LECTURE NOTES ON

ADVANCED COMMUNICATION ENGINEERING

6^{TH} SEMESTER ETC

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RADAR & NAVIGATION AIDS

RADAR

RADAR stands for Radio Detection and Ranging System. It is basically an electromagnetic system from the point where the RADAR is placed. It operates in the UHF and Microwave range. A radar is an electromagnetic sensor used to notice-track, locate & identify different objects which are at certain distance. The working of radar is it transmits electromagnetic energy in the direction of targets to observe the echos and return from them.

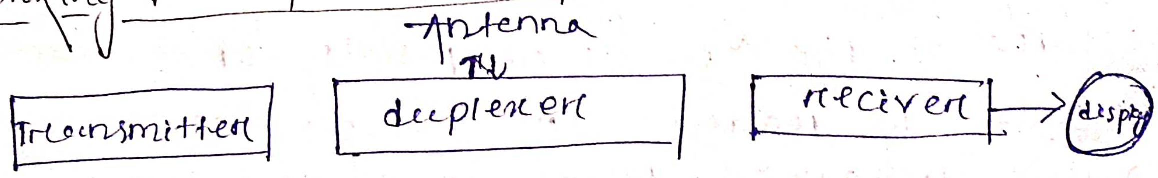
Advantages

→ RADAR signal can penetrate medium such as clouds fogs, snow
→ It can given the exact position, velocity and distance of an object.
→ It can tell the difference between stationary & moving targets.
→ Radar signal do not requires a medium of transportation.
→ Radar signal can target several object simultaneously
→ It is wireless and does not rely on wire connectivity.
→ It is cheaper as compared to other.
→ It covered a wide geographical area

Application

(I) Military purpose
(II) Air Traffic control
(III) Remote sensing
(IV) Ground Traffic control
(V) Space

Working principle of simple RADAR



The radar antenna radiates microwave signal towards target which is then reflected and picked up by a receiving device.

Transmitter

The radar transmitter produces the short duration high power radio frequency pulses of energy that are into space by the antenna.

Duplexer

The duplexer alternately switches the antenna between the transmitter & receiver so that only one antenna need be used. This switching is necessary because the high power pulses of the transmitter would destroy the receiver if energy were allowed to enter the receiver.

Reciver

The receiver amplify & demodulate the receivers RF signal The receiver provide video signals on the output

Radar antenna

The antenna transfers the transmitter energy to signals in space with the required distribution and efficiency. This process is applied in an identical way on reception.

Indicator

The indicator should present to the observe a continous easily understandable graphic picture of the relative position of radar targets. The radar screen displays the output produced from the echo signal.

Receiver

The receiver amplify & demodulate the received RF signal the receiver provide video signals on the output

Indicator

The indicator should present to observer a continuous easily understandable graphic picture of the relative position of radar targets. The radar screen displays the output produced from the echo signal.

Types

There are two types of RADAR

(I) pulsed RADAR → short rectangular pulses

(II) Continous wave RADAR → continuous sinusodial signal

→ The pulsed RADAR transmits short rectangular pulse where as the continous wave RADAR transmitts the continuous sinusodical signal.

Pulsed RADAR

The RADAR which operates with pulse signal is called the pulse RADAR. The pulse RADAR can be classified into the following two types based on target detection

(I) Basic pulse RADAR

(II) Moving Target Indication Radar.

→ The radar which operates which pulse signal for detecting stationary target is called the Basic pulse RADAR.

→ The radar which operates with pulse signal for detecting non-stationary target is called MTI RADAR

→ It is use the principle of Doppler effect for differentiate between non-stationary target from stationary objects.

Continous wave RADAR:

The RADAR which operates with continous signal or wave is called continous wave RADAR.

(I) Unmodulated continuous wave RADAR

(II) frequency modulated continous wave RADAR.

→ The radar which operates with continous signal for detecting non-stationary target is called unmodulated contin

→ It required two antenna one for transmiting and other for receiving. It measures only the speed of the target but not the distance.

→ frequency modulated continuous Wave RADAR is also called continuous wave frequency modulated RADAR or CWFM Radar. It measure not only the speed but also the distance.

