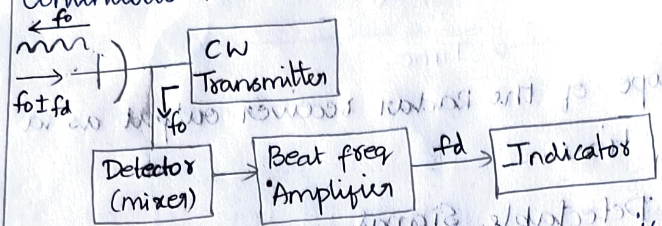
13/2/23

UNIT II - MOVING TARGET INDICATOR (MTI) & PULSE DOPPLER RADAR.

Continuous Wave Radar System (Block Diagram).



1. Beat freq amplifier amplifies change is frequency component (or) doppler shifted components.

$R \rightarrow$ Range of target / Distance between the radar.

Total no of wavelength contained in the 2-way Tx between Radar & target is $2R/\lambda$.

$\rightarrow$ The wavelength $\rightarrow$ angular excursion of 2π rad.

Total angular excursion $\varphi = 4\pi R/\lambda$ radians

Target is in motion $\rightarrow \varphi$ & R changes continuously

Change in φ w.r.t the time = freq $\rightarrow$ doppler angular freq

$$\omega_d = \frac{d\varphi}{dt} = \frac{d}{dt}\left[\frac{4\pi R}{\lambda}\right]$$ $f_d \rightarrow$ doppler freq

$$= \frac{4\pi}{\lambda}\frac{dR}{dt} = \frac{4\pi}{\lambda} V_r.$$ $V_r \rightarrow$ relative Velocity of target.

$$\omega_d = \frac{4\pi V_r}{\lambda}, \quad f_d = \frac{2V_r}{\lambda} = \frac{2V_r f_0}{c}$$ $f_0 \rightarrow$ transmitter freq

f_d in Hz, V_r in Knots, λ in m.

$$f_d = \frac{1.03 V_r}{\lambda}$$

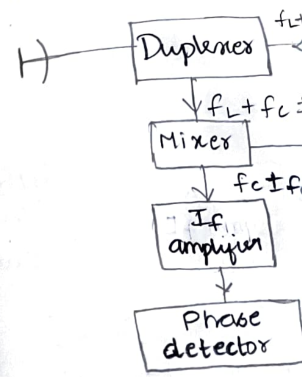
$\theta = 0^\circ$ f_d is max

$\theta = 90^\circ$ f_d is zero.

Relative Velocity $V_r = V\cos\theta$.

$\theta \rightarrow$ angle made by target trajectory and the line joining radar and target

MTI RADAR.



Stalo $\rightarrow$ stable

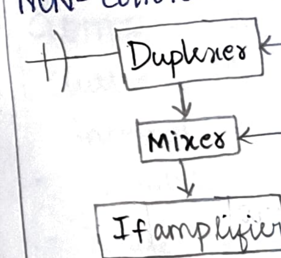
Coho $\rightarrow$ coheren

Combination of

$f_d \rightarrow$ doppler f

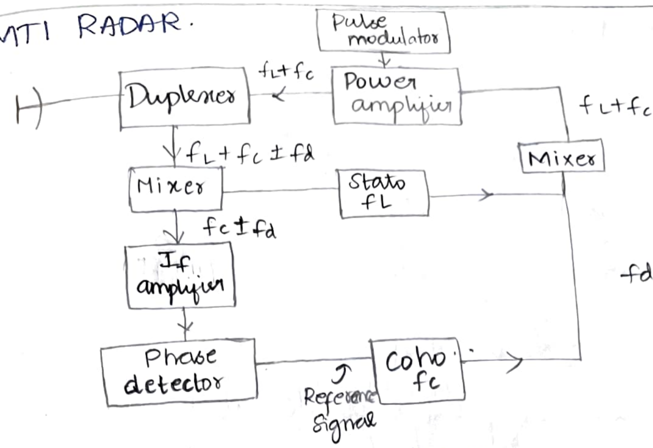
IF $\rightarrow$ Intermed

NON-COHERENT



Reference S/g

MTI RADAR.



$f_d \rightarrow$ to delay line canceler.

