USN

Internal Assessment Test 1 – March 2023 (QP-1)

Sub:	RADAR ENGINEERING				Sub Code:	18EC823	Branch:	ECE
Date:	11-03-2023	Duration:	90 minutes	Max Marks: 50	Sem/Sec:	8^{th} (A,B,C,D)		OBE

ANSWER ANY 5 FULL QUESTIONS

		MARKS	CO	RBT
1	Derive an expression for simple form of the RADAR range equation in three different forms starting from the power density of isotropic antenna.	10	CO1	L2
2	With a neat block diagram, explain the conventional pulse radar with a super heterodyne receiver.	10	CO1	L2
3	Write a note on (i) Origin of RADAR (ii) Applications of RADAR.	4 + 6	CO1	L1
4	What do you understand by the term RADAR? Explain the importance of Radar. With a neat diagram, explain the basic principle of Radar.	1+2+7	CO1	L2
5	What is meant by Minimum detectable signal power of receiver? Write a brief note on maximum unambiguous range. Tabulate the IEEE standard radar frequency range and their letter band nomenclature.	2+3+5	CO1	L2
6	a) A ground based RADAR operates at 3cm. The RADAR transmitter using an antenna of gain 50dB produces 100kW. The receiver minimum detectable signal is Smin $=10^{-13}$W. The maximum RADAR range is given as 259km. Find the cross section of the target the radar can detect. → $\sigma = 0.992\ m^2$, $R_{max} = \left[\frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 S_{min}}\right]^{1/4}$ b) A 10 GHZ radar has the following characteristics Pt = 250 kW , p.r.f = 1500 pps, pulse width = 0.8μs, power gain of antenna = 2500, Smin=10^{-14} W , Ae = 10 m² , σ = 2 m² . Find (i) R unambiguous (ii) Maximum possible range (iii) Duty cycle (iv) Average power. → 300W 100Km ← ; R_{max} = 298 Km ; t_{fp} = 0.12%	4 + 6	CO1	L3

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IAT-1

(Q1) A radar eqn relates the radar range to the characteristics of Transmitter, Receiver, Antenna, Target and Environment.

Let 'P_t' be the transmitted power
The Power Density of isotropic antenna is given by.

$$PD_{iso} = \frac{P_t}{4\pi R^2}$$

where R is the radar range of the target.
Radars employ directive antennas
Gain of an antenna is defined by

$$G = \frac{\text{Max value of Power Density of directivity antenna}}{\text{Power Density of isotropic antenna supplied with the same i/p power.}}$$

The Power Density of directive antenna is given by.

$$PD = \frac{P_t G}{4\pi R^2}$$

Let 'σ' be radar cross section.

The Rereflected power density is given by

$$PD = \frac{P_t G}{4\pi R^2} \times \frac{\sigma}{4\pi R^2}$$

For maximum range Subs $P_r = S_{min}$
Where S_{min} is the minimum detectable signal

$$S_{min} = \frac{P_t G \sigma}{}$$

The received power is given by

P_r = incident PD x Aperture efficiecy.

$$A_e = P_a A$$

where P_a = effective capture area
A = physical area.

$$P_r = \frac{P_t G \sigma}{(4\pi)^2 R^4} \times A_e$$

For maximum range subs $P_r = S_{min}$

$$S_{min} = \frac{P_t G \sigma A_e}{(4\pi)^2 R_{max}^4}$$

$$R_{max}^4 = \frac{P_t G \sigma A_e}{(4\pi)^2 S_{min}}$$

$$R_{max} = \left(\frac{P_t G \sigma A_e}{(4\pi)^2 S_{min}} \right)^{1/4} \quad (1)$$

This is known as radar equation.

But
we know that

$$G = \frac{4\pi A_e}{\lambda^2} \quad \text{——— (2)}$$

Subs (2) in (1) we get

$$R_{max} = \left(\frac{P_t \, A_e^2 \, \sigma}{4\pi \, \lambda^2 \, S_{min}}\right)^{1/4} \quad \text{——— (3)}$$

$$\frac{P_t \cdot 4\pi A_e \cdot A_e \, \sigma}{(4\pi) \, \lambda^2 \, S_{min}}$$

