Scheme Of Evaluation
Internal Assessment Test II – March 2019

Sub:	RADAR Engineering							**Code:**	15EC833
Date:	20/04/2019	Duration:	90mins	Max Marks:	50	**Sem:**	8	**Branch:**	ECE

Note: Answer Any Five Questions

Question #	**Description**	**Max Marks**	
1.	**Describe the characteristics of the radar echo from a target of sphere cross section when it is in (a) Rayleigh region (b) Resonance region (c) optical region.** (i) Explanation of sphere as radar cross section (ii) Rayleigh region (iii) Resonance region (iv) Opticalregion	3 M 2 M 2.5 M 2.5 M	10 M

Simple Targets

Sometimes σ of complex targets can be calculated by describing the target as a collection of simple shapes whose cross sections are known. The total cross section is obtained by summing vectorially the contributions from the individual simple shapes.

Sphere

- This is the simplest object for illustrating radar scattering since it has the same shape no matter from what aspect it is viewed.
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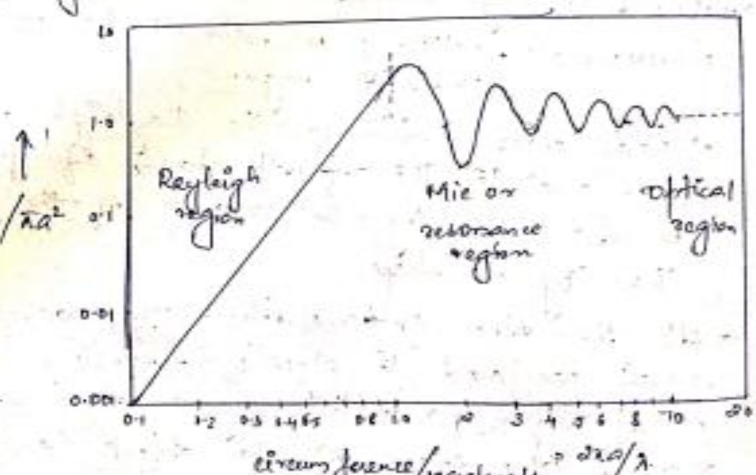

fig. 2.4 Normalized radar cross section of a sphere as a function of its circumference (2πa) measured in wavelengths. a = radius

· fig 2.4 shows its calculated radar cross section as a function of $2\pi a/\lambda$.

· σ is normalized by the projected physical area of the sphere, πa^2.

· In Rayleigh region ($2\pi a/\lambda << 1$), σ is proportional to λ^{-4} (or f^4)

· In optical region, ($2\pi a/\lambda >> 1$), the radar cross section approaches the physical area of the sphere as the frequency is increased.

↳ This can mislead one into thinking that the radar cross section is a measure of geometrical area of the target → it applies only to sphere.

· In optical region, scattering does not take place over the entire hemisphere that faces the radar, but only from a small bright spot at the tip of the smooth sphere. → The only illumination is at the tip. rather than from the entire hemispherical surface.

· The radar cross section of the sphere in the resonance region oscillates as a function of freq. or $2\pi a/\lambda$. Its maximum occurs at $2\pi a/\lambda = 1$ & is 5.6 dB greater than its value in optical region. The first null is 5.5 dB below the optical region value. Changes in cross section occur with changing freq bcos there are two waves that interfere constructively & destructively.

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(b)

- One is the direct reflection from the front face of the sphere → specular return.
- The other is the creeping wave that travels around the back of the sphere & returns to the radar where it interferes with the reflection from the front of the sphere.
- Longer the electrical path around the sphere, greater the loss, so smaller will be the magnitude of the fluctuation with increasing freq.

