USN

Internal Assessment Test 3 – May 2023 (QP-1)

Sub:	**RADAR ENGINEERING**				Sub Code:	**18EC823**	Branch:	ECE
Date:	13-05-2023	Duration:	90 minutes	Max Marks:	50	Sem/Sec:	8^{th} (A,B,C,D)	OBE

	ANSWER ANY 5 FULL QUESTIONS	MARKS	CO	RBT
1	**Define the term "Tracking" in Radar Systems. Mention the various types of tracking employed in Radars. Compare monopulse and conical radar tracking systems.**	1+4+5	CO4	L1
2	**Define monopulse tracker. Using block diagram, explain amplitude comparison monopulse tracking radar in one angle coordinates.**	2 + 8	CO4	L2
3	**With a neat block diagram, explain conical scan tracking radar.**	10	CO4	L3
4	**Define an Antenna. List the different functions served by the radar antenna. Explain the different types of radar display systems.**	1+4+5	CO3	L1
5	**With neat sketches, write notes on –** **1) Reflector Antennas , 2) Electronically Steered Phased Array Antennas.**	5 + 5	CO3	L2
6	**Write a note on the importance and the functions served by the radar receiver. Explain Noise Temperature with relevant equations.**	6 + 4	CO3	L2
7	**Define Noise Figure of a receiver with relevant equations. Derive expression for Noise Figure of N networks in cascade. Explain the Superheterodyne Receiver with the functions of its various blocks.**	1+4+5	CO3	L2
8	**What is the role of duplexers in radar system? Illustrate the transmit condition and receive condition in the case of balanced duplexer.**	2 + 8	CO3	L2

Course Instructor **Chief Course Instructor** **HOD**

USN

Internal Assessment Test 3 – May 2023 (QP-1)

Sub:	**RADAR ENGINEERING**				Sub Code:	**18EC823**	Branch:	ECE
Date:	13-05-2023	Duration:	90 minutes	Max Marks:	50	Sem/Sec:	8^{th} (A,B,C,D)	OBE

	ANSWER ANY 5 FULL QUESTIONS	MARKS	CO	RBT
1	**Define the term "Tracking" in Radar Systems. Mention the various types of tracking employed in Radars. Compare monopulse and conical radar tracking systems.**	1+4+5	CO4	L1
2	**Define monopulse tracker. Using block diagram, explain amplitude comparison monopulse tracking radar in one angle coordinates.**	2 + 8	CO4	L2
3	**With a neat block diagram, explain conical scan tracking radar.**	10	CO4	L3
4	**Define an Antenna. List the different functions served by the radar antenna. Explain the different types of radar display systems.**	1+4+5	CO3	L1
5	**With neat sketches, write notes on –** **1) Reflector Antennas , 2) Electronically Steered Phased Array Antennas.**	5 + 5	CO3	L2
6	**Write a note on the importance and the functions served by the radar receiver. Explain Noise Temperature with relevant equations.**	6 + 4	CO3	L2
7	**Define Noise Figure of a receiver with relevant equations. Derive expression for Noise Figure of N networks in cascade. Explain the Superheterodyne Receiver with the functions of its various blocks.**	1+4+5	CO3	L2
8	**What is the role of duplexers in radar system? Illustrate the transmit condition and receive condition in the case of balanced duplexer.**	2 + 8	CO3	L2

Course Instructor **Chief Course Instructor** **HOD**

Q1) Solution:

A radar not only recognizes the presence of target, but also determines the range.
Radar determines the Target's location in Range and in one or two angle coordinates.
After continuous observation of target over a time, radar provides the target's trajectory, or track, and predicts its future location also.
This is called Tracking With Radar.

- Atleast 4 types of Radars that can provide the tracks of Targets.

1) Single Target Tracker (STT).
   Continuously Tracks a single Target at a relatively Rapid data rate (10 observations per second - "typical").
   The antenna beam of the STT follows the target by obtaining an angle-error signal.
   Error signal is kept small by using a closed loop servo system.
   Used Popularly as a Continuous Tracking Radar.
   Application in tracking the Aircraft and/or Missile Targets to support a military weapon control system.
2) Automatic Detection and Track (ADT).
   Used in almost all modern Civil Air-Traffic Control & Military Air-Surveillance Radars.
   Observation rate depends on one rotation time of the Antenna ("few" to 12 seconds).
   Has lower data rate than STT.
   Advantage – can track a large number of targets ("many hundreds" to "a few thousands" of aircrafts).
   Tracking is done in Open Loop (unlike STT).
3) Phased Array Radar Tracking.
   Tracks large number of Targets with a High Data Rate.
   Uses an Electronically Steered Phased Array Radar.
   Multiple Targets Tracked on a Time-Shared basis under Computer Control.
   The Beam can be Rapidly Switched between angular directions (sometimes in a few microseconds).
   Has High Data Rate (like STT) & Tracks many Targets (like ADT).
   Basis for Air-Defense weapon systems like Aegis & Patriot. Example is a Radar called MOTR (a C-band instrumentation Radar).
4) Track While Scan (TWS).
   Rapidly scans a limited angular sector to maintain tracks.
   Scans more than one Target within the coverage of the Antenna.
   Data Rate is Moderate.
   Used in past for – Air-Defense Radars, Aircraft Landing Radars & some Airborne Intercept Radars – to track multiple targets.
   Unfortunately, in past, same name was used for ADT also, but now, they are different.

   Comparison of monopulse & conical scan tracking systems.

   Signal To Noise ratio (SNR) : The SNR of Monopulse is 2 to 4 dB greater than that of Conical Scan.
   The monopulse views the target at the peak of its sum pattern.
   The conical-scan radar views the target at some angle off the peak of the antenna beam.
   The above reason gives more SNR from a monopulse than from a conical-scan radar.

