UNIT – 8

MTI AND PULSE DOPPLER RADAR: Introduction to Doppler and MTI Radar, delay line Cancellers, digital MTI processing, Moving target detector, pulse Doppler Radar.

7 Hours

TEXT BOOKS:

1. **Microwave Devices and circuits**- Liao / Pearson Education.
2. **Introduction to Radar systems**-Merrill I Skolnik, 3rd Ed, TMH, 2001.
3. **Microwave Engineering** – Annapurna Das, Sisir K Das TMH Publication, 2001.

REFERENCE BOOK:

1. **Microwave Engineering –** David M Pozar, John Wiley, 2e, 2004

UNIT - 8

MTI AND PULSE DOPPLAR RADAR

The ability of a radar receiver to detect a weak echo signal is limited by the noise energy that occupies the same portion of the frequency spectrum as does the signal energy. The weakest signal the receiver can detect is called the ***minimum detectable signal.***

8.1 THE DOPPLER EFFECT

A radar detects the presence of objects and locates their position in space by transmitting electromagnetic energy and observing the returned echo. A pulse radar transmits a relatively short burst of electromagnetic energy, after which the receiver is turned on to listen for the echo. The echo not only indicates that a target is present, but the time that elapses between the transmission of the pulse and the receipt of the echo is a measure of the distance to the target. Separation of the echo signal and the transmitted signal is made on the basis of differences in time.

The radar transmitter may be operated continuously rather than pulsed if the strong transmitted signal can be separated from the weak echo. The received-echo-signal power is considerably smaller than the transmitter power; it might be as little as $\mathbf{10^{18}}$ that of the transmitted power-sometimes even less. Separate antennas for transmission and reception help segregate the weak echo from the strong leakage signal, but the isolation is usually not sufficient. **A** feasible technique for separating the received signal from the transmitted signal when there is relative motion between radar and target is based on recognizing the change in the echo-signal frequency caused by the doppler effect.

It is well known in the fields of optics and acoustics that if either the source of oscillation or the observer of the oscillation is in motion, an apparent shift in frequency will result. This is the *doppler effect.*

If R is the distance from the radar to target, the total number of wavelengths ***L*** contained in the two-way path between the radar and the target is *2R/λ*. The distance R and the wavelength ***L*** are assumed to be measured in the same units.

Since one wavelength corresponds to an angular excursion of **2**∏ radians, the total angular excursion made by the electromagnetic wave during its transit to and from the target is **4**∏**R /** *λ* radians. If the target is in motion, R and the phase **φ** are continually changing.

The doppler angular frequency ωd is given by

$$\omega_d = 2\pi f_d = \frac{d\phi}{dt} = \frac{4\pi}{\lambda}\frac{dR}{dt} = \frac{4\pi v_r}{\lambda}$$

where **fd** = doppler frequency shift and **L).** = relative (or radial) velocity of target with respect to radar. The doppler frequency shift

$$f_d = \frac{2v_r}{\lambda} = \frac{2v_r f_0}{c}$$

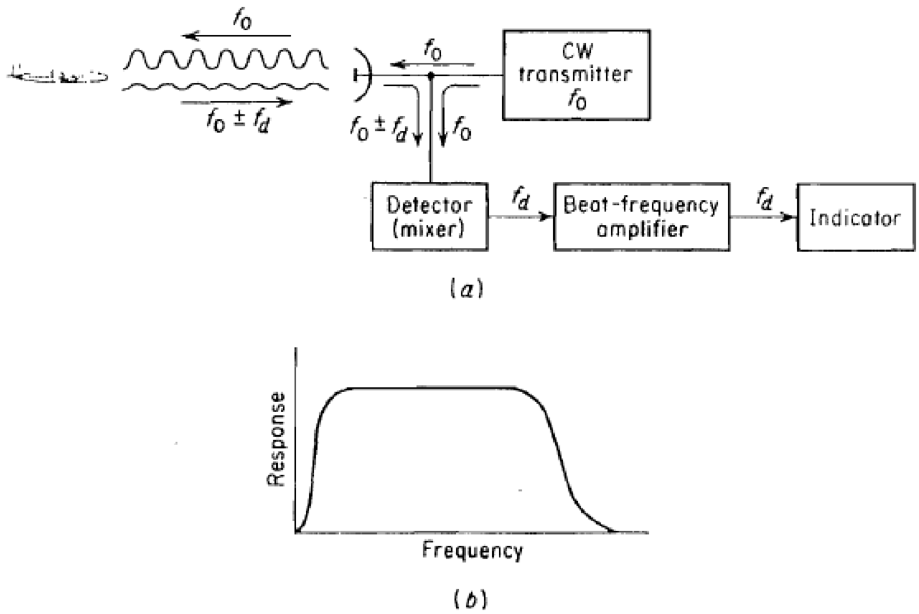
8.2 CW RADAR

Let us consider the simple CW radar as illustrated by the block diagram below. The transmitter generates a continuous (unmodulated) oscillation of frequency fo, which is radiated by **the** antenna. **A** portion of the radiated energy is intercepted by the target and is scattered, some of it in the direction of the radar, where it is collected by the receiving antenna.

If the target is in motion with a velocity ***v*,** relative to the radar, the received signal will be shifted in frequency from the transmitted frequency fo by an amount + or – *fd.*The plus sign associated with the doppler frequency applies if the distance between target and radar is decreasing (closing target), that is, when the received signal frequency is greater than the transmitted signal frequency. The minus sign applies if the distance is increasing (receding target).

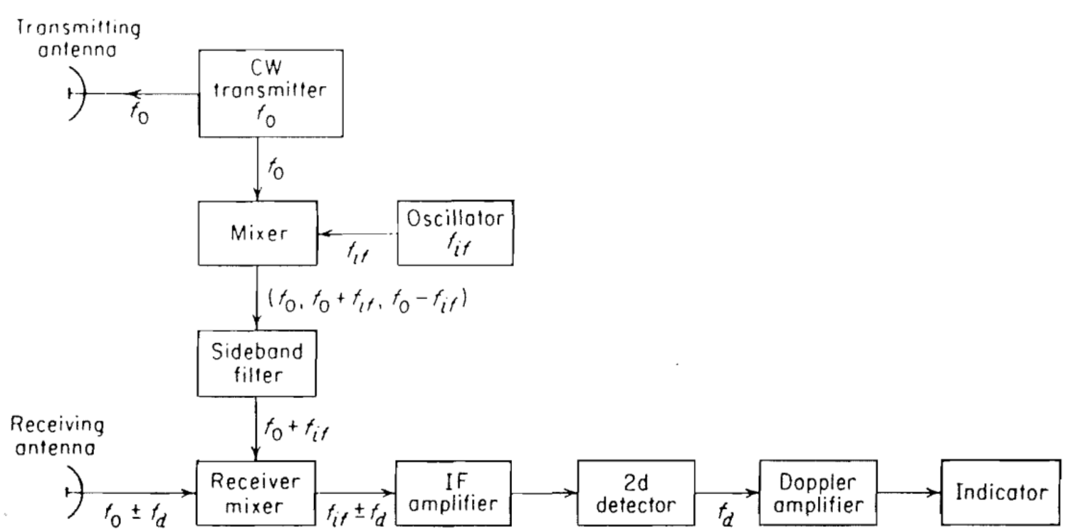
The received echo signal at a frequency enters the radar via the antenna and is heterodyned in the detector (mixer) with a portion of the transmitter signal fo to produce a doppler beat note of frequency fd. The sign of fd is lost in this process.

The purpose of the doppler amplifier is to eliminate echoes from stationary targets and to amplify the doppler echo signal to a level where it can operate an indicating device. The low-frequency cutoff must be high enough to reject tile d-c component caused by stationary targets, but yet it must be low enough to pass the smallest doppler frequency expected. Sometimes both conditions cannot he met simultaneously and a compromise is necessary. The upper cutoff frequency is selected to pass the lightest doppler frequency expected. The indicator might be a pair of earphones or a frequency meter.



