Receiver noise

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

Available thermal noise power $= kTB_n$

$$B_n = \frac{\int_0^\infty |H(f)|^2}{|H(f_0)|^2}$$

$H(f) \rightarrow$ frequency response of IF amp — to is matched filter used to improve SNR.

$H(f_0) \rightarrow$ max frequency response.

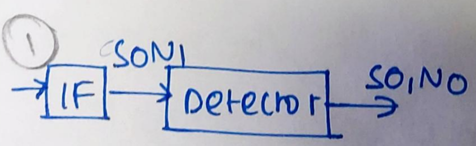
Noise figure: (F_n):

$$F_n = \frac{(S/N)_i}{(S/N)_o} = \frac{S_i/N_i}{S_o/N_o} \Rightarrow S_i = \frac{S_o}{N_o} F_n N_i$$

$$= \frac{S_o}{N_o} F_n k T_o B_n$$

$$F_n = \frac{N_o}{kT_o B_n G_a}$$

(1)



$$S_i = \frac{kT_o B_n F_n S_o}{N_o}$$

$$\boxed{S_{min} = \frac{kT_o B_n F_n S_o}{N_o}}$$

Boltzmann noise.

$$R_{max}^4 = \frac{P_t G \sigma A_e}{(4\pi)^2 \, kT_o B_n F_n (S_o/N_o)_{min}}$$

* semiconductors are mostly exposed only to thermal noise, Johnson noise etc. - But, not short noise.

Integration of radar pulses

$$n_B = \frac{\theta_B f_p}{\theta_s} = \frac{\theta_B f_p}{6\omega_m}$$

$n_B \Rightarrow$ no of pulses returned from a point target.

$\theta_B \Rightarrow$ antenna bandwidth

$\theta_s \Rightarrow$ scanning rate

$f_p \Rightarrow$ pulse repetition frequency.

* Integrator can be used before or after detector and is called pre detection ~~detector~~ integrator and post detection integrator respectively.

Effeciency:

$$E_p(n) = \frac{(S/N)_1}{n(S/N)_n}$$

$E_i(n) \rightarrow$ Efficiency of n pulses.

$n(E_i)_n \rightarrow$ Integration improvement factor

$$R^4_{max} = \frac{P_t\, G\, A_e\, \sigma_i\, n_i E_i(n)}{(4\pi)^2 k T_0 B_n F_n (S/N)_1}$$

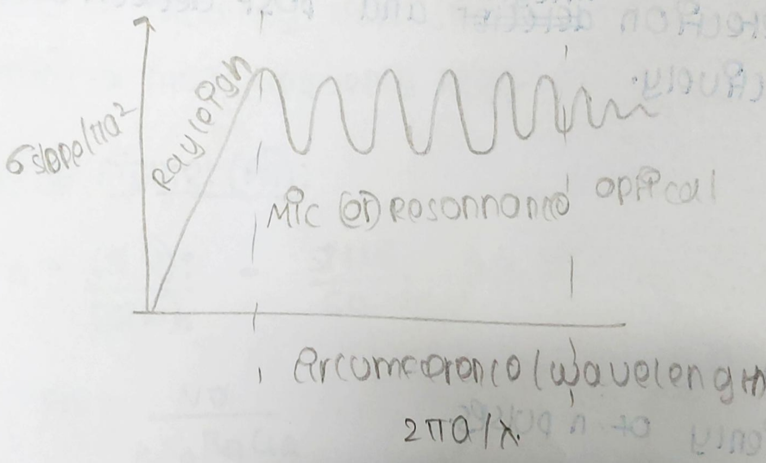
Radar cross-section of target

$$\sigma = \frac{\text{power reflected toward source / unit solid angle}}{\text{incident power density} / 4\pi}$$

$$= 4\pi R^2 \frac{|E_r|^2}{|E_i|^2}$$

$E_r \rightarrow$ electric field strength of the echo signal back at radar

$E_i \rightarrow$ incident electric field strength.



$\sigma \rightarrow$ dimension of object compared to λ

$\lambda >>$ dimension $\rightarrow$ Rayleigh region

$\sigma \propto f^4$ (or) $\frac{1}{\lambda^4}$

$\lambda <<$ dimension of object $\rightarrow$ optical

scattering affects cross section w.r.to change in f or aspect angle

$\sigma \rightarrow$ more affected by shape of object than by projected area.