Stalo $\rightarrow$ stable local oscillator

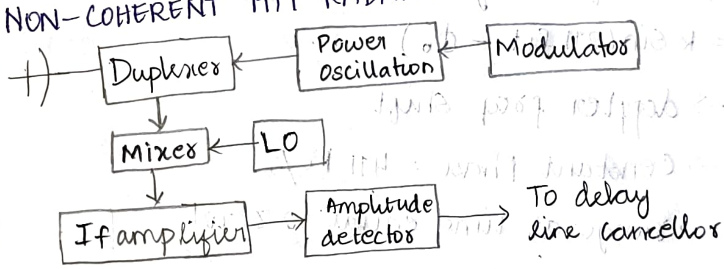
Coho $\rightarrow$ coherent local oscillator.

Combination of stalo & Coho gives transmitter freq.

$f_d \rightarrow$ doppler freq.

IF $\rightarrow$ Intermediate freq.

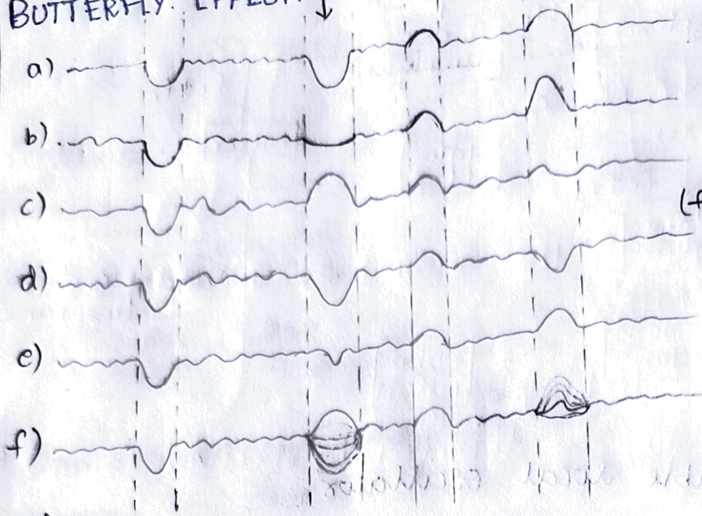
NON-COHERENT MTI RADARS.



Reference S/g $\rightarrow$ echo S/g received from the stationary field.

A-scope compatible for movable targets

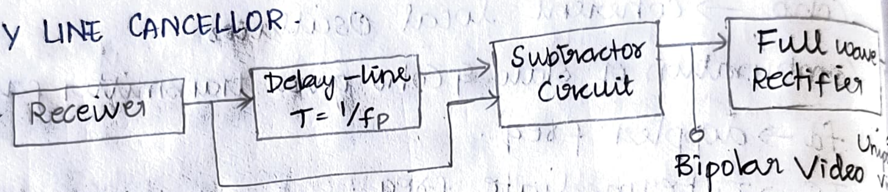
BUTTERFLY EFFECT → used to distinguish moving target



(f) Superposition of many sweeps

DLC

DELAY LINE CANCELLOR.



Freq Response of Delay line cancellor.

$V_1 = K \sin(2\pi f_d t - \phi_0)$

$f_d \rightarrow$ doppler freq shift

$\phi_0 \rightarrow$ constant phase $= 4\pi R_0/\lambda$

$R_0 \rightarrow$ range at time equal to zero.

$\lambda \rightarrow$ wavelength

$K \rightarrow$ amplitude.

Signal from previous transmission.

$V_2 = K \sin[2\pi f_d(t - T_P) - \phi_0]$.

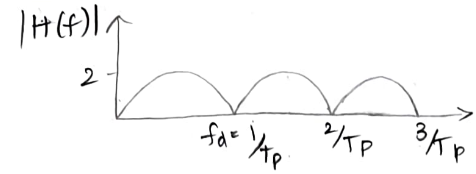
Output of DLC

$\sin a - \sin b$
$= 2\sin\left(\frac{a-b}{2}\right)\cos\left(\frac{a+b}{2}\right)$

$V = V_1 - V_2$

$= 2K\sin(\pi f_d T_P)\cos[2\pi f_d(t - T_P) - \phi_0]$

$|H(f)| = 2\sin(\pi f_d T_P)$



$n = 1, 2, 3 \ldots$

Blind Speed.

$n \rightarrow$ number of blind speed

$$f_d = \frac{2V_r}{\lambda} = n f_p = \frac{n}{T_p}.$$

velocity of the target that travels with blind Speed, $V_n = \frac{n\lambda}{2T_p} = \frac{n\lambda f_p}{2}$

∴ METHODS TO ELIMINATE BLIND SPEED.