Rearranging (2) we get

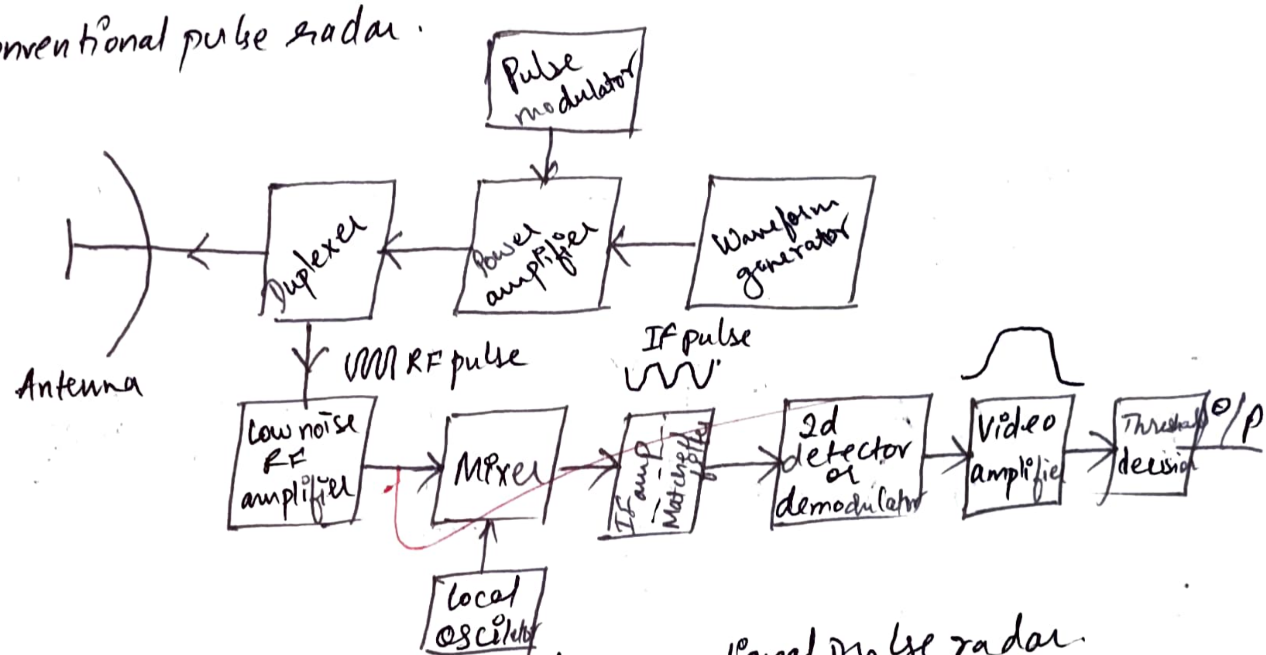
$$A_e = \frac{G \lambda^2}{4\pi} \quad \text{——— (4)}$$

Subs (4) in (1)

$$R_{max} = \left(\frac{P_t \, G^2 \, \lambda^2 \, \sigma}{(4\pi)^3 \, S_{min}}\right)^{1/4} \quad \text{——— (5)}$$

Eq (1) & (3) & (5) are the three different forms of radar equation.

(Q2) Conventional pulse radar.



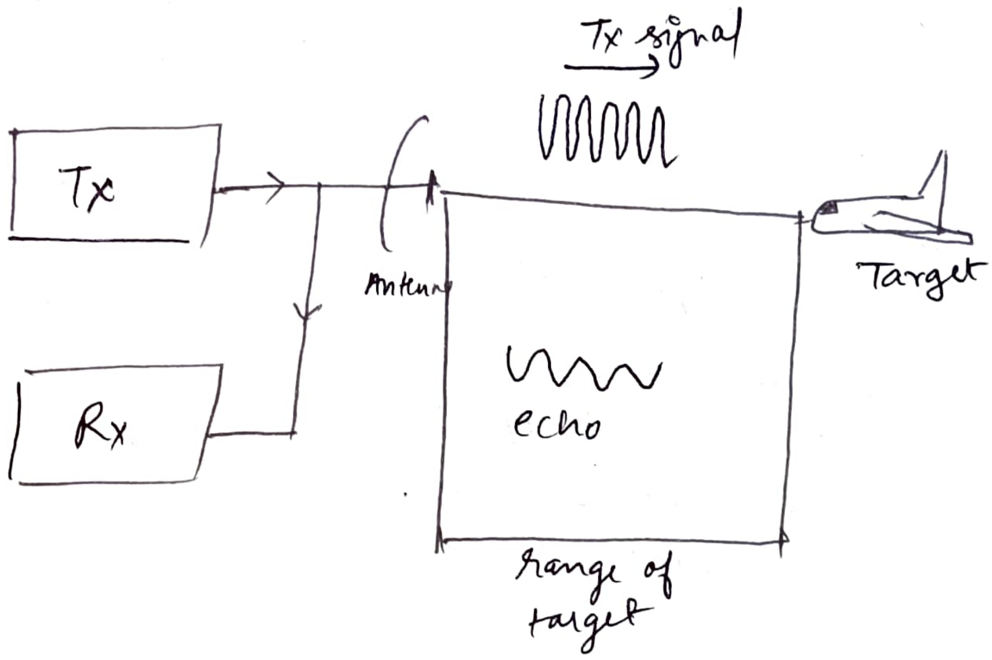
Block diagram of conventional pulse radar.