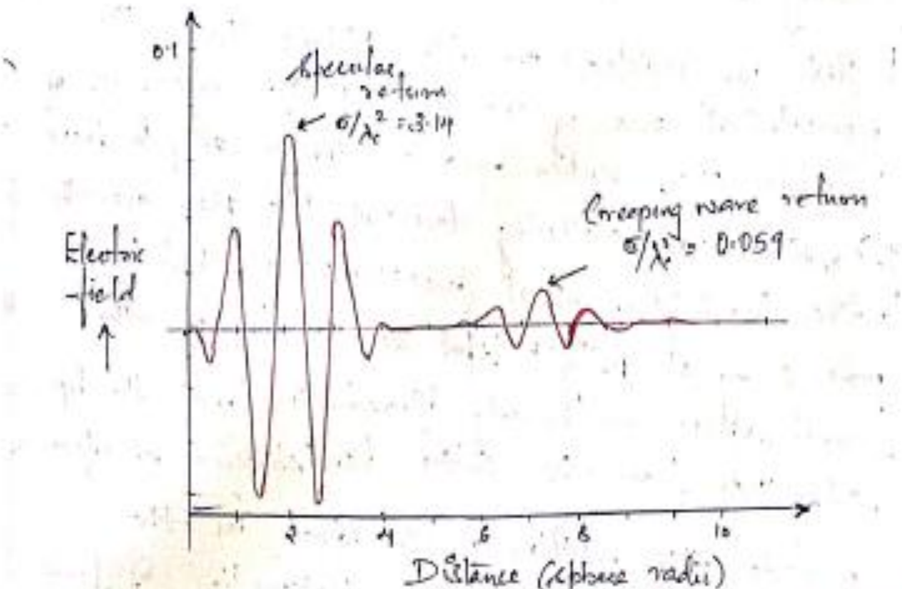

fig 2.5 Backscattered electric field from a short pulse scattered from a conducting sphere showing the specular return from the front of the sphere & the creeping wave that travels around the back.

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What is meant by Minimum detectable signal power of receiver? Explain how this affects detection of signals in noise and gives rise to false alarm and missed detection.

(i) Smin explanation
(ii) False alarm
(iii) Missed detection
(iv) Detection of radar
(v) Figure

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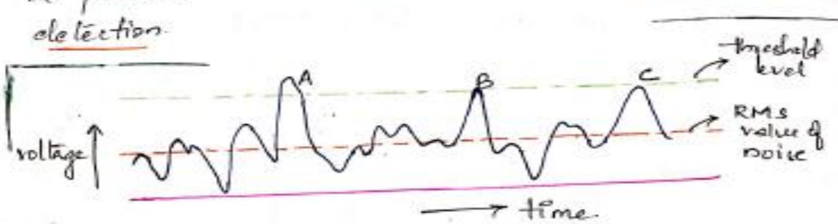
Minimum detectable signal

The weakest signal the receiver can detect is called "minimum detectable signal Smin".

A threshold level is established at the o/p of receiver. If Receiver o/p exceeds this threshold, target echo sle is assumed to be present.

The ability of a radar receiver to detect a weak echo signal is limited by the ever-present noise that occupies the same part of freq. spectrum as the signal.

If the receiver o/p is not of sufficient amplitude to cross the threshold, only noise is said to be present. → This is called threshold detection.



fig(3) Envelope of RADAR receiver o/p as a function of time (or range)

A, B, C → represent signal plus noise
A, B → valid detections
C → missed detection.

fig(3) represents the o/p of Rxr vs. time. The fluctuating appearance of o/p is due to random nature of receiver noise.

- When a large echo sle from target is present, (as at A), it can be recognized on the basis of its amplitude relative to rms noise level.
- If the threshold level is set properly, the receiver o/p should not normally exceed the threshold if noise alone were present, but the o/p would exceed the threshold if a strong target echo signal were present along with the noise.
- If the threshold level is set too low, noise might be mistaken [for a] target

this is called → false alarm

. If the threshold were set too high, noise might not be large enough to cause false alarms, but weak target echoes might not exceed the threshold, & would not be detected.

→ this is called missed detection.

*Selection of proper threshold is therefore a compromise that depends upon how important it is to avoid missed detection & false alarm.

. SNR is a better measure of radar's detection performance than min. detectable signal (S_{min})

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Obtain an expression for modified radar range equation considering the receiver noise and SNR.

(i) Available thermal noise
(ii) Noise Bandwidth
(iii) Noise figure
(iv) Final modified radar range eqn

. At microwave frequencies → noise with which the target echo signal competes is usually generated within the receiver itself.

. If radar were to operate in a perfectly noise free env't, & if receiver itself were so perfect that it did not generate any excess noise,

↳ there would still be noise generated by thermal agitation of conduction electrons in the ohmic portion of receiver i/p stages.

↓

This is called thermal noise or Johnson noise.

↳ Its magnitude $\propto$ BW & abs. Temp of ohmic (dissip) portions of i/p circuit.