   Accuracy : Due to higher SNR, the monopulse radar will have greater angle accuracy and also better range accuracy than conical scan radar.
   Complexity : The monopulse radar is the more complex of the 2 radars.
   Monopulse requires RF combining circuitry at the antenna & 3 receiving channels.
   Conical Scan has only 1 receiving channel & uses a single feed.
   But, conical scan radar has to rotate or nutate the antenna beam at a high speed.

   Minimum Number of Pulses : Due to its 2 to 4 dB lower SNR than the monopulse tracker, the conical scan tracker has to process more pulses.
   The Conical-Scan tracker requires a minimum of 4 pulses (10 pulses usually) per revolution of the beam to find angle in 2 coordinates.
   A Monopulse radar can perform an angle meas. in 2 coordinates on the basis of a single pulse (usually a no. of pulses

used to increase SNR & accuracy).

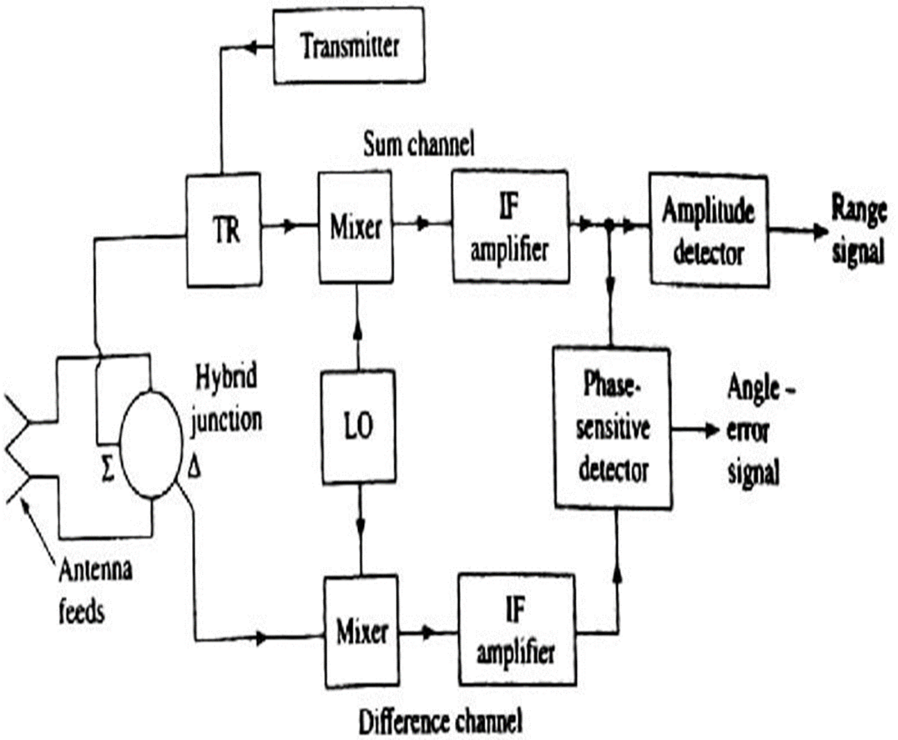
Susceptibility to Electronic Countermeasures (ECM) :
A military conical-scan tracker is more vulnerable to spoofing countermeasures.
The spoofing countermeasures take advantage of its conical-scan frequency.
It can also suffer from deliberate amplitude fluctuations.
A well-designed monopulse tracker is much harder to deceive.

Application :
Monopulse trackers should be used when good angle accuracy is wanted and/or when susceptibility to ECM is to be minimized.
Conical-Scan trackers might be used when high-performance tracking is not necessary.
Conical-Scan trackers have lower cost and reduced complexity.

Q2) Solution :

Angle Measurement is based on signals that appear simultaneously in more than one Antenna Beam.
The Accuracy is Improved in comparison with Conical Scan or Sequential Lobing (Time-Shared Single-Beam Tracking Systems).
Accuracy of Monopulse is not affected by Amplitude Fluctuations of the Target Echo.
Preferred for Accurate Angle Measurements.
2 Main Types –
Amplitude-Comparison Monopulse (More Popular).
Phase-Comparison Monopulse.
Generally, the Term Monopulse (without any descriptors), refers to the Amplitude-Comparison Version.

Figure 4.4 Simple block diagram of the amplitude-comparison monopulse in one angle coordinate. Σ denotes the sum channel. Δ denotes the difference channel.



The 2 adjacent antenna feeds are connected to the two input arms of a Hybrid Junction.
Hybrid Junction is a 4 port microwave device with 2 input & 2 output ports.
When 2 signals (from the 2 squinted beams), are inserted at the 2 input ports, the sum & difference are found at the 2 output ports.
On reception, the output of the sum & diff. ports are each heterodyned to an Intermediate Frequency and amplified in the Superheterodyne Receiver.

A single Local Oscillator (LO) is shared between the 2 channels (Sum & Diff.).
This ensures same Phase & Amplitude characteristics for the 2 channels (Important).
The Transmitter (TX) is connected to the sum port of the Hybrid Junction.