(a) Simple CW radar block diagram; (b) response characteristic of beat-frequency amplifier.

Fig 8.1



Block diagram of CW doppler radar with nonzero IF receiver, sometimes called *sideband* ***Fig 8.2***

Intermediate-frequency receiver. The receiver of the simple CW radar of Fig 2 is in some respects analogous to a superheterodyne receiver. Receivers of this type are called homodyne receivers, or superheterodyne receivers with zero IF.

The function of the local oscillator is replaced by the leakage signal from the transmitter. Such a receiver is simpler than one with a more conventional intermediate frequency since no IF amplifier or local oscillator is required.

However, the simpler receiver is not as sensitive because of increased noise at the lower intermediate frequencies caused by flicker effect. Flicker-effect noise occurs in semiconductor devices such as diode detectors and cathodes of vacuum tubes.

For short-range, low-power, applications this decrease in sensitivity might be tolerated since it can be compensate by a modest increase in antenna aperture and/or additional transmitter power. But for 'maximum efficiency with CW radar, the reduction in sensitivity caused by the simple Doppler receiver with zero IF, cannot be tolerated.

The effects of flicker noise are overcome in the normal superheterodyne receiver by using an intermediate frequency which is high enough to render . the flicker noise small compared with the normal receiver noise. This results from the inverse, frequency dependence of flicker noise.

Separate antennas are shown for transmission and reception instead of the usual local oscillator found in the **convenient** receiver, the local oscillator (or reference signal) is derived in the receiver from a portion of the transmitted signal mixed with a locally generated signal of frequency equal to that of the receiver IF. Since the output of the mixer consists of two sidebands on either side of the carrier plus higher harmonics, a narrowband filter selects one of the sidebands as the reference signal. The improvement in receiver sensitivity with an intermediate-frequency super heterodyne might be as much as 30 dB over the simple receiver.

Applications of CW radar:

1. The chief use of the simple, unmodulated CW radar is for the measurement of the relative velocity of a moving target, as in the police speed monitor or in the previously mentioned rate-of-climb meter for vertical-take-off aircraft.

2. In support of automobile traffic, CW radar has been suggested for the control of traffic lights, regulation of toll booths, vehicle counting, as a replacement for the " fifth-wheel" speedometer in vehicle testing as a sensor in antilock braking systems, and for collision avoidance.

3. For railways, CW radar can be used as a speedometer to replace the conventional axle-driven tachometer.

4. It has been used for the measurement of **railroad-freight-car velocity** during humping operations in marshalling yards, and as

a detection device to give track maintenance personnel advance warning of approaching trains..

5. CW radar is also employed for monitoring the docking speed of large ships.

6. It has also seen application for intruder alarms and for the measurement of the velocity of missiles, ammunition, and baseballs.

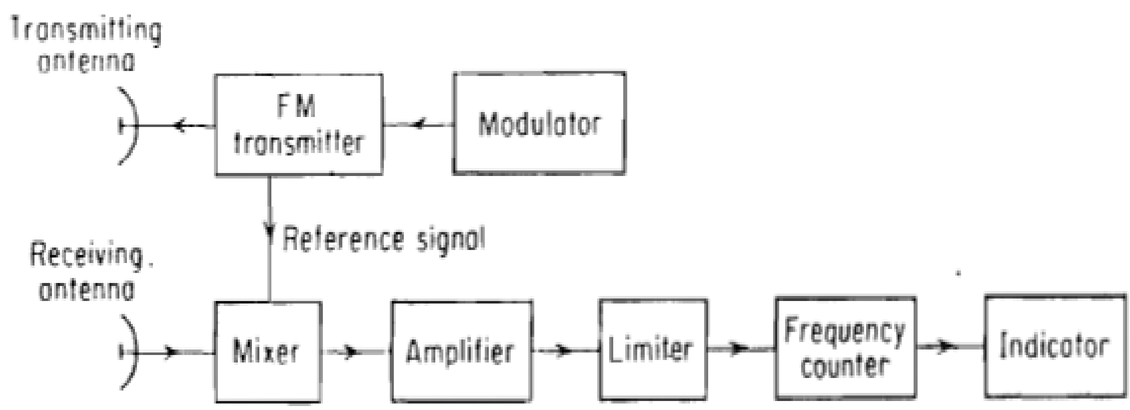
The principal advantage of a CW doppler radar over other (nonradar) methods of measuring speed is that there need not be any physical contact with the object whose speed is being measured. In industry this has been applied to the measurement of turbine-blade vibration, the peripheral speed of grinding wheels, and the monitoring of vibrations in the cables of suspension bridges.

8.3 FREQUENCY - MODULATED CW RADAR:

The inability of the simple CW radar to measure range is related to the relatively narrow spectrum (bandwidth) of its transmitted waveform. Some sort of timing mark must be applied to a CW carrier if range is to be measured. The timing mark permits the time of transmission and the time of return to be recognized. The sharper or more distinct the mark, the more
accurate the measurement of the transit time. But the more distinct the timing mark, the broader will be the transmitted spectrum. This follows from the properties of the Fourier transform.

The spectrum of a CW transmission can be broadened by the application of modulation, either amplitude. frequency, or phase. An example of an amplitude modulation is the pulse radar. The narrower the pulse, the more accurate the measurement of range and the broader the transmitted spectrum.

A block diagram illustrating the principle of the FM-CW radar is shown in above figure. A portion of the transmitter signal acts as the reference signal required to produce the beat frequency. It is introduced directly into the receiver via a cable or other direct connection.



Block diagram of FM-CW radar.

Fig 8.3

Ideally, the isolation between transmitting and receiving antennas is made sufficiently large so as to reduce to a negligible level the transmitter leakage signal which arrives at the receiver via the coupling between antennas. The beat frequency is amplified and limited to remove any amplitude fluctuations. The frequency of the amplitude-limited beat note is measured with a cycle-counting frequency meter calibrated in distance. The target was assumed to be stationary. If this assumption is not applicable, a doppler frequency shift will be superimposed on the FM range beat note and an erroneous range measurement results. The doppler frequency shift causes the frequency-time plot of the echo signal to be shifted up or down

$$f_b(\text{up}) = f_r - f_d$$
$$f_b(\text{down}) = f_r + f_d$$

When more than one target is present within the view of the radar, the mixer output will contain more than one difference frequency. If the system is linear, there will be a frequency component corresponding to each target. In principle, the range to each target may be determined by measuring the individual frequency components.

To measure the individual frequencies, they must be separated from one another. This might he accomplished with a bank of narrowband filters, or alternatively, a single frequency corresponding to a single target may be singled out and continuously observed with a narrow band tunable filter. If the FM-CW radar is used for single targets only, such as in the radio altimeter, it is not necessary to employ a linear modulation waveform.

