unit-1

Basics of RADAR

* RADAR : A RADAR is a system that uses radio waves to determine the distance, direction and radial velocity of objects is called RADAR.

-> It is a radiodetermination method.

-> An elementary form of RADAR consist of transmitting antenna and receiving antenna.

-> RADAR is invented by "James wattson watt".

* simple form of RADAR Equation :

-> Ro RADAR equation relates the range of a RADAR to characteristic of the transmitter receiver, antenna, Target, and Enviroment.

-> The simple form of RADAR equation can be determined by the distance b/w the target and RADAR.

→ ~~The power of RADAR transmitter is denoted by Pt.~~ → Transmitted power is given by P_t

→ RADAR is equal to transmitted power $R = P_t$.

→ The power density from isotropic antenna is given by $\frac{P_t}{4\pi R^2}$ — (1).

where

$4\pi R^2$ = surface area of the sphere.

→ Isotropic antenna radiates equall in all directions.

→ The power density from directional antenna is given by $\frac{P_t G}{4\pi R^2}$ — (2)

→ RADAR cross-section represented as 'σ'

→ The power density of echo signal at RADAR is given by $\frac{P_t G}{4\pi R^2} \cdot \frac{\sigma}{4\pi R^2}$ — (3).

→ The power P_r received by the RADAR is given by $P_r = \frac{P_t G}{4\pi R^2} \cdot \frac{\sigma}{4\pi R^2} \cdot A_e$ — (4).

∴ A_e = effective area,

→ The maximum RADAR range R_{max} is given by, $R_{max} = \left[\frac{P_t G \sigma A_e}{(4\pi)^2 S_{min}}\right]^{1/4}$ — (5)

∴ Equations (4) and (5) are called RADAR equations

→ The effective area of the antenna is given by

$$G = \frac{4\pi A_e}{\lambda^2} \quad \text{— (6).}$$

$$A_e = \frac{G\lambda^2}{4\pi} \quad \text{— (7).}$$

→ RADAR uses same antenna for Tx ssion and Rx ssion, R_{max} is.

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

sub eq (7) in eq (5).

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

$$R_{max} = \left[\frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 S_{min}}\right]^{1/4} \quad \text{— (8).}$$

Sub eq (6) in eq (8).

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

$$R_{max} = \left[\frac{P_t (4\pi)^{\cancel{2}} A_e^{\cancel{2}} \lambda^{\cancel{2}} \sigma}{\lambda^{\cancel{4}} (4\pi)^{\cancel{3}} S_{min}}\right]^{1/4} = \left[\frac{P_t A_e^2 \sigma}{4\pi \lambda^2 S_{min}}\right]^{1/4} \quad (9)$$

∴ This is the modified RADAR equation.

* System losses

Def : In RADAR system, system losses are the losses that occur throughout the radar system and reduce the signal to noise ratio at receiver end is called system losses

1. Beam-shape losses :

-> This loss occurs because the radar equation uses the maximum gain, rather than the gain that changes pulse to pulse.

2. Collapsing losses

-> This loss occurs, if the unwanted signal enters into the wanted signal and creates disturbance

$$L(m,n) = \frac{L(m+n)}{L(n)} \rightarrow \text{wanted signal}$$

3. Transmitter power degradation loss :

-> This loss occurs when the transmitter power degrades.

4. operator losses :

-> This loss occurs due to tired, overloaded, poorly trained operator will perform less efficiently.

5. Scanning loss

-> Scanning loss is associated with scanning pattern of an antenna.

6. plumbing losses

-> It is associated with microwave components used in RADAR.

-> Microwave components

- Duplexer
- couplers, circulators
- waveguides
- Transmission lines.

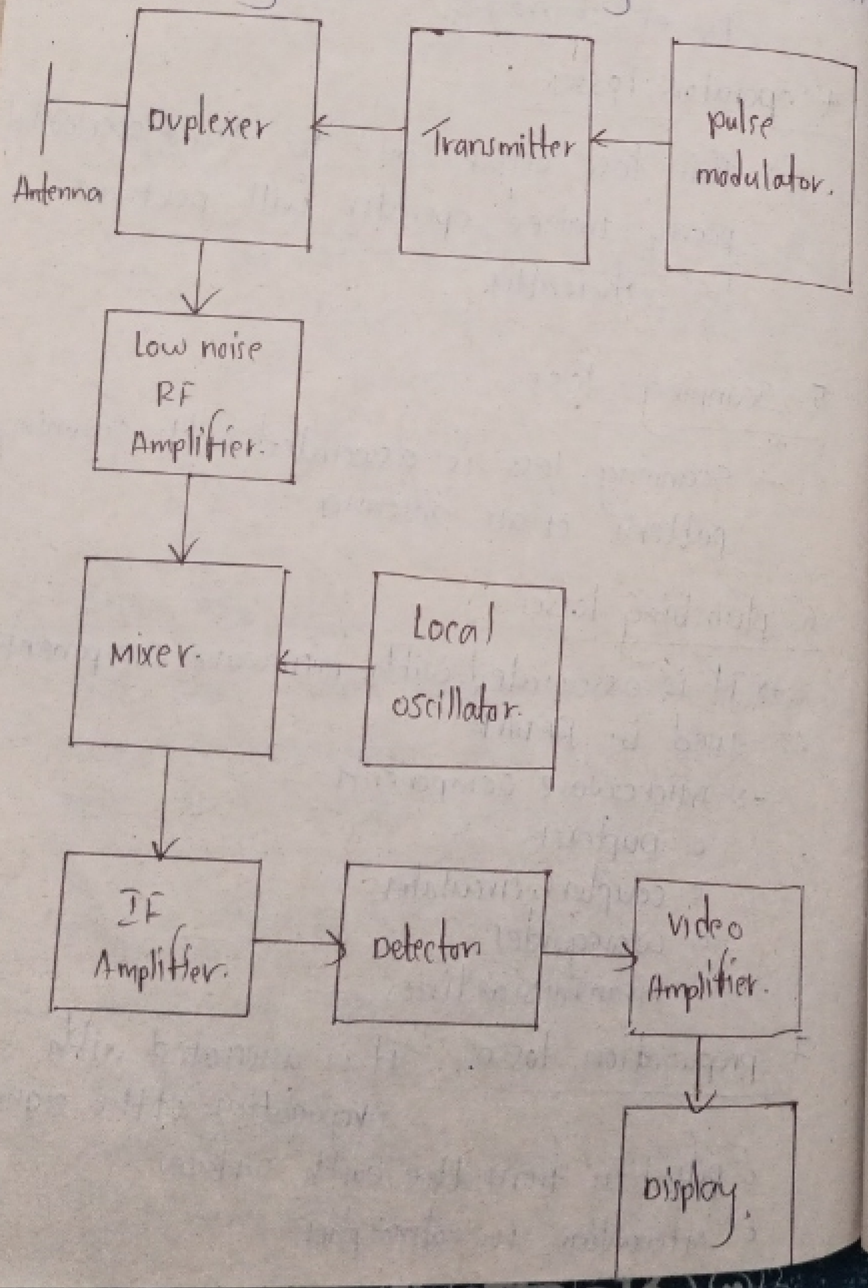
7. propagation losses

: It is associated with propagation of the signal

- Reflection from the earth surface
- Attenuation in atmosphere.

* Block diagram of RADAR

-> Following is the blok diagram of RADAR



-> let us see the function of each block.

pulse modulator: It produces pulse modulated signal and applied to the transmitter.

Transmitter: It transmits the pulse modulated signal.

Duplexer; It is a microwave switch which connects the antenna to both transmitter section and Receiver section

Low noise RF Amplifier; It amplifies the weak RF signal.

-> Duplexer o/p connected to Low noise RF Amplifier.

Mixer; we know that mixer can produce both sum and difference of the frequencies

-> Mixer o/p connected to IF amplifier.

-> Local oscillator given as input to the mixer.

IF Amplifier; IF Amplifier amplifier the Intermediate frequency (IF) signal

-> IF amplifier amplifier only Intermediate frequency obtained from mixer.

Detector: It demodulates the signal, which is obtained at the o/p of the IF amplifier.

Video Amplifier: It amplifies the video signal, which is obtained at the o/p of detector.

Display: It displays the amplified video signal on CRT Screen.

* Applications of RADAR

-> RADAR is a shorthand for Radio detection and Ranging.

-> It is a technology that uses radio waves to detect object.

1. Air traffic control:

-> RADAR plays a crucial role in air traffic control systems worldwide.

-> It helps monitor and manage the movement of aircraft in the sky.

-> It prevents collisions.

2. Weather Forecasting

-> Radar is import in weather forecasting and meteorology.

-> It tracks atmospheric conditions.

-> weather radars can scan the sky to detect, such as, rain, snow, hail etc.

3. military:

-> Radar is a cornerstone of military.

-> Radar detects ~~th~~ and tracks aircrafts, ships, missiles, of the opponents

-> military radars ~~po~~ provide early warning of threats.

4 Space:

-> space Radars guide the space vehicle for a safe landing on the moon.

-> To detect and track satellites.

5 Ground Traffic control

-> Radars can also be used by traffic police to determine speed of the vehicle, movement of the vehicles etc.

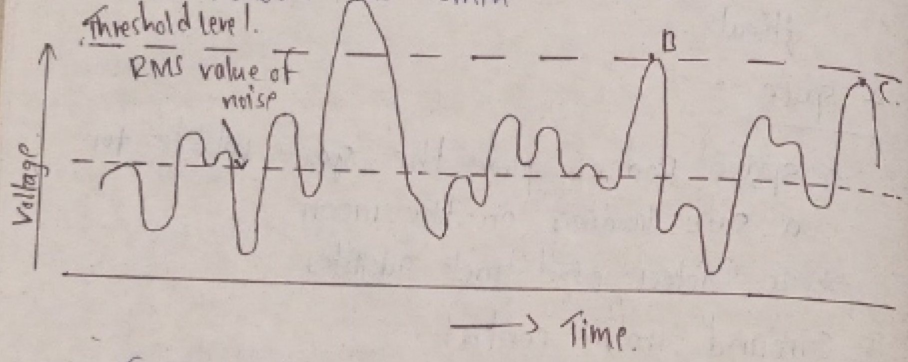
6 Remote sensing

-> It can be used for observing whether (or) planetary positions and monitering sea ice to ensure a smooth route for ships.

* minimum detectable signal

Def:- The weakest signal receiver can detect is called minimum detectable signal.

-> Denoted as 'S_{min}'



-> If threshold voltage level is high, then original targets may be treated as noise.

-> If threshold voltage level is low, noise peaks are treated as original targets

-> we need to choose the threshold level properly.

* Receiver noise

Def:- Receiver noise is an error that can occur in a receiver. is called receiver noise.

-> It can be caused by factors,

- Thermal noise.
- Random motion of e^-
- Dynamic stress.

-> Hence it is called white gaussian noise, (or) thermal noise (or) Johnson noise etc.

-> The avoidable Thermal noise = KTB_n — (1)

$\therefore$ K = Boltzmann contant
T = Room temperature
B_n = Bandwidth

-> Bandwidth $B_n = \dfrac{\int_{-\infty}^{\infty} |H(f)|^2 df}{|H(f_0)|^2}$ — (2)

-> Noise margin, $F_n = \dfrac{N_o}{K T_o B_n G_a}$ — (3)

N_o = o/p noise

G_a = avaliable gain = $\dfrac{S_o}{S_i} = \dfrac{o/p\ s/g}{I/p\ s/g}$

$\therefore F_n = \dfrac{S_i/N_i}{S_o/N_o}$ — (4)

$\therefore S_i = \dfrac{K T_o B_n F_n S_o}{N_o}$ — (5)

$\therefore \left(\dfrac{S_o}{N_o}\right)_{min} = \boxed{S_{min} = \left(\dfrac{S_o}{N_o}\right)_{min}}$ — (6)

$S_{min} = K T_o B_n F_n \left(\dfrac{S_o}{N_o}\right)_{min}$ — (7)

$R_{max} = \left[\dfrac{P_t G \sigma A_e}{(4\pi)^2 S_{min}}\right]^{1/4}$ — (8)

Sub eq (7) in eq (8)

$$R_{max} = \left[\frac{P_t G \sigma A_e}{(4\pi)^2 k T_0 B_n F_n \left(\frac{S_0}{N_0}\right)_{min}}\right]^{1/4}$$

$$\boxed{R_{max} = \frac{P_t G \sigma A_e}{(4\pi)^2 k T_0 B_n F_n \left(\frac{S_0}{N_0}\right) min}}$$

* Maximum unambigious Equation:

Def:- The maximum unambigious range (R_{max} is the maximum rate at which a radar system can detect targets without ambiguity.

-> The Range 'R' is given by $\boxed{R = \frac{CT_r}{2}}$

- factor 2 represents two-way propagation.
- The Range 'R' represented in kilometers.
- T_r is in microseconds.