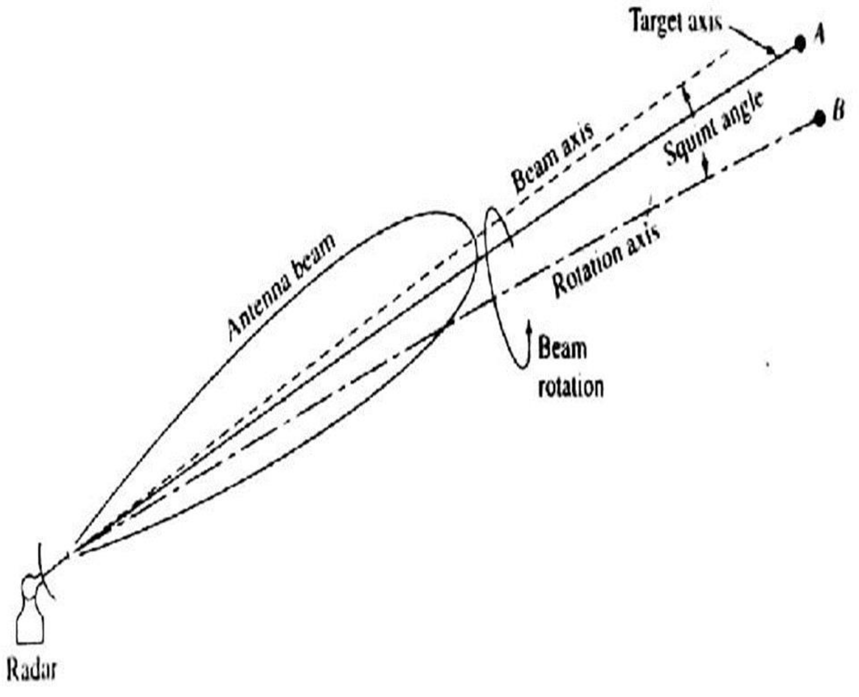
A Duplexer (TR) is included between TX and the Sum channel for receiver protection.
Often, TR is inserted in diff. channel (though not needed) to maintain phase & amplitude balance of the 2 channels (sum & diff.).

Automatic Gain Control (not shown in Fig.4.4) is also used to help maintain balance.
The outputs of Sum & Diff. channels are inputs to the Phase Sensitive Detector (PSD).
PSD is a nonlinear device that compares 2 signals of the same frequency.
The output of the PSD is the Angle-Error Signal (AES).
AES magnitude is proportional to thetaT (Target Angle) – theta0 (Boresight or Crossover Angle).
The sign of the output of PSD indicates the direction of AES relative to the Boresight.

Q3) Solution :

The basic concept of Conical Scan, or, Con-Scan, is shown in Fig.4.11.
The angle between the axis of rotation (Rotation axis) & the axis of the antenna beam (Beam axis) is the Squint angle.
Consider a Target located at position A.
The Squinted Beam rotates around the Rotation Axis.
The Target is having an offset from the Rotation Axis.
The above 2 situations result in the amplitude of the echo signal to be modulated at a frequency equal to the Beam Rotation Frequency.
Beam Rotation Frequency is also called the Conical-Scan frequency.
The amplitude of the modulation depends on the angular distance between the Target direction & the Rotation axis.
The location of the Target in 2 angle coordinates is determined.
This gives the phase of the conical-scan modulation , relative to the conical-scan beam rotation.

Figure 4.11 Conical-scan tracking.



The conical-scan modulation is extracted from the echo signal and applied to a servo control system (SCS).
The SCS continually positions the antenna rotation axis in the direction of the Target.
This is done by moving the antenna such that the Target line of sight lies along the Beam rotation axis (Position B in Fig.4.11).

2 Servos are required, one for the azimuth and the other for elevation.
When the Antenna is "On Target", the Conical-scan modulation is of zero amplitude.

Figure 4.12 Block diagram of conical-scan tracking radar.

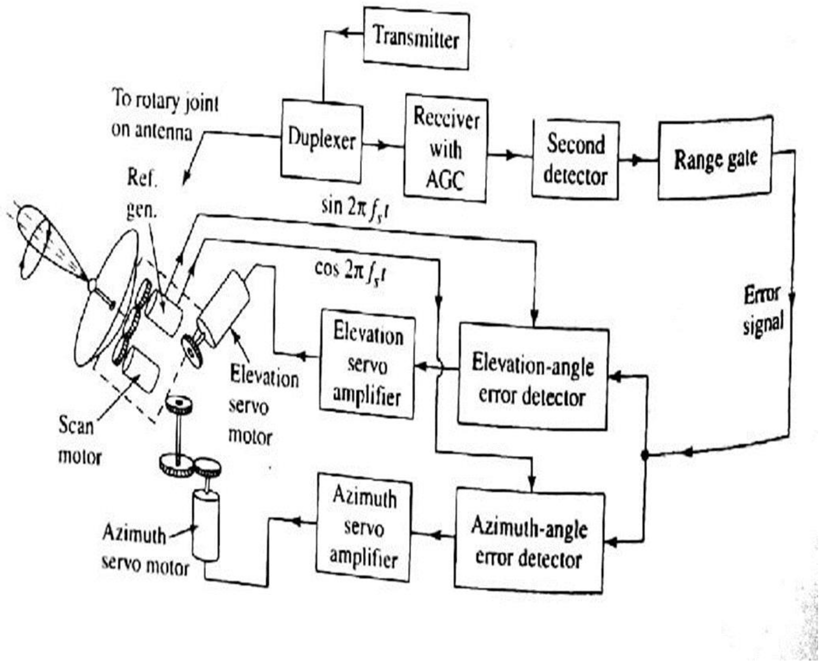


Fig.4.12 shows the block diagram of the angle-tracking portion of a conical-scan tracking radar.
The Antenna is mounted such that it can be mechanically positioned in both azimuth & elevation by separate motors.
The Antenna beam is squinted by displacing the feed slightly off the focus of the parabola.
When the feed is designed to maintain the same plane of polarization while rotating about the axis, it is called a Nutating feed.

If the plane of polarization is made to rotate, the feed is called a Rotating feed.
Nutating feed is preferred over Rotating feed.
A rotating polarization can cause the amplitude of the Target echo signal to change with time even for a stationary target on-axis.
This results in degraded angle-tracking accuracy.
However, a Nutating feed is usually more complicated than the Rotating feed.

The same motor provides the Conical Scan rotation & also drives a 2-phase Reference Generator (Ref.gen.).
The Ref.gen. has electrical outputs at the conical scan frequency that are 90° apart in phase.
These 2 outputs serve as reference signals to extract elevation error and azimuth error, as in Fig.4.12.
The echo signal received is fed to the receiver from the antenna via 2 rotary joints (not shown in Fig.4.12).
One joint permits azimuth motion & the other permits elevation motion.
The receiver is a superheterodyne receiver, except for features related to the conical-scan tracking.
The error signal is extracted in the video after the second detector.

