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Internal Assessment Test 3 – June 2022 (QP-3) (Solution)

Sub:	RADAR ENGINEERING					Sub Code:	17EC833/ 15EC833	Branch:	ECE
Date:	18-06-2022 (Saturday)	Duration:	90 mins (08.30am-10.00am)	Max Marks:	50	Sem/Sec:	VIII - E		OBE

Answer any **FIVE FULL** Questions.

		MARKS	CO	RBT
1	a) A 3.25 cm pulse Doppler radar has a pulse repetition frequency of 4000 pps. Find (i) Run (ii) maximum Doppler shift (iii) maximum radial velocity of the target Soln.	[10= 3+7]	CO 2	L3

Q) A 3.25cm pulse doppler radar has a ~~pulse~~ prf of 4000 pps. find Run & f_{dmax}, v_{rmax} (6M)

Soln: $\lambda = 3.25cm$ $f_p = 4000$ pps.

$$R_{un} = \frac{c}{2\,prf} = \frac{3\times10^8}{8000} = 37.5\,km.$$

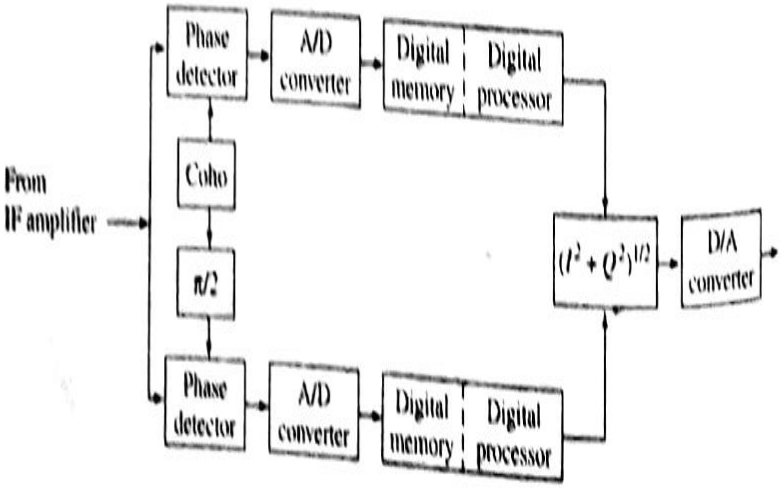
$$f_{dmax} = \frac{c}{4 R_{un}} = \frac{prf}{2} = 2000\,pps = 2\,KHz$$

$$v_{rmax} = prf\cdot\left(\frac{\lambda}{4}\right) = 4000 \times \frac{3.25\times10^{-2}}{4}$$

$$= 32.5\,m/s$$

b) Explain the operation of Digital MTI Doppler Signal Processor with a neat block diagram.
Soln.

Figure 3.29 Block diagram of a digital MTI doppler signal processor.



- The block diagram of a digital MTI signal processor with I and Q channels is shown in Fig.3.29.
- The signal from the IF amplifier is split into 2 channels.

- The phase detectors in each channel extract the doppler-shifted signal.
- In the I channel, the doppler signal is represented as $A_d \cos(2\pi f_d t + \phi_0)$ & the Q channel it is the same except that the sine replaces the cosine.

- The signals are then digitized by the analog-to-digital (A/D) converter.
- A sample & hold circuit usually is needed ahead of the A/D converter for more effective digitizing.
- Sample & hold is often on the same chip as the A/D converter.
- Some A/D converters, such as the flash type, do not require a sample & hold.
- The digital words are stored in a digital memory for the required delay time(s).
- They are then processed with suitable algorithm to provide the desired doppler filtering.

- The magnitude of the doppler signal is obtained by taking the square root of $I^2 + Q^2$.
- If required, the combined unipolar output can be converted to an analog signal by a digital-to-analog (D/A) converter for display.
- Otherwise, the digital output might be subject to further processing.

2	Define the term “Tracking” in Radar Systems. Mention the various types of tracking employed in Radars. Soln.	[10]	CO4	L1

- 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.