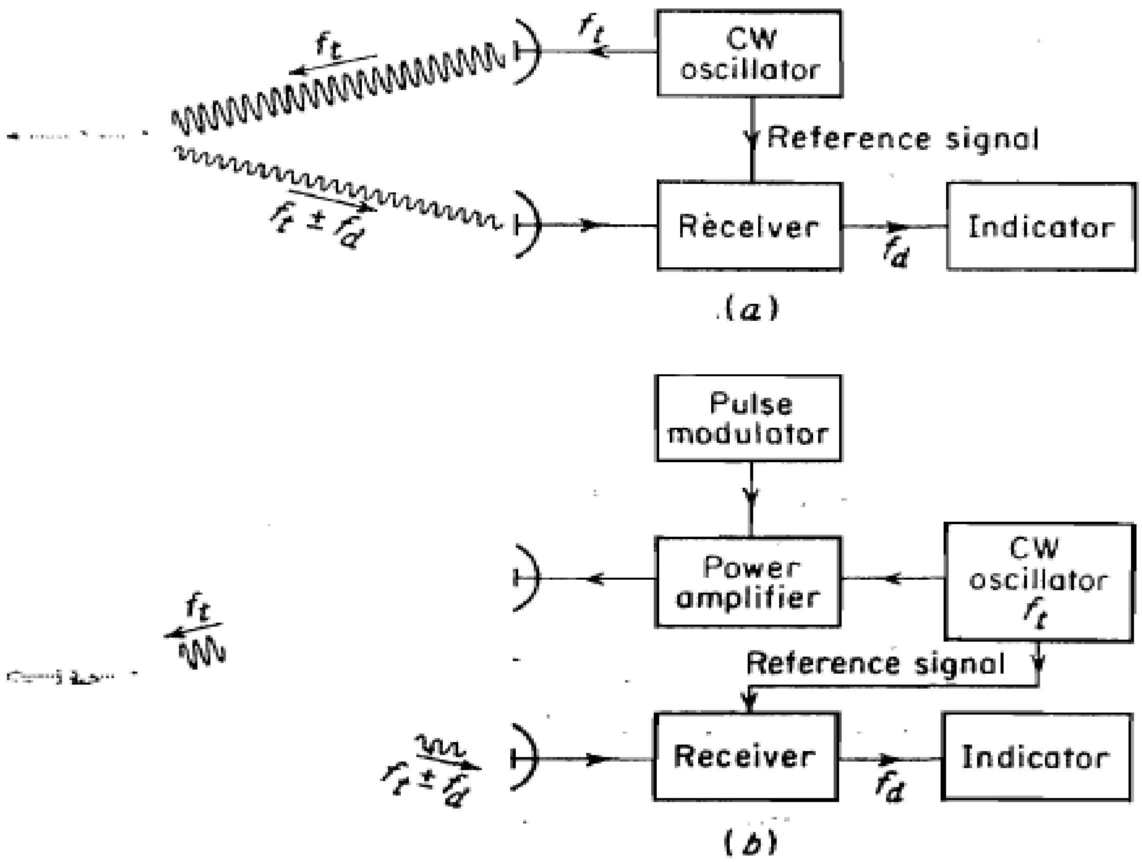
8.4 MTI RADARS

The doppler frequency shift produced by a moving target may be used in a pulse radar. just as in the CW radar to determine the relative velocity of a

target or to separate desired moving targets from undesired stationary objects (clutter). Although there are applications of pulse radar where a determination of the target's relative velocity is made from the doppler frequency shift, the use of doppler to separate small moving targets in the presence of large clutter has probably been of far greater interest. Such a pulse radar that utilizes the doppler frequency shift as a means for discriminating moving from fixed targets is called an ***MTI*** (moving target indication) or a ***pulse doppler*** radar. The two are based on tile same physical principle, but in practice there are generally recognizable differences between them .

The MTI radar, for instance, usually operates with ambiguous doppler measurement but with unambiguous range measurement (no second-time'-around echoes). The opposite is generally the case for a pulse doppler radar. Its pulse repetition frequency is usually high enough to operate with unambiguous doppler (no blind speeds) but at the expense of range ambiguities. The discussion in this chapter, for the most part, is based on tile MTI radar, but much of what applies to MTI can be extended to **pulse** doppler radar as well.

MTI is a necessity in high-quality air-surveillance radars that operate in the presence of clutter. Its design is more challenging than that of a simple pulse radar or a simple CW radar. **An MTI** capability adds to a radar's cost and complex.

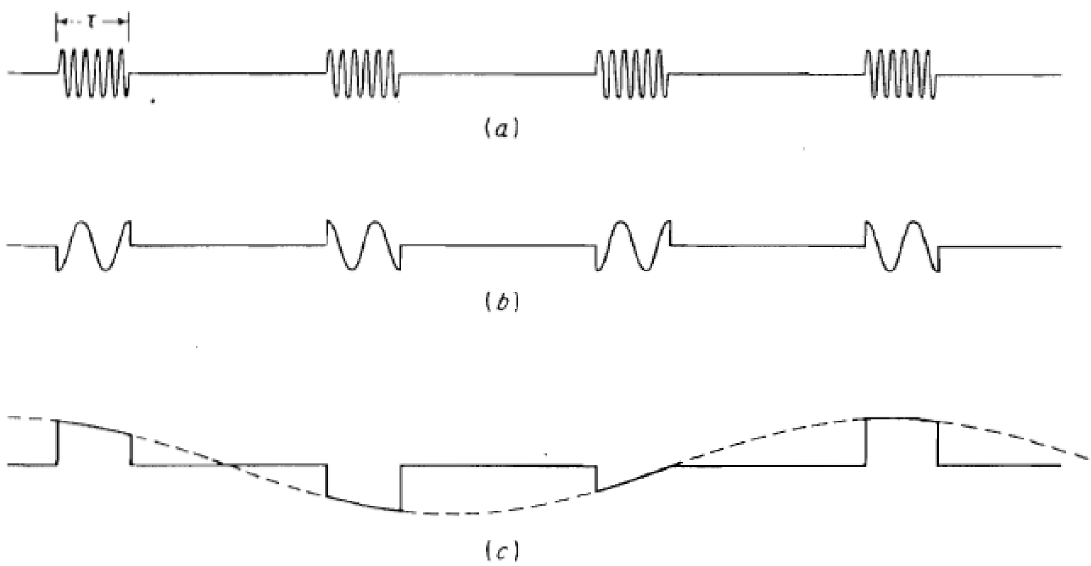


(*a*) Simple CW radar; pulse radar using doppler information.

Fig 8.4

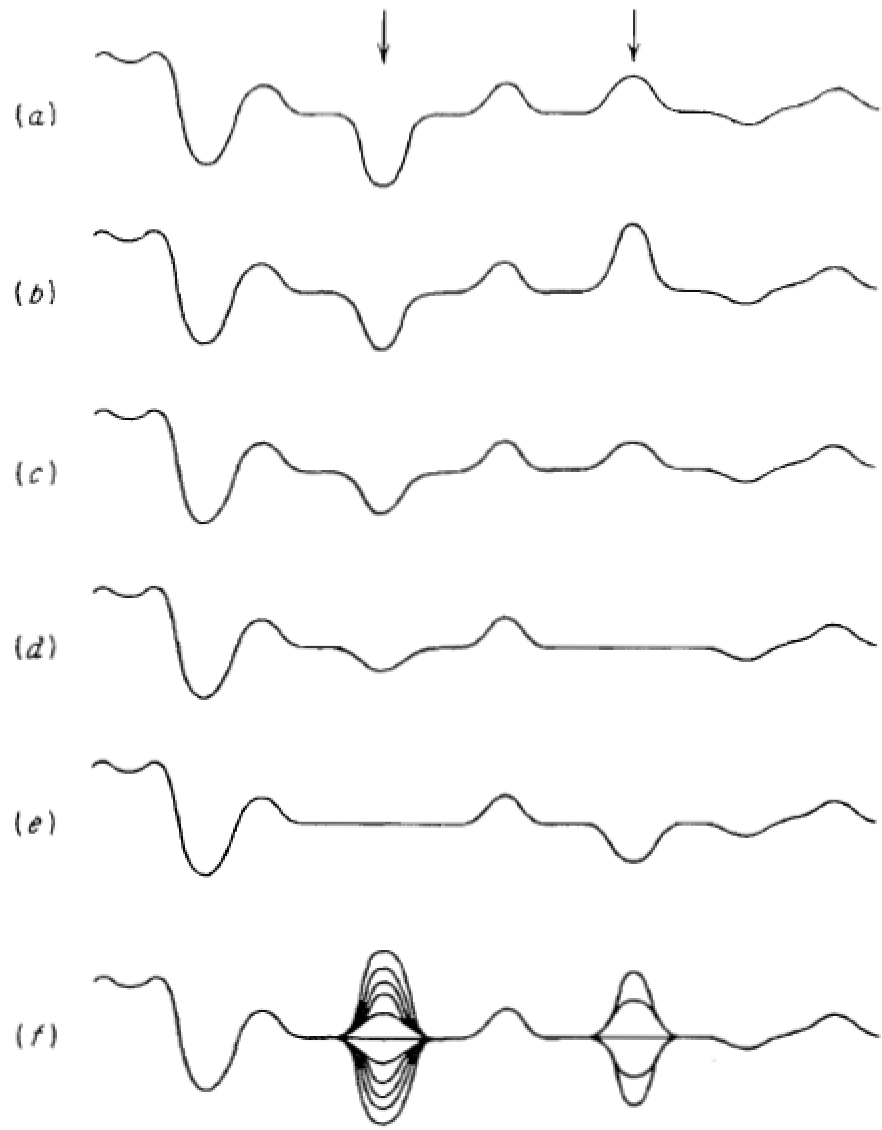
The doppler signal may be readily discerned from the information contained in a single pulse. If, on the other hand, f b is small compared with the reciprocal of the pulse duration, the pulses will be modulated with an amplitude.

