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ECE-B

ASSIGNMENT-1

1. Derive the expression for simple form of radar range equation.

Ans: Before deriving the radar range equation it is necessary to make the meaning of certain terms clear.

R - distance of target from radar antenna.

σ - Area of cross section of target.

P_t - Peak value of transmitted power.

G_t - power gain of transmitted antenna.

G_r - Power gain of receiving antenna

P_r - Received power by receiving antenna.

S_{min} - Minimum detectable signal by receiving antenna.

→ Assuming that the transmitting antenna is isotropic antenna i.e, one which radiates uniformly in all directions.

→ The power density (power per unit area) at a distance R from the radar is equal to the transmitter power divided by the surface area $4\pi R^2$ of an imaginary sphere of radius 'R'.

→ The power density at the target from antenna of transmitting gain G_t is power density from directive antenna.

$$P_d = \frac{P_t}{4\pi R^2} \quad -(1) \qquad = \frac{P_t G_t}{4\pi R^2} \quad -(2)$$

→ Power density of echo signal at radar $= \frac{P_t G_t}{4\pi R^2} \cdot \frac{\sigma}{4\pi R^2} = P'$ — (3)

→ The received power by antenna is $P_r = P' \times A_e$

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

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

→ The maximum radar range R_{max} is the distance beyond which the target cannot be detected. It occurs when the received echo signal power P_r just equals the minimum detectable signal S_{min} i.e $P_r = S_{min}$ rearranging the terms in equation (4)

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

This equation is called fundamental radar equation.

→ According to antenna theory

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

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

Sub (6) in (5) $R_{max} = \left[\frac{P_t A_e^2 \sigma}{4\pi\lambda^2 S_{min}}\right]^{1/4}$ — (8) $\quad R_{max} = \left[\frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 S_{min}}\right]^{1/4}$ — (9)

2. Discuss the concept of maximum ambigious range and derive its expression in range.

Ans: * Once the transmitter pulse is emitted by the radar, sufficient time must elapse to allow any echo signals to return and be detected before the next pulse is transmitted.

* Therefore, the rate at which the pulses maybe transmitted is determined by the longest range at which targets are expected.

* If the pulse repetetion frequency is too high, echo signals from some targets might arrive after the transmission of the next pulse and ambiguities in measuring range might result.

* The range beyond which targets appear as second-time around echoes is called the maximum unambigious range.

→ It is given by $R_{unamb} = c/2f_p$.

where f_p = Pulse Repetition frequency (PRF), in Hz.

* This can also be explained with the following simple relations.

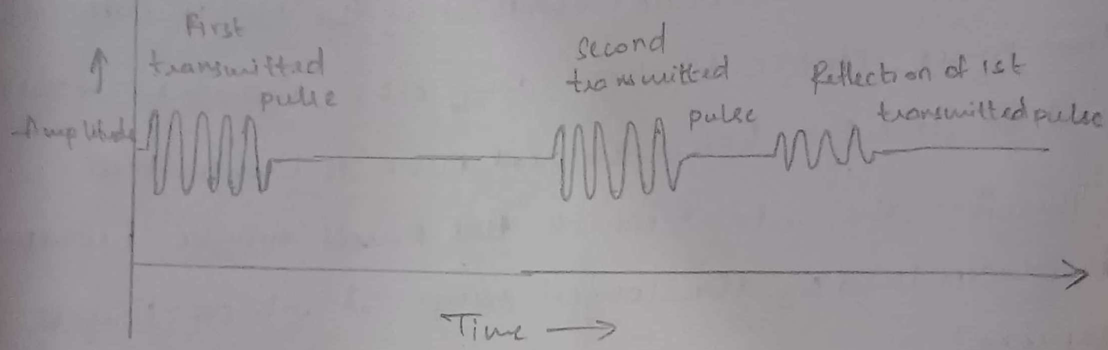
T_R is the time elapsed between transmission pulse and echo pulse.

$T_R = 2R/c$ where R = Range of target

* T_p = pulse repetition period

* $T_{R\,max} = T_P = 2R_{max}/c$ and so $R_{max} = cT_P/2 = c/2f_p = R_{unambig}$

* Therefore $R_{unambig}$ is directly proportional to the pulse period T_P (or inversely proportional to the PRF f_P)



The maximum unambigious is also called as maximum usable range, it is the range where radar has sufficient power and sensitivity.