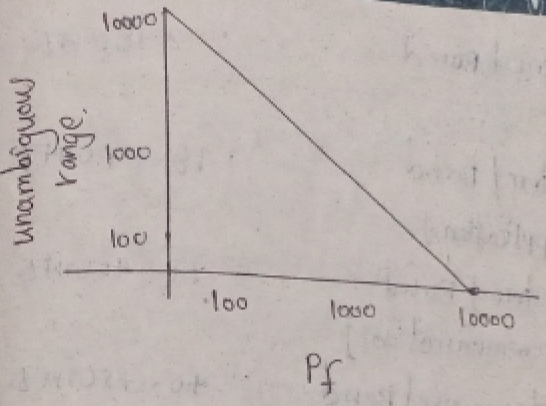
$$\boxed{\therefore R(KMs) = 0.15\, T_R (Msec)}$$

-> Maximum unabigious Range $= \frac{c}{2f_p}$.

(or)

$$\boxed{R_{unambigious} = \frac{c}{2f_p}}$$

where f_p = pulse repetetion frequency.



* Radar frequencies

-> HF (High frequency) (surface wave Radar) : 3-30 MHZ

-> VHF (very high frequency) (weather Radar) : 30 - 300 MHZ.

-> UHF (ultra high frequency) (Air traffic control) : 300 - 1000 MHZ.

-> L (long) Band (Air Surrelliance) : 1-2 GHZ.

-> S (short Band) (weather Radar) : 2-4 GHZ.

-> C (centimetric) Band (missile guidence) : 4-8 GHZ.

-> X (centimetric) Band military applications : 8-12 GHZ.

-> ku (centimetric) Band (Radar) : 12-18 GHz.

-> k (centimetric) Band (Military applications) : 18-27 GHz.

-> ka (centimetric) Band (satellite communications) : 27-40 GHz.

-> v (millimeter wave) Band (Automotive Radar) : 40-75 GHz.

-> w (millimeter-wave) Band (military applications) : 75-110 GHz.

* prediction of Range performance

-> ~~predil~~ predicting range performance is crucial in radar system design to detecting and tracking of targets.

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

where, P_t = transmitted power.

G = Antenna gain.

A = effective area

σ = Radar crosssection.

S_{min} = minimum Detectable signal

* Modified Radar range equation

$$P_r = \frac{P_t G A_e \sigma}{(4\pi)^2 R^4} \quad (1)$$

$$\boxed{G = \frac{4\pi A_e}{\lambda^2} \qquad A_e = \frac{G\lambda^2}{4\pi}}$$

sub G and Ae values in eq (1)

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

$$R_{max} = \left[\frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 S_{min}}\right]^{1/4}$$

$$R^4_{max} = \left[\frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 k T_0 B_n F_n \left(\frac{S_0}{N_0}\right)_{min}}\right]$$

$$\boxed{SNR = \frac{S}{N} = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 k T_0 B_n F_n R^4 + L}}$$

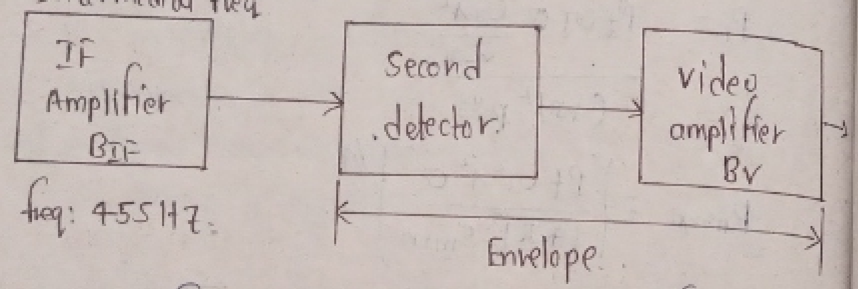
$$\boxed{L = L_t = L_r = L_{other}}$$

• The SNR equation is called standard radar equation.

* Envelope Detector

Def: ~~Ev~~ Envelope detector is an electronic circuit that can be used in radar engineering to detect the amplitude of signal across frequencies.

Intermediat freq



freq: 455 HZ

-> Above figure shows block diagram of Envelope detector.

-> Block diagram consist of IF amplifier, second detector, video amplifier.

-> consider an intermediate frequency 455 HZ

-> second detector and video amplifier sections called as Envelope.

-> IF amplifier Bandwidth B_{IF} followed by second detector and video amplifier Bandwidth is B_V.

-> B_V must be greater than $\frac{B_{IF}}{2}$ or $\boxed{B_V > \frac{B_{IF}}{2}}$

-> probability density function is given by

$$\boxed{p(v) = \frac{1}{\sqrt{2\pi\psi_0}} \exp -\frac{v^2}{2\psi_0} dv}$$

where $p(v) \times dv$ is the probability of finding noise v/g b/w v and v+dv.

ψ_0 = variance

$v = 0$.

-> $$P(R) = \frac{R}{\psi_0} \exp\left(\frac{-R^2}{2\psi_0}\right)$$

$$\boxed{\text{probability}(v_1 < R > v_2) = \int_{v_1}^{v_2} \frac{R}{\psi_0} \exp\left(\frac{-R^2}{2\psi_0}\right) dR}$$

-> Threshold voltage V_T

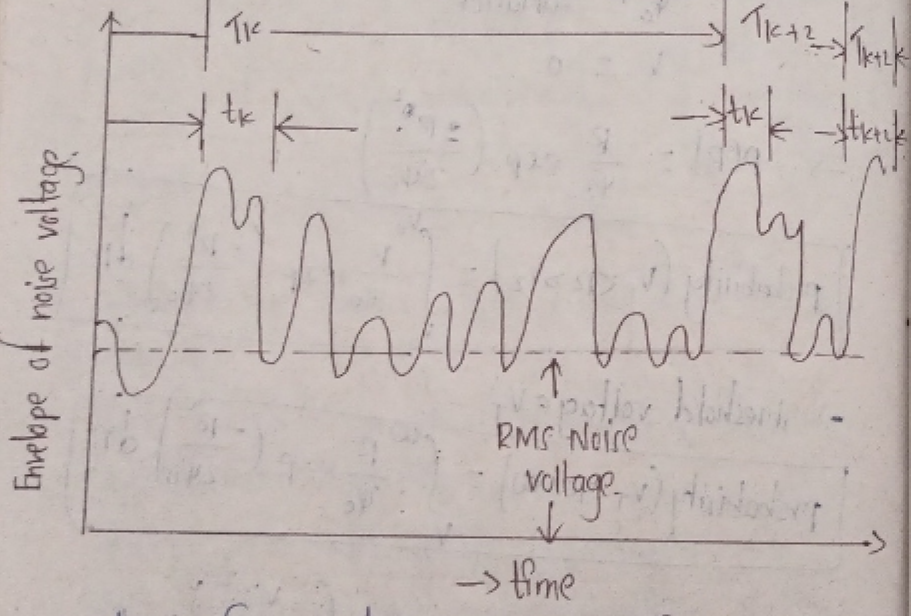
$$\boxed{\text{probability}(V_T < R > \infty) = \int_{V_T}^{\infty} \frac{R}{\psi_0} \exp\left(\frac{-R^2}{2\psi_0}\right) dR}$$

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

$$\boxed{T_{Fa} = \lim_{N \to \infty} \frac{1}{N} \sum_{k=1}^{N} T_k}$$

* False alarm time probability :-

Def: FATP is the probability that a radar system will detect a false target within a specified time period, is called FATP



-> Above figure shows Envelope of receiver o/p illustrating false alarms due to noise.

-> $P_{fa} = \dfrac{\sum_{k=1}^{N} t_k}{\sum_{k=1}^{N} T_k} = \dfrac{\langle t_k \rangle av}{\langle T_k \rangle av}$

$\langle t_k \rangle av$ -> particular time

$\langle T_k \rangle av$ -> overall time

$$\boxed{P_{fa} = \frac{1}{T_{fa} B}}$$ $\because B$ = Bandwidth

$$T_{fa} = \frac{1}{B_{IF}} \exp\left(\frac{-V_t^2}{2\psi_0}\right)$$

where,

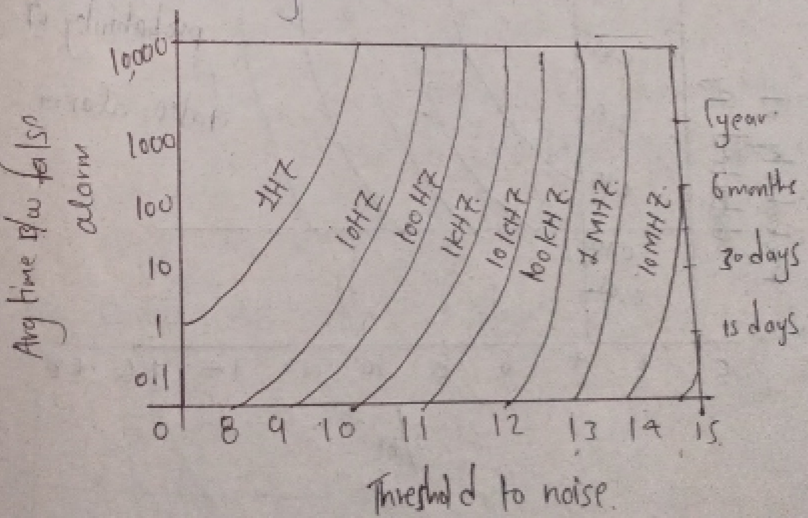
B_{IF} = Bandwidth of intermediate freq.

ψ_0 = mean square

V_t = threshold voltage

$\therefore I_0(z) \cong e^{z} / \sqrt{2\pi z}\left[1 + \frac{1}{2z} + \cdots\right]$

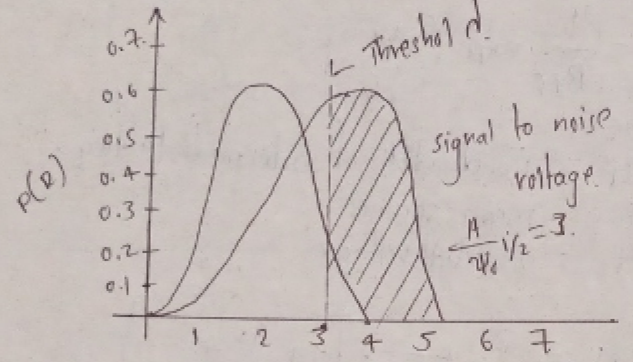
-> when the signal is absent at A = 0, (Amplitude)

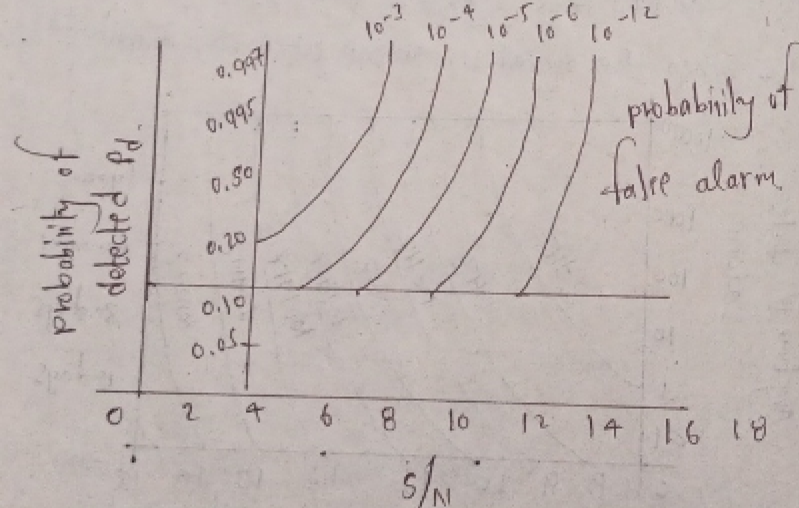


$$P_s(R) = \frac{R}{\psi_0} \exp\left[\frac{-R^2 + A^2}{2\psi_0}\right] I_0\left[\frac{RA}{\psi_0}\right] \quad \text{— (a)}$$

$$P_d = \int_{V_T}^{\infty} P_s(R)\, dR$$

$$P_d = \int_{V_T}^{\infty} \frac{R}{\psi_0} \exp\left(-\frac{R^2+A^2}{2\psi_0}\right) I_0 \left[\frac{RA}{\psi_0}\right] dR$$





* Radar cross-section of Target (sphere, cone sphere)

Def: RCS(σ) is the measure of the power scattered by a target in the direction of the radar receiver.