Moving targets may be distinguished from stationary targets by observing the video output on an A-scope. O n the basis of a single sweep, moving targets cannot be distinguished from fixed targets. **I t** may be possible to distinguish extended ground targets from point targets by the stretching of the echo pulse. However, this is not a reliable means of discriminating moving from fixed targets since some fixed targets can look like point targets, e.g., a water tower. Also, some moving targets such as aircraft flying in formation can look like extended targets.)Successive A-scope sweeps (pulse-repetition intervals).



(a) RF echo pulse train; (b) video pulse train for doppler frequency $f_d > 1/\tau$; (c) video pulse train for doppler freuqncy $f_d < 1/\tau$.

Fig 8.5



(*a–e*) Successive sweeps of an MTI radar A-scope display (echo amplitude as a function of time); (*f*) superposition of many sweeps; arrows indicate position of moving targets.

Fig 8.5

Although the butterfly effect is suitable for recognizing moving targets on an A-scope, it is not appropriate for display on the PPI. One method commonly employed to extract Doppler information in a form suitable for display on the PPI scope is with a delay-line canceller.. The delay-line canceller acts as a filter to eliminate the d-c component of fixed targets

and to pass the a-c components of moving targets. The video portion of the receiver is divided into two channels. One is a normal video channel. In the other, the video signal experiences a time delay equal to one pulse-repetition period (equal to the reciprocal of the pulse-repetition frequency). The outputs from the two channels are subtracted from one another. The fixed targets with unchanging amplitudes from pulse to pulse are canceled on subtraction. However, the amplitudes of the moving-target echoes are not constant from pulse **to** subtraction results in an uncancelled residue. The output of the subtraction circuit is bipolar video, just as was the input. Before bipolar video can intensity-modulate a PPI display, it must be converted to unipotential voltages (unipolar video) by a full-wave rectifier.

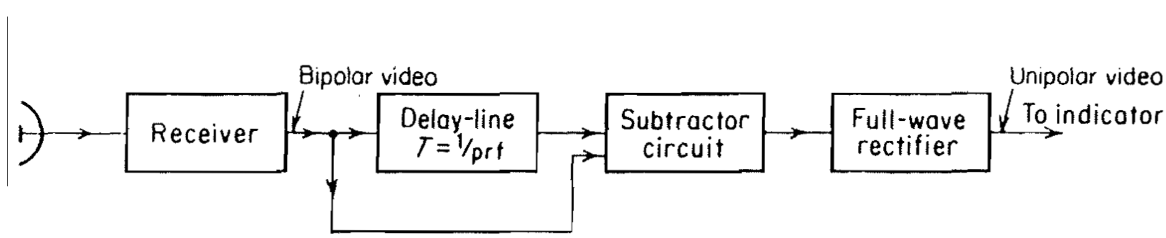
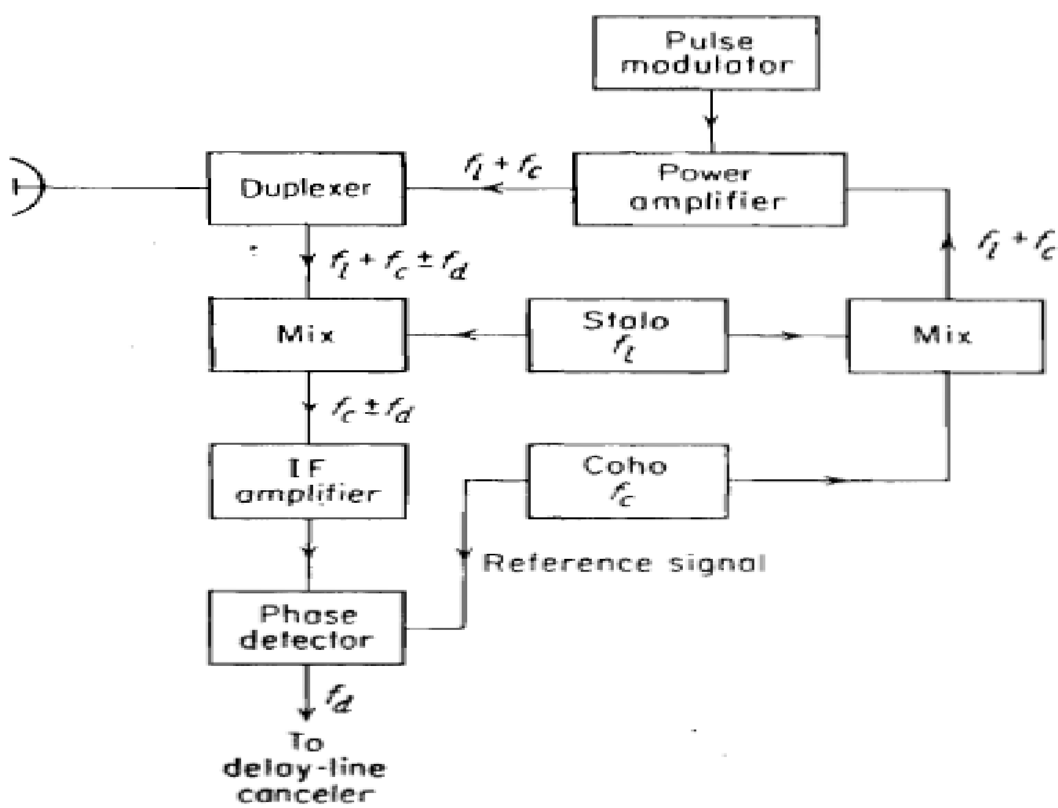


Fig : 8.6 MTI receiver with delay-line canceller

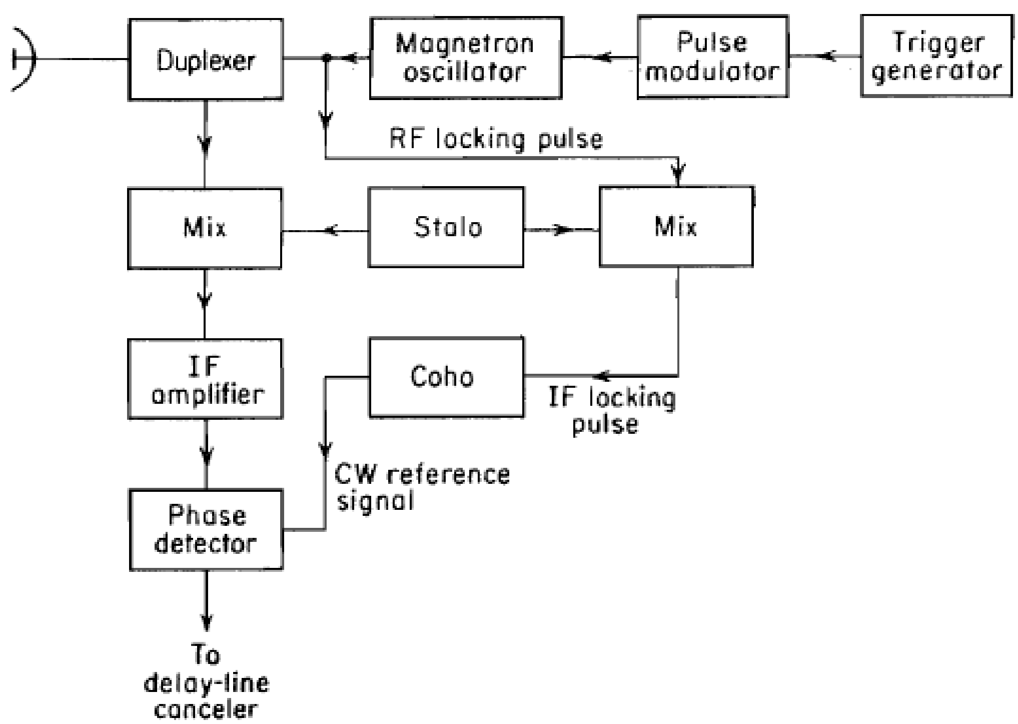
8.5 MTI RADAR WITH POWER AMPLIFIER TRANSMITTER:

The block diagram of a more common MTI radar employing a power amplifier is shown.The significant difference between this MTI configuration is the manlier in which the reference signal is generated. the coherent reference is supplied by the oscillator called the COHO, which stands for coherent oscillator. The coho is a stable oscillator whose frequency is the same as the intermediate frequency used in the receiver. In addition to providing the reference signal the output of the COHO fc; is also mixed with the local-oscillator frequency. The local oscillator- must also have a stable oscillator and is called STALO, for stable local oscillator. The RF echo signal is heterodyned with the stalo signal to produce the IF signal just as in conventional super heterodyne receiver.



Block diagram of MTI radar with power-amplifier transmitter.

Fig 8.7



Block diagram of MTI radar with power-oscillator transmitter.

Fig 8.8

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

A block diagram of an MTI radar (with a power oscillator) is shown **A** portion of the transmitted signal is mixed with the stalo output to 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 step with the phase of the

IF reference pulse. The phase of the coho is then related to the phase of the transmitted pulse and may be used as the reference signal for echoes received from that particular transmitted pulse.

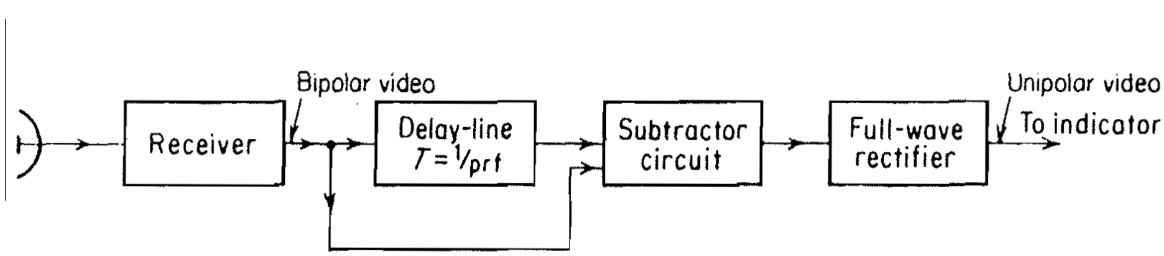
Upon the next transmission another IF locking pulse is generated to relock the phase of the CW coho until the next locking pulse comes along.

8.6 DELAY-LINE CANCELERS

The simple MTI delay-line canceller The simple MTI delay-line canceller The capability of this device depends on the quality of the medium used iis the delay line. The Pulse modulator delay line must introduce a time delay equal to the pulse repetition interval.

For typical ground-based air-surveillance radars this might be several milliseconds. Delay times of this magnitude cannot be achieved with practical electromagnetic transmission lines. By converting the electromagnetic signal to an 'acoustic signal it is possible to utilize delay lines of a reasonable physical length since the velocity of propagation of acoustic waves After the necessary delay is introduced by the acoustic line, the signal is converted back to an electromagnetic signal for further processing.

Fig 8.9



The early acoustic delay lines developed during World War 11 used liquid delay lines filled with either water or mercury.' Liquid delay lines were large and inconvenient to use. They were replaced in the mid-1950s by the solid fused-quartz delay line that used multiple internal reflections to obtain a compact device. These analog acoustic delay lines were, in turn supplanted in the early 1970s by storage devices based on digital computer technology. The use of digital delay lines requires that the output of the MTI receiver phase-detector be quantized into a sequence of digital words. The compactness and convenience of digital processing allows the implementation of more complex delay-line cancellers with filter characteristics not practical with analog methods.

One of the advantages of a time-domain delay-line canceller as compared to the more conventional frequency-domain filter is that a single network operates at all ranges and does not require a separate filter for each range resolution cell. Frequency-domain doppler filterbanks are of interest in some forms of MTI and pulse-doppler radar.

Filter characteristics of the delay-line canceller

The delay-line canceller acts as a filter which rejects the d-c component of clutter. Because of its periodic nature, the filter also rejects energy in the vicinity of the pulse repetition frequency and its harmonics.

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

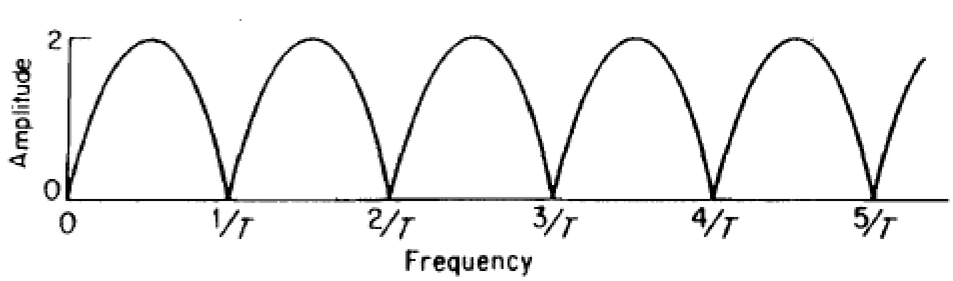
where Φ_0 = phase shift and k = amplitude of video signal. The signal from the previous transmission, which is delayed by a time T = pulse repetition interval, is

$$V_2 = k \sin [2\pi f_d(t - T) - \phi_0]$$

Everything else is assumed to remain essentially constant over the interval T so that k is the same for both pulses. The output from the subtractor is

$$V = V_1 - V_2 = 2k \sin \pi f_d T \cos \left[2\pi f_d\left(t - \frac{T}{2}\right) - \phi_0\right]$$

It is assumed that the gain through the delay-line canceller is unity. Thus the amplitude of the canceled video output is a function of the Doppler frequency shift and the pulse-repetition interval, or prf. The magnitude of the relative frequency-response of the delay-line canceler [ratio of the amplitude of the output from the delay-line canceler, to the amplitude of the normal radar video .



Frequency response of the single delay-line canceler; T = delay time = $1/f_p$.

Fig 8.9

Blind speeds: The response of the single-delay-line canceller will be zero whenever the argument Πfd T in the amplitude factor.

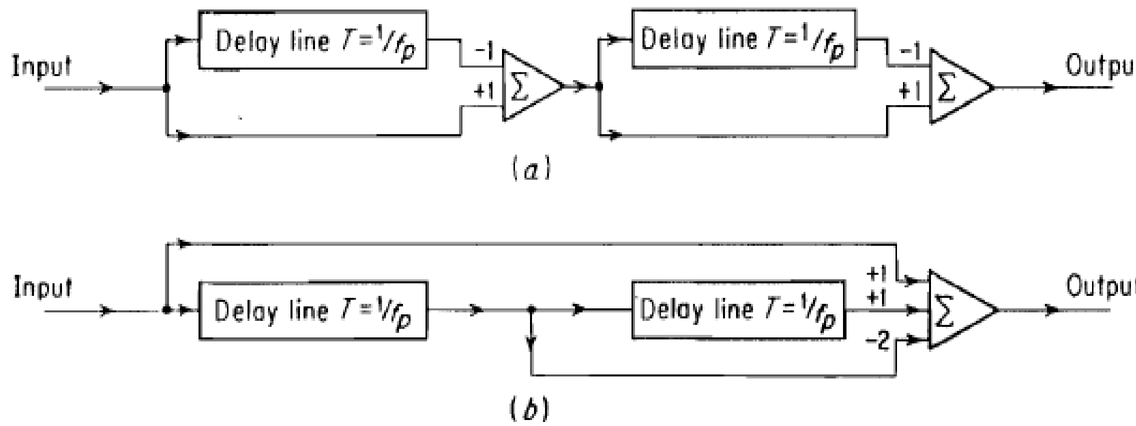
The blind speeds are one of the limitations of pulse MTI radar which do not occur with CW radar. They are present in pulse radar because doppler is measured by discrete samples (pulses) at the prf rather than continuously. If the first blind speed is to be greater than the maximum radial velocity expected from the target, the product ,If the first blind speed must be large. Thus the MTI radar must operate at long wavelengths (low frequencies) or with high pulse repetition frequencies, or both.