A single Target is tracked by having the receiver scan a range gate to search for the target, lock onto it & continually track it in range.
Range Gating eliminates Noise & excludes all targets other than the desired target.
The ERROR SIGNAL from the range gate is compared with both elevation & azimuth reference signals in the angle-error detectors.
Angle-Error Detectors are Phase-Sensitive Detectors.

The Magnitude of the dc output from the angle-error detector is proportional to the angle error.
Its Sign (Polarity) indicates the direction of the error.
The angle error outputs are amplified and used to drive the antenna elevation & azimuth servo motors.
The angular position of the target is found from the elevation & azimuth of the antenna axis.

Q4) Solution :

The radar antenna is a distinctive & important part of any radar.
It serves the following functions :
Acts as the Transducer between propagation in space & guided-wave propagation in the transmission lines.
Concentrates the radiated energy in the direction of the Target (as measured by the antenna gain).

Collects the echo energy scattered back to the radar from a Target (as measured by the Antenna Effective Aperture).
Measures the angle of arrival of the received echo signal so as to provide the location of a target in azimuth, elevation, or both.
Acts as a spatial filter to separate (resolve) targets in angle (spatial) domain, and rejects undesired signals from directions other than the main beam.

Provides the desired volumetric coverage of the radar.
Usually establishes the time between radar observations of a target (revisit time).
In addition, the antenna is that part of a radar system that is most often portrayed when a picture of a radar is shown.

Radar Displays :

Originally, the radar display had the important purpose of visually presenting the output of the radar receiver.
The output was presented in a form such that an operator could easily & accurately detect the presence of a target.
Additionally, it could extract information about its location.
The display had to be designed so as not to degrade the radar information.
Also, it had to make it easy for the operator to perform with effectiveness the detection & information extraction function.

It was not uncommon for an operator to employ a grease pencil to mark on the face of a cathode-ray-tube display.
Marking was done for the location of a target from scan to scan & manually extract the target speed & direction.
As digital signal processing & digital data processing improved, more & more of the detection & information extraction was done.
This was done automatically by electronic means so that the role of the operator was less.

When the display is connected directly to the output of the radar receiver without further processing, the output is called raw video.
When the receiver output is first processed by an automatic detector or automatic detector & tracker before display, it is called synthetic video or processed video.
The requirements for the display differ somewhat depending on whether raw or processed video is displayed.
Some radar operators prefer to see, on a display, the raw video lightly superimposed on the processed video.
Thus, the role of the display has changed as the need for operator interpretation has decreased.
Given next are some of the more popular formats that have been employed.

A-Scope-
A deflection-modulated rectangular display.
The vertical deflection is proportional to the amplitude of the receiver output.
The horizontal coordinate is proportional to range (or time delay).
This display is well suited to a staring or manually tracking radar.
It is not appropriate for a continually scanning surveillance radar.
This is because the ever-changing background scene makes it difficult to detect targets & interpret what the display is seeing.

B-Scope-
An intensity-modulated rectangular display.

Azimuth angle is indicated by one coordinate (usually horizontal) and range by the orthogonal coordinate (usually vertical).
It has been used in airborne military radar.
In these radars, the range & angle to the target are more important than concern about distortion in the angle dimension.

C-Scope-
A two-angle intensity-modulated rectangular display.
The azimuth angle is indicated by the horizontal coordinate & elevation angle is indicated by the vertical coordinate.
One application is for airborne intercept radar.
In this radar, the display is similar to what a pilot might see when looking through the windshield.
It is sometimes projected on the windshield as a heads-up display.
The range coordinate is collapsed on this display.
So, a collapsing loss might occur, depending on how the radar information is processed.

E-Scope-
An intensity-modulated rectangular display.
Range is indicated by the horizontal coordinate & elevation angle by the vertical coordinate.
The E-scope provides a vertical profile of the radar coverage at a particular azimuth.
It is of interest with 3D radars & in military airborne terrain-following radar systems.
In these systems, the radar antenna is scanned in elevation to obtain vertical profiles of the terrain ahead of the aircraft.
The E-Scope is related to the RHI display.

PPI-display, or plan-position indicator-
An intensity-modulated circular display.
In this, echo signals from reflecting objects are shown in plan view.
The range & azimuth angle are displayed in polar (rho-theta) coordinates to form a map-like display.
Usually, the centre of the display is the location of the radar.
A sector-scan PPI might be used with a forward looking airborne radar to provide surveillance or ground mapping over a limited azimuth sector.
An offset PPI is one where the origin (or location of the radar) is at a location other than the centre of the display.
This provides a larger display area for a selected portion of the coverage.
The location of the radar with an offset PPI may be outside the face of the display.

RHI-display, or range-height indicator-
An intensity-modulated rectangular display with height (target altitude) as the vertical axis & range as the horizontal axis.
The scale of the height coordinate is usually expanded relative to the range coordinate.
It has been used with meteorological radars to observe the vertical profile of weather echoes.

In addition, imaging radars such as synthetic aperture radar (SAR) & side-looking airborne radar (SLAR) generally display their output as a strip map.
The strip map has range as one co-ordinate and cross-range as the other coordinate.
With expanding graphics technology, available from the computer industry, there is much more flexibility available in displaying radar information than previously.