. The available thermal noise power (watts) generated at the i/p of receiver of BW B_n (Hz) at a temperature T (deg. Kelvin) is :

$$\boxed{\text{available thermal noise power} = kTB_n} \quad (2.2)$$

where, k = Boltzmann's constant = 1.38×10^{-23} J/deg

BW of superheterodyne receiver is taken to be that of IF amplifier (or matched filter).

$$\boxed{B_n\ (\text{noise BW}) = \frac{\int_{-\infty}^{\infty} |H(f)|^2 df}{|H(f_0)|^2}} \quad (2.3)$$

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(4)

where. $H(f)$ = freq response for of IF amplifier (filter)
f_0 = freq of max^n response (midband)

Eqn (2.3) states that the noise BW is the BW of the equivalent rectangular filter whose noise-power o/p is same as the filter with freq response for $H(f)$.

. The half-power BW is a reasonable approximation for many practical radar receivers.

↳ Half-power bandwidth B is normally used to approximate the noise bandwidth B_n

. The noise power in practical receivers is > (that from thermal noise alone)

Noise figure => Measure of noise power out of a real receiver to that from an ideal Rxr with only thermal noise.

→ NF, F_n = $\dfrac{\text{noise out of Practical receiver}}{\text{noise out of ideal receiver at std temp } T_0}$

$$\rightarrow \boxed{F_n = \frac{N_{out}}{kT_0 B G_a}} \quad \text{———} (2.4)$$

where N_{out} = noise out of the receiver
G_a = available gain = S_{out} / S_{in} (with i/p & o/p matched)
T_0 = std temp (290K or 62°F by IEEE)

N_{in} (noise i/p pwr) in an ideal Rxr = kT_0B_n

⑤

∴ NF, $F_n = \frac{N_{out}}{N_{in}\,(S_{out}/S_{in})}$

$\Rightarrow \boxed{F_n = \frac{(S_{in}/N_{in})}{(S_{out}/N_{out})}}$ —— (2.5)

↳ NF can be interpreted as measure of deviation of SNR as signal passes thro receiver.

Rearranging eqn (2.5)

i/p signal. $\boxed{S_{in} = \frac{kT_0 B_n F_n S_{out}}{N_{out}}}$ —— (2.6)

If min. detectable signal S_{min} is that value of S_{in} which corresponds to the min. detectable SNR at the o/p of IF, $(S_{out}/N_{out})_{min}$, then:

$\boxed{S_{min} = kT_0 B F_n \left(\frac{S_{out}}{N_{out}}\right)_{min}}$ —— (2.7)

Substituting (2.7) into (2.1) (omitting the subscripts on S & N):

$\boxed{R_{max}^4 = \frac{P_t G A_e \sigma}{(4\pi)^2 k T_0 B F_n (S/N)_{min}}}$ —— (2.8)

(Modified Radar range eqn)

S_{min} in radar eqn is replaced by min. detectable signal-to-noise ratio $(S/N)_{min}$

adv. → $(S/N)_{min}$ is independent of rcvr BW & NF.

↳ this ratio is that at the o/p of the IF amplifier. Since maximizing the SNR at o/p of IF is equivalent to maximizing video o/p where threshold decision is made.

4		**Explain how transmitter average power is an important measure of radar performance. Also obtain radar equation in terms of total energy of n pulses.** (i) Expression for P_{av} (ii) Rmax in terms of P_{av} (iii) Integration factor Ei(n) explanation (iv) Final expression in terms of E_{av} and E_T	 2 M 3 M 2 M 3 M	

		TRANSMITTER POWER · The power P_t in radar eqn is usually peak power of the pulse. · The avg power P_{av} of a radar is more important measure of radar performance than the peak power. · It is defined as the avg transmitter power over the duration of the total transmission. $$\boxed{P_{av} = \frac{P_t \cdot \tau}{T_p} = P_t \tau f_p} \quad \text{——— 2.23}$$ where. τ = pulse width, T_p = pulse repetition period f_p = prf · The radar duty cycle can be expressed as $\frac{P_{av}}{P_t}$ or τ/T_p or τf_p. · Pulse radars might typically have duty cycles from 0.001 to 0.5. A CW radar has a duty cycle of unity. Writing range eqn in terms of P_{av} by substituting eq. (2.23) for P_t gives, $$\boxed{R^4_{max} = \frac{P_{av} G A_e \sigma\, n\, E_i(n)}{(4\pi)^2 k T_0 F_n (B\tau)(S/N)_1 f_p}} \quad \text{——— 2.24}$$ where $E_i(n)$ = integration efficiency factor · To improve the performance, multiple pulses received from target could be integrated. · Though pre detection is better, post detection is usually employed for integrating the pulses. · This integration may not be ideal → so $E_i(n)$ is used based on the no. of pulse integrated. · BW & τ are grouped together since the product is usually of the order of unity. · In pulse integration, $\boxed{E_i(n) = \frac{(S/N)_1}{n(S/N)_n}}$ ——— 2.25		10 M