Double cancellation:

The frequency response of a single-delay-line canceller does not always have as broad a clutter-rejection null as might be desired in the vicinity of d-c. The clutter-rejection notches may be widened by passing the output of the delay-line canceller through a second delay-line canceller. The output of the two single-delay line cancellers in cascade is the square of that from a single canceller.

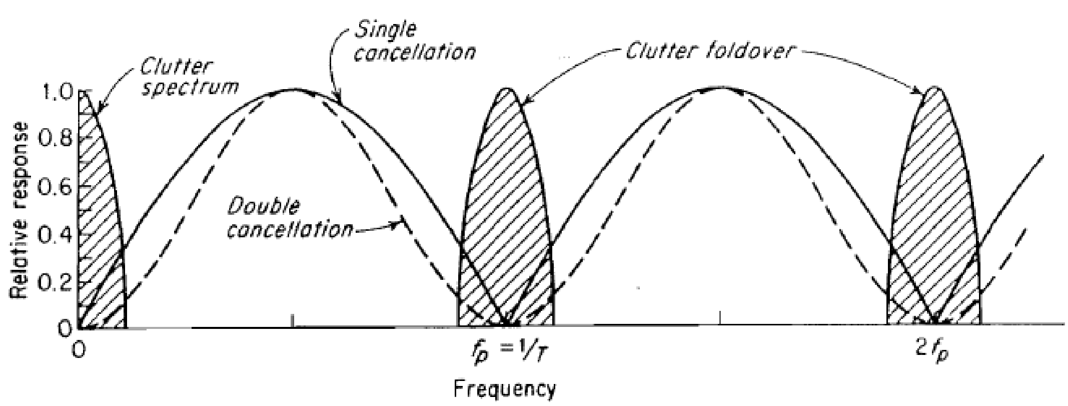
The two-delay-line configuration has the same frequency-response characteristic as the double-delay-line canceler. The operation of the device is as follows. **A** signal $\boldsymbol{f(t)}$ is inserted into the adder along with the signal from the preceding pulse period, with its amplitude weighted by the factor - 2, plus the signal from two pulse periods previous. The output of the adder is therefore

$$f(t) - 2f(t + T) + f(t + 2T)$$



(*a*) Double-delay-line canceler; (*b*) three-pulse canceler.

Fig 8.10



Relative frequency response of the single-delay-line canceler (solid curve) and the double-delay-line canceler (dashed curve). Shaded area represents clutter spectrum.

Fig 8.11

which is the same as the output from the double-delay-line canceller

$$f(t) - f(t+T) - f(t+T) + f(t+2T)$$

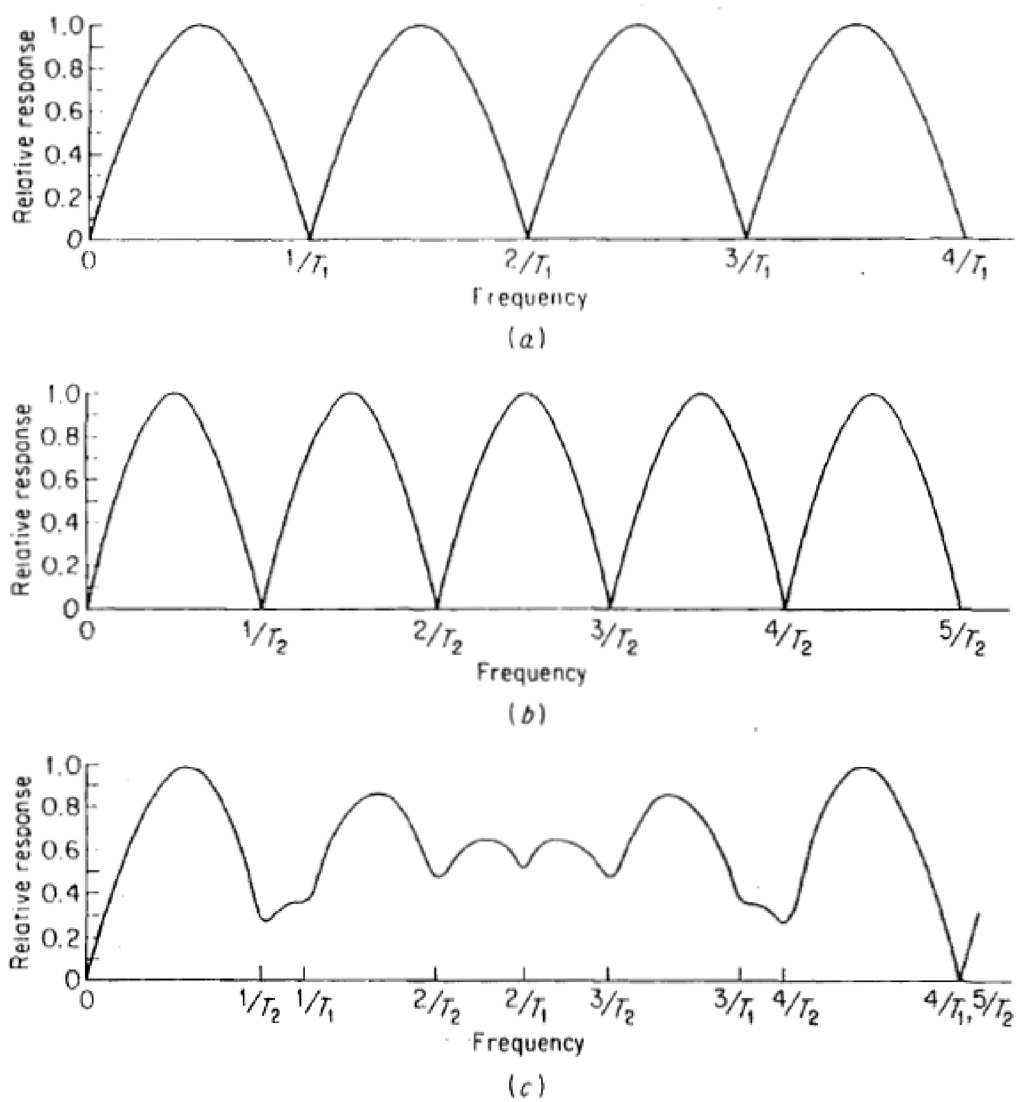
This configuration is commonly called the **three-pulse canceller**.

8.7 MULTIPLE, OR STAGGERED, PULSE REPETITION FREQUENCY

The use of more than one pulse repetition frequency offers additional flexibility in the design of MTI doppler filters. It not only reduces the effect of the blind speeds but it also allows a sharper low-frequency cutoff in the frequency response than might be obtained with a cascade of single-delay-line cancelers.

The blind speeds of two independent radars operating at the same frequency will be different if their pulse repetition frequencies are different. Therefore, if one radar were " blind " to moving targets, it would be unlikely that the other radar would be " blind" also. Instead of using two separate radars, the same result can be obtained with one radar which time-shares its pulse repetition frequency between two or more different values (multiple prf's). The pulse repetition frequency might be switched every other scan or every time the antenna is scanned a half beamwidth, or the period might be alternated on every other pulse. When the switching is pulse to pulse, it is known as a staggered prf.