→ Operate the radar at ~~high~~ long wavelength.

→ Operate the radar at high Prf

→ operate the radar with more than one Prf

→ Operate the radar at RF frequency.

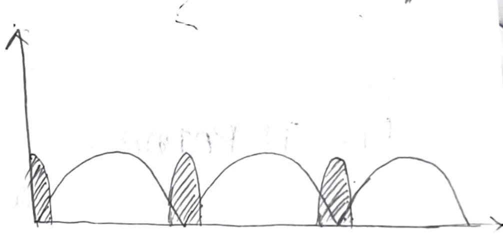
DLC.

Stable local oscillator & Coho → Present in MTI

CLUTTER ATTENUATION.

Clutter Spectrum has finite width

1. Internal motion of the clutter
2. Instabilities of stalo & Coho.
3. finite Signal duration



Single DLC

$$CA = \frac{f_p^2 \lambda^2}{T_b \pi^2 \sigma_v^2}$$

2-DLC.

$$CA = \frac{f_p^4 \lambda^4}{T_b \pi^4 \sigma_v^4}$$

MTI Improvement factor = $\dfrac{\text{SNR at the o/p of clutter filter}}{\text{Signal to clutter ratio of the O/P of the clutter filter}}$

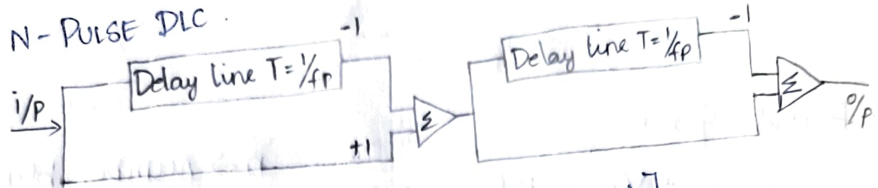
Clutter ↓ ~~unwante~~ signal which has no information

$$I_f = \frac{(\text{Signal}/\text{clutter})_{i/p}}{(\text{signal}/\text{clutter})_{o/p}} \Big/ f_d.$$

$$= \frac{C_{in}}{C_{out}} \times \frac{S_{out}}{S_{in}} \Big/ f_d. = CA \times \text{avg power}$$

TYPES OF DLC

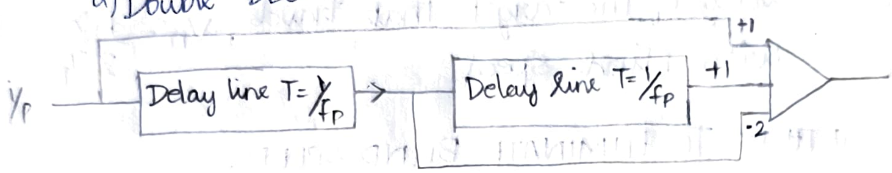
1. N-PULSE DLC



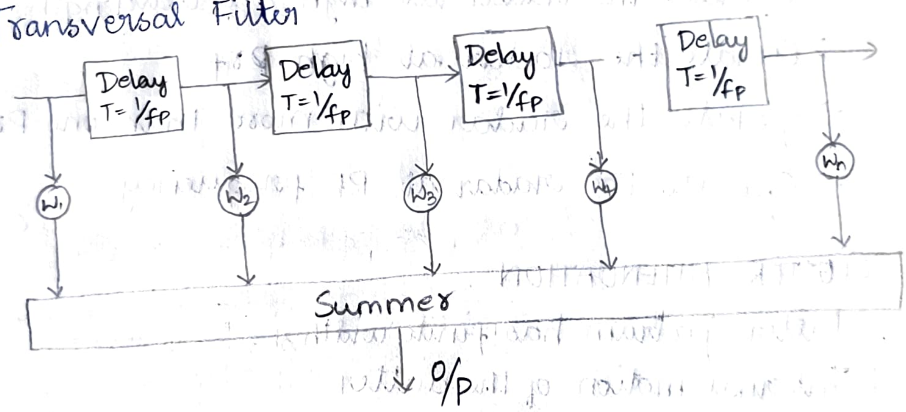
$S(t) - S(t+T_p) - [S(t+T_p) - S(t+2T_p)]$