Radar Range Equation

The power density is nothing but the ratio of power and area, so the power density pdi at a distance "R" from the radar can be represented as

$$pdi = \frac{Pt}{4\pi R^2} \quad \text{—— (1)}$$

Pt = The amount of power transmitted by the radar transmitter.

It is for isotropic antenna. In general radar use directional Antennas. Therefore the power density pdd due to directional Antenna will be.

$$pdd = \frac{Pt\,G}{4\pi R^2} \quad \text{—— (2)}$$

target radiates the power in different direction from the received input power. The amount of power which is reflected back towards the Radar depend on its cross section. so the power density ide of echo signal at radar

$$P_{de} = P_{dd}\left(\frac{\sigma}{4\pi R^2}\right) \quad \text{—— (3)}$$

substitute eqn (2) in eqn (3)

$$P_{de} = \left(\frac{P_t G}{4\pi R^2}\right)\left(\frac{\sigma}{4\pi R^2}\right) \quad \text{—— (4)}$$

substitute eqn (4) in eqn (5)

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

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

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

$$\Rightarrow R = \left[\frac{P_t G \sigma A_e}{(4\pi)^2 P_r}\right]^{1/4} \quad \text{—— (6)}$$

If the echo signal is having the power less than the power of the minimum detectable signal then RADAR can't detect the target since it is beyond the minimum limit of the RADAR's Range.

By substituting $R = R_{max}$ & $P_r = P_{r(min)}$ we get

$$R_{max} = \left[\frac{P_t G \sigma A_e}{(4\pi)^2 P_{r(min)}}\right]^{1/4} \quad \text{—— (7)}$$

Modified forms of RADAR Range Equation

We know the following relation between the gain of directional Antenna "G" and effective Aperture "Ae".

$$G = \frac{4\pi A_e}{\lambda^2} \quad \text{———— (8)}$$

Substitute eqn (8) in eqn (7)

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

$$= \left[\frac{P_t \sigma A_e^2}{4\pi \lambda^2 P_r(min)} \right]^{1/4} \quad \text{———— (9)}$$

$$A_e = \frac{G\lambda^2}{4\pi} \quad \text{———— (10)}$$

Substitute eqn (10) in eqn (7) we get

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

$$R_{max} = \left[\frac{P_t G^2 \sigma \lambda^2}{(4\pi)^3 P_r(min)} \right]^{1/4} \quad \text{———— (11)}$$

Performance factor of RADAR

The performance of a radar system can be judged by the following (1) The maximum range at which it can see a target of a specified size.

(2) The accuracy of its measurement of target location in range and angle.

(3) Its ability to distinguish one target from another.

(4) Its ability to detect the desired target echo when masked by large clutter echoes, unintentional interfering signals from other transmitters or intentional radiation from hostile jamming.

(5) Its ability to recognize the type of target.

(6) Its availability (ability to operate when needed), reliability and maintainability.

Some of the major factors that affect performance are discussed below.

Transmitter power and antenna size :-

The maximum range of a radar system depends in large part on the average power of its transmitter and the physical size of its antenna.

Reciver noise

The sensitivity of a radar reciver is determined by the unavoidable noise that appears at its input.

Target size

The size of a target as "seen" by radar is not always related to the physical size of the object. The measure of the target size as observed by radar is called the radar cross section and it given in units of area. It is possible for two targets with the same physical cross-sectional area to differ considerably in radar size or radar on radar cross section.

Cluter

Echoes from land, sea, rain, snow, hill and birds are a noise to those who want to detect aircraft, ships, missiles or other similar targets. Clutter echoes can seriously limit the capability of a radar system.