An example of the composite (average) response of an MTI radar operating with two separate pulse repetition frequencies on a time-shared basis is shown below

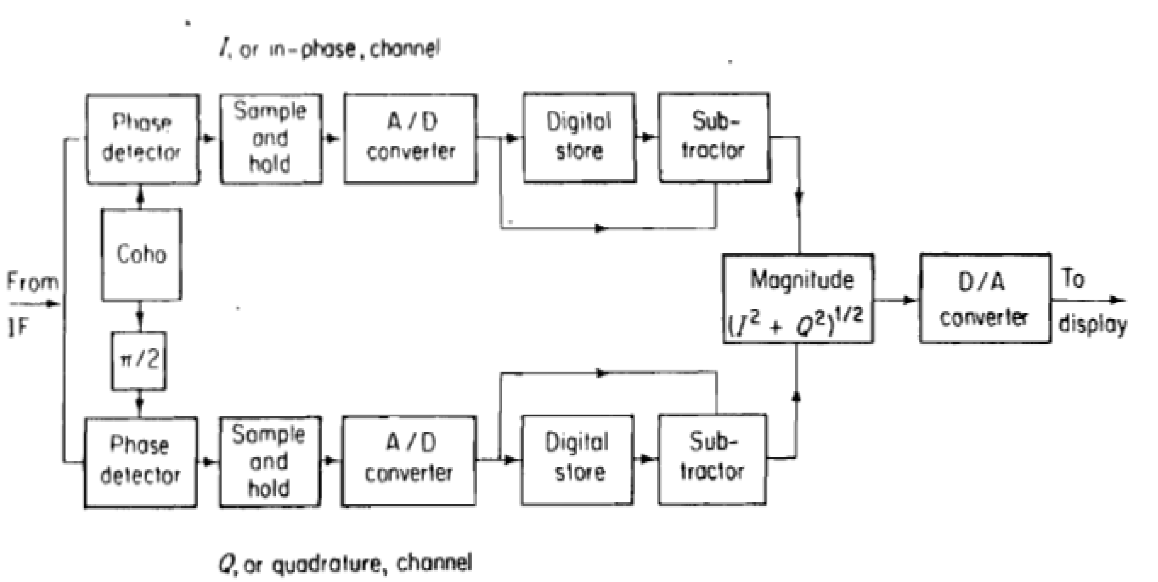


(a) Frequency-response of a single-delay-line canceler for $f_p = 1/T_1$; (b) same for $f_p = 1/T_2$; (c) composite response with $T_1/T_2 = \frac{4}{5}$.

Fig 8.12

8.8 DIGITAL MTI SIGNAL PROCESSOR:

A simple block diagram of a digital MTI processor is shown in Fig below. From the output of the IF amplifier the signal is split into two channels. One is denoted **I,** for ***in-phase channel.***The other is denoted **Q,** for ***quadrature*** channel, since a 90" phase change *(Π/2* radians) is introduces into the coherent reference signal at the phase detector. This causes the outputs of the two detectors to be 90 degrees out of phase.
The purpose of the quadrature channel is to eliminate the effects of blind phases.It is desirable to eliminate blind phases in any MTI processor, but it is seldom done with analog delay-line cancelers because of the complexity of the added analog delay lines of the second channel. The convenience of digital processing allows the quadrature channel to be added without significant burden so that it is often included in digital processing systems. It is for this reason it is shown in this block diagram, but was not included in the previous discussion of **MTI** delay-line cancellers.



Block diagram of a simple digital MTI signal processor. ***Fig 8.13***

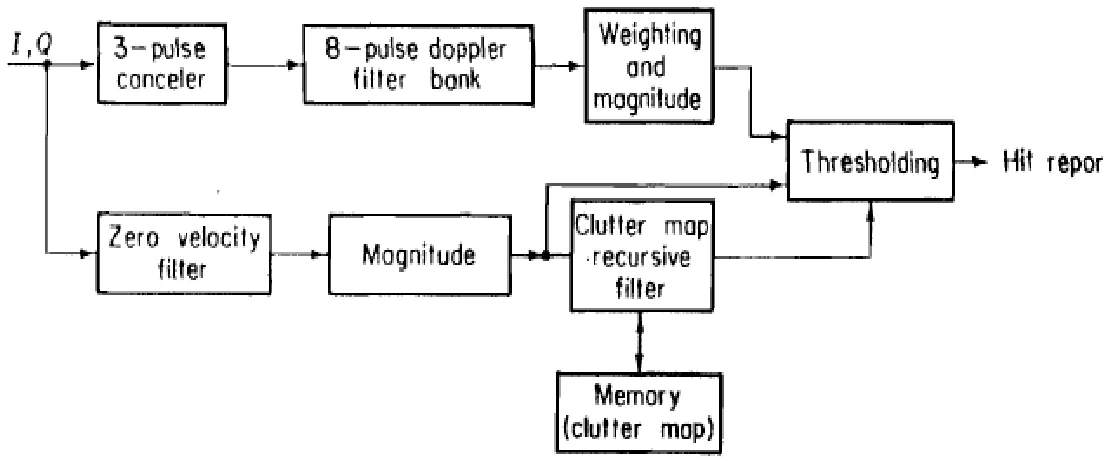
Following the phase detector the bipolar video signal is sampled at a rate sufficient to obtain one or more samples within each range resolution cell. These voltage samples are converted to a series of digital words by the analog-to-digital **(A/D)** converter.

The digital words are stored in a digital memory for one pulse repetition period and are then subtracted from the digital words of the next sweep. The digital outputs of the I and Q channels are combined by taking the square root of I^2 and Q^2 · The combined output is then converted to an analog signal by the digital-to-analog **(D/A)** converter. The unipolar video output is then ready to be displayed.

8.9 MOVING TARGET DETECTOR

A block diagram of the MTD processor is shown in Fig . The input on the left is from the output of the ***I*** and Q AID converters. The three-pulse canceler and the eight-pulse Doppler filter-bank eliminate zero-velocity clutter and generate eight overlapping filters covering the doppler interval, as described in the previous section. The use of a three-pulse canceler ahead of the fi1ter:bank eliminates stationary clutter and thereby reduces the dynamic range required of the doppler filter-bank.

The fast Fourier transform algorithm is listed to implement the doppler filter-bank. Since the first two pulses of a three-pulse canceler are meaningless only the last eight of the ten pulses output from the canceler are passed to the filter-bank. Following the filter-bank, weighting is applied in the frequency domain to reduce the filter sidelobes .



Simple block diagram of the Moving Target Detector (MTD) signal processor.

Fig 8.14

Separate thresholds are applied to each filter. The thresholds for the nonzero-velocity resolution cells are established by summing the detected outputs of the signals in the same velocity filter in 16 range cells, eight on either side of the cell of interest. Thus, each filter output is averaged over cne mile in range to establish the statistical mean level of nonzero-velocity clutter (such as rain) or noise. The filter thresholds are determined by multiplying the mean levels by an appropriate constant to obtain the desired false-alarm probability. This application of an adaptive threshold to each doppler filter at each range cell provides a constant false-alarm rate (CFAR) and results in ***Subweather visibility*** in that an aircraft with a radial velocity sufficiently different from the rain so as to fall into another filter can be seen even if the aircraft echo is substantially less than the weather echo.

A digital clutter map is generated which establishes the thresholds for the zero-velocity cells. The map is implemented with one word for each of the 365,000 range-azimuth cells. The original MTD stored the map on a magnetic disc memory. The purpose of the zero-velocity filter is to recover the clutter signal eliminated by the MTI delay-line canceler and to use this signal as a means for detecting targets on-crossing trajectories with zero velocities that would normally be lost in the usual MTI. Only targets larger than the clutter would be so detected.

8.10 LIMITATIONS TO MTI PERFORMANCE

The improvement in signal-to-clutter ratio of an MTI is affected by factors other than the design of the doppler signal processor. Instabilities of the transmitter and receiver, physical motions of the clutter, the finite time on target (or scanning modulation), and limiting in the receiver can all detract from the performance of an MTI radar.