B. Explain the different range of frequency bands are used in radar systems and applications.

Ans:- Conventional radars generally have been operated at frequencies extending from about 100MHz. to 3GHz, a spread of more than 8 octaves.

These are not necessarily the limits, since radars can be and have been operated at frequencies outside either end of this range. Skywave HF over-the-horizon (OTH) radar might be at frequencies as low as 4 (or) 5 MHz and groundwave HF radars as low as 2MHz. operated at 240GHz. Laser radars operate at even higher frequencies.

* Early in the development of, radar a letter code such as S, X, L etc. was employed to designate radar frequency band.

* Although its original purpose was to maintain military secrecy, the

Band designation	Nominal frequency range
HF	3-30MHz
VHF	30-300MHz
UHF	300-1000MHz
L	1000-2000MHz
S	2000-4000MHz
C	4000-8000MHz
X	8000-12,000MHz
ku	12-18 GHz
k	18-27GHz
ka	27-40GHz
V	40-75GHz
W	75-110GHz
Mm	110-300GHz

Radar Application:-

Radar has been employed on the ground, in the air, on the sea and in space.

→ Now Radar is used for variety of applications.

Major areas of application can be categorised into three types i.e civilian application, military application, scientific application.

Applications of Radar.

Civilian

* Airport survillance
* Marine navigation
* Weather forecasting
* Altimeter
* Mapping
* Police radar for speed measurement
* Aircraft landing system

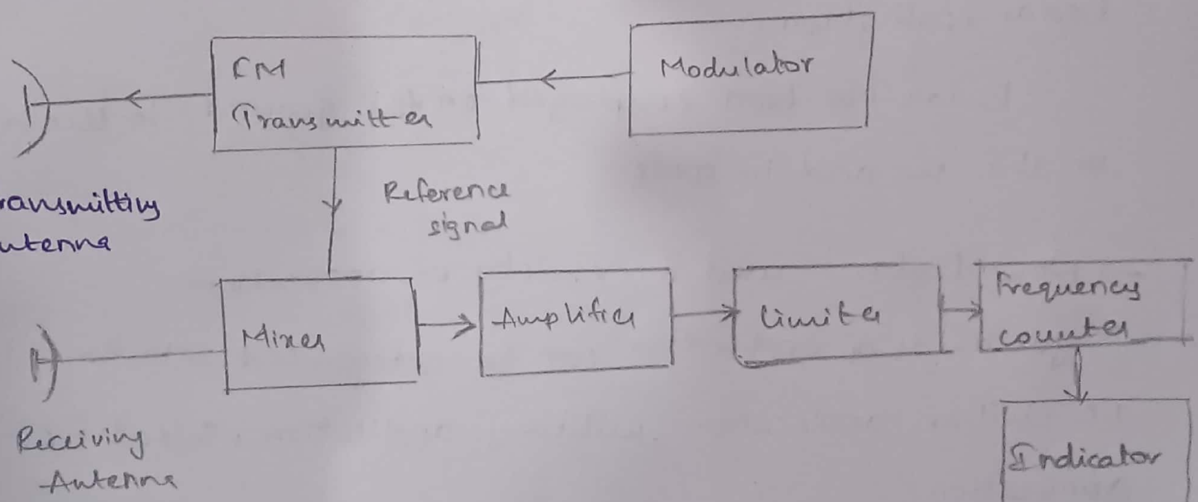
Military

* Air & Marine navigation
* Detection & tracking of aircrafts, missiles
* Guided missilies
* Aircraft landing systems

Scientific

* Geographical mapping
* Astronomy
* Distance
~~* D~~ measurement
* Remote sensing.

3. Draw the block diagram of FMCW radar and explain how Doppler measurements are ?.

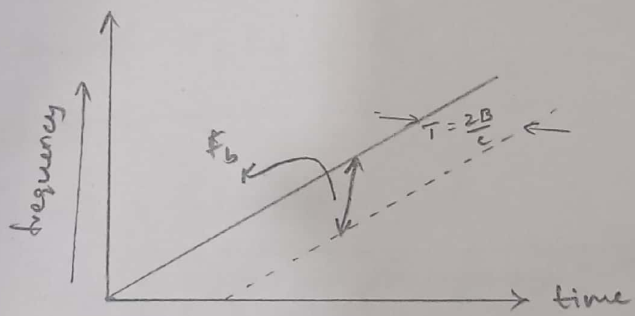


Ans: A widely used technique to broaden the spectrum of CW radar is to frequency - modulate the carrier. This radar is called "FMCW Radar". Timing mark is the main feature of this type of radar. The timing mark is the changing frequency. The transit time is proportional to the difference in frequency between the echo signal and the transmitter signal.