3	Define monopulse tracker. Using block diagram, explain amplitude comparison monopulse tracking radar in one angle coordinates. Soln.	[10]	CO4	L2

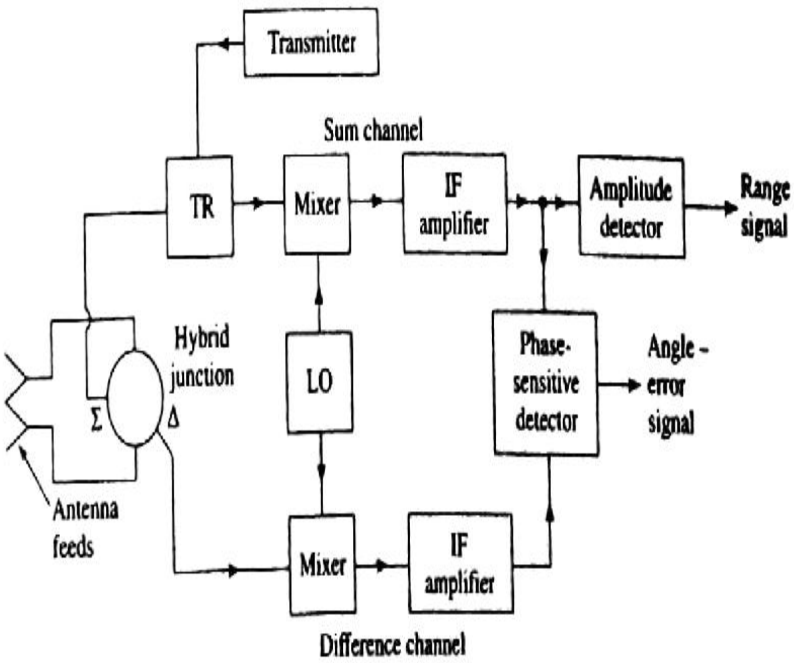
- Definition : A Monopulse Tracker is one which obtains angular location of a target by comparison of signals received in 2 or more **Simultaneous Beams**.
- A Measurement of Angle may be made on the basis

of a single pulse; hence, called **Monopulse**.

- In Practice, Multiple Pulses are used for –
  1) Increasing the Probability of Detection.
  2) Improving the accuracy of the angle estimate.
  3) Providing Resolution in Doppler when needed.

Amplitude-Comparison Monopulse:

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.).

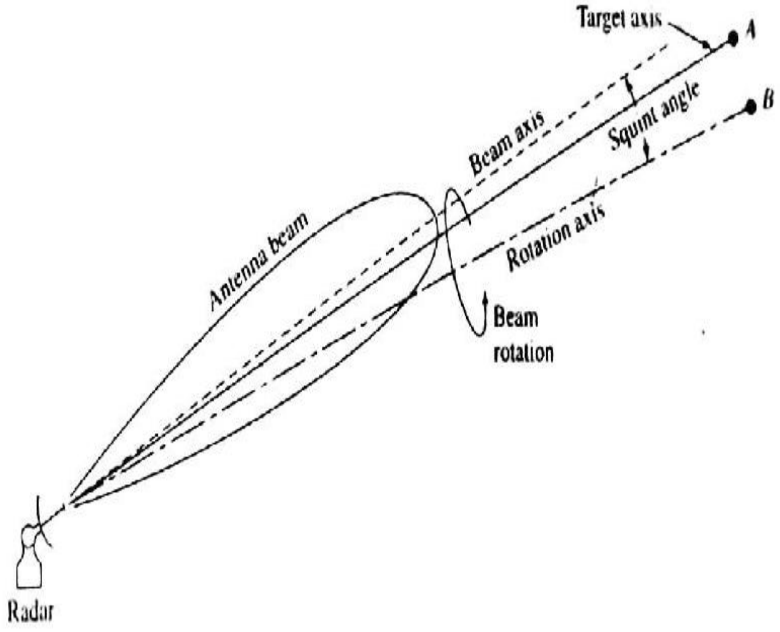
- Automatic Gain Control (not shown in Fig.4.4) is also used to help maintain balance.
- The outputs of Sum & Diff. channels are inputs to the Phase Sensitive Detector (PSD).
- PSD is a nonlinear device that compares 2 signals of the same frequency.
- The output of the PSD is the Angle-Error Signal (AES).
- AES magnitude is proportional to $theta_T$ (Target Angle) – $theta_0$ (Boresight or Crossover Angle).
- The sign of the output of PSD indicates the direction of AES relative to the Boresight.