MTI improvement f actor: The signal-to-clutter ratio at the output of the MTI system divided by the signal-to-clutter ratio at the input, averaged uniformly over all target radial velocities of interest.

Subclutter visibility : The ratio by which the target echo power may be weaker than the coincident clutter echo power and still be detected with specified detection and false alarm probabilities.

Clutter visibility factor : The signal-to-clutter ratio, after cancellation or doppler filtering, that provides stated probabilities of detection and false alarm.

Cltrtter attenuation: The ratio of clutter power at the canceller input to the clutter residue at the output, normalized to the attenuation of a single pulse passing through the unprocessed channel of the canceller.

Cancellation ratio: The ratio of canceller voltage amplification for the fixed-target echoes received with a fixed antenna, to the gain for a single pulse passing through the unprocessed channel of the canceller.

Equipment instabilities : Pulse-to-pulse changes in the amplitude, frequency, or phase of the transmitter signal, changes in the stalo or coho oscillators in the receiver, jitter in the timing of the pulse transmission, variations in the time delay through the delay lines, and changes in the pulse width can cause the apparent frequency spectrum from perfectly stationary clutter to broaden and thereby lower the improvement factor of an MTI radar.

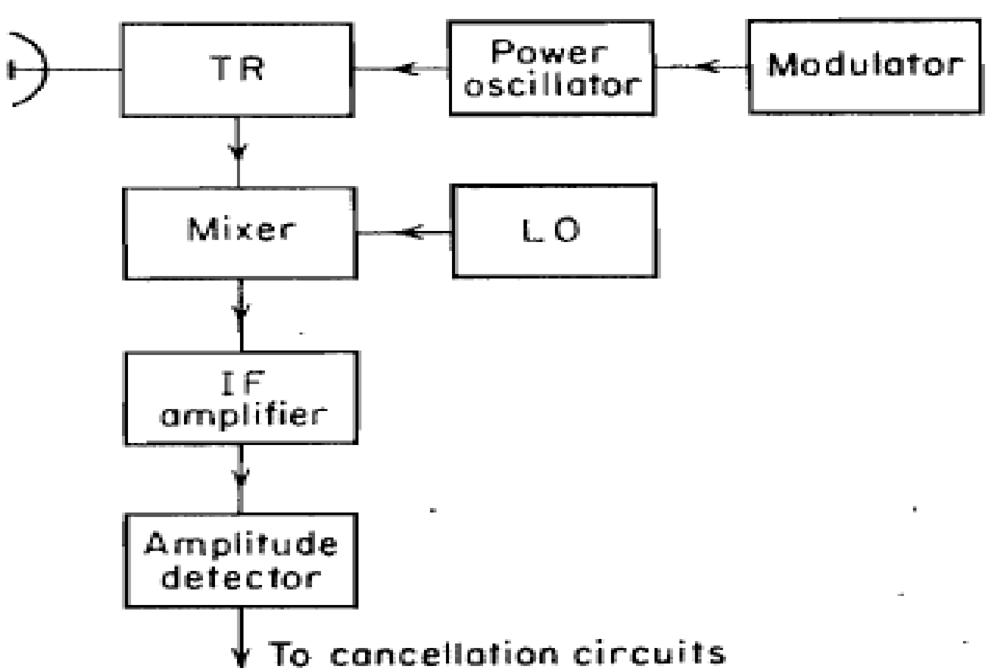
Internal fluctuation of clutter : Although clutter targets such as buildings, water towers, bare hills. or mountains produce echo signals that are constant in both phase and amplitude as a function of time, there are many types of clutter that cannot be considered as absolutely stationary. Echoes from trees, vegetation, sea, rain, and chaff fluctuate with time, and these fluctuations can limit the performance of MTI radar.

Antenna scanning modulation: As the antenna scans by a target, it observes the target for a finite time equal to , to = n where n, = number of hits received, fp = pulse repetition frequency, 0, = antenna beamwidth and antenna scanning rate. The received pulse train of finite duration to has a frequency spectrum (which can be found by taking the Fourier transform of the waveform) whose width is proportional to l/to. Therefore, even if the clutter were perfectly stationary, there will still be a finite width to the clutter spectrum because of the finite time on target. If the clutter spectrum is too wide because the observation time is too short, it will affect the improvement factor. This limitation has sometimes been called scanning fluctuations or scanning modulation.

8.11 NONCOHERENT MTI

The composite echo signal from a moving target and clutter fluctuates in both phase and amplitude. The coherent MTI and the pulse-doppler radar make use of the phase fluctuations in the echo signal to recognize the doppler component produced by a moving target. In these systems, amplitude fluctuations are removed by the phase detector. The operation of this type of radar, which may be called coherent MTI, depends upon a reference signal at the radar receiver that is coherent with the transmitter signal.

It is also possible to use the amplitude fluctuations to recognize the doppler component produced by a moving target. MTI radar which uses amplitude instead of phase fluctuations is called noncoherent.



Block diagram of a noncoherent MTI radar.

Fig 8.15

The noncoherent MTI radar does not require an internal coherent reference
signal or a phase detector as does the coherent form of MTI. Amplitude limiting cannot be employed in the non coherent MTI receiver, else the desired amplitude fluctuations would be lost. Therefore tile IF amplifier must be linear, or if a large dynamic range is required, it can be logarithmic. A logarithmic gain characteristic not only provides protection from saturation, but it also tends to make the clutter fluctuations at its output more uniform with variations in the clutter input amplitude.

The detector following the IF amplifier is a conventional amplitude detector. The phase detector is not used since phase information is of no interest to the non coherent radar. The local oscillator of the noncoherent radar does not have to he as frequency-stable as in the coherent MTI. The transmitter must be sufficiently stable over the pulse duration to prevent beats between overlapping ground clutter, but this is not as severe a requirement as in the case of coherent radar. The output of the amplitude detector is followed by an MTI processor such as a delay-line canceller.

The advantage of the noncoherent MTI is its simplicity; hence it is attractive for those applications where space and weight are limited. Its chief limitation is that the target must be in the presence of relatively large clutter signals if moving-target detection is to take place.

Clutter echoes may not always be present over the range at which detection is desired. The clutter serves the same function as does the reference signal in the coherent MTI. If clutter were not present, the desired targets would not be detected. It is possible, however, to provide a switch to disconnect the non coherent MTI operation and revert to normal radar whenever sufficient clutter echoes are not present. If the radar is stationary, a map of the clutter might be stored in a digital memory and used to determine when to switch in or out the non coherent **MTI .**

8.12 PULSE DOPPLER RADAR

A pulse radar that extracts the doppler frequency shift for the purpose of detecting moving targets in the presence of clutter is either an MTI radar or a ***pulse doppler radar.*** The distinction between them is based on the fact that in a sampled measurement system like a pulse radar, ambiguities can arise in both the doppler frequency (relative velocity) and the range (time delay) measurements. Range ambiguities are avoided with a ***low*** sampling rate (low pulse repetition frequency), and doppler frequency ambiguities are avoided with a high sampling rate. However, in most radar applications the sampling rate, or pulse repetition frequency, cannot be selected to avoid both types of measurement ambiguities.

Therefore a compromise must be made arid the nature of the compromise generally determines whether the radar is called an MTI or a pulse doppler. MTI usually refers to a radar in which the pulse repetition frequency is chosen low enough to avoid ambiguities in range (no multiple-time-around echoes). but with the consequence that the frequency measurement is ambiguous and results in blind speeds.

RECOMMENDED QUESTIONS ON UNIT- 8

1. Distinguish between MTI and pulse dopplar radar
2. With a neat block diagram explain the operation of CW radar.
3. With neat block diagram explain the operation of MTI radar.
4. What is blind speed? Obtain the expression for blind speed .
5. With a neat block diagram explain the operation of digital MTI processor
6. With a neat block diagram explain the operation of MTD processor
7. With a neat block diagram explain the operation of pulse Doppler radar.