In FMCW radar, the transmitter frequency is changed as a function of time in a known manner.

1) When the modulation is linear:

Assume that the transmitter frequency increases line-arly with time as shown by solid line.



If there is a reflecting object at a distance 'R' an echo signal with return after a time $T = \frac{2R}{c}$. The dashed line in the figure represents echo signal. If echo signal is heterodyned with a portion of the transmitter signal in a non-linear element such as diode, a beat note f_b will be produced. This beat frequency will represent the target's range. and $f_b = f_r$, in the absence of doppler frequency shift. Then, the respective beat frequency only due to the target's range is

$$f_r = \dot{f_0} T$$

$= \left(\frac{2R}{c}\right) f_0$

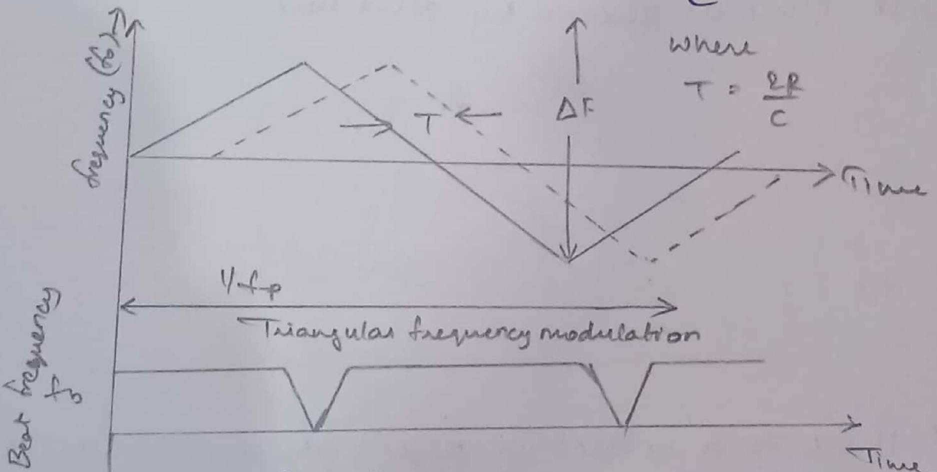
where $f_0 \rightarrow$ Rate of change of carrier frequency

$c \rightarrow$ propagating velocity.

When modulation is triangular:

In any practical CW radar, the frequency cannot be continuously changed in one direction only. Thus, periodicity in the modulation is necessary, as in triangular frequency-modulation. The modulation need not be necessarily triangular it can be sawtooth, sinusoidal or some other shape.