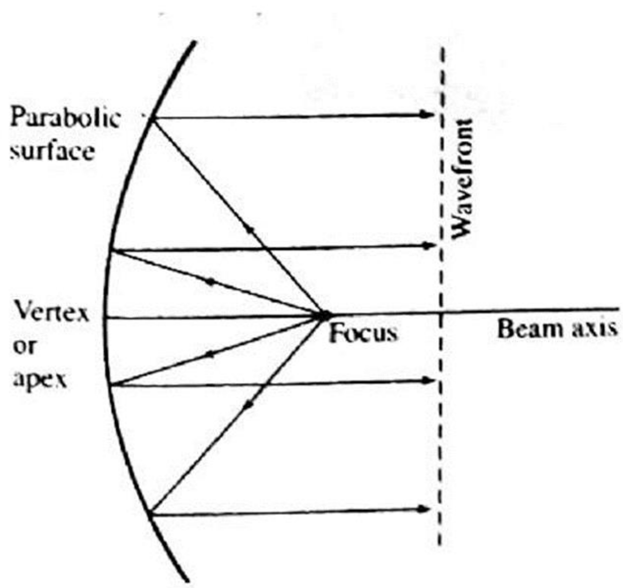
Q5) Solution :

Reflector Antennas-

The Parabola, sketched in Fig.9.7, works well as a reflector of electromagnetic energy.
It has been the basis for many radar antennas.
The parabolic surface is illuminated by a source of radiated energy called the feed.
The feed is placed at the focus of the parabola.
The parabola converts the spherical wave radiated from the feed to a plane wave.

The reasons for the above conversion are :
The rays are radiated from the focus of the parabola.
When they intersect the parabolic surface, they are reflected.
The direction of reflection is parallel to the axis of the parabola.
The distance travelled by the rays from the focus to the parabola & by reflection to a plane perpendicular to the parabola’s axis is the same.
This is applicable for all the rays no matter what angle they emanate from the focus.

Figure 9.7 Contour of a parabolic-reflector antenna.



Paraboloid :
There are several ways in which the parabola is used for antennas.

Rotating the parabolic curve shown in Fig.9.7 about its axis produces a surface.
This surface which is a parabola of revolution is called a circular parabola or a paraboloid.
When properly illuminated by a source at the focus, the paraboloid generates a nearly symmetrical pencil-beam antenna pattern.
This has been a popular antenna for tracking radars. (The paraboloid reflector is sometimes called a dish.)

Electronically Steered Phased Array Antennas-

A phased array is a directive antenna made up of a number of individual antennas, or radiating elements.
Its radiation pattern is determined by the amplitude & phase of the current at each of its elements.
The phased array antenna has the advantage of being able to have its beam electronically steered in angle.
This is done by changing the phase of the current at each element.
The beam of a large fixed phased-array antenna can be rapidly steered from one direction to another.
There is no need for mechanically positioning a large & heavy antenna.

A typical phased array radar for microwave radar might have several thousand individual radiating elements.
These radiating elements are, for eg., ferrite or diode phase shifters that allow the beam to be switched.
The switching is done from one direction to another in several microseconds, or less.

Electronically steerable phased arrays are of interest because they can provide:

- Agile, rapid beam-steering.
- Potential for large peak and large average power. Each element can have its own transmitter. The power-aperture product can be large, especially at the lower frequencies.
- Multiple-target tracking. This can be accomplished either by generating multiple, simultaneous, independent beams or by rapidly switching a single beam to view more than one target in sequence.
- A convenient means to employ solid-state transmitters.
- Convenient shape for flush mounting or for blast hardening.
- Control of the aperture illumination because of the many antenna elements available.
- A lower radar cross section, if properly designed.
- Operation with more than one function (a multifunction radar), especially if all functions are best performed at the same frequency.

The chief disadvantages of a phased array radar are that :
It is complex.
Can be of high cost.
Its ability to employ multiple functions requires serious compromises for some applications.
A linear array consists of antenna elements arranged in a straight line in one dimension.
A planar array is a 2-dimensional configuration of antenna elements arranged to lie in a plane.

In both linear & planar arrays, the element spacings usually are uniform (equal spacing).
The planar array may be thought of as a linear array of linear arrays.
Most phased arrays of interest for radar are planar.
A broadside array is one in which the direction of maximum radiation is perpendicular (or almost so) to the plane (or line) of the antenna.
An endfire array has its maximum radiation parallel to the array or at a small angle to the plane of the array.
Fig.9.14, shows a receiving linear array made up of N elements equally spaced a distance d apart.

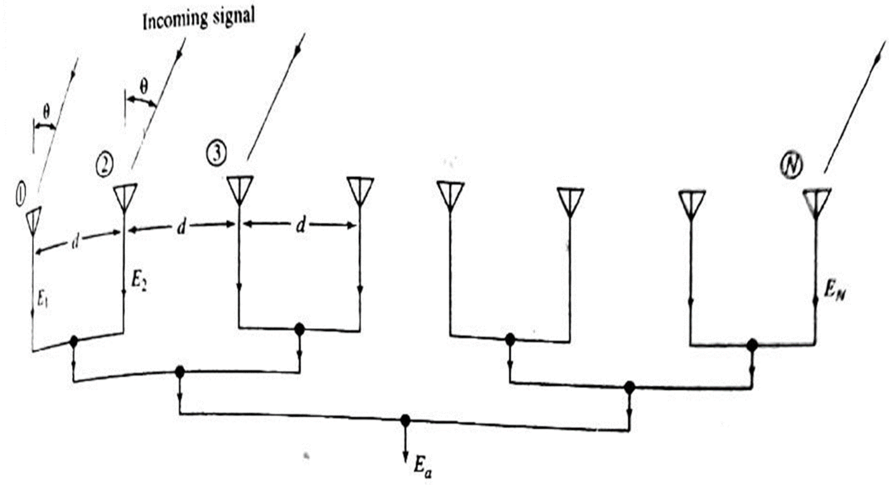


Figure 9.14 N-element receiving, parallel-feed, linear array, with equal lengths of transmission lines between each antenna element and the antenna output (at the bottom on the figure).

Q6) Solution :

The radar receiver is almost always a superheterodyne, or superhet.
The essential characteristic of a superheterodyne is that it converts the RF input signal to an intermediate frequency (IF).
At IF frequency, it is easier than at RF to achieve:
The necessary filter shape.
The necessary bandwidth.
The necessary gain.
The necessary stability.