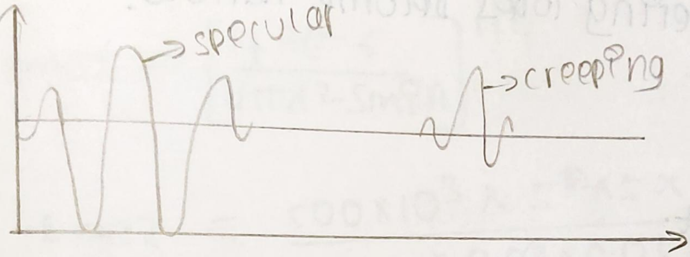
Sphere → Simple Targets

$2\pi a/\lambda << 1 \rightarrow \sigma \propto f^4$

$2\pi a/\lambda >> 1 \rightarrow \sigma$ approaches physical area of sphere (πa^2)

changes in σ occurs with changing frequency

2 waves → specular creeping.



Complex Targets

* Aircraft, missiles, ships, ground vehicles, fabricated structures, buildings, terrain.
* σ varies w.r.to viewing aspect and freq
* multiple indu scatterers cause change in σ.
* Each indu scatteres → has A & phase.
* change in relative phases from indu scatters → w.r.to viewing aspect.

σ → cross section of target

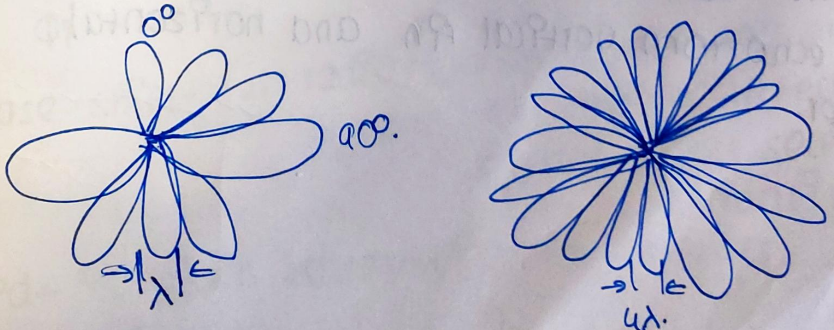


Fig:- Target with 2 scatteres.

$$\frac{\sigma_{ar}}{\sigma_0} = 2\left[1+\cos\left(\frac{4\pi l}{\lambda}\sin\theta\right)\right]$$ $\sigma_T \rightarrow$ resultant cross-section.

$\sigma_0 \rightarrow$ cross section of each scatteres.

$l \rightarrow$ separation

$\theta \rightarrow$ viewing angle w.r.to the normal of the line joining the scatterers.

* As λ ↑es, scattering lobes become narrow.

<u>Jet aircraft</u>

① nose-on aspect.

→ reflection from jet engines and intake ducts

→ compressor blades → modulates the echo signal

② At angles few degrees off the nose.

→ σ decreases.

③ vicinity of Broadside

→ fuselage & engine nacelles → source of back scatter.

→ vertical stabilizers contribute to echoes.

④ Above the plane of the wing.

* Backscatter from corner of wing and fuselage.
* strong echo from vertical fin and horizontal stabilizer.

Q) A Radar operates at 10GHz, at peak power of 500kW. Its min receivable power is 0.1 pW, its antenna has a capture area of & radar C.S of target is, 20 sq.m. Find max. range of radar

Ans: $f_p = 10GHz$, $P_t = 500kW$, $S_{min} = 0.1 \times 10^{-12} W$

$A_e = 5m^2$, $\sigma = 20m^2$

$$R_{max} = \left[\frac{P_t A_e^2 \sigma}{4\pi \lambda^2 S_{min}}\right]^{1/4}$$

$f = \frac{c}{\lambda}$

$\Rightarrow \lambda = 0.03$

$$R_{max} = \frac{500 \times 10^3 \times 5 \times 5 \times 20 \times 10^{-3} \times 10^{-3}}{4 \times \pi \times 0.03 \times 0.03 \times 0.1 \times 10^{-12}}$$

$= 685.6$ km.