$$f_r = \frac{2R}{c} \; 2f_m \Delta f = \frac{4Rf_m\Delta f}{c}$$

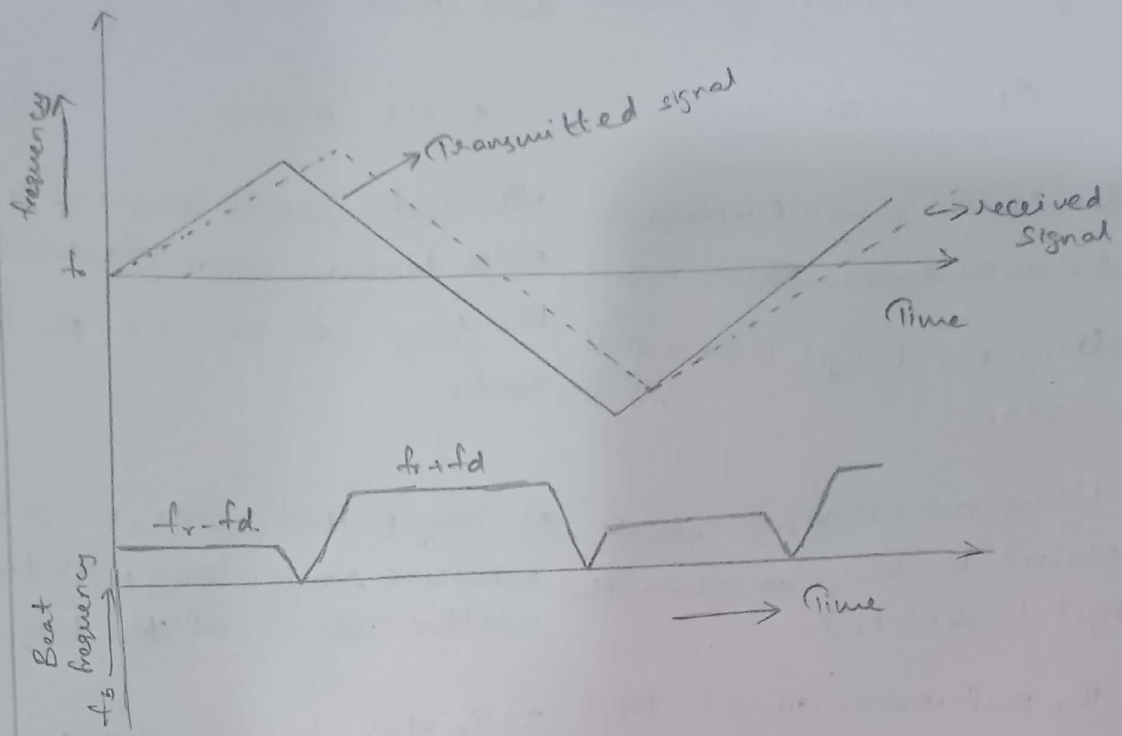


Beat frequency

$$\boxed{\therefore R = \frac{c f_r}{4 f_m \Delta f}}$$

When the target is moving away from the radar i.e the beat frequency f_b (up) is produced during increasing portion of FM cycle given by

$$f_b(up) = f_r - f_d \quad \text{— ①}$$



Similarly, for decreasing position of FM cycle, the beat frequency $f_b(down)$ is

$$f_b(down) = f_r + f_d \quad - (2)$$

Adding (1) & (2),

$$f_b(up) + f_b(down) = 2f_r$$

$$f_r = \frac{1}{2}\left[f_b(up) + f_b(down)\right]$$

Subtracting (1) from (2)

$$f_b(down) - f_b(up) = 2f_d$$

$$\therefore f_d = \frac{1}{2}\left[f_b(down) - f_b(up)\right]$$

The transmitted frequency 'f_0' is calculated using

$$f_r = \left(\frac{2R}{c}\right) f_0$$

4.

4. Distinguish between CW radar and pulse radar.

CW radar	pulse radar
1) The radar which employs a continuous transmission for detecting the target is known as CW radar.	1. The radar which employs a pulse transmission for detecting the targets is known as pulse radar.
2) Using CW radar, we cannot measure the range at which the target is detected.	2) Using pulsed radar, we can measure range along with the relative velocity of the target.
3) The performance of detection is limited by transmitter leakage or by signals reflected from nearby clutter or from the randome.	3) In this, transmitter leakage can be avoided by turning off the receiver during transmission.
4) Simple circuitary and small size.	4) complex circuitary and large size.
5) CW radar most likely to use IF doppler filter banks.	5) Pulsed radar most likely to use range gated doppler filter banks.
6) More sensetive to clutter and they cannot use gating to ignore clutter.	6) These radars are more capable of reducing clutter.
7) Due to the absence of blind spots in the range, the detection capability of CW radar is better.	7) Due to the presence of blindspots in the range resulting from high PRF, the detection capability of pulse radar is bound.