-> units - m^2

-> $$\sigma = \lim_{R \to \infty} 4\pi R^2 \left[\frac{E_r}{E_i}\right]^2$$

where, 4π = incident power density

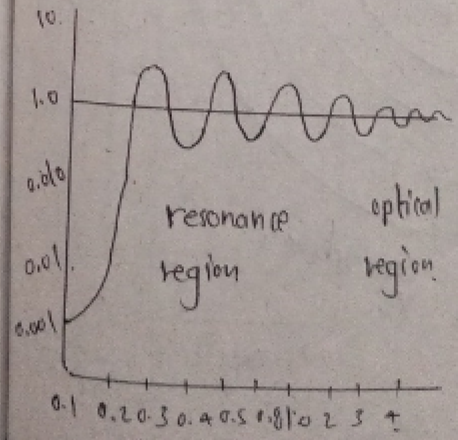
R^2 = radius of respective path

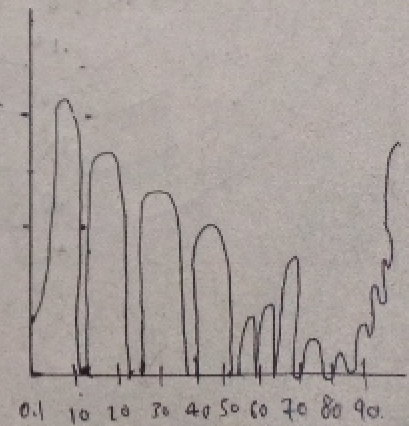
R = distance b/w radar & target

E_r = Reflected field strength at radar.

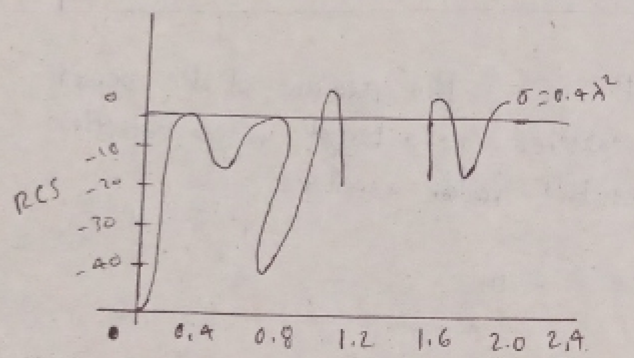
E_i = Incident " " "

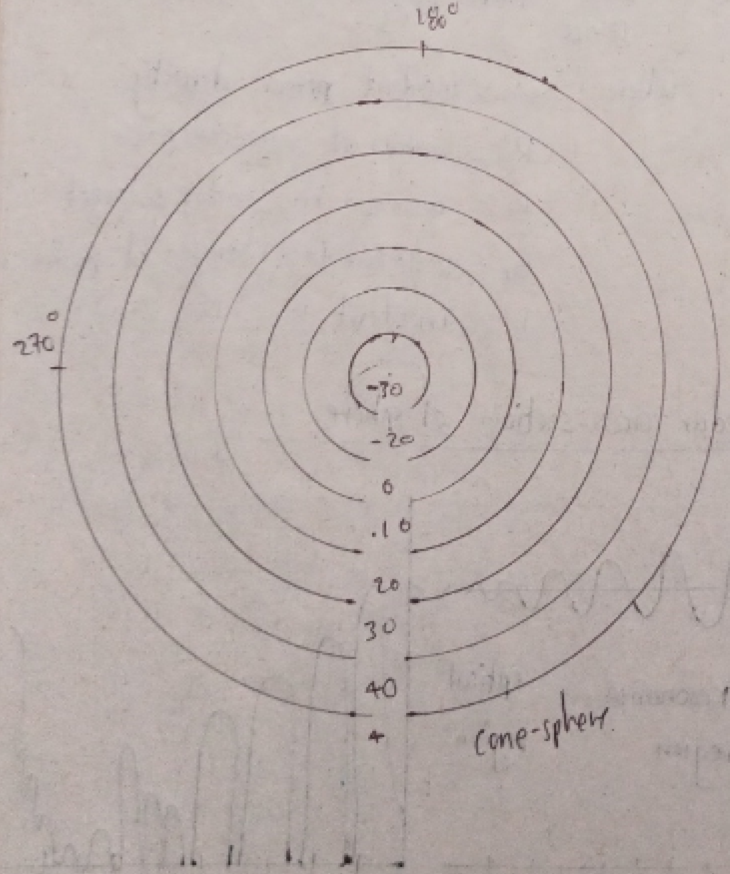
-> Radar cross-section of sphere.





Radar cross-section of cone-sphere





* Transmitting power

Transmitting power is a critical component of radar engineering, that determines radar's range, resolution, and detection capabilities

-> peak power (P_p) = Energy / pulse width

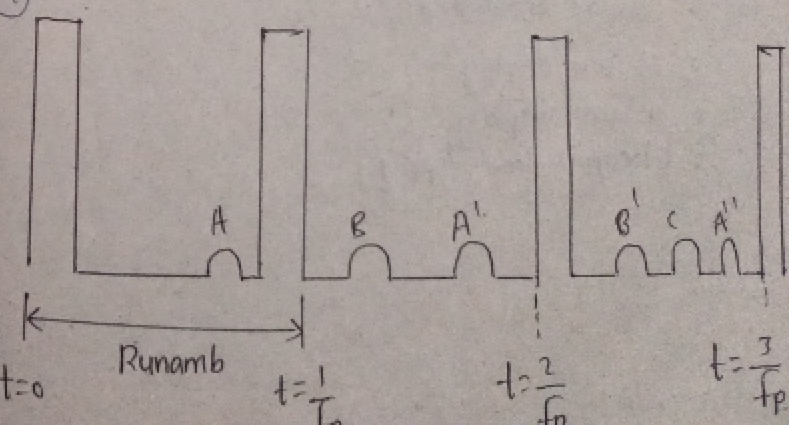
-> Average power (P_a) = P_p * Duty cycle

-> Radiated power (P_r) = P_p x Antenna gain gain

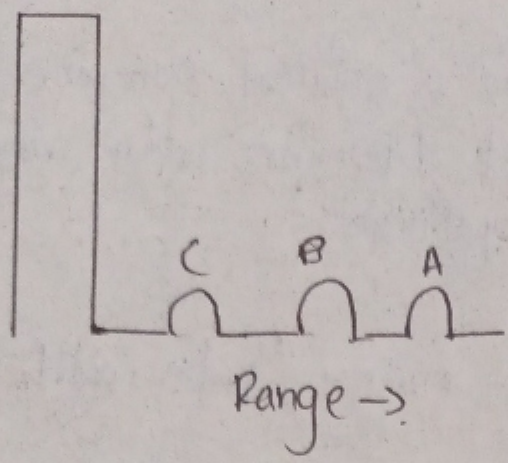
* **Duty cycle** : It is critical parameter in RF, it defines the ratio of transmission time to total time.

* pulse repetetion frequency and Range Ambigious

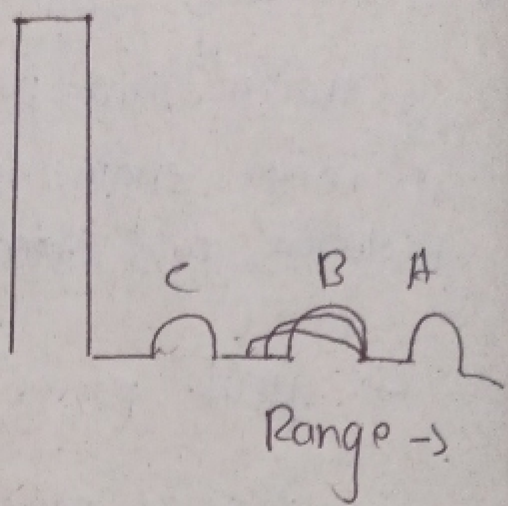
(a)



(b).



(c).



-> The PRF is determined primarily by max Range

* Displays

-> Radar displays ~~visualize radar data, enabling~~ used to present the information contained in the radar return signal in a format.

-> Types

- plan position indicator
- plan view display
- Range Azimuth display
- B-scan display
- A-scan display
- Electronic scan display

Unit-2

Doppler effect

Def : The Doppler effect is a physical phenomena that is used in radar to measure speed of objects in motion is called Doppler effect.

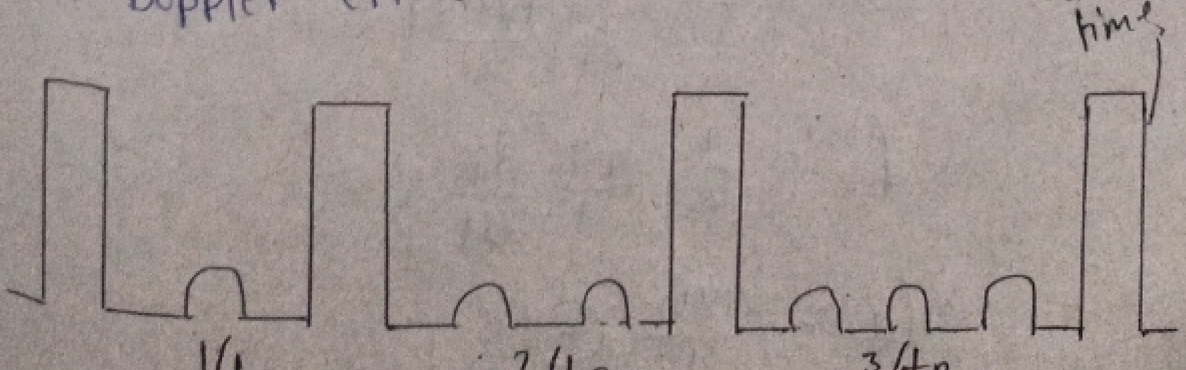
-> Doppler effect is an ~~a~~ important phenomena.

-> Doppler effect is also known as doppler shift.

-> According to the doppler effect, we will get the following two possible cases -

- The freq. of received signal will increase, when the target moves towards the direction of Radar.
- The freq. of received signal will decrease when the target moves ~~towar~~ away from the radar.

-> Doppler effect.



-> **Derivation.**

-> The distance b/w Radar and Target is nothing but the Range (R), for two way (2R)

-> λ = wavelength.

-> Two way communication path b/w Radar & target is $2R/\lambda$

-> $\frac{4\pi R}{\lambda}$ Radians

-> Angular frequency $\omega = 2\pi f$ — (1).

-> Relation b/w ω and ϕ is $\omega = \frac{d\phi}{dt}$ — (2).

-> equate RHS terms of eq (1) and LHS terms of eq (2).

$$2\pi f = \frac{d\phi}{dt}$$

$$f = \frac{1}{2\pi}\frac{d\phi}{dt} \quad (3)$$

sub $f = f_d$, and $\phi = 4\pi R/\lambda$ in eq (3).

$$f_d = \frac{1}{2\pi}\frac{d}{dt}\left[\frac{4\pi R}{\lambda}\right]$$

$$f_d = \frac{1}{2\pi}\frac{4\pi}{\lambda}\frac{dR}{dt}$$

$$f_d = \frac{2V_r}{\lambda} \quad (4)$$

f_d = Doppler frequency

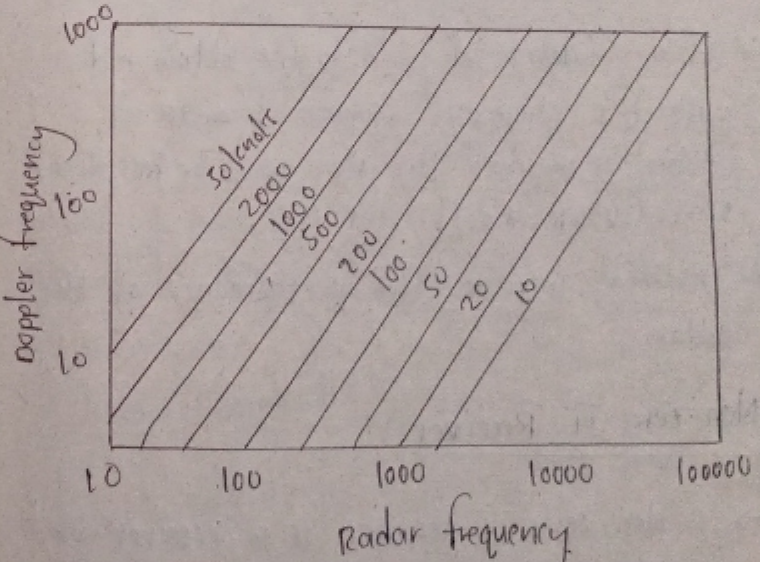
V_r = relative velocity

sub V_r and λ values in eq (4)

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

$$f_d = \frac{2V_r}{c/f}$$

$$\boxed{f_d = \frac{2V_r f}{c}} \quad (5)$$



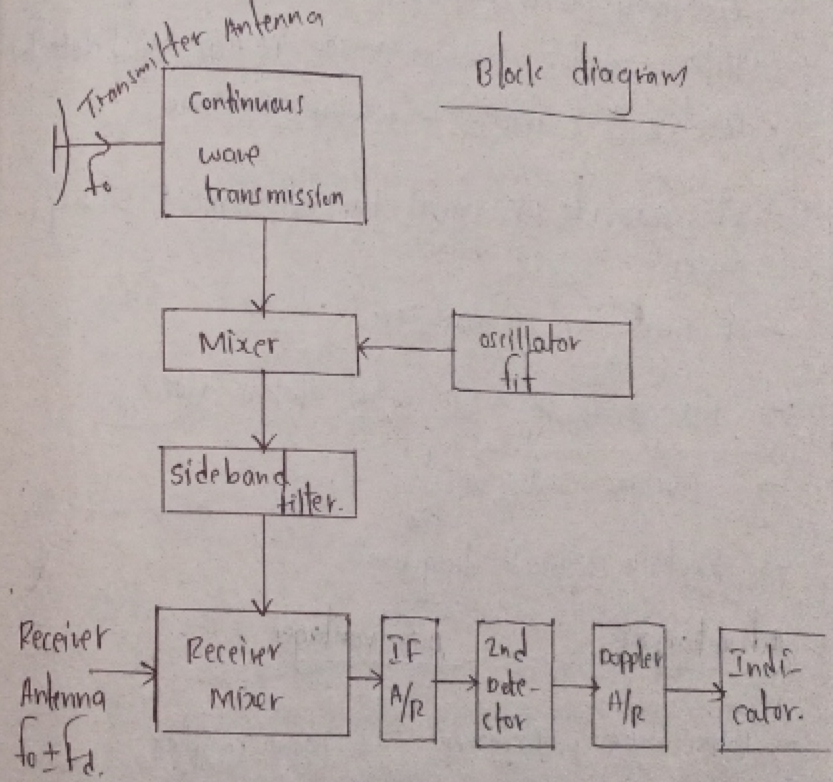
* Isolation b/w transmitter & Receiver

- In radar engineering, isolation between transmitter and receiver refer to the separation of transmitting and receiving components to prevent interferences, noise degradation.
- Isolation is of three types, electrical, RF and spatial isolations etc.
- improves radar sensitivity
- Increases system reliability
- Enhances signal-to-noise ratio (SNR).
- If an isolation of 20dB is to be obtained with the VSWR < 1.2. suppose if 40dB of isolation is required the VSWR must be less than 1.02. (VSWR < 1.02)
- Isolation improves the performance of the radar.