$S(t) + 2S(t+2T_p) - 2S(t+T_p)$

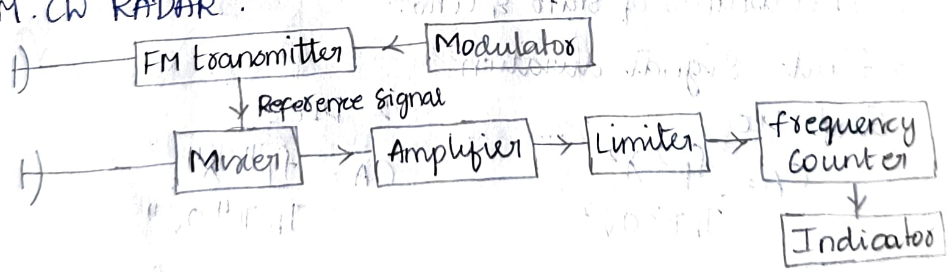
a) Double DLC.

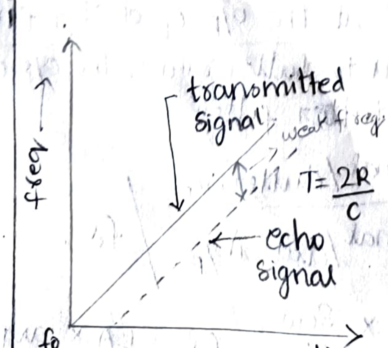


Transversal Filter

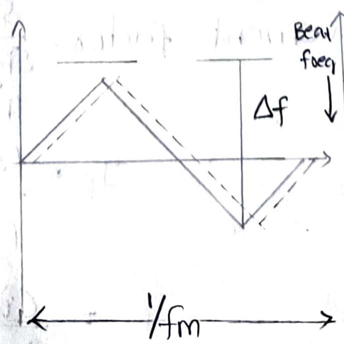


FM. CW RADAR.

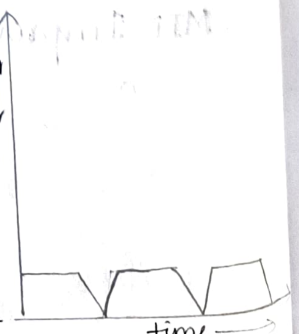




Linear freq modulator



triangular freq modulator



MOSFET

$f_r \rightarrow$ Beat freq due to target

$$f_r = f_0 T_r = \frac{2R}{c} f_0 .$$
(transit time)

Beat freq modulated at rate f_m.

$$f_r = \frac{2R}{c} 2 f_m .$$

$$= \frac{4 R f_m}{c} .$$

$f_{bup} = f_r - f_d$. → approaching the target

$f_{b\,down} = f_r + f_d$. → away from the target

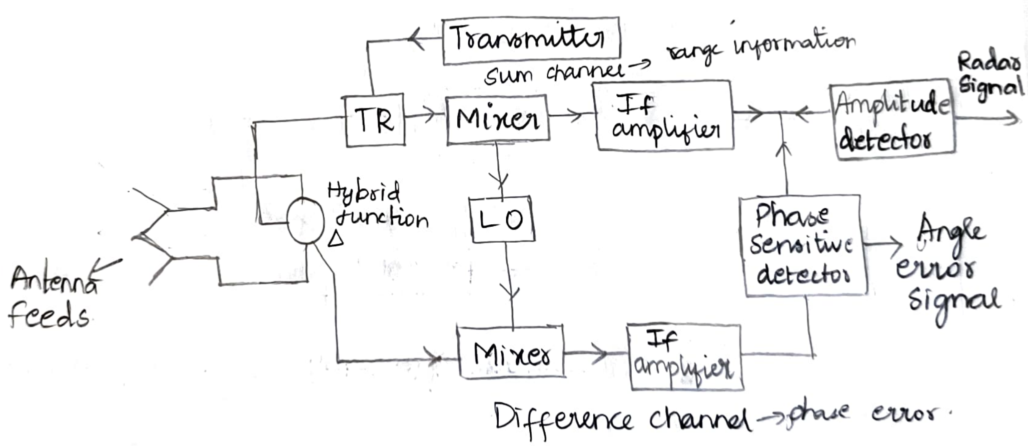
TRACKING RADARS.

