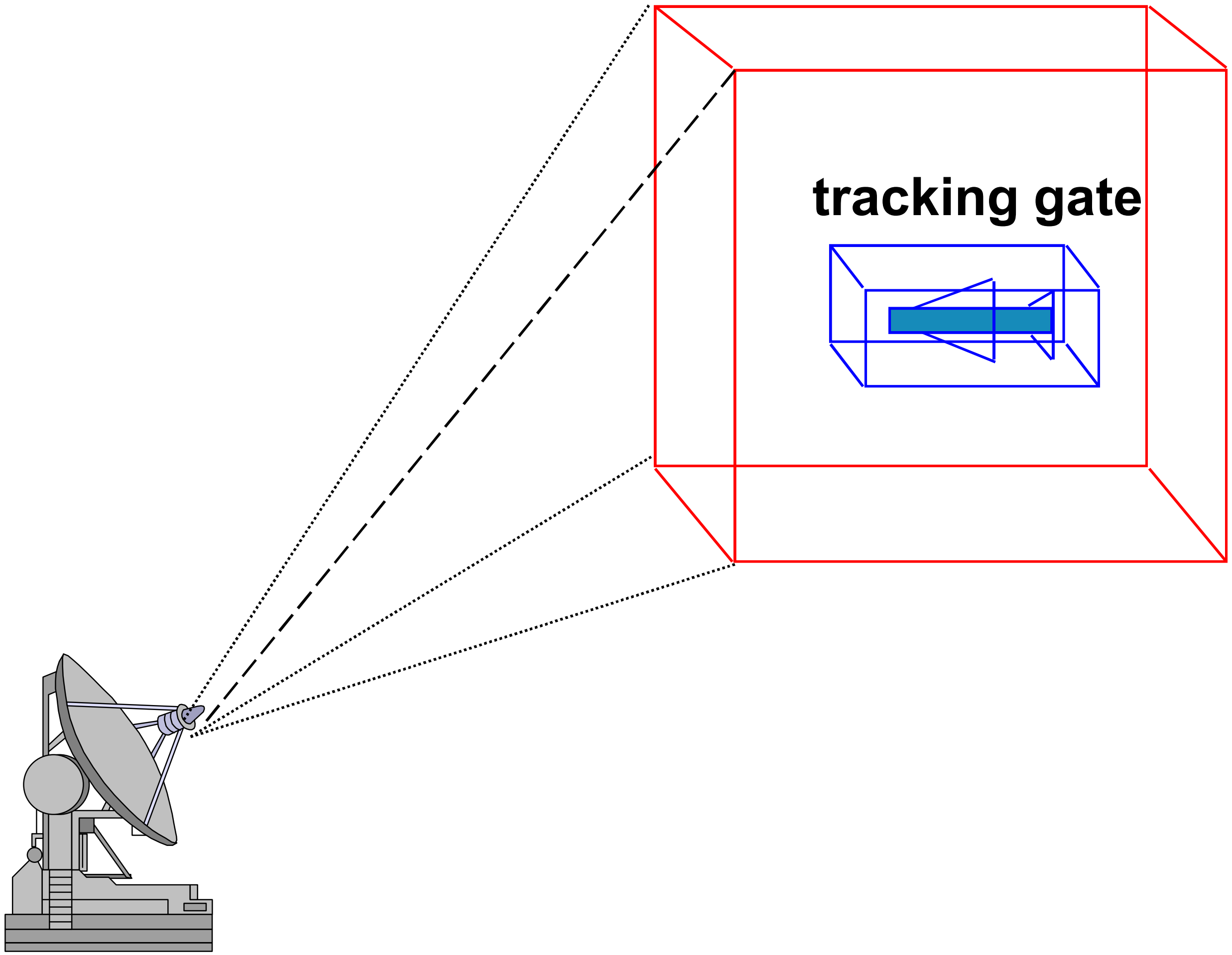
Turning gate

- It is generated if the observation within the tracking gate doesn’t appear

- It has larger size than tracking gate

- Tracking gate included by it

Turning gate



Target track correlation and association

- All observations site on the boundary of tracking gate must be correlate with that track

- Each observation is compared with all track files

- Perhaps, observation is correlated with one track files ,several tracks or no tracks

Tracking Ambiguity Results

- If the observation correlates with more one track files, tracking ambiguity is appear.

- Two reasons cause this result:

1- several targets site in the same gate
2- several gates overlap on a single target

How To Solve Ambiguity?