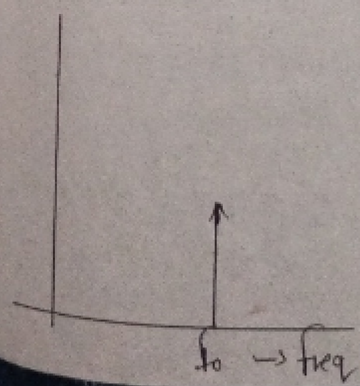
* Non-Zero IF Receiver :

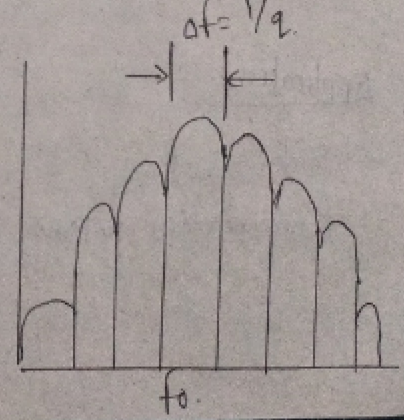
- A Non Zero IF receiver is a receiver that operates with a non-zero intermediate frequency. is called Non-Zero IF Receiver.
- It has Receiver noise
- A Non-Zero IF receiver is a type of radio frequency (RF) receiver that uses an IF and not equal to zero.

Block diagram



- Receiver Bandwidth





-> Above Block diagram show Non-Zero IF Receiver.

-> Block diagram consist of Transmitting antenna, continuous wave propagation, Mixer, sideband filter, oscillator, Receiver Mixer, IF A/R, 2nd detector, Doppler A/R, Indicator, Receiver Antenna.

-> It converts RF signal to IF signal using mixer.

-> IF frequency is Non-Zero.

-> This is used to avoid flicker Noise.

-> Flicker noise $\propto \frac{1}{f_{in}}$

-> Explain block diagram...

Advantages

-> Better noise performance
-> Improved selectivity

Disadvantages

-> More complex
-> High cost.

Applications

-> Radar systems
-> Communication systems.

* Receiver Bandwidth Requirements

Requirements

- Sufficient Bandwidth to accomodate, pulse width and modulation
- High selectivity
- compatability with transmitter frequency and pulse characterictics
- accurate stability and Linearity.
- Adequate noise figure and Sensitivity

* FM-CW Radar :

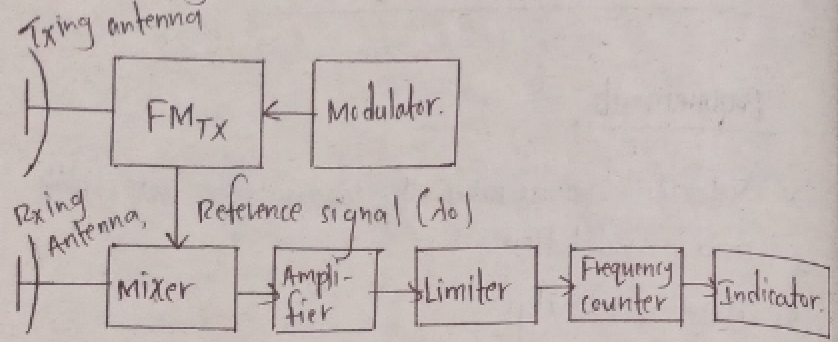
Def: Frequency modulated continuous wave (FMCW) radar is a type of radar that transmits a continuous wave signal with a frequency that varies over time is called FMCW Radar.

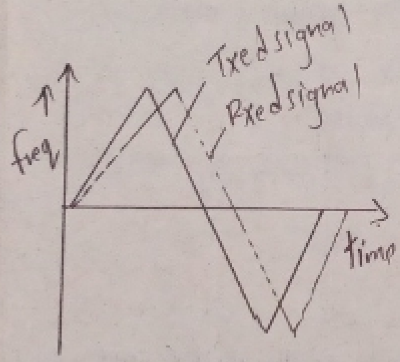
-> FMCW transmits a stable frequency signal

-> FMCW have high spectral purity, high sensitivity, low cost, low sampling frequency.

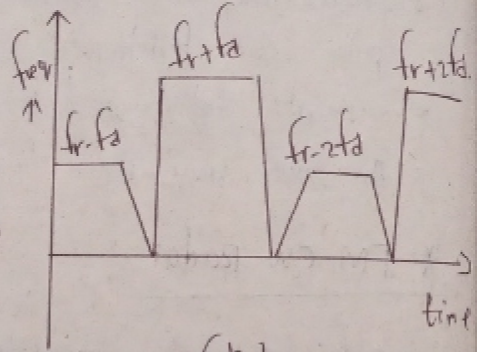
-> FMCW radar can generate, triangle, saw-tooth, Square waveforms.

Block diagram





(a)



(b)

-> Block diagram shows FMCW radar.

-> It consist of FM$_{Tx}$, modulator, mixer, Amplifier, Limiter, frequency counter, Indicator.

-> FMCW radar transmits a continuous wave signal with a linear frequency modulation.

-> The receiver measures the frequency difference b/w transmitted and received signals.

-> Key components of FMCW
- Mixer
- Low-Noise-Amplifier.
- Filter.
- Detector.
- Analog to Digital converter (ADC)

Advantages

-> Low cost.

-> implementation is easy.

Disadvantages

-> Limited range accuracy

Applications

- Automotive radar.
- weather radar.
- Industrial radar.

* FMCW Altimeter

An FMCW altimeter is a type of radar altimeter that used frequency modulated continuous wave technology to measure the distance b/w an aircraft ~~and~~ and the ground is called FMCW altimeter.

-> The FMCW altimeter transmits a continuous wave signal with a linear frequency modulation ~~to~~ towards the ground.

-> The signal is reflected back to the altimeter, which measures the frequency difference b/w transmitted and received signals.

-> The frequency difference is directly proportional to distance between the aircraft and ground.

-> FMCW altimeter have:

- High accuracy
- " resolution
- Low power consumption.
- Limited range

-> FMCW ~~used~~ altimeter used in

- Aviation
- space exploration.

* Multiple Frequency CW Radar

Def :- A multiple frequency CW Radar is a radar that transmits multiple frequencies to measure range, velocity, (or) motion is called MFCW radar.

-> MFCW is also used to detect small motions.

-> MFCW Radar is used to determine the Range (R) and the motion (v).

Working MFCW

-> let assume two frequencies f_1 and f_2 are used with CW Radar.

-> Transmitted signals by CW Radar are given by:

$V_{1t} = \sin(2\pi f_1 t + \phi_1)$ ϕ_1 and ϕ_2 = Arbitary phase constants

$V_{2t} = \sin(2\pi f_2 t + \phi_2)$

$\phi_1 = \frac{2\pi R f_1}{c}$

$\phi_2 = \frac{2\pi R f_2}{c}$

- Time delay $(T) = \frac{2R}{c}$
- phase delay $(\phi) = 2\pi T f$

$\therefore f_1 = f_1 \pm f_d$

$\therefore f_2 = f_2 \pm f_d$

-> Received echo signal is given by

$V_{1r} = \sin\left(2\pi(f_1 \pm f_d)t - \frac{4\pi R f_1}{c} + \phi_1\right)$

$V_{2r} = \sin\left(2\pi(f_2 \pm f_d)t - \frac{4\pi R f_2}{c} + \phi_2\right)$

-> If the received echo signal given to detector, then output of detector is :

$V_{1r} = \sin\left(2\pi(f_1 \pm f_d)t - \frac{4\pi R f_1}{c} + \phi_1\right)$.

$V_{2r} = \sin\left(2\pi(f_2 \pm f_d)t - \frac{4\pi f_2}{c} + \phi_2\right) \rightarrow \boxed{\text{Detector}} \rightarrow$

$V_{1D} = \sin\left(\pm 2\pi(f_d)t - \frac{4\pi R f_1}{c}\right)$

$V_{2D} = \sin\left(\pm 2\pi(f_d)t - \frac{4\pi R f_2}{c}\right)$

$\uparrow$

$V_{1t} = \sin(2\pi f_1 t + \phi_1)$

$V_{2t} = \sin(2\pi f_2 t + \phi_2)$

→ if the o/p of detector is given to phase detector then the phase change will be:-

$V_{1D} = \sin\left(\pm 2\pi(f_d)t - \frac{4\pi R f_1}{c}\right)$

$V_{2D} = \sin\left(\pm 2\pi(f_d)t - \frac{4\pi R f_2}{c}\right) \rightarrow \boxed{\text{phase Detector}} \rightarrow \Delta\phi = \frac{4\pi(f_2 - f_1)R}{c}$

→ so the Range is given by $\boxed{R = \frac{c\Delta\phi}{4\pi\Delta f}}$;

→ so, maximum unambiguous range is given by. $\boxed{R_{unamb} = \frac{c}{2\Delta F}}$

* MTI RADAR

Def :-

Moving target indication (MTI) radar is a radar mode that uses the Doppler frequency shift to differentiate moving ~~tro~~ targets from stationary clutter.

(or)

Radar uses the principle of Doppler effect for distinguishing the non-stationary targets from stationary objects. This type of Radar is called Moving Target Indicator.

-> MTI Radar works on the principle of Doppler effect.

-> MTI radar is designed to detect and track moving targets.

° Types of MTI Radar :

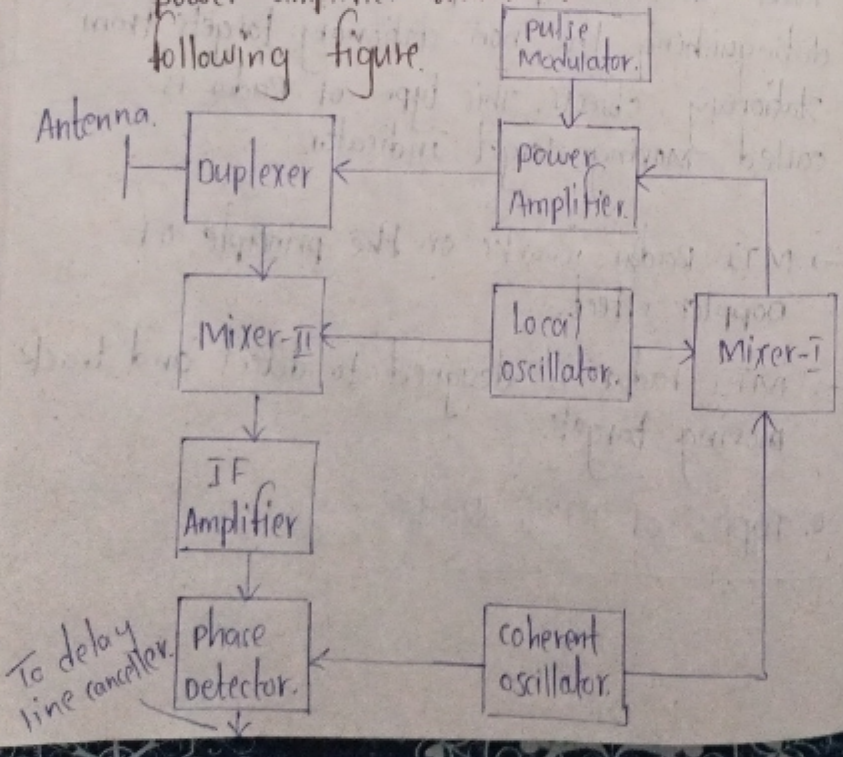
-> we can classify the MTI Radars into the following two types

- MTI Radar with power Amplifier Transmitter
- MTI " " " oscillator "

MTI Radar with power Amplifier Transmitter

-> MTI Radar uses single Antenna for both transmission and reception of signals with the help of Duplexer.