* The Transmitter can be a power amplifier like Klystron
* The signal is generated in the waveform generator and passed to the power amplifier for amplification
* The pulse modulator turns ON and OFF the transmitter in synchronization with the input pulse to generate a pulse wave form.
* The signal is ~~they~~ delivered to the antenna by the means of transmission lines or wave guides.
* A duplexer is used so that one ~~sign~~ single antenna can be used for both Transmitting and Receiving on a time shared basis.
* The receiver is almost always a superheterodyne.
* The received signal is passed to the Low noise RF amplifier for amplification.
* The mixer and local oscillator together convert the RF pulse into an IF pulse.
* Then it is passed to the IF amplifier for amplification.

* The matched filter attenuates the unwanted noise signals
* A 2d detector or demodulator is used to demodulate the received signal.
* The IF amplifier, demodulator and the video amplifier together form the envelope detector.
* The final decision to predict a target is present or not is done with the help of Threshould detector.

If the ~~thres~~ amplitude of the signal crosses the threshould then a target is present, else target is not there.

(Q4)



Basic block diagram of radar.

* RADAR is the combination of the words RAdio Detection And Ranging.
* Radar is an electromagnetic system that relies on electromagnetic waves.
* The importance of radar is, a radar is used to detect reflective objects like
  1. Ships
  2. Planes
  3. Cars
  4. Pedestrians
* The Basic principle of radar is that, it emits radiation energy into free space and then detects the echo of the target.
* This gives us the location of the target and other target related information.

Eqns.

* The main benefit of radar is that it can be used in
↳ Darkness
↳ Haze
↳ Fog
↳ Rain
↳ Snow.

The Advantages of radar is that
(1) It can be used in all types of weather.
(2) It gives a very precise and accurate reading of the targets location.

Applications
(1) Radars are used in planes to navigate in bad weather.
(2) Radars are used in cars for emergency braking

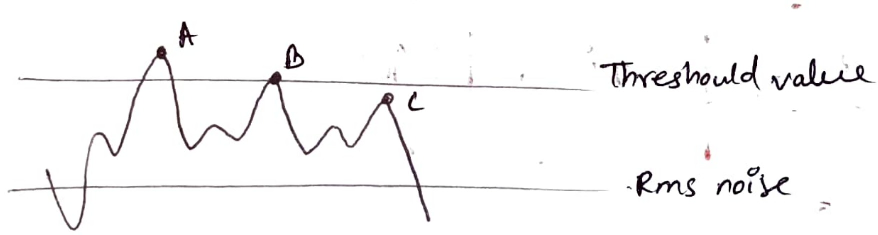
Explain More

(Q5)

⇒ Minimum detectable signal.

It is the weakest signal that a radar can detect.
If the echo ~~of the~~ has minimum power, then the detection by radar is known as minimum detectable signal.
Therefore if the echo does not have the minimum power limit then the radar will not detect it.

In any practical conditions radars receive signals that have noise. A Threshoud value is used to determine if a target is present, this is called threshould detection.



A → vaild
B → vaild
C → no target.

⇒ Maximum unambigues range

The Maximum unambiguous range is the longest range upto which a transmitted pulse can go from the radar and back between consecutive transmitted pulses.

WKT PRF is

$$T_R \propto \frac{1}{f_R}$$

Suppose a radar sends a pulse and it returns back in round trip time 't' then :

If $(t < T)$ the return signal arrives before the next ~~signal~~ pulse is transmitted

If $(t = T)$ the return signal arrives just as the next pulse is transmitted.

If $(t > T)$ the return signal arrives after the next pulse is transmitted (ambiguity).

In the third case the radar is not able to distinguish whether if the return pulse is from 1st pulse or 2nd pulse, this causes an ambiguity.

$$R_{un} = \frac{c}{2 f_R}$$

IEEE Freq range of Bands.