→

→

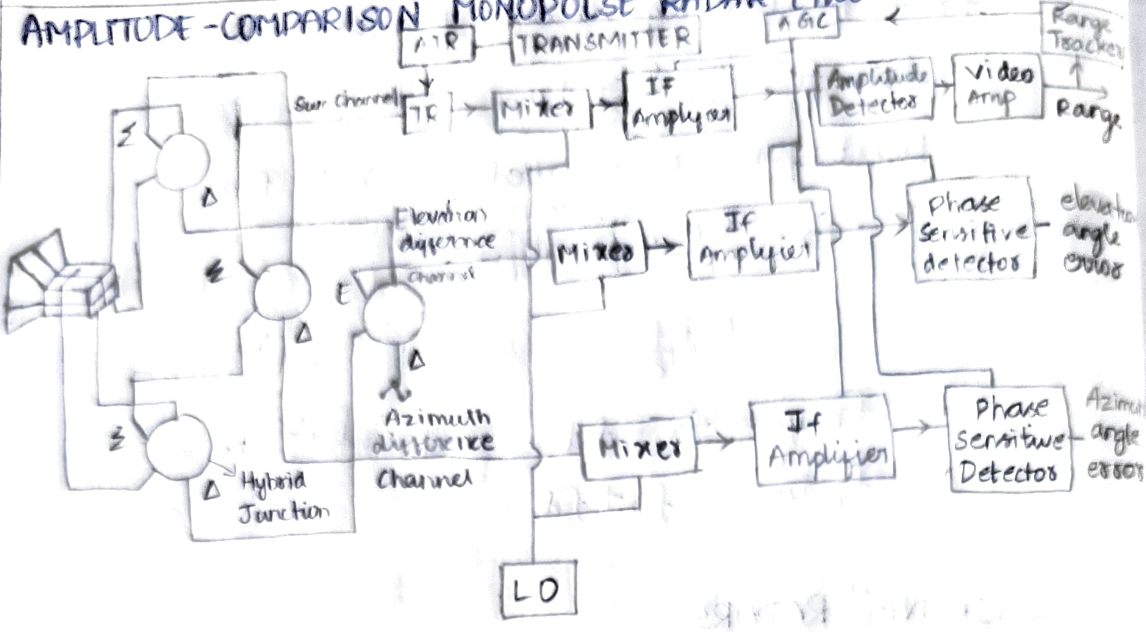
→

AMPLITUDE - COMPARISON MONOPULSE RADAR (One Coordinate)



2-12 GHz 2.24 - 3.6 GHz
MO-T 3-75 → 5G

AMPLITUDE-COMPARISON MONOPULSE RADAR (TWO coordinate)



Automatic detection
↓
operator can't fix problms always so we go for Auto-

17/3

CFAR (Const false alarm receiver) clutter, Pulse compression

UNIT-3: DETECTION OF SIGNALS IN NOISE.

Detection Criteria:

1. Neyman Pearson Observer. — mistake noise for signal → false alarm, Type I - error; Signal considered as noise Type II - error. → missed detection
2. Likelihood Ratio Receiver → statistical analysis tool
3. Inverse Probability Receiver. Bayes Criteria
4. Sequential Observer → no need to track signal continuously

type I → fixed, should be decreased

$$L_r(\gamma) = \frac{P_{sn}}{P_n}, \quad L_r(\gamma) \uparrow \rightarrow \text{likelihood Ratio}$$

Bayes

$$P(B) = \frac{P(B/A) \times P(A)}{P(A/B)}$$

AUTOMATIC DETECTION.

Steps involved in Automatic Detection.

Clutter → unwanted information

1. Sampling
2. Quantization
3. A-D conversion.
4. Signal Processing
5. Integration
6. CFAR → Setting thresold.
7. Clutter Map.
8. Thresold detection
9. Angle & Range measurement.

MATCHED FILTER.

Freq Response

$$H(f) = G_a S^*(f) \exp(-j2\pi f t_m).$$

G_a → Constant (Gain parameter)

t_m → time at which the o/p of the matched filter is max.

$S^*(f)$ → Complex Conjugate of the Spectrum of the received Spectrum o/p signal $s(t)$.