		where n = no. of pulses integrated $(S/N)_1$ = value of SNR of single pulse required to produce given P_d (for $n=1$) $(S/N)_n$ = value of SNR per pulse reqd to produce same P_d when n pulses are integrated. Now, Energy per pulse, $E_p = P_t \tau$. Substituting this into 2.24 gives radar eqn in terms of energy, or $R^4_{max} = \frac{E_p G A_e \sigma n E_i(n)}{(4\pi)^2 k T_0 F_n (B\tau)(S/N)_1}$ ← 2.26. $\Rightarrow R^4_{max} = \frac{E_T G A_e \sigma E_i(n)}{(4\pi)^2 k T_0 F_n (B\tau)(S/N)_1}$ where E_T = total energy of n pulses = nE_p		
5		**Derive an expression for probability of false alarm, P_{fa} in terms of false alarm time, T_{fa} with the help of neat figure illustrating the duration of false alarms and time between false alarms.** (i) Expression for p(R) (ii) Final Pfa expression (iii) Tfa expression and explanation (iv) Relation between Pfa and Tfa (v) Figure	2 M 2 M 2 M 2 M 2 M	10 M

(6) Probabilities of Detection & False Alarm

↳ It is shown how to find min. SNR reqd to achieve a specified probability of detection & probability of false alarm.

Envelope Detector

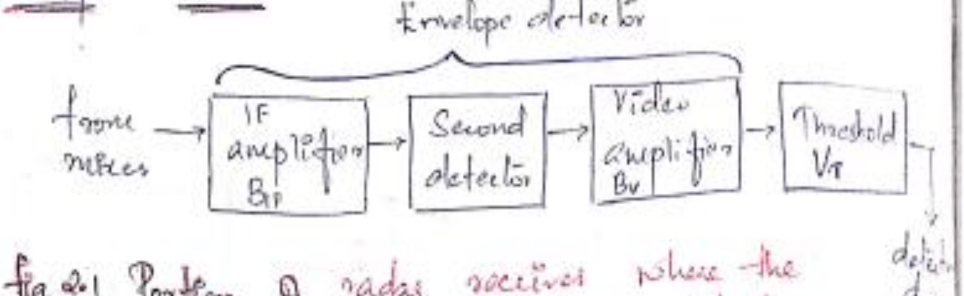


fig 2.1 Portion of radar receiver where the echo signal is detected & the detection decision is made.

- IF filter, second detector & video filter form an envelope detector in that the o/p of video amplifier is the envelope, or modulation of the IF signal.
- Video BW must be wide enough to pass the low frequency components generated by the second detector, but not so wide as to pass the high-frequency components at or near IF.
- $B_V > B_{IF}/2$ in order to pass all the video modulation.
- Envelope detector passes the modulation (envelope) & rejects the carrier. (Mag)
- Second detector is a non-linear device (such as diode).
- Either a linear or a sq. law detector characteristic may be assumed since the effect on the detection probability is relatively insensitive to the choice. (eg. law- easier to handle linear - preferable)

①

BW of radar receiver is the BW of IF amplifier.
Envelope of IF amplifier o/p is the signal applied to the threshold detector.

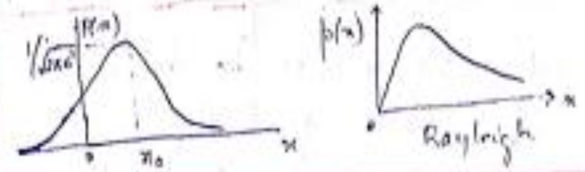
Probability of False Alarm

The receiver noise at the i/p to the IF filter is described by the gaussian probability density function with zero mean.

$$\boxed{p(v) = \frac{1}{\sqrt{2\pi \psi_0}} \exp\left(\frac{-v^2}{2\psi_0}\right)} \quad \text{—— 2.9}$$

Gaussian pblity density fn has a bell shaped appearance & is given by:

$$p(x) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left[\frac{-(x-x_0)^2}{2\sigma^2}\right]$$



where,
$p(v)dv$ = pblity of finding noise voltage v btwn values of v & $v+dv$

ψ_0 = mean eq. value of the noise vltg (mean noise power)

S.O Rice has shown that when gaussian noise is passed thru IF filter, the pblity density fn of the envelope R is given by a form of the Rayleigh pdf:

$$\boxed{p(R) = \frac{R}{\psi_0} \exp\left(\frac{-R^2}{2\psi_0}\right)} \quad \text{——} \rightarrow (2.10)$$

The pblity that the envelope of the noise vltg will exceed the vltg threshold V_T is the integral

(8) of p(R) evaluated from V_T to ∞, or

$$\text{Probability}\,(V_T < R < \infty) = \int_{V_T}^{\infty} \frac{R}{\psi_0} \exp\left(\frac{-R^2}{2\psi_0}\right) dR \qquad \text{—(2.11)}$$

$$= \exp\left(\frac{-V_T^2}{2\psi_0}\right)$$

→ This is the pblity of false alarm since it represents the pblity that noise will cross the threshold & be called a target when only noise is present.