An advantage of the superheterodyne receiver is that its frequency can be readily changed by changing the frequency of the local oscillator.
The 1st stage, or front-end, of a radar superheterodyne receiver can be an RF low-noise amplifier (LNA) such as a transistor.
Before the availability of low-noise transistors, the receiver front-end was the mixer stage without an RF amplifier preceding it.
This is still desired in some applications.

A receiver with a mixer as the 1st stage has a greater dynamic range than the one with a low-noise amplifier.
This might be important when large MTI improvement factors are needed to remove clutter echoes.
The extra dynamic range also reduces the likelihood of receiver saturation when large signals or jamming are present.

The large receiver noise figure of a mixer might be compensated with greater transmitter power and/or a bigger antenna.
Both of the above are beneficial when a military radar is faced with hostile noise jamming.
Thus, the mixer front-end might have some advantage over a low-noise transistor amplifier front-end.
But, those who buy radars seem to prefer generally a low-noise amplifier as the 1st stage of a superheterodyne receiver.
A high-performance air-surveillance radar sometimes employs more than one type of receiver.
Each would share the front-end, mixer & IF stages.

One receiver might be a linear amplifier and envelope detector for detection of targets in the clear (no competing clutter).
A second receiver might be for doppler processing to remove clutter, as in an MTI radar.
It (2nd receiver) would use I & Q channels and digital signal processing to filter the moving targets.

A third receiver might be a log-FTC, or something similar.
The 3rd receiver could aid in detecting targets located within moving weather clutter beyond the range of surface clutter.

A radar receiver has to have sufficient gain to increase the level of the weak echo signal so that it can be processed or displayed.
In the superheterodyne, the total receiver gain is divided between the IF & the video amplifiers.
The receiver should have adequate dynamic range (where the receiver is linear).
This is so that large clutter echoes do not cause the receiver to saturate & reduce the MTI improvement factor.

Noise Temperature-

The noise introduced by a network may also be expressed as the effective noise temperature, Te.
It is defined as the (fictional) temperature at the input of the network, that accounts for the additional noise ΔN at the output.
Therefore, ΔN = kTeBnG and from Eq.(11.2), we have,

and from Eq. (11.2) we have

$$F_n = 1 + \frac{T_e}{T_0} \qquad [11.5]$$

$$T_e = (F_n - 1)T_0 \qquad [11.6]$$

The *system noise temperature* T_s is defined as the effective noise temperature of the receiver including the effects of antenna temperature T_a. If the receiver effective noise temperature is T_e, then

$$T_s = T_a + T_e = (F_s - 1)T_0 \qquad [11.7]$$

where F_s is the *system noise figure*. This equation also defines the system noise figure when it includes the effects of the antenna temperature T_a and receiver effective noise temperature T_e.

The effective noise temperature of a receiver consisting of a number of networks in cascade is

$$T_e = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_1 G_2} + \cdots \qquad [11.8]$$

where T_i and G_i are the effective noise temperature and gain of the *i*th network.

The effective noise temperature and the noise figure both describe the same characteristic of a network. The effective noise temperature generally is used to describe the noise performance of very low-noise receivers, lower than might be of interest for radar. It is also preferred by some radar engineers and many receiver designers as being more useful than noise figure for analysis purposes. The noise figure, however, seems to be the more widely used term to describe radar receiver performance, and is used in this text for that purpose.

Q7) Solution :

Receiver Noise Figure-

Definition – The receiver noise figure is a measure of the noise produced by a practical receiver compared to that of an ideal receiver.
The noise figure of a linear network may be defined as :

$$F_n = \frac{N_{out}}{kT_0 B_n G} \quad \text{or} \quad \frac{S_{in}/N_{in}}{S_{out}/N_{out}} \tag{11.1}$$

where N_{out} = available output noise power; $kT_0B_n = N_{in}$ = available input noise power. k = Boltzmann's constant = 1.38×10^{-23} J/deg; T_0 = standard temperature of 290 K (approximately room temperature); B_n = noise bandwidth defined by Eq. (2.3); $G = S_{out}/S_{in}$ = available gain; S_{out} = available output signal power; and S_{in} = available input signal power. The term "available power" refers to the power that would be delivered to a matched load. (The term "available" will be understood in the following discussion of noise figure and is not mentioned further.) The product $kT_0 = 4 \times 10^{-21}$ W/Hz

The reason for a standard temperature To in the definition of noise figure is to refer measurements made under different temperatures to a common basis.
Equation (11.1) permits 2 different, but equivalent, interpretations of the noise figure.
It may be considered (RHS) as the degradation of the SNR as the signal passes through the network.
It may be interpreted (LHS) as the ratio of the noise-power out of the actual network to the noise-power out of an ideal network.
The ideal network above is that which amplifies the input thermal noise & introduces no additional noise of its own.
The noise figure of Eq.(11.1) can be expanded as

$$F_n = \frac{kT_0B_nG + \Delta N}{kT_0B_nG} = 1 + \frac{\Delta N}{kT_0B_nG} \qquad [11.2]$$

where ΔN is the additional noise introduced by the practical (nonideal) network.

The noise figure is commonly expressed in decibels; that is, 10 log F_n. The term *noise factor* has also been used at times instead of noise figure. The definition of noise figure assumes that the input and output of the network are matched. In some devices, less noise is obtained under mismatched, rather than matched, conditions. In spite of definitions, such networks would be operated so as to achieve the maximum output signal-to-noise ratio.