Cross section fluctuations:-

$$S_r(t) - \sum_{i=1}^{N} a_i \sin(2\pi f t + \phi_i)$$

$$= A \sin(2\pi f t + \phi)$$

$$A = \left[\left(\sum a_i \sin\phi\right)^2 + \left(\sum_i a_i \cos\phi_i\right)^2\right]^{1/2}$$

$a_i \Rightarrow$ Amplitude of ith point scatterer

$\phi_i - 2\pi f T_i$

phase shift $> 2\pi$ radians $\rightarrow$ amplitude and phase of composite echo signal $\Rightarrow$ cross section fluctuations.

* pdf is given by swelling parameters.

Swerling Target Model

case (i) Echo pulse have constant Amplitude throughout a scan

- scan to scan fluctuations (slow) / Rayleigh scatters.

$$P(\sigma) = \frac{1}{\sigma_{av}} \exp\left[-\frac{\sigma}{\sigma_{av}}\right], \quad \sigma \geq 0.$$

case (ii)

- fluctuation independent from pulse to pulse
- fast fluctuations

$P(\sigma) \rightarrow$ same as case (i).

case - (iii) → Large scatterers with n number of small scatters

$$P(\sigma) = \frac{4\sigma}{\sigma_{av}^2} \exp\left[\frac{-2\sigma}{\sigma_{av}}\right]; \quad \sigma \geq 0.$$

case (iv) fluctuations pulse to pulse

$P(\sigma) \rightarrow$ same as (iii).

Transmitter Power

$P_t \Rightarrow$ peak power

$P_{av} \Rightarrow$ average power

$$P_{av} = \frac{P_t \tau}{T_P} = P_t \tau f_P.$$

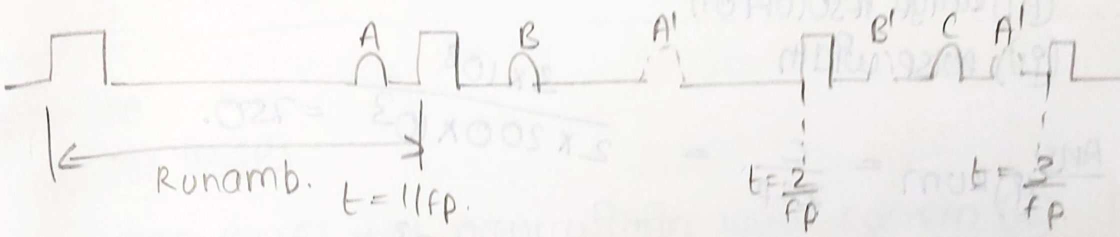
$$\frac{P_{av}}{P_t} = \frac{\tau}{T_P} \text{ (or) } \tau f_P \rightarrow \text{duty cycle.}$$

Type of waveform
pulse width
type of Tx used
If pulse compression is used

parameters effecting duty cycle.

$$R_{max}^{4} = \frac{P_{av}\, G\, A_e\, \sigma\, n\, E_i(n)}{(4\pi)^2\, k\, T_0\, F_n\, (B_n \tau)\, (S/N)_1\, f_p}$$

Pulse Repetition Frequency



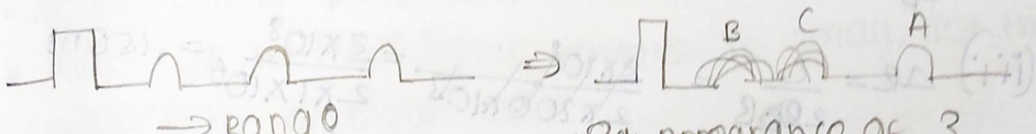


Fig: Appearance of 3 echoes on A scope

Fig: Appearance of 3 echoes with changing prf in A scope display.

prf1, R1, Runamb1

$R_{true} = R_1$ (or) $(R_1 + R_{unamb1})$ or $(R_1 + 2R_{unamb1})$.

prf2, R2, Runamb2

$R_{true} = R_2$ (or) $(R_2 + R_{unamb2})$ or $(R_2 + 2R_{unamb2})$.

Q) The Runamb is 200km, Band width = 1MHz

Find required

(i) Pulse rep freq

(ii) Pulse rep. interval

(iii) Range resolution

(iv) Pulse width

ANS: (i) $R_{UM} = \frac{c}{2f_P} = \frac{3\times10^8}{2\times200\times10^3} = 750.$

(ii) $\frac{1}{f_P} = 1.33\times10^{-3}$

(iii) $\Delta R = \frac{c}{2B} = \cancel{\frac{3\times10^8}{2\times200\times10^3}} = \frac{3\times10^8}{2\times1\times10^6} = 150m$

(iv) Pulse width $= \frac{2\Delta R}{c} = \frac{2\times150}{3\times10^8} = \underline{\underline{1\times10^{-6}}}$

Q) If pulse radar op with P.W of 2µs & PRF of 800Hz then, find max Runamb.