Fourier transform of $s(t)$.

$$S(f) = \int_{-\infty}^{\infty} s(t)\, \exp[-j2\pi f t_m].dt$$

$S^*(f)$ → Complex Conjugate

received signal spectrum

$$S(f) = |S(f)| \exp[-j\,\phi_s(f)]$$

$|S(f)|$ → amplitude spectrum

$\phi(f)$ → phase spectrum.

matched filter response

$$H(f) = |H(f)| \exp[-j\,\phi_m(f)]$$

$$G_a = 1$$

$$|H(f)| \exp[-j\,\phi_m(f)] = |S(f)| \exp[-j(\phi_s(f) - 2\pi f t_m)]$$

equating amplitude & phase

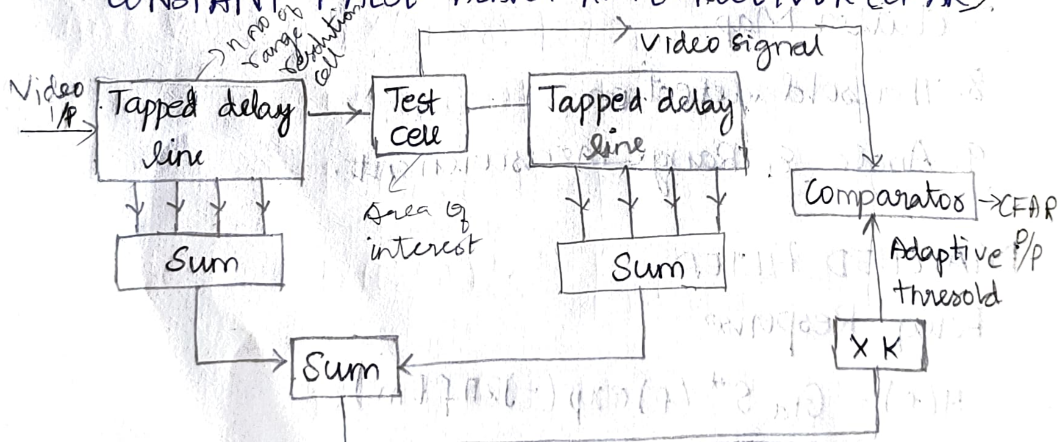
$$|H(f)| = |S(f)|$$

$$\phi_m(f) = -\phi_s(f) + 2\pi f t_m$$

→ to fix the thresold

→ firing thresold

CONSTANT FALSE ALARM RATE RECEIVER (CFAR)



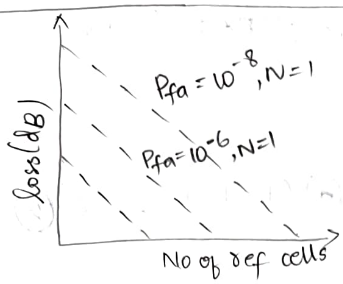
Cell-Averaging CFAR

$$\text{Loss (dB)} = \frac{-5}{M} \log P_{fa}$$

M → no of reference cell

N → no of pulses integrated

P_{fa} → Probability of false alarm.



CLUTTER EDGE(S.

Sum up seperately leading & trailing edges

Seperately → fix up > 0 < thresold. (GO-CFAR)

los → 0.1 to 0.3dB.

CENSORED MEAN-LEVEL DETECTOR (CMLD)

→ To remove the O/P of those reference cells that are much larger predefined no J of ref cells are remove

→ Thresold by M-T cells.

clutter map → gives location & range & angular

ORDERED STATISTICS

→ O/P of ref cells put in order from smallest to largest Pick k^{th} ordered value.

AMBIQUITY DIAGRAM:

represents the response of the matched filter to the signal of which it is matched. It provides an indication of & utility of the particular classes ~~of~~ radar waveform. It gives the Radar designer general guideliness for the selection of suitable waveform for various application

$$\text{O/P of matched filter} = \int_{-\infty}^{\infty} S_r(t)\, S^*(t-T_R)\, dt \quad \text{—— (1)}$$

$S_r(t)$ → received signal

$S(t)$ → Transmitted signal

$S^*(t)$ → complex conjugate

T_R → estimate of the time-delay

* detection Criteria, CFAR, Ambiguity, Pulse compression, range eqn of surface clutter.

Tx-ed Signal in complex ~~j2πf₀t~~ form.

$u(t)\,e^{j2\pi f_0 t}$.

The received echo signal

$S_r(t) = u(t-T_R)\,e^{j2\pi(f_0+f_d)(t-T_0)}$. —— (2).

O/P of matched filter.

$$= \int_{-\infty}^{\infty} u(t-T_0)\,e^{j2\pi(f_0+f_d)(t-T_0)} \left[u(t-T_R')\,e^{j2\pi f_0(t-T_R')}\right]^* dt$$

$$= \int_{-\infty}^{\infty} u(t-T_0)\,u^*(t-T_R')\,e^{j2\pi(f_0+f_d)(t-T_0)} \cdot e^{-j2\pi f_0(t-T_R')}\,dt \quad \text{—(3)}$$

Let $T_0 = 0$, $f_0 = 0 \Longrightarrow T_0 - T_R' = -T_R' = T_R$.

