... and Pulse Doppler Radar (3) 1

...red ...: Any unwanted radar echo is called clutter Such e...oes Can 'Clutter' the radar output and thus mak... difficult to detect the desired targets. examples. ...f clutter include the reflections from land, sea ...rain, birds insects and craft.

-> clutter can also be due to clean-air turbulance and other atmospheric effects as well as due to ionized media like the aurora and meteor, trails.

-> Un wanted echoes might also be obtained from 'point' or fixed targets as poles, towers and Similar objects.

-> echoes from land or Sea are called surface clutter while those from rain or other atmospheric phenomena are called volume clutter.

-> The pulsed radar System shows echoes from any reflecting object in the signal Path. These stationary objects may be buildings, towers, hills, geographic features. The echoes Created due to these objects are unwanted. These Stationary objects are called as clutter. and Can affect the radar performance.

-> The echoes of the clutter do not change on successive sweeps of radar antenna. It is very difficult to trace echoes when a target is Moving Constantly e.g in airport landing System or in vehicle direction system.

-> Because of the ...

is affected in two ways.

1. The clutter provides many reflections which slow down the radar signal processing capability.

2. If the reflections due to clutter are larger compared to reflection of moving targets, this smaller echo due to moving target may not be distinguished.

→ The radars were required to detect targets in the presence of noise.

→ In the real world, radars have to deal with more than received noise when detecting targets since they can also receive echoes from the natural environment such as land, sea and weather. These echoes are called clutter since they can "clutter" the radar display.

→ clutter echoes can be many orders of magnitude larger than aircraft echoes.

→ when an aircraft echo and a clutter echo appear in the same radar resolution cell, the aircraft might not be detectable.

→ clutter echoes can be greater than the desired target echoes by as much as 60 or 70 dB more depending on the type of the radar and the environment.

→ 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 target from undesired stationary objects.

→ Although there are applications of pulse radar where a determination of targets 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 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 Indicator) or pulse doppler radar. The two are based on the same physical principle but in practice, there are generally recognizable differences between them.

The MTI radar, for instance, usually operates with ambi-guous doppler measurement (so called blind speed) but with unambiguous range measurement (no second time around echoes).

→ The opposite is generally the case for pulse doppler radar. Its pulse repetition frequency is usually high enough to operate with a unambiguous doppler (no blind speeds) but at the expense of range ambiguities.

→ An MTI radar has a low Prf and a low duty cycle.

→ A pulse doppler radar, on the other hand, has a high Prf

→ A moving target indicator (MTI) uses the doppler effect to minimize the clutter effects to locate the target that is moving. The relative phase of echo signals received from a moving target continuously change with respect to the phase of the transmitted pulse when there is a continuous change in the distance of the target. The MTI senses the target movement by comparing the phase shift of the received signal with respect to the transmitted signal.

→ MTI