ANS.

$R_{UM} = \frac{3\times10^8}{2\times800} = 187.5\,km.$

Q) A pulse radar has peak power (P.P) = 5kW. The require avg. power is 1kW. Determine duty cycle.

Ans:

$$\frac{P_{av}}{P_t} = \frac{1k}{5k} = 0.2$$

↳ Duty cycle.

System losses

* ~~loss due~~ losses that occur within radar system (L_S)
* Some can be predicted and some cannot.
* loss due to individual factors is small, but they add up to a bigger loss.
* 10dB – 20dB → system loss.

Types:

1) Microwave plumbing loss:-
* includes losses that pertain to transmission line ~~one~~ antenna and other microwave components.

(i) Transmission line loss:
* Flexible waveguides have higher loss.
* loss increases with frequency
* loss can occur at each connection bend.

(ii) Duplexer loss:-
* The loss due to a gas duplexer that protects the receiver from high power of the transmitter
* Different for Tx' & Rx'

* loss value available in manufacturers catalog
* waveguide shutter must be used inorder to ~~dec~~ reduce.

2) Antenne loss

Reduction of power in the transmitted or received signal due to imperfections in the antenna.

(i) Beam-shaped losses

* loss due to shape of radar beam
* It can be mitigated by designing the antenna for specific beam shape, using directional antennas and using signal ~~directional antennas~~ processing techniques to optimize the beam shape

$$\text{Beam-shape-loss} : \frac{n}{1+2\sum_{k=1}^{(n-1)/2} \exp\left[-5.55k^2/(n_B-1)^2\right]}$$

(ii) scanning loss:

when the antenna scans rapidly enough, relative to the round trip-time of the echo signal, the antenna gain in the direction of the target on transmit might not be the same as that on receive.

3) Radome:-

* Radome is protective covering placed over antenna
* This can interfer with radar signals
* Minimized by designing radome for specific frequency band, using low-loss materials.

(i) Phased array losses:

* they radars can experience additional transmission line losses due to distribution network.

4) Signal processing losses

* losses that occur while sophisticated signal processing is being done.

the factors contributing to these losses are:

1) Non-matched filter loss
2) constant false-alarm rate
3) Automatic integrators
4) threshold level
5) limiting loss
6) sampling loss.

5) collapsing loss:-

If radar were to integrate additional noise pulses, the added along with signal-pulse-noise pulses, noise would result in collapsing loss.

6) operator loss:-

loss due to human-operation error.

7) Equipment degradation

8) Propagation effects:-

1) Reflection
2) Refraction
3) propagation in atmospheric ducts
4) Attenuation in atmosphere / precipitation.

Detection of signal in noise

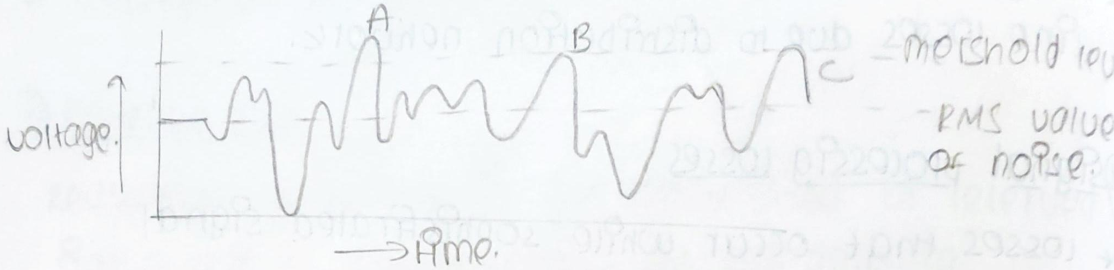


Fig: Envelope of the radar receiver output function of time.

Minimum detectable signal (Smin)

* weakest signal detected by receiver.

False alarm:-

* threshold too low → noise exceeds it.

Missed detection:-

* threshold too high → weak signal might not exceed it.

Threshold detection is used:-