-> The block diagram of MTI Radar with power amplifier transmitter is shown in following figure.



-> The function of each block of MTI Radar

pulse Modulator : It produces a pulse modulated signal and applied to power amplifier.

power Amplifier : It amplifier the power levels of the pulse modulated signal.

Local oscillator : It produces a signal having stable freq. f_1.

-> It is also called as stable local oscillator.

-> output of local oscillator applied to mixer I and II.

coherent oscillator : It produces a signal having intermediate frequency f_c.

-> The o/p of coherent oscillator given to Mixer-I and phase detector.

Mixer-I : Mixer can produce either sum (or) difference of the frequency that are applied to it.

-> f_1 and f_c are applied to it.

-> o/p frequency is $f_1 + f_c$

Duplexer : It is a microwave switch which connect Antenna to either transmitter (or) receiver section.

Mixer II

-> Mixer can produce either sum (or) difference of frequency that are applied it.

-> output is $f_c \pm f_d$.

IF Amplifier : IF amplifier amplifies intermediate frequency signal.

phase Detector : It is used to produce o/p signal

-> frequency f_d.

-> The o/p of phase detector connected to Delay line canceller.

- MTI RADAR with power oscillator Transmitter

-> The block diagram MTI Radar with power oscillator Transmitter is similar as MTI Radar with power Amplifier Transmitter.

-> Block diagram shown in below figure.

Block diagram is same as before page but in place of power Amplifier place Magnetron oscillator.

-> MTI Radar uses single Antenna for both transmission and Reception.

-> The output of Magnetron oscillator and local oscillator are applied to Mixer-I

-> The o/p of mixer-1 applied to the coherent oscillator.

-> The o/p of coherent oscillator can be used as reference signal.

* Delay line cancellers :

Def : A Delay-line canceller is a filter that removes the DC components of echo signals from stationary targets, while allowing the AC components of echo signals from moving targets.

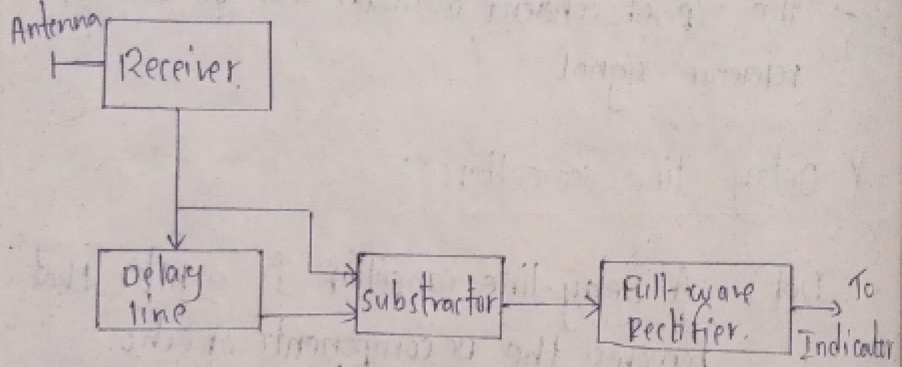
-> It is a technique used in Moving target Indicator radar.

-> Types of delay line cancellers.

- Single Delay-line-canceller.
- Double Delay-line canceller.

∘ Single Delay line canceller

- The combination of delay line and subtractor is known as Delay line canceller.
- It is also called as single delay line canceller.
- The block diagram of MTI Receiver with single delay line canceller shown in below fig.



- The single delay line canceller stores the previous radar pulse in a delay line.
- when new radar pulse returs, it subsbacts the stored pulse from current one.
- provides resultant as output.
- It is simple to design.
- It Act as high-pass filter.
- it is used in radar systems.

$$V_1 = A\sin[2\pi f_d t - \phi_0] \quad -(1)$$

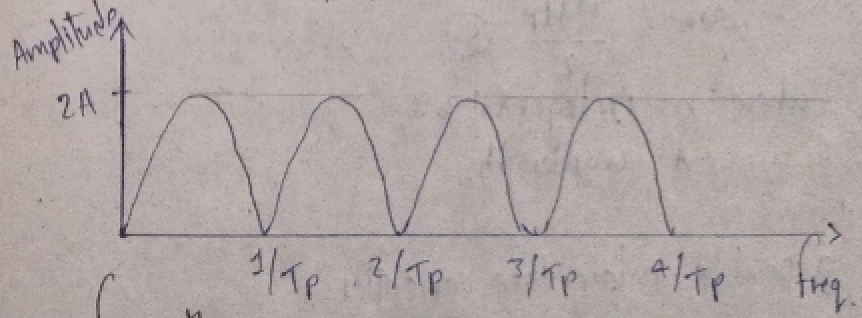
$$V_2 = A\sin[2\pi f_d(t - T_p) - \phi_0] \quad -(2)$$

substract eq (2) from (1)

$$V_1 - V_2 = A\sin[2\pi f_d t - \phi_0] - A\sin[2\pi f_d(t - T_p) - \phi_0]$$

$$V_1 - V_2 = 2A\sin[\pi f_d T_p]\cos\left[2\pi f_d\left(t - \frac{T_p}{2}\right) - \phi_0\right] \quad (3)$$

- The o/p of substractor is applied as input to Full wave rectifier.
- Therefore o/p of full wave rectifier looks like as shown below:



- $f_d = \frac{n}{T_p}$ (4)
- $\frac{1}{T_p} = f_p$ - (5).
- $f_d = n f_p$ (6)

◦ Blind speeds :

- single delay canceller eliminates the DC components of echo signals received from stationary targets.
- It eliminates the AC components received from non-stationary targets.
- The relative velocities for which the frequency responses of the single delay line canceller becomes zero are called blind speeds.
- Mathematical expression for blind speed is

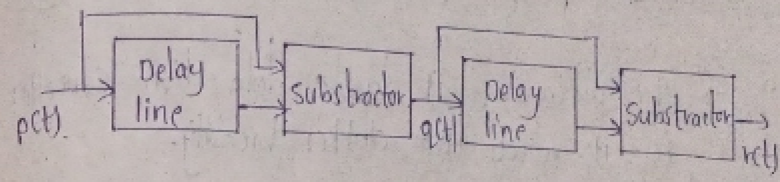
$$v_n = \frac{n\lambda}{2T_p} \quad (7)$$

$$v_n = \frac{n\lambda f_p}{2} \quad (8)$$

where n = integer (1, 2, 3 ....)
λ = wavelength.

◦ Double Delay line canceller :

- we know know that single delay line canceller consist of a delay line and substractor.
- If two delay line cancellers are cascaded together, then that combination is called double delay line canceller.
- The block diagram of double delay canceller is shown in below figure.



- Here p(t) and q(t) be the input and output of first delay line canceller.

$$q(t) = p(t) - p(t - T_p) \quad (9)$$

- The o/p of first delay line canceller applied as an input to the second delay line canceller.
- Let r(t) be the o/p of the ~~de~~ 2nd delay line canceller.

$$r(t) = q(t) - q(t - T_p) \quad (10)$$

replace t by $t - T_p$ in eq (9).

$\cancel{q(t) = p(}$

$$q(t - T_p) = p(t - T_p) - p(t - T_p - T_p)$$

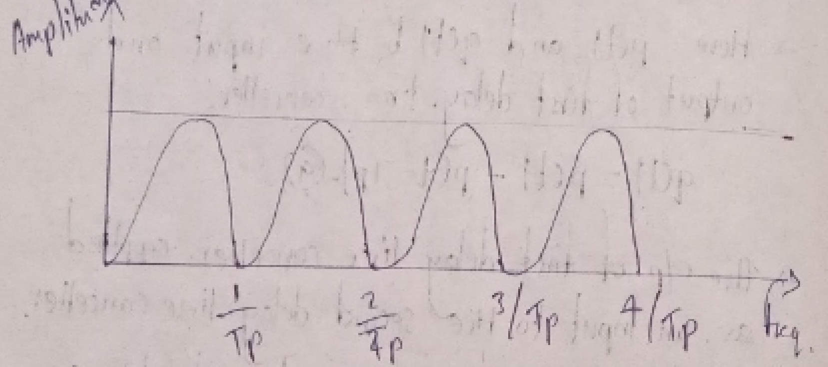
$$q(t - T_p) = p(t - T_p) - 2(t - 2T_p) \quad (11)$$

sub eq (9) and (11) in eq (10)

$$r(t) = p(t) - p(t-T_p) - [p(t-T_p) - p(t-2T_p)]$$

$$r(t) = p(t) - 2p(t-T_p) + p(t-2T_p) \quad -(12)$$

-> The advantage of double delay line canceller is it rejects the clutter broadly.



* MTI PARAMeters

-> MTI radar parameters

1. MTI improvement factor

-> MTI improvement factor is the ratio of the output target-to-clutter ratio to the input target to clutter ratio. is called MTI improvent factor

-> It is the measure of how well cutter is attenuated.

2. Subclutter visibility:

-> Subclutter visibility is the ratio of the smallest signal that can be detected in the presence of a large signal

-> It's also proportional to dynamic range.

3. Clutter visibility factor

-> It is the signal to clutter-ratio, after cancellation (or) doppler filtering that provides probabilities of detection and false alarm.

4 clutter Attenuation:

-> clutter Attenuation is the ratio of clutter power at the filter input to the clutter power at the filter output is called clutter Attenuation

5 Cancellation Ratio:

-> Cancellation ratio is the ratio of the canceller voltage amplification for fixed target echoes to the inter clutter visibility. is called cancellation Ratio.

* Limitations of MTI performance

1 Equipment Instabilities :-

-> pulse to ~~pl~~ pulse changes in the amplitude, frequency, (or) phase of the transmitter signal, stalo (or) coho oscillators in the Receiver etc.

-> Jitter in the timing of the pulse transmission

-> variations in the time delay through delay lines.

-> changes in the pulse width.

-> These instabilities limit the improvement factor of the MTI Radar.

2. Scanning Modulation :

-> The scanning modulation and the error signal would be lost if the receiver saturates.

$$t_0 = \frac{n_B}{f_p} = \frac{\theta_B}{\dot{\theta}_s}$$

where

θ_B = Antenna Beamwidth , n_B = no. of Bandwidth

θ_s = Antenna scanning rate , f_p = pulse repetition frequency

This limitation has sometime be called scanning fluctuation (or) scanning modulation.

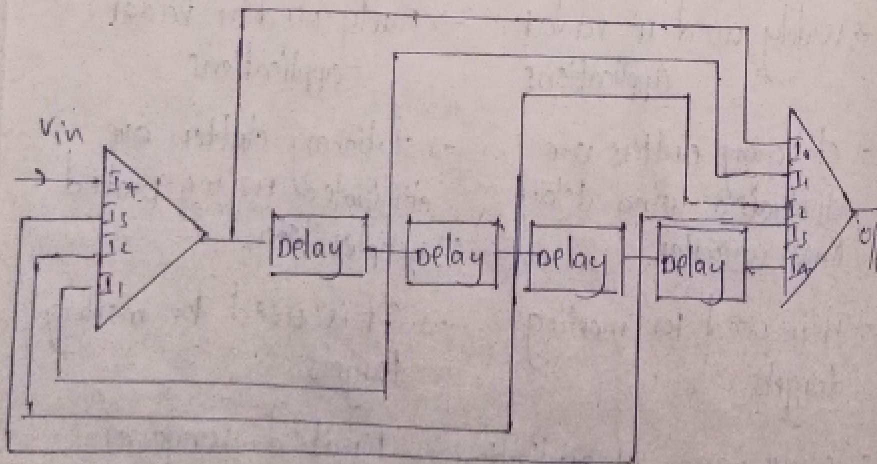
* Difference b/w MTI and pulse Doppler Radar

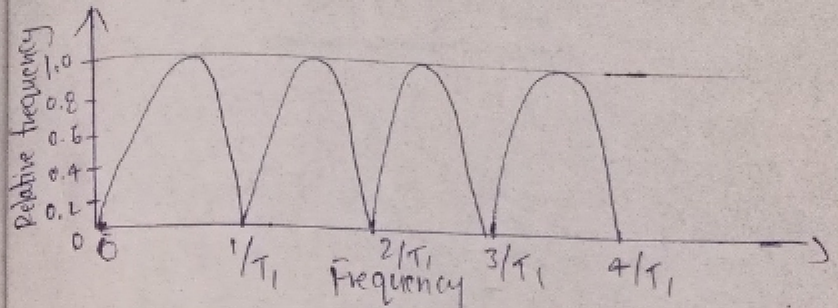
MTI Radar	pulse Doppler Radar
-> MTI Radar suffers from blind speed effect	-> pulse Doppler Radar doesn't suffer's from blind speed effect
-> It has unambiguous range.	-> It has ambiguous range.
-> It uses Magnetron oscillators.	-> It uses klystron oscillators.
-> widely used in radar Applications.	-> Rarely used in radar applications.
-> stationary clutters are eliminated using delay line cancellers.	-> stationary clutters are eliminated using Gated doppler filters.
-> It is used for moving targets.	-> It is used for moving targets.
-> wide range of applications for detection of moving targets.	-> limited range of applications for detection of moving targets.