Noise Figure of Networks in Cascade-

Consider 2 networks in cascade, each with the same noise bandwidth Bn but with different noise figures & gain, Fig.11.1.
Let F1, G1 be the noise figure & gain of the first network & F2,G2 be similar parameters for the second network.
The problem is to find F0, the overall noise figure of the 2 networks in cascade.
From the definition of noise figure given by Eqs.(11.1) and (11.2), the output noise Nout of the 2 networks in cascade is :

N_{out} = noise from network 1 at output of network 2 + noise ΔN_2 introduced by network 2

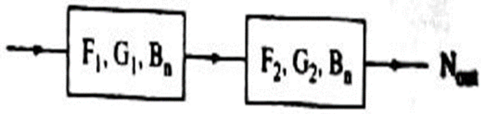
$$= F_0kT_0B_nG_1G_2 = F_1kT_0B_nG_1G_2 + \Delta N_2 = F_1kT_0B_nG_1G_2 + (F_2 - 1)\,kT_0B_nG_2$$

which results in

$$F_0 = F_1 + \frac{F_2 - 1}{G_1} \qquad [11.3]$$

It is not sufficient that the first stage of a low-noise receiver have a low noise figure. The second stage must also have a low noise figure or, if not, the gain of the first stage needs to be large. Too large a first-stage gain, however, is not always desirable since the dynamic range of the receiver is reduced by the gain G_1 of the low-noise amplifier. If the first network is not an amplifier, but is a diode mixer, the gain G_1 should be interpreted as a number less than unity (a loss).

Figure 11.1 Two networks in cascade with different noise figures and gains, but the same noise bandwidths.



The noise figure of N networks in cascade may be shown to be

$$F_0 = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \cdots + \frac{F_N - 1}{G_1 G_2 \cdots G_{N-1}} \qquad (11.4)$$

Similar expressions may be derived when the bandwidth and/or temperature of the individual networks are not the same.[4]

Superheterodyne Receiver-

Low-Noise Front-End
Mixers
Dynamic Range
Flicker Noise, or 1/f Noise
Oscillator Stability
Types of Stable Oscillators
A/D Converters
Bandpass Sampling at IF
Digital Radar Receiver
Phase Detector, Phase-Sensitive Detector

The 1st stage of a superheterodyne receiver for radar application can be a transistor amplifier.
At the lower radar frequencies, the silicon bipolar transistor has been used.
Gallium-Arsenide field-effect transistors (FET), are found at the higher frequencies.
Other types of transistors also can be used.
This depends on the trade-off between the desired noise figure & the ability of the transistor to withstand burnout.

Whether or not it is used as the front-end, the mixer is a key element in a superheterodyne receiver.
It is a means by which the incoming RF signal is converted to IF (intermediate frequency).
When the down conversion from RF to IF is performed in one step, it is called single conversion.
Sometimes, the down conversion is done in 2 steps with 2 mixers and IF amplifiers.
This is known as dual conversion.
Dual conversion superheterodyne receivers are used to avoid some forms of interference and (spoofing) electronic countermeasures.
An integral part of the mixer is the local oscillator.

There seems to be no unique definition for the dynamic range of a radar receiver.
It can generally be described as the ratio of the max. input signal power to the min. input signal power the receiver can handle without degradation in performance.
The min. signal is sometimes taken to be the receiver rms noise level, which depends on the receiver bandwidth.
The max. signal might be the signal that causes the receiver to saturate (the output no longer increases with an increase in input).

There exists in semiconductors, a noise mechanism whose spectral density is inversely proportional to the frequency.
It is called flicker noise or 1/f noise.
It can be of importance at the lower frequencies.
It is quite different from the thermal noise or shot noise, which are independent of frequency.
Flicker noise occurs in semiconductor devices such as diodes or transistors, & also in vaccum tubes with oxide-coated cathodes.
The 1/f noise is not important for radar receivers whose IF frequencies are greater than a few hundred kilohertz.
This is the case for most radar IF frequencies.

In conventional pulse radars that do not perform doppler processing, stability of the local oscillator, or LO, cannot be ignored.
It is usually not a major concern.
When doppler processing is used to detect moving targets in clutter, as in the MTI radar, the LO has to be quite stable.
This is in order to reliably detect the doppler shift.
This is why, the LO in an MTI radar is called a stalo, or stable local oscillator.

Almost all of the oscillators used for stable sources can be thought of as consisting of:
An amplifier.
A resonant circuit that determines the frequency and the phase noise.
Feedback to generate oscillation.
The amplifier is often a transistor.
The various oscillators used as stable sources are :
Crystal Oscillator.
Frequency Multiplier.
Dielectric Resonator Oscillator (DRO).
SAW (Surface Acoustic Wave) Oscillator.
YIG (Yttrium Iron Garnet) Oscillator.
Klystron Oscillator and Gunn Oscillator
High-Temperature Superconducting Oscillators
Direct Digital Synthesis

The A/D converter, which changes analog signals to digital signals, is an important component of digital processing.
There are many different ways it has been implemented.
Its performance for radar is judged by the no. of bits into which it can quantize a signal & the sampling rate at which it can operate.
The no. of bits into which the A/D converter can quantize a signal, decreases as the sampling rate, or bandwidth, increases.
Thus, larger the bandwidth of the signal, the more difficult it is to maintain good performance.
The A/D converter can sometimes be a limitation in wideband radar or when large clutter attenuation is required.

Digital signal processing that is conducted at baseband(video), requires 2 baseband A/D converters & an in-phase & a quadrature channel.
Although baseband digital processing has been widely used, there are limitations.
The 2 baseband converters have to be well balanced over a wide dynamic range.
There also cannot be significant phase errors between the 2 channels (phase difference between the 2 channels cannot differ significantly from 90°).

There does not seem to be a unique, well accepted definition of a digital receiver.
A digital receiver, ideally, could be thought of as one that is completely digital, with a wide dynamic range A/D converter.
The A/D converter operates directly on the signal received at the antenna terminals.
This would be followed by a highly capable computer to perform the functions found in a radar receiver.
More realistically, a digital radar receiver might be one that uses an analog RF amplifier & mixer, & even analog IF circuitry.
This can be followed by an IF A/D converter & digital video processing.

It is a device in an MTI receiver, that extracts the doppler frequency shift of an echo signal.
It compares the echo signal to a reference signal (the coho), which is coherent with the MTI transmitter signal.