- If the system designed so that an operator initiate the tracks, then solution by delete track

- But for the automatic systems , the solving by maintain software rules

Target track initiation and track file generation

- The track file is initiated when acquisition gate is generated
- Track file store position and gate data
- Each track file occupies position in the digital computer's high-speed memory
- Cont. refreshed data

Track gate prediction, smoothing and positioning

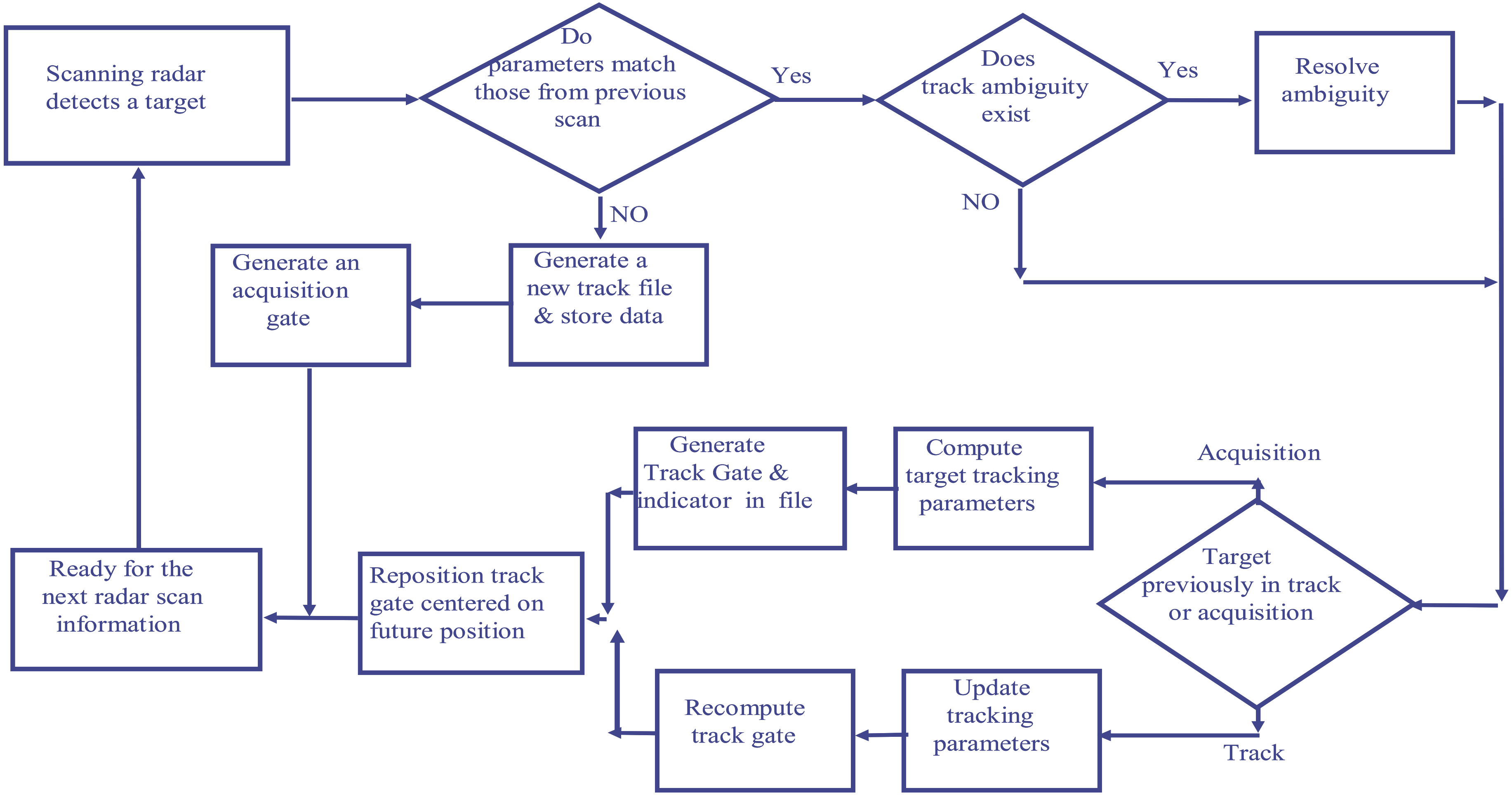
- Error → Repositioning → Smoothing

- The system lagged the target

- The system leading the target

- smoothing is completed by comparing predicted parameters with observed parameters

TWS System Operation



Conclusion

- We discussed the concepts of the different ways to determine the angle of a target and its range
- We show the different between single and multiple targets tracking
- We try to apply that on Matlab .

References

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2- Radar Systems Analysis and Design Using MATLAB
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3-Fundamentals of Naval Weapons Systems
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Questions?