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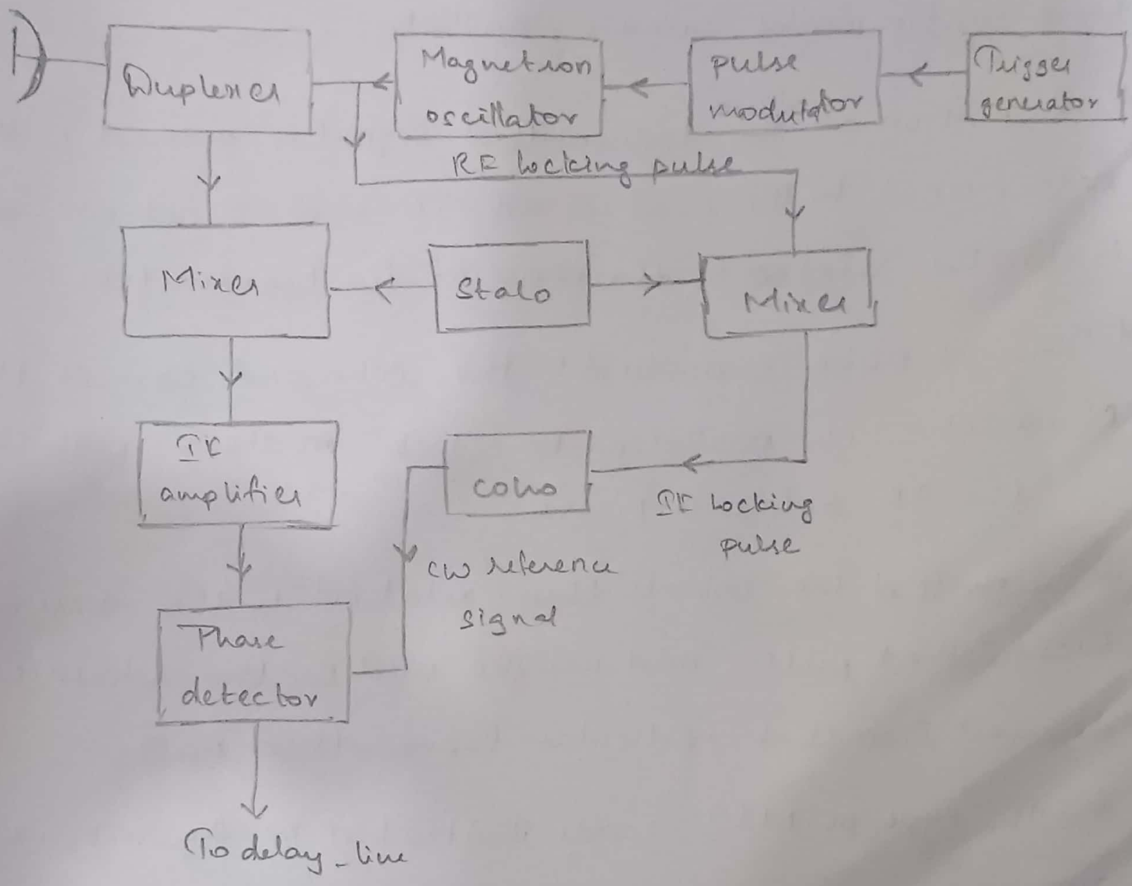
5. Explain MTI radar that uses a power oscillator transmitter with neat block diagram.



* One of a number of transmitting - ~~tube~~ types might be used as a power amplifier.

* These include the triode, tetrode, klystron, travelling-wave tube and the crossed-field amplifier.

* The transmitter which consists of a stable low-power oscillator followed by a power amplifier is sometimes called MOPA, which stands for Master-oscillator power amplifier.

* Before the development of the klystron amplifier, the only high power transmitter available at microwave frequencies for radar application was the magnetron oscillator.

* In an oscillator the phase of the RF bears no relationship from pulse to pulse.

* For this reason the reference signal cannot be generated by a continuously running oscillator.

* A portion of the transmitted signal is mixed with the data output to the produce an IF beat signal whose phase is directly related to the phase of the transmitter.

* This IF pulse is applied to the coho and causes the phase of the coho CW oscillation to "lock" in steps with the phase of the IF reference pulse.

* The phase of the coho is then related to the phase of the transmitted pulse and maybe used as the reference signal received from that particular transmitted pulse.

* The type of MTI radar illustrated in figure has had wide application.

6. What are the advantages of pulse dopler radar over tradition -al MTI radar?

MTI radar	Pulse doppler Radar
1) Range ambiguity is avoided with low RF.	1) Doppler frequency ambiguities are avoided with high PRF.
2) It has line speed effects.	2) No blind speed effects.
3) MTI radar has unambigious range.	3) Pulse doppler radar has ambigious range
4) MTI radar uses delay line cancellers for separating moving targets from stationary clutters.	4) Pulse doppler radar uses range gate doppler filters for separating moving targets from stationary clutters.
5) MTI radars are widely used in radar applications.	5) Pulse doppler radar are rarely used in radar applications