4	With a neat block diagram, explain conical scan tracking radar. Soln.	[10]	CO4	L3

- 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.

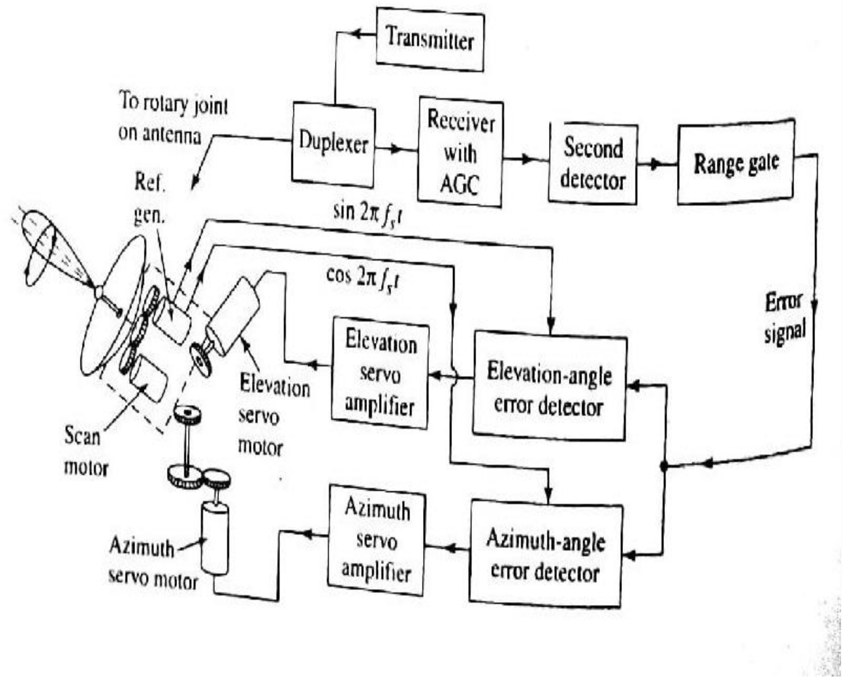


- The conical-scan modulation is extracted from the echo signal and applied to a servo control system (SCS).
- The SCS continually positions the antenna

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.

5	Explain the Superheterodyne Receiver with the functions of its various blocks. Soln.	[10]	CO3	L2

- 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

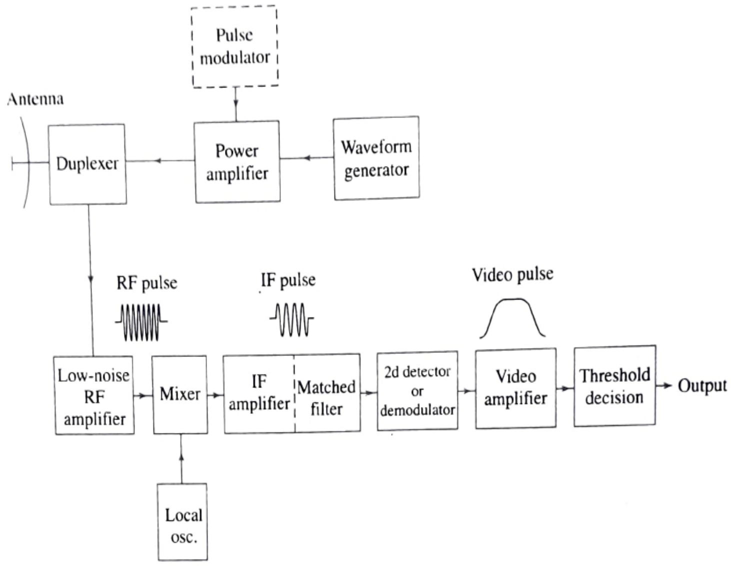


Figure 1.4 Block diagram of a conventional pulse radar with a superheterodyne receiver.

- The receiver is almost always a *superheterodyne*.
- The input, or RF, stage can be a low-noise transistor amplifier.
- The mixer & local oscillator (LO) convert the RF signal to an intermediate frequency

(IF), where it is amplified by the IF amplifier.

- The signal bandwidth of a superheterodyne receiver is determined by the bandwidth of its IF stage.