Atmospheric effects

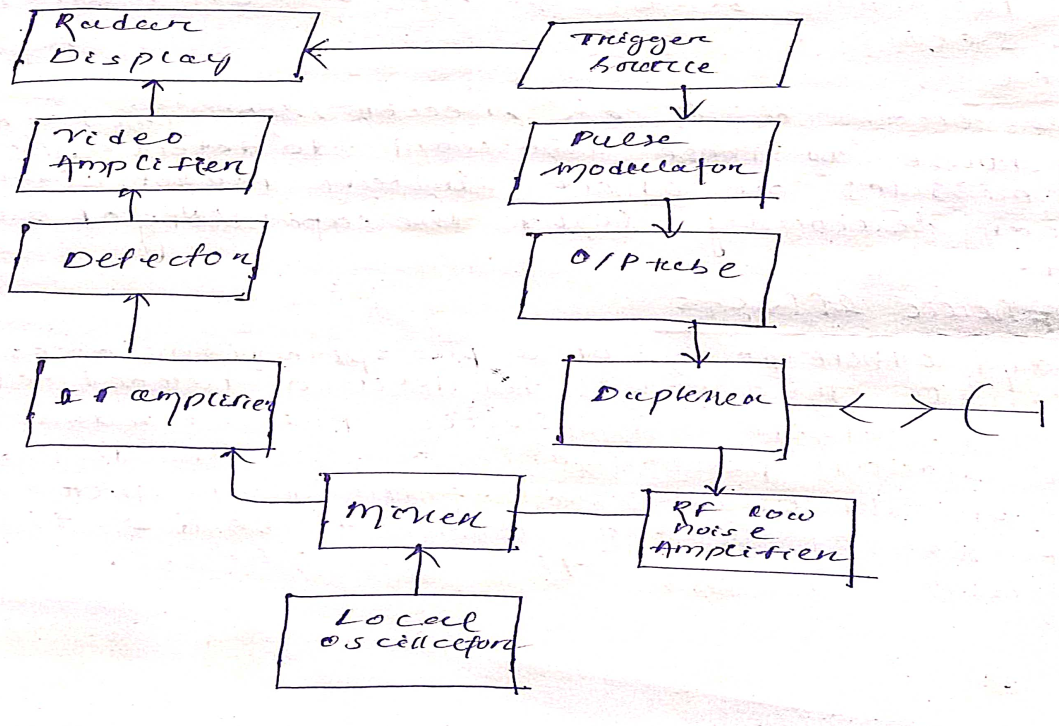
Rain and other forms of a precipitation can cause echo signals that makes the desired target echoes. There are other atmospheric phenomena that can affect radar performance as well. The decrease in density of the earth's atmosphere with increasing altitude causes radar waves to bend as they propagate through the atmosphere.

Interference

Signals from nearby radar and other transmitters can be strong enough to enter a radar receiver and produce spurious by automatic detection and tracking system however and so some method is usually needed to recognized and remove interference pulses before they enter the automatic detector and tracker of a radar.

Working principle of pulsed RADAR system:-

Pulse Radar uses single Antenna for both transmitting and receiving of signal with the help of Duplexer.