Band nomenclature		Frequency range
HF	HF (High frequency)	3 – 30 MHz
VHF	Very HF	30 – 300 MHz
UHF	Ultra HF	300 – 1000 MHz
L		1 – 2 GHz
S		2 – 4 GHz
C		4 – 8 GHz
X		8 – 12 GHz
Ku		12 – 18 GHz
K		18 – 27 GHz
Ka		27 – 40 GHz
V		40 – 75 GHz
W		75 – 110 GHz
mm		110 – 300 GHz

(Q5)

(i) Origin of Radar

* The first conventional experiment on radar was done by Helrick Hearty in the ~~early~~ years 1885-1888.

* Helrick Hearty verified the James Clark Maxwells theory that was published in 1864.

* Helrick Hearty proved that there were similarities between radio waves and light waves but differed in frequencies.

* The radio waves would reflect off smooth surfaces but would refract through a prism.

* H. Hearty's apparatus was similar to the pulse modulator which operated at 455MHz.

* H. Hearty did not conduct any practical experiments, this was done by Cristian Helbinky. a german.

* In the 1900's Cristian developed an instrument/device that was far better than H. Hearty. which can be compared to the monostable pulse modulators of today.

* In 1904 his patent was approved in england and he marketed his device.

* His device was used a ship collision avoidance system.

(ii) Applications of Radar

Radar is used to detect targets in the air, ground, sea, space and even below the earth's surface.
Some of the applications of Radar are.

1) Military
* Radars are used in missle guidance systems.
* Radars are used in air defence systems on military bases.

2) Remote sensing.
Radars are used in.
* weather observation
* planetary observation.
* sea Ice observation to map ship routes.

3) Air Traffic Control.
* Radars are used for Air Traffic surveillance.
* Radars are used to reroute planes due to bad weather

4) Law Enforcement and Highway Safety.
* The Police use Radar guns to stop ~~high~~ overspeeding on highways.

5) Ship safety
* Ships use radars to avoid collisions with other ships and ice bergs.

6) Space
* Radars were used to land moon rover.

7) Aircraft safety.

8) Radars in Cars for emergency braking.

3.01

1 Q6)

(a) $\lambda = 3cm = 3 \times 10^{-2} m$

$G_t = 50dB = 10^{\frac{50}{10}} = 10^5$

$P_t = 100 \times 10^3 W$

$S_{min} = 10^{-13} W$

$R_{max} = 259 \times 10^3 m$

$\sigma = ?$

50 dB

$G = 10 \log(G)$

$\frac{G}{10}$

(10)

WKT

$$R_{max}^4 = \left(\frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 S_{min}} \right)$$

$$\sigma = \frac{R_{max}^4 \cdot (4\pi)^3 S_{min}}{P_t G_t^2 \lambda^2}$$

$$= \frac{(259 \times 10^3)^4 \cdot (4\pi)^3 \cdot 10^{-13}}{100 \times 10^3 \times (10^5)^2 \times (3 \times 10^{-2})^2}$$

$\sigma = 0.9921$

$\boxed{\sigma \approx 1 m^2}$

CMR

Q6

(b) Given

~~$P_t = 10 \times 10^6$ Hz~~ $f = 10 \times 10^6$ Hz

$P_t = 250 \times 10^3$ W

PRF = 1500 pps

$\tau = 0.8\,\mu s$

$G = 2500$

$S_{min} = 10^{-14}$ W

$A_e = 10\,m^2$

$\sigma = 2\,m^2$

(i) $(R_{un}) = \frac{c}{2f_R} = \frac{3 \times 10^8}{2 \times 1500}$

$(R_{un}) = 100000$ m.

$R_{un} = 100$ KM.

(ii) $R_{max} = \left(\frac{P_t\, G\, \sigma\, A_e}{(4\pi)^2 S_{min}}\right)^{1/4}$

$= \frac{250 \times 10^3 \times 2500 \times 2 \times 10}{(4\pi)^2\, 10^{-14}}$

$= 298278.92$ m

$R_{max} = 298.27$ km.

(iii) $DC = \frac{\tau}{T} = \tau f_P$

~~$= (0.8 \times 10^{-6})(1000)$~~ (10×10^{9})

~~$DC = 8000$~~ $= 0.8 \times 10^{-6} \times 1500$

$DC = 1.2 \times 10^{-3}$

(iv) Avg power

$P_{avg} = \frac{P_t \tau}{T} = P_t \, DC$

~~$= P_t \cdot DC$~~

~~$= 250 \times 10^3 \times 8000$~~

~~$= 2000 \times 10^3 \times 10^3$~~

~~$P_{avg} = 2\,GW$~~

$= 250 \times 10^3 \times 1.2 \times 10^{-3}$

$= 300\,W$

$P_{avg} = 300$ Watts.