* Staggered PRFs

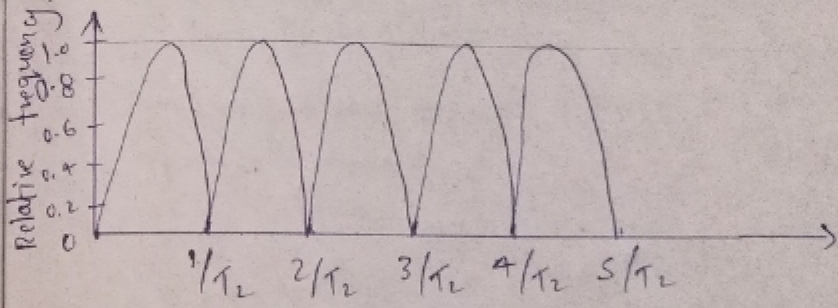
Def: staggered PRF (pulse repetition frequency) is a technique used in MTI radars to detect moving targets in clutter is called staggered PRF.

- Staggered PRF eliminates blind speeds caused by aliasing target and clutter.
- In staggered PRF, the transmitted PRF switches from pulse to pulse.
- Staggered PRFs used in modern Radars.

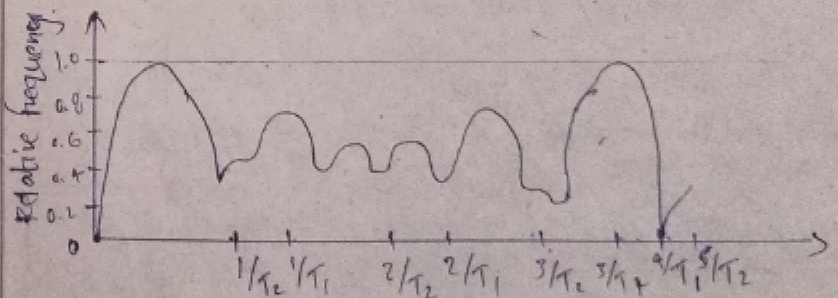




(a)



(b)



(c)

fig (a) = Freq. response of single delay canceller ($1/T_1$)

fig (b) = Same as fig (a) but ($1/T_2$)

fig (c) : Composite response with $4/T_1 = 5/T_2$.

Unit-4

* Tracking with Radar

Def:- The Radar, which is used to track the path of one (or) more targets is known as Tracking Radar.

-> Tracking Radar performs following functions

- Target detection.
- Range of the target.
- Finding elevation and azimuth angles.
- Finding Doppler frequency shift.

-> Most of the Tracking Radars use the principle of tracking in angle.

- Angular Tracking : Angular Tracking refers to the process of measuring and tracking the angular position of a target relative to the radar system.

-> Techniques used in Angular Tracking.

- sequential lobing
- Conical lobing

A-JINU

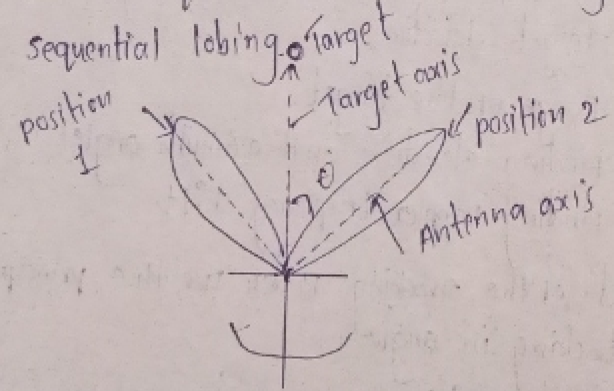
- sequential lobing :-

-> sequential lobing is a radar technique that uses two antenna elements to improve tracking accuracy.

-> It is also known as sequential switching (or) lobe switching.

-> This technique is used to find the angular error.

-> sequential lobing



-> Antenna beams switch b/w position 1 and 2

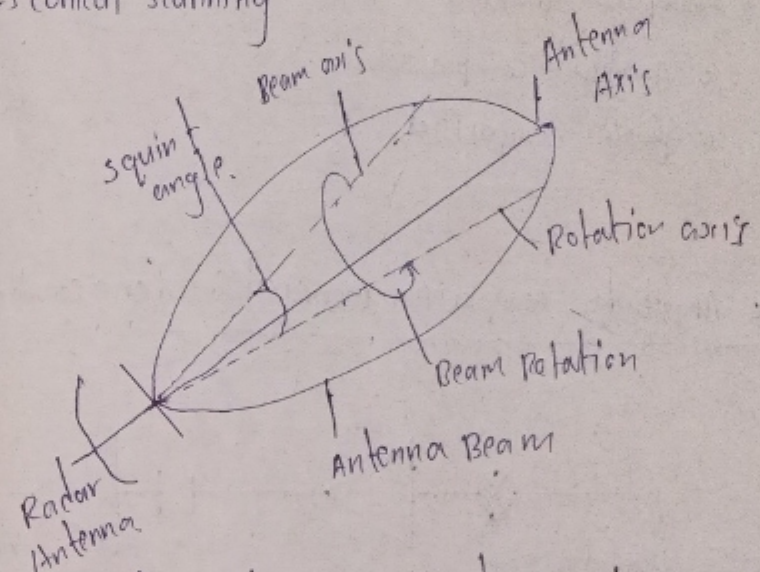
- Conical scanning

-> If the antenna beam continuously ~~routes~~ rotates for tracking a target, then it is called conical scanning.

-> Conical scan modulation is used to find the position of the target.

Unit..!

-> conical scanning



-> squint angle is the angle b/w beam axis and rotation axis.

-> Conical scan modulation extracted from echo signal

* Monopulse Tracking Radar

Def :- Monopulse tracking radar is a radar system that uses a single signal pulse to extract both the range and direction of a target

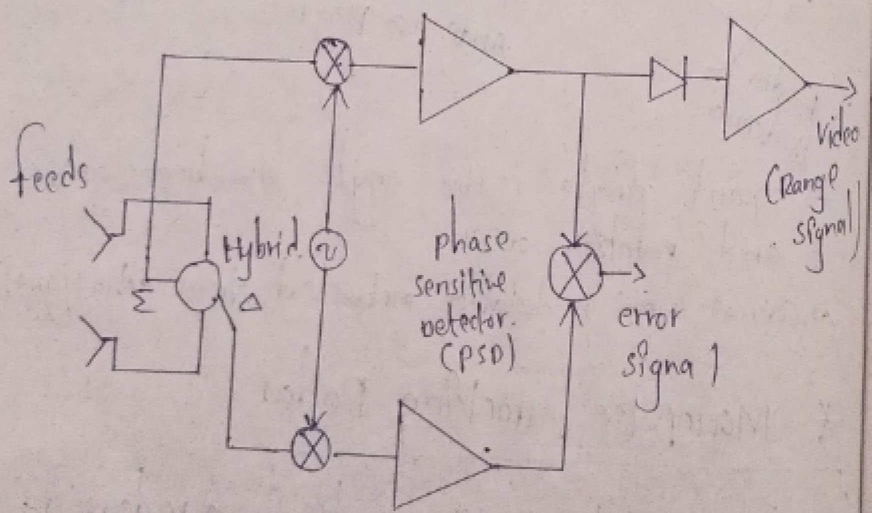
-> It is used to track single (or) multiple targets.

-> Monopulse - single pulse.

-> Monopulse tracking radar is of two types

- Amplitude comparision.
- phase comparision.

- Amplitude comparision monopulse :- (one coordinate)



-> Two adjacent antenna feeds are connected to the 2 input arms of a hybrid junction.

-> sum and difference signal.

-> Difference channel produce error signal.

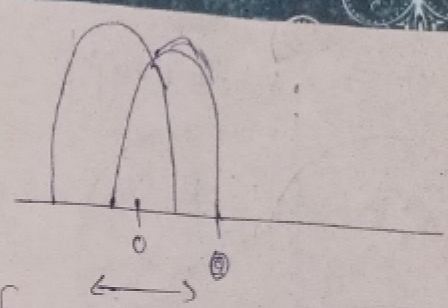


fig: overlapping antenna patterns.

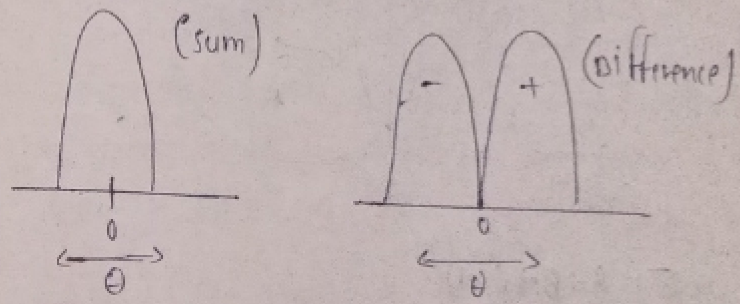


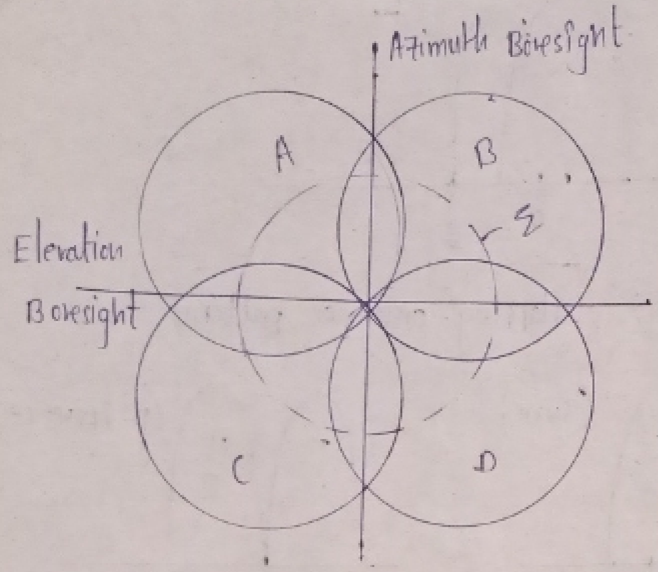
fig: sum and Difference patterns

-> By comparing the phase of sum and difference signal direction of angle error is found.

-> phase sensitive detector is used to compare the phase of two signals.

- Amplitude comparision Monopulse (Two coordinate)

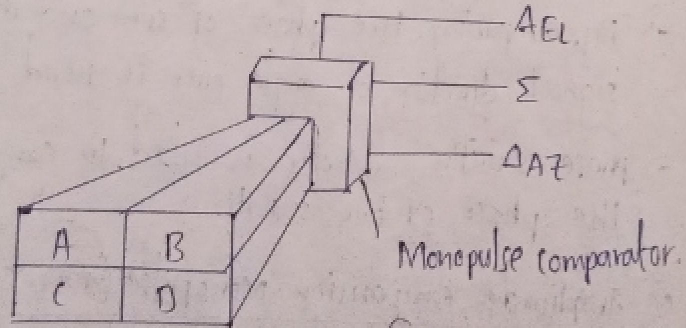
-> Monopulse two angle coordinate.



$\Sigma = A+B+C+D$

$\Delta_{AZ} = (A+C) - (B+D)$

$\Delta_{EL} = (A+B) - (C+D)$



∴ Four horn monopulse feed

-> All four feeds are used to generate sum pattern

-> i.e A+B+C+D.

-> Azimuth difference channel (A+B) - (C+D)

-> Elevation difference channel (B+D) - (A+C)

-> Two angle errors
- Elevation angle error.
- Azimuth angle error.