O/P of matched filter

$$X(T_R, f_d) = \int_{-\infty}^{\infty} u(t)\,u^*(t+T_R)\,e^{j2\pi f_d}\,dt \quad \text{—— (4)}$$

$|X(T_R, f_d)|^2 \rightarrow$ ambiguity function & plot $\rightarrow$ ambiguity diagram.

*: PROPERTIES OF AMBIGUITY DIAGRAM. $E \rightarrow$ Energy of the Signal.

max values of $|X(T_R, f_d)^2| = (2E)^2$ —— (1).

$$|X(-T_R, -f_d)|^2 = |X(T_R, f_d)|^2 \quad \text{—— (2).}$$

$$|X(T_R, 0)|^2 = \left|\int u(t)\,u^*(t+T_R)\,dt\right|^2 \quad \text{— (3).}$$

$$|X(0, f_d)|^2 = \left|\int u^2(t)\,e^{j2\pi f_d}\,dt\right|^2 \quad \text{—— (4)}$$

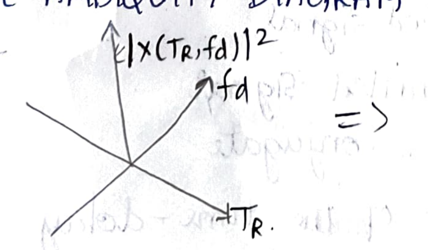
$$\iint |X(T_R, f_d)|^2\, dT_R\, df_d = (2E)^2 \quad \text{—— (5).}$$

Volume

max magnitude of $(2E)^2$ obtained at origin $T_R = 0$, $f_d = 0$.

IDEAL AMBIGUITY DIAGRAM

*.



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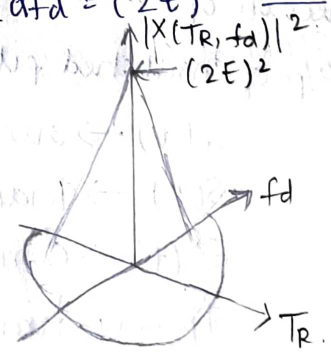

1. An MTI Radar ... wavelength is ...

Blind speed = ...

$f_p = $ ...

2. If a stat... of 6 GHz, ... moving wit... freq, fd ...

fd ...

1. An MTI Radar operates at a PRF of 1.5 KHz its operating wavelength is 3cm determine lowest blind speed.

Blind speed $= \frac{n\lambda f_p}{2}$.

$f_p = 15\,\text{KHz}$, $\lambda = 3\,\text{cm}$.

$$= \frac{1 \times 3 \times 10^{-2} \times 1.5 \times 10^{3}}{2}$$

$$= \frac{45 \cancel{\times 10^{1}}}{2} = 22.5\ \text{m/sec}$$

2. If a stationary CW radar transmits at a freq. of 6 GHz, find the doppler freq. due to a target moving with a radial velocity of 200 km/hr.

freq, $f_d = 6\,\text{GHz}$.

$$f_d = \frac{2V_r}{\lambda} \qquad V_r = \frac{200 \times 10^{3}}{3600}\ \text{m/sec}$$

$f = 6\,\text{GHz}$.

$$\lambda = \frac{c}{f} = \frac{3 \times 10^{8}}{6 \times 10^{9}} = 0.5 \times 10^{-1}$$

$$= \frac{2 \times 200 \times 10^{3}}{3600 \times 0.5 \times 10^{-1}}$$

$$= 0.222 \times 10^{3+1}$$

$$= 2.22\ \text{KHz}.$$

Q) MTI radar op at 5GHz with PRF of 1kHz, find 2nd and 3rd blind speeds of the radar.

Ans:-

* Matched filter receiver

* Detection criteria
  - ↳ threshold → Enwo
  - ↳ 4 detection criteria
  - ↳ 2 types of error is neaman person
  - ↳ reduce F.A rate → 2nd one. (likely hood ratio)
  - ↳ inverse prob. → 3rd one.
  - ↳ sequential oscillator

* Automatic Detection (4M)
  ↳ steps involved
    ↳ 6 (or) 7 steps

* CFAR

* Ambiguity diagram.
  ↳ 4 properties.