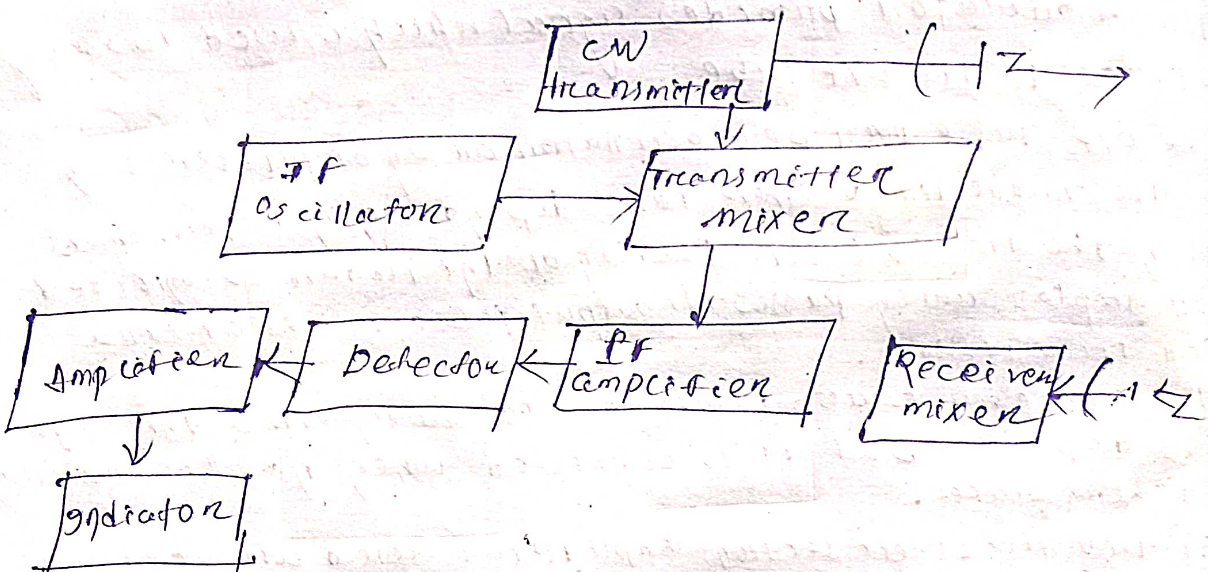


- The trigger source provides pulse for the pulse modulator and radar display.
- The modulator provides signal which is used to supply voltage to the O/P tube.
- The O/P tube may be a oscillator or an amplifier such as the travelling wave tube depending on requirement.
- Then the transmitter portion of the radar is connected with duplexer which passes the output pulse to the antenna for transmission.
- The receiver is also connected to the antenna through the duplexer. But it is connected when no transmission is taking place.
- At the receiver section amplifier is used which is a transistor or IC for amplification. It is a low noise amplifier.
- A Local oscillator frequency is applied to the mixer than the mixer generates an intermediate frequency. This intermediate frequency is applied to the IF amplifier.
- The output of the IF amplifier is fed into the detector and we get a demodulated signal.
- The detector whose output is amplified by video amplifier having the same bandwidth as the IF display the result.

Doppler Effect :-

- The Doppler Effect is the change in frequency of a wave in relation to an observer who is moving relative to the wave source.
- The reason for the Doppler effect is that when the source of the wave is moving towards the observer each successive wave crest is emitted from a position closer to the observer than the crest of the previous waves.
- It is possible to detect moving targets by radiating unmodulated continuous wave (CW) energy instead of radiating in the form of pulses continuous wave (CW) radar makes use of the Doppler effect for target speed measurements.

CW RADAR



- The transmitter oscillator send signal to the transmitting antenna i.e the transmitting antenna transmit the signal to the space.
- A small portion of the transmitter output is mixed with the output of the local oscillator and the sum is fed to the reciver mixer.
- The receiver mixer also receives the Doppler shifted signal from its antenna and produces an output difference i.e typically somHz.
- The output of this mixer is amplified demodulated the signal from the detector is just the Doppler frequency.
- The detector output is fed into audio amplifier where it is amplified.
- Then the output of audio amplifier fed into the indicator to show the result.

Advantages of CW Doppler radar:-

1. CW RADAR is capable of giving accurate measurements of relatives velocies.
2. CW RADAR are always on, they need low power and are compact in size.
3. They can be used for small to large range with high degree of efficiency

and accuracy.