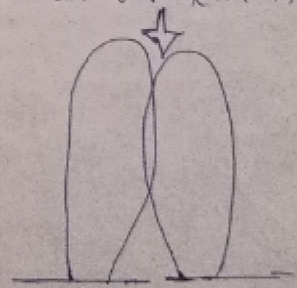
o phase comparision monopulse

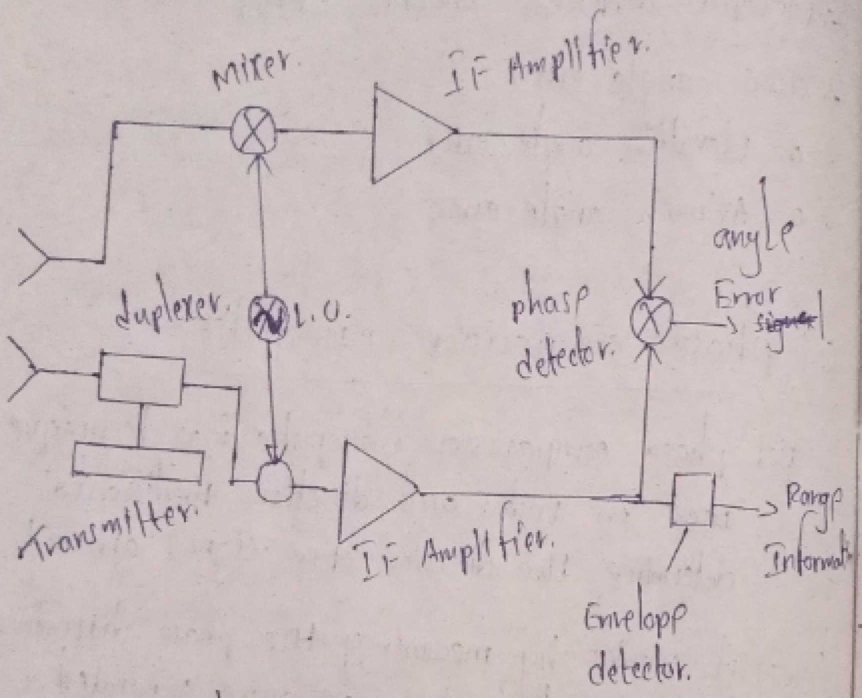
Def phase comparision monopulse is a technique used in radar and direction finding to determine the direction of a signal arrival.

-> It works by measuring the phase difference of a signal on two or more separated antennas.

-> It performs both sum and difference

-> phase comparision monopulse radars are used in air traffic control, missile tracking etc





-> $X = d\sin\theta$

-> $\Delta\psi = 2\pi d \sin\theta / \lambda$

-> phase detector is used to find the angle error.

* Detector characteristics

-> Here are some characteristics of radar detectors.

- **Range** : The Max Range at which a radar can detect a target.
- **Accuracy** :- How accurately a radar measures the location of a target in Range.
- **Target discrimination** : How well a radar can distinguish one target from another.
- **Reliability** : How Reliable a Radar is.
- **Target Identity** : How well a radar can Identify the type of target.
- **Maintainability** : How easy a radar is to maintain.
- **pulse length** : The length of the radar pulse which can vary from 0.05 to 1.0.

* Noise figure :

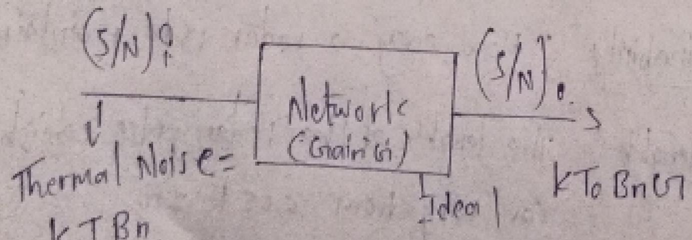
Def: Noise figure is defined as the ratio of noise out of practical receiver to the noise out of ideal Receiver is called Noise figure.

-> Noise figure is represented by Fn.

$$\boxed{F_n = \frac{\text{Noise out of practical } R_x}{\text{Noise out of ideal } R_x}}$$

(or)

$$\boxed{F_n = \frac{(S/N)_i}{(S/N)_o}}$$



$$F_n = \frac{N_{out}(\text{practical})}{N_{out}(\text{Ideal})} = \frac{N_{out}}{KT_oB_nG}$$

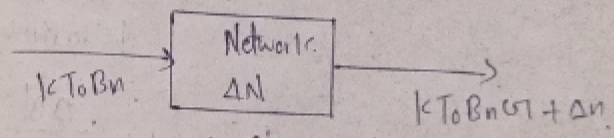
wher K = Boltzmen's constant $= 1.38 \times 10^{-3}$

T_o = Room Temperature

B_n = Noise Bandwidth

G = Avaliable gain $= \frac{S_{out}}{S_{in}}$

-> Assume Δn be Noise introduced by practical N/w.



$$F_n = \frac{N_{out}(\text{practical})}{KT_oB_nG}$$

$$F_n = \frac{KT_oB_nG + \Delta N}{KT_oB_nG}$$

$$F_n = 1 + \frac{\Delta n}{KT_oB_nG}$$

-> The noise due to the n/w alone

$$\boxed{\Delta n = (F_n - 1)\, KT_oB_nG}$$

* Noise Temperature :

Def: Noise Temperature in radar systems is a measure of how much noise an antenna produces in a given environment is called Noise temperature.

→ Here introducing
- Effective Noise Temperature (T_e)
- System Noise Temperature (T_s)

$$F_n = \frac{N_{out}\,(\text{practical})}{N_{out}\,(\text{Ideal})} = \frac{N_{out}}{K T_0 B_n G}$$

$$= \frac{K T_0 B_n G + \Delta n}{K T_0 B_n G}$$

$$\boxed{F_n = 1 + \frac{\Delta N}{K T_0 B_n G}} \quad (1)$$

$$\boxed{\Delta n = K T_e B_n G}$$

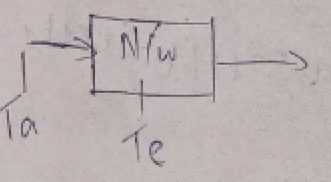
where T_e = effective Noise Temperature

Sub ΔN in eq (1)

$$F_n = 1 + \frac{\Delta N}{K T_0 B_n G} = 1 + \frac{\cancel{K} T_e \cancel{B_n G}}{\cancel{K} T_0 \cancel{B_n G}}$$

$$= 1 + \frac{T_e}{T_0}$$

$$\boxed{T_e = (F_n - 1)\, T_0}$$



$$T_s = T_e + T_a$$
$$= T_0 \cdot F_s$$

F_s = system Noise figure

T_0 = Room Temperature

Matched Filter Receiver

Def: A matched filter is a linear filter that improves signal-to-noise ratio (SNR) by maximizing the output SNR for a given transmitted symbol waveform. is called Matched filter.

→ Let us discuss respons characteristics.

- Frequency Respons function of matched filter:

→ The frequency Respons function of the matched filter, will be proportional to the complex conjugate of the input signals spectrum

→ Frequency response function is denoted by 'H(f)'

$$\boxed{H(f) = G_a S^*(f)\, e^{-j2\pi f t_1} \quad -(1)}$$

where,

G_a = Max gain.

$S(f)$ = fourier transform of input signal. $s(t)$

$S^*(f)$ = complex conjugate of $S(f)$.

t_1 = time instant.

→ In general, the value of G_a is '1'

$$\boxed{H(f) = S^*(f)\, e^{-j2\pi f t_1} \quad -(2).}$$

○ Impuls Response function of matched filter

→ In time domain, we will get the output $h(t)$ of matched filter receiver. by apply Inverse fourier transform of the frequency response function $H(f)$

$$h(t) = \int_{-\infty}^{\infty} H(f)\, e^{-j2\pi f t_1}\, df \quad -(3).$$

sub eq (1) in (3).

$$h(t) = \int_{-\infty}^{\infty} \{G_a S^*(f)\, e^{-j2\pi f t_1}\}\, e^{-j2\pi f t} \cdot df$$

$$h(t) = \int_{-\infty}^{\infty} G_a S^*(f)\, e^{-j2\pi f(t_1 - t)} \quad -(4).$$

$$S^*(f) = S(-f) \quad -(5)$$

sub eq (5) in (4)

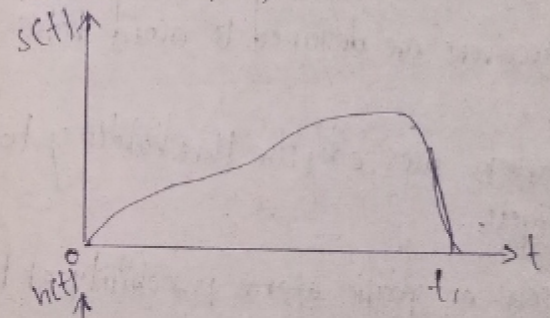
$$h(t) = \int_{-\infty}^{\infty} G_a S(-f)\, e^{-j2\pi f(t_1 - t)}\, df$$

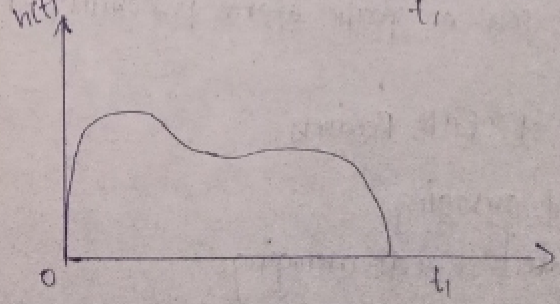
$$h(t) = \int_{-\infty}^{\infty} G_a S(f)\, e^{j2\pi f(t_1 - t)}\, df$$

$$h(t) = G_a s(t_1 - t) \quad -(6)$$

→ In general, the value of G_a is '1'

$$h(t) = s(t_1 - t)$$





Advantages

- cost is low.
- Efficient.

Disadvantages

- it consumes more power
- It has high complexity.

* Constant false alarm Rate (CFAR) Receiver :-

-> A constant false alarm rate (CFAR) Receiver is a ~~detection algorithm~~ radar system component that uses an adaptive threshold to detect targets while maintaining a constant false alarm probability is called CFAR.

-> CFAR receivers are designed to avoid false detection.

-> CFAR Receivers uses adaptive thresholding to detect targets.

-> CFAR sets a specific ~~alarm~~ probability of false alarm.

-> Types of CFAR Receivers

- o. cell averaging.
- o greatest-of-cell averaging.
- o. smallest of-cell averaging.

-> CFAR Receiver block diagram consist of Receiver, detector, CFAR processor, Threshold, Alarm. etc.

Advantages	Disadvantages
o Improved detection	o. complexity
o. clutter rejection	o False alarms.
o. Noise robustness.	
o Adaptability	

* Correlation Detection :-

Correlation detection is a method for extracting a signal with a known form from noisy background. is called correlation detection

-> It can be used in variety of applications.

* Automatic Detection

Automatic detection in a radar system is a process that uses a dataprocessor to automatically detect and track targets.

-> This process is also known as Automatic Detection and Tracking.

Unit - 5:

* phased Array Antennas

Def A phased Array Antenna is a group of antennas that work together to create a directional beam of radio waves. is called PAA

-> PAA antennas are made up of multiple antennas arranged in a grid.

-> Each antenna sends out the same signal.

-> PAA antennas are used in variety of applications.

-> key components of PAA.

- o Radiating elements.
- o phase shifters
- o Beamforming Network.
- o control system.

* Electronically steered phased array Antennas

An electronically steered Antenna is a type of antenna that uses electronic signals to steer and shape the beam. is called ESA.

-> These antennas are usually avaliable in the form of flat module with small Identical Antennas each one capable of transmitting and receiving.

-> Electronically steered antennas are also called as phased array antennas because of their working principle.

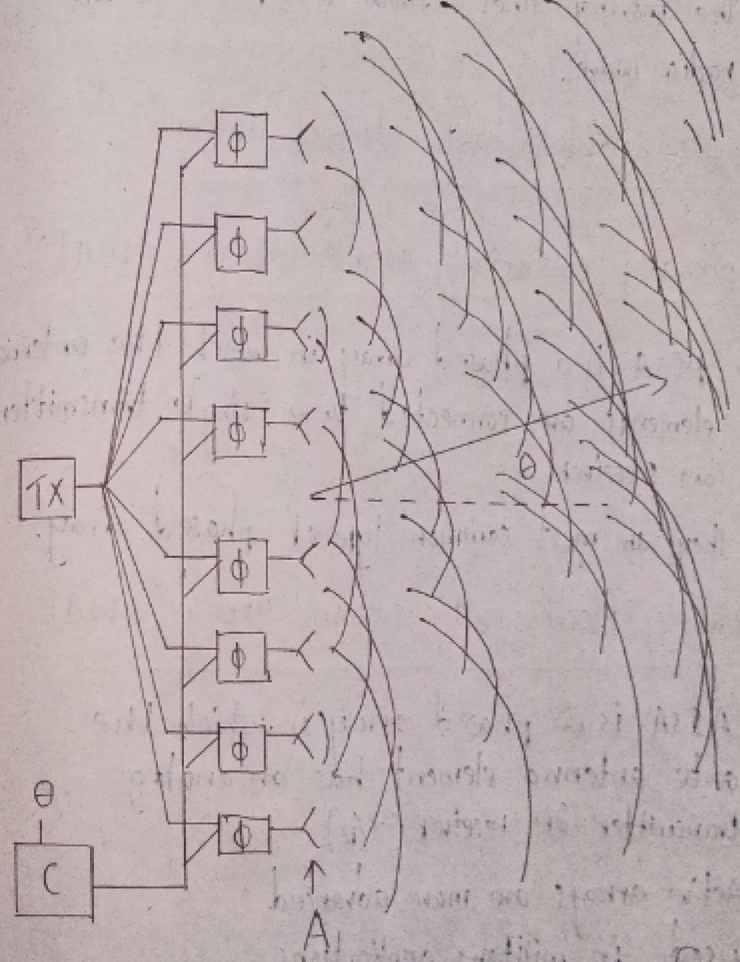
operation:

-> In array antennas, the RF signal from the transmitter can be fed to the individual antenna elements.