• Thus the pblity of false alarm, denoted P_{fa}, is:

$$\boxed{P_{fa} = \exp\left(-\frac{V_T^2}{2\psi_0}\right)} \qquad \text{—(2.12)}$$

→ This eqn does not indicate whether or not a radar will be troubled by excessive false indications of targets.

* The time btwn false alarms is a better measure of the effect of noise on radar performance.

Fig 2.2 illustrates occurrence of false alarm.
The avg time btwn crossings of the decision threshold when noise alone is present is called false-alarm time T_{fa}, & is given by:

$$T_{fa} = \lim_{N \to \infty} \frac{1}{N} \sum_{k=1}^{N} T_k \qquad \text{—(2.13)}$$

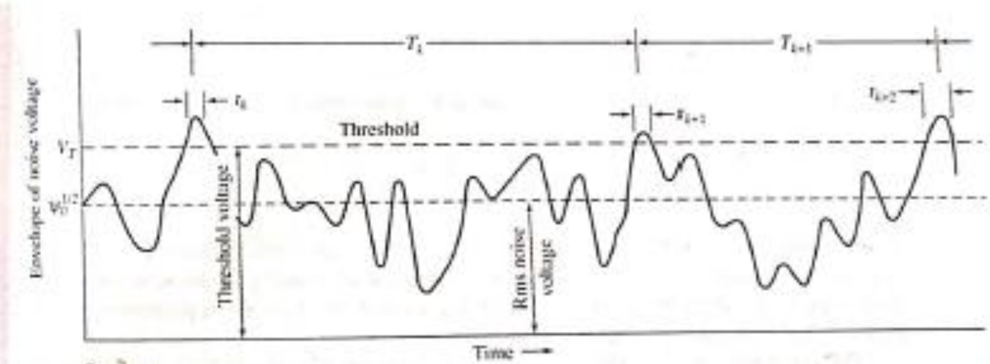


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Figure 2.4 Envelope of the receiver output with noise alone, illustrating the duration of false alarms and the time between false alarms.

where T_k = time btwn crossings of the threshold V_T by the noise envelope. (9)

P_{fa} can be expressed in terms of T_{fa}.

P_{fa} is the ratio of the time the envelope is actually above the threshold to the total time it could have been above the threshold; i.e.:

$$\boxed{P_{fa} = \frac{\sum_{k=1}^{N} t_k}{\sum_{k=1}^{N} T_k} = \frac{\langle t_k \rangle_{av}}{\langle T_k \rangle_{av}} = \frac{1}{T_{fa}\, B}} \quad (2.14)$$

~~where~~, t_k.

The avg duration of a noise pulse is approximately the reciprocal of the bandwidth B, which in case of envelope detector is B_{IF}.

Equating eqns (2.12) & 2.14 ⇒

$$\boxed{T_{fa} = \frac{1}{B}\exp\left(\frac{V_T^2}{2\psi_0}\right)} \quad (2.15)$$

False alarm probabilities of radars are generally quite small since a decision as to whether a target is present or not is made every $\frac{1}{B}$ second. The BW B is usually large so there are many opportunities during one second for a false alarm to occur.

6		**What is monopulse tracking? With a neat block diagram, explain amplitude comparison monopulse in one angle coordinate.** (i) Monopulse tracking (ii) Block diagram (iii) Explanation with beams	2M 3M 5M	10 M
7		**What is tracking radar? Explain the types of tracking radars that provide track of targets** (i) Tracking radar explanation (ii) 4 types	2M 2*4M	10 M
8	(a)	**With a neat block diagram, explain two coordinate (azimuth and elevation angles) amplitude comparison monopulse tracking radar.** (i) Block diagram (ii) Explanation	3M 3M	10 M
	(b)	**With appropriate figures, explain how phase comparison monopulse type of tracking is used to obtain angle errors.** (i) Figure (ii) Explanation	2M 2 M	