4. The performance of radar is not affected by stationary object.

Disadvantages of CW Doppler Radar:-

1. The maximum range of CW Doppler radar is limited by the power that radar can radiate.

2. The target range cannot be calculated by CW Doppler radar.

3. There is possibility of ambiguous results when number of targets are more.

Application

1. Traffic counters
2. Runway monitors
3. Measuring motion of waves on water level.

AIDS TO Navigation

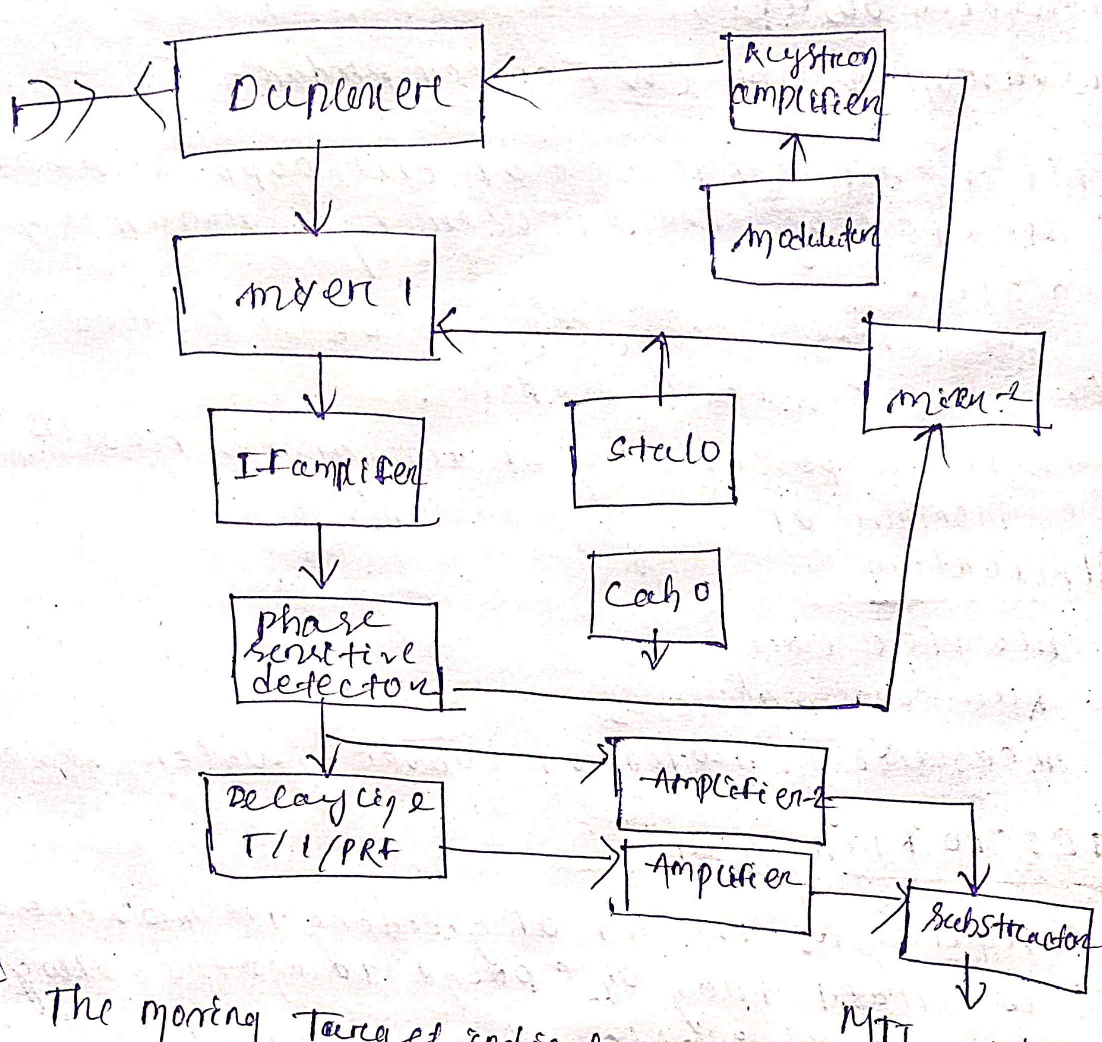
-/ Navigation is the art of guiding the movement of a craft from one point to another along a desired path. In olden days long journeys over sea were accomplished with the knowledge of the movement of sun and various stars.

-/ These days most of the navigational work is done with electronic navigational aids. Electronics navigational aids are based on the use of EM waves to find the position of the craft.

-/ Long Range Navigation is based on the measurement of the difference in the time of arrival of EM waves from two transmitters to the receiver in the crafts.

-/ Another one navigational aid is radio range navigation.

⇒ ~~The~~ Moving Target Indication RADAR:-



→ The moving target indicator radar Block diagram compares a set of received echos with those received during the previous sweep. Thoses echos whose phase has remained constant are then cancelled out by this applies to echos due to stationary objects but those due to moving targets do show a phase change they are thus not cancelled for is noise for obvious reasons.

→ The fact that clutter due to stationary target is removed makes it much easier to determine which targets are moving and reduce the time taken by an operator to take in the display

+ It also allows the detection of moving targets whose echos are hundreds of times smaller than those of nearby stationary targets and which would otherwise have been completely masked. MTI can be used with a radar using a power oscillator output.

+ The transmitted frequency in the moving target indication Radar is the sum of the outputs of two oscillators produced in mixer 2, or stable local oscillator. The first is the stalo or coherent oscillator.
+ The second is the coho operating at the same frequency as the intermediate frequency and providing the coherent signal which is used mixer 1 & 2 are identical and both use the same local oscillator (the stalo). thus phase relations existing in their inputs are preserved in their output.

+ This makes it possible to us the Doppler shift at the IF instead of the less convencial radio frequency. The output of the IF amplifier and a reference signal from the coho are fed to the phase senesitive detector, a circuit very similar to the phase discriminator.