In the MTI phase detector, it is the rate of change of phase of the echo signal with time that is of interest.
This is because it determines the doppler frequency shift of the echo from a moving target.
In both MTI radar & the monopulse tracker, two sinusoidal voltage inputs were available to a non-linear device.
The 2 were coherent with respect to one another, in that they could be thought of as being from the same source.
In both these detectors, one of the 2 voltages is the reference & the other is the received echo signal.

Q8) Solution :

A pulse radar can time share a single antenna between the transmitter and receiver by employing a duplexer.
Duplexer is a fast-acting switching device.
On transmission, the duplexer must protect the receiver from damage or burnout.
On reception, it must channel the echo signal to the receiver & not to the transmitter.
Furthermore, it must accomplish the switching rapidly, in microseconds or nanoseconds, & it should be of low loss.

For high power applications, the duplexer is a gas-discharge device called a TR (transmit-receive) switch.
The high-power pulse from the transmitter causes the gas discharge device to break down.
This causes the receiver to be short circuited to protect it from damage.
On receive, the RF circuitry of the "cold" duplexer directs the echo signal to the receiver rather than the transmitter.

Solid state devices have also been used in duplexers.
In a typical duplexer application, the transmitter peak power might be a megawatt or more.
The maximum safe power that can be tolerated by the receiver might be less than a watt.
The duplexer, therefore, must provide more than 60 dB to 70 dB of isolation between the transmitter and recovery.
It should accomplish this with negligible loss on transmit and receive.

The duplexer cannot always do the entire job of protecting the receiver.
In addition to the gaseous TR switch, a receiver might require diode or ferrite limiters.
This is to limit the amount of leakage that gets by the TR switch.
These limiters have been called receiver protectors.
They also provide protection from the high-power radiation of other radars.
This radiation might enter the radar antenna.
The power may be less than necessary to activate the duplexer, but greater than that which can be safely handled by the receiver.

There might also be a mechanically actuated shutter to short-circuit & protect the receiver whenever the radar is not operating.
Sometime, the entire package of devices has been known as a receiver protector.
The term receiver protector is also used to denote the limiter that follows the duplexer.
The duplexer, receiver protector & other devices for preventing receiver damage are better known as the duplexer system.
This is to prevent confusion by the same term (receiver protector) being used to describe the entire receiver protection system as well as one part of it.

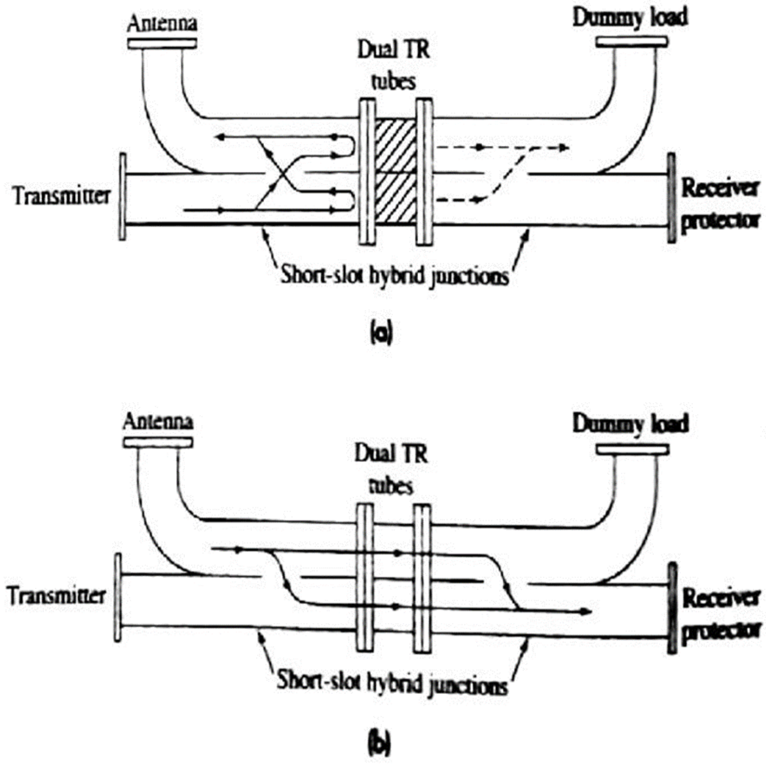
Balanced Duplexer-

The balanced duplexer is a popular form of duplexer with good power handling capability and wide bandwidth.
The balanced duplexer, shown in Fig.11.3, is based on the short-slot hybrid junction.
This junction consists of 2 sections of waveguides joined along one of their narrow walls.
A slot is cut in the common wall to provide coupling between the two.
The slot hybrid junction may be thought of as a broadband directional coupler with a coupling ratio of 3dB (Half Power).

2 TR tubes are used, one in each section of waveguide.
In the transmit condition, Fig.11.3a, power is divided equally into each waveguide.
This is done by the 1st hybrid junction (on the left).
Both gas-discharge TR tubes break down & reflect the incident power out of the antenna arm as shown.
The short-slot hybrid junction has the property that each time power passes through the slot in either direction, its phase is advanced by 90°.

The power travels as indicated by the solid lines.
Any power that leaks through the TR tubes (shown by the dashed lines) is directed to the arm with the matched dummy load.
It is not directed to the receiver.
In addition to the attenuation provided by the TR tubes, the hybrid junctions provide an additional 20dB to 30dB of isolation.

Figure 11.3 Balanced duplexer using dual TR tubes and two short-slot hybrid junctions. (a) Transmit condition and (b) receive condition.



On reception, the TR tubes do not fire and the echo signals pass through the duplexer & into the receiver as shown in Fig.11.3b.
The power splits equally at the 1st junction.
Because of the 90° phase advance on passing through the slot, the signal recombines.
This happens in the receiving arm & not in the arm with the dummy load.