- The IF frequency, for example, might be 30 or 60 MHz when the pulse width is of the order of 1 μs.
- With a 1 μs pulse width, the IF bandwidth would be about 1 MHz.
- The IF amplifier is designed as a *matched filter* ; that is, one which maximizes the output peak-signal-to-mean-noise ratio.
- Thus, the matched filter maximizes the detectability of weak echo signals & attenuates unwanted signals.

- With the approx. rectangular pulse shapes commonly used in many radars, conventional radar receiver filters are close to that of a matched filter.
- The above assumption is true when the receiver bandwidth B is the inverse of the pulse width τ, or $B\tau = 1$.

- Sometimes, the low-noise input stage is omitted & the mixer becomes the 1st stage of the receiver.
- A receiver with a mixer as the input stage will be less sensitive because of the mixer's higher noise figure.
- But, compared to a receiver with low-noise 1st stage, it will have –

➢ Greater dynamic range.

➢ Less susceptibility to overload.

- ➢ Less vulnerability to electronic interference.
- These attributes of a mixer input stage might be of interest for military radars subject to the noisy environment of hostile electronic counter measures (ECM).

- The IF amplifier is followed by a crystal diode, which is traditionally called the *second detector*, or *demodulator*.
- Its purpose is to assist in extracting the signal modulation from the carrier.
- The combination of IF amplifier, second detector,

& video amplifier acts as an *envelope detector*.

- This is because it passes the pulse modulation (envelope) & rejects the carrier frequency.
- In radars that detect the doppler shift of the echo signal, the envelope detector is replaced by a *phase detector*.

- The combination of IF amplifier & video amplifier is designed to provide sufficient amplification, or gain.
- This gain is used to raise the level of the input signal to a magnitude

where it can be seen on a display.

- The display can be a cathode-ray tube (CRT), or be the input to a digital computer for further processing.

- At the output of the receiver, a decision is made whether or not a target is present.
- The decision is based on the magnitude of the receiver output.
- If the output is large enough to exceed a predetermined threshold, the decision is that a target is present.
- If it does not cross the threshold, only noise is assumed to be present.

- The threshold level is set so that the rate at which false alarms occur due to noise crossing the threshold (in the absence of signal), is below some specified, tolerable value.
- An *integrator* is often found in the video portion & a *signal processor* (eg. Matched Filter) is found in the receiver before detection decision is made.

6	What is the role of duplexers in radar system? Illustrate the transmit condition and receive condition in the case of balanced duplexer. Soln.	[10]	CO3	L2

- 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.

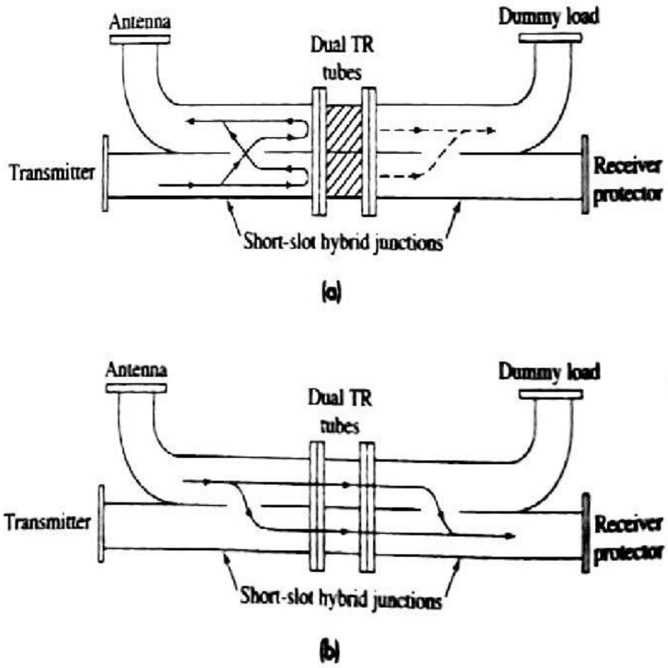
The balanced duplexer is a popular form of duplexer with good power handling capability and wide bandwidth.
The balanced duplexer, shown in Fig.11.3, is based on the short-slot hybrid junction.
This junction consists of 2 sections of waveguides joined along one of their narrow walls.
A slot is cut in 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.

7	Define an Antenna. List the different functions served by the radar antenna. Soln.	[10]	CO3	L1

- 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).

Functions of The Radar Antenna:

- 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.

ALL THE BEST

CCI **HOD**