-> The signal from the transmitter is fed to the antennas through devices called phase shifters.

-> phase shifters are electronically controlled to alter the phase.

-> This is the basic principle of ESA.



-> A shown in the fig ESA consist of an array of antenna elements (A) and Transmitter Tx.

-> The fed current for each antenna pass through ψ.

-> controlled by computer / circuit 'C'

-> The moving lines show wavefronts of the radio waves.

○ Types of Electronically steered Antennas

1. Passively Electronically steered Array (PESA):-

-> PESA is a phased array in which the antenna elements are connected to a single transmitter (or) Receiver.

-> They are most common type of phased array.

○ Actively Electronically steered Array (AESA):

-> AESA is a phased array in which the ~~ante~~ antenna element has an analog transmitter (or) receiver (T/R).

-> Active arrays are more advanced

-> used in military applications.

○ Hybrid Beam forming

-> A hybrid beam forming phased array is a combination of an AESA and digital beamforming phased array.

X. Phase shifters:-

Def:- A phase shifter is a device that controls the phase difference b/w the input and output ports of a system is called phase shifter.

-> In Radar phase shifters are used to adjust the phase of each antenna path.

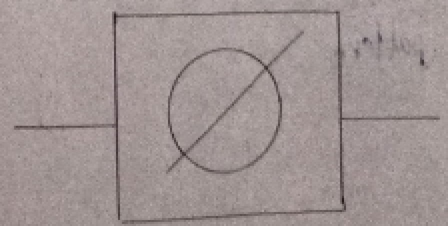
-> phase shifters are crucial components in RF, radar, phased array antennas.

-> Types of phase shifters

○ Digital phase shifter:- digital phase shifters are used to control beam scanning in phased array antenna systems.

○ Analog phase shifter:- Analog phase shifter is a device that changes the phase of microwave, millimeterwave, and RF signals.

-> symbol of phase shifter



○ Ferrite phase shifter: A ferrite phase shifter is a magnetic material used to change the phase of a microwave signal.

○ PIN Diode s phase shifter

→ positive Intrinsic Negative phase shifter

→ Types:

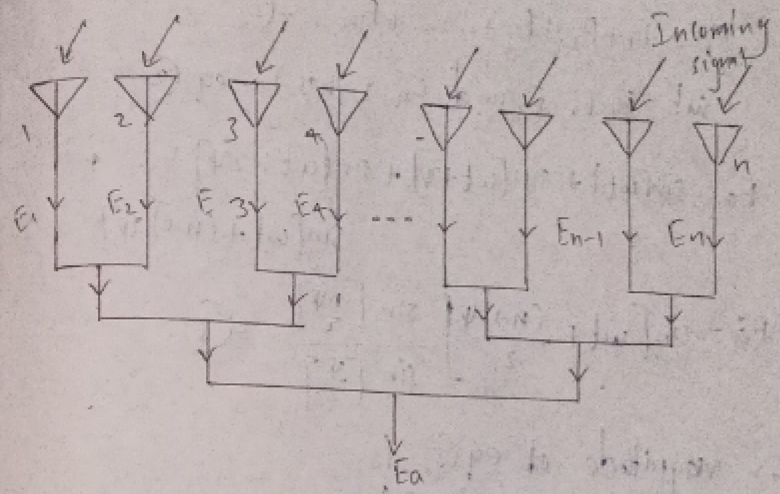
○ SAW phase shifter
○ Micro electromagnetic " "
○ Liquid crystal " "
○ photonic " "
○ Hybrid " "

Radiation pattern (phased Array)

→ Let us consider an 'n' isotropic radiation elements, which combinely form an array

→ Let the spacing b/w elements is 'd' units.

→ Radiation pattern



→ As shown in figure all radiation elements receive the same incoming signal.

→ Each element produce an equal o/p voltage of $\sin(\omega t)$.

→ phase difference $\psi = \frac{2\pi d \sin\theta}{\lambda}$ — ①

→ output voltages of 'n' radiation elements

$$E_1 = \sin(\omega t)$$
$$E_2 = \sin(\omega t + \psi)$$
$$E_3 = \sin(\omega t + 2\psi)$$
$$\vdots$$
$$E_n = \sin[\omega t + (N-1)\psi]$$

→ we will get overall o/p voltage E_a.

$$E_a = E_1 + E_2 + E_3 + \dots + E_n \quad -(2)$$

sub E_1, E_2, E_3 and E_n values in eq (2).

$$E_a = \sin[\omega t] + \sin[\omega t + \psi] + \sin[\omega t + 2\psi] + \dots + \sin[\omega t + (n-1)\psi]$$

$$E_a = \sin\left[\omega t + \frac{(n-1)\psi}{2}\right] \frac{\sin\left[\frac{n\psi}{2}\right]}{\sin\left[\frac{\psi}{2}\right]} \quad -(3)$$

-> Magnitude of eq (3) is

$$|E_a| = \left| \frac{\sin\left[\frac{n\psi}{2}\right]}{\sin\left[\frac{\psi}{2}\right]} \right| \quad -(4)$$

sub eq (1) in eq (4).

$$|E_a| = \left| \frac{\sin\left[\frac{n\pi d \sin\theta}{\lambda}\right]}{\sin\left[\frac{\pi d \sin\theta}{\lambda}\right]} \right| \quad -(5)$$

-> If eq (5) numerator is 0

$$\sin\left[\frac{n\pi d \sin\theta}{\lambda}\right] = 0$$

$$\frac{n\pi d \sin\theta}{\lambda} = \pm m\pi$$

$$nd \sin\theta = \pm m\lambda$$

$$\sin\theta = \pm \frac{m\lambda}{nd}$$

-> If eq (5) denominator is 0

$$\sin\left[\frac{\pi d \sin\theta}{\lambda}\right] = 0$$

$$\frac{\pi d \sin\theta}{\lambda} = \pm p\pi$$

$$d \sin\theta = \pm p\lambda$$

$$\sin\theta = \pm \frac{p\lambda}{d}$$

* Navigational Aids :

A Navigational aid (NAVAID) is a signal, marker, (or) guidence equipment that helps with navigation. such as in aviation travel.

○ **Direction Finder** A direction finder (DF) is a tool used in radar systems to determine the direction of radio source is called DF.

-> A direction finder measures the direction of radio signal from two (or) more locations, is called triangulation.

-> Direction finder is used to fir radio navigation, locating emergency transmitters, tracking wildlife.

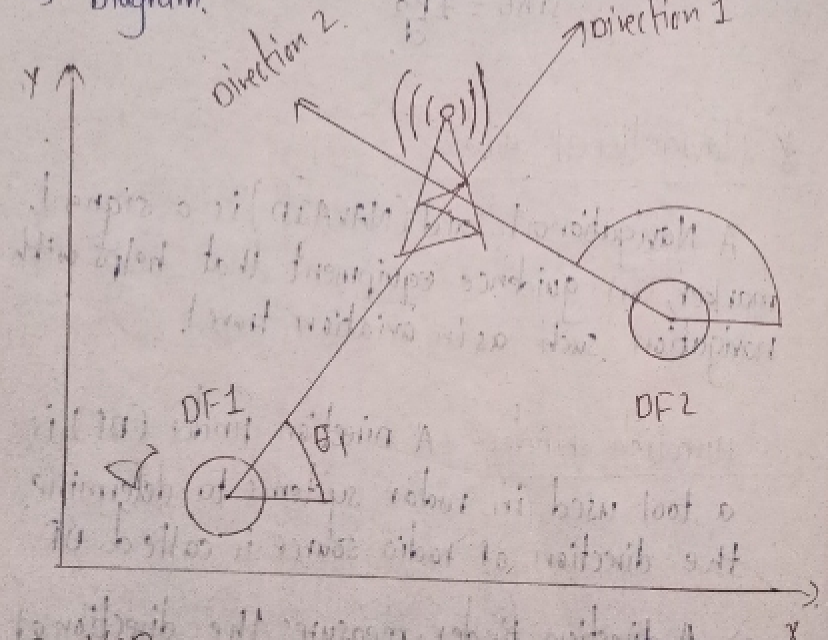
-> The direction finders are mostly now-a-days replaced by modern Gps.

-> Factors that effect DF

- signal Reflection
- polarization

-> A Direction finder can be used by an aircraft on ship.

-> Diagram.



o VOR

-> VOR stands for very high frequency omni-directional Range.

-> VOR is a type of short range radio navigation system for aircraft, enabling aircraft with a receiving unit.

-> VOR is used for

- Navigation
- orientation
- positioning

-> Working of VOR

- VOR Transmitter sends the signals
- Aircraft receives signals
- VOR receiver calculates phase difference
- Bearing information displayed on cockpit instruments.

-> Components used for VOR

- VOR Transmitter
- VOR Receiver
- Antenna

-> The signals from VORs have a Range of approximately 200 miles.

Advantages	Disadvantages
o simple installation	o line-of-sight limitations
o Low maintenance	o Limited range
o High accuracy	
o wide coverage.	

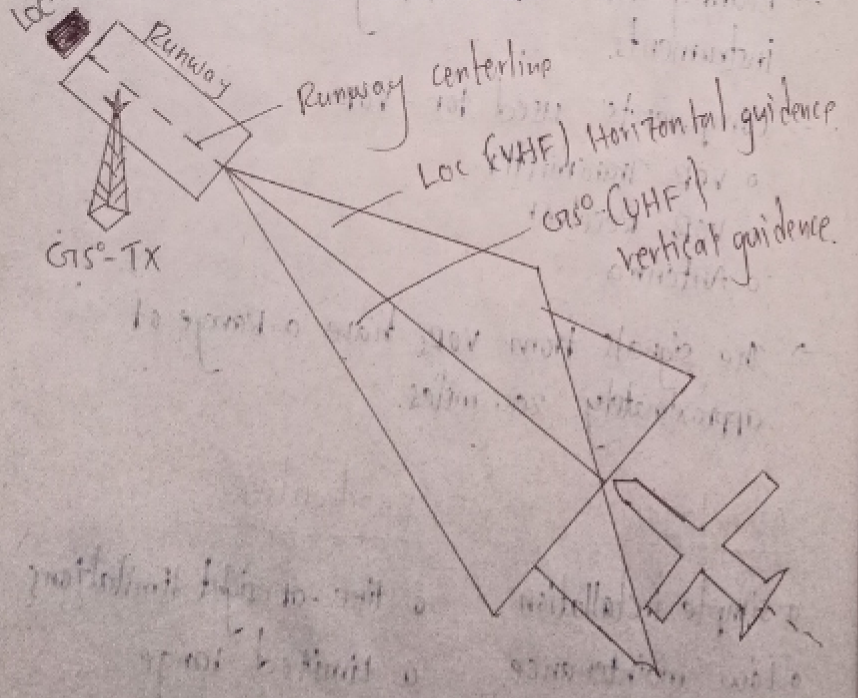
o ILS (Instrument Landing system):

-> ILS stands for Instrument Landing system.

-> Def: An ILS is a precision navigation aid used to guide aircraft to a safe landing is called ILS.

-> ILS is a standard landing aid used by ICAO.

-> ILS helps to pilots safely land even in adverse weather conditions.



-> Above figure shows block diagram of Instrument Landing system.

-> Aircraft receives LLZ and GS signals

-> LLZ guides aircraft to runway centerline.

-> GS guides aircraft to optimal descent path.

-> pilot follows ILS indicators on cockpit instruments.

-> components used in ILS.

- o Localizer (LLZ) :
- o Glideslope (GS) :
- o Marker Beacons :
- o Approach lighting system.

Advantages	Disadvantages
-> very Accurate	-> More cost
-> Improved safety	-> limited flexibility
-> Reduced pilot workload	-> More maintenance.

o LORAN (Long Range Navigation) :-

Def :- Long-Range Navigation is a radio navigation system that uses radio waves to calculate a relative position is called LORAN.

- LORAN developed in the united states during world war-II.
- LORAN was used by ships and aircrafts in the atlantic and pacific.
- LORAN is more effective at Night.
- LORAN is still used by many marine craft.
- LORAN is a hyperbolic radio Navigation.
- It is operated at lower frequencies.
- Range 1500 miles.
- Three types of LORAN.
  - o LORAN-A (obsolete)
  - o LORAN-C (Most widely used)
  - o LORAN-D (enhanced version)
- components of LORAN
  - o LORAN Transmitters
  - LORAN Receivers.
  - Antennas.

Advantages

- Low cost.
- long Range coverage.

Disadvantages

- Less accurate than GPS.
- Requires multiple transmitters.

Applications

- Land surveying
- Military operations.
- Aviation navigation

* **Beam steering** Beam steering is the process of changing the direction of the main lobe of a radiation pattern is called Beam steering

* **Beam width changes** Beam width changes refers to the angular width at which the power of radar's transmitted energy is half of it maximum power is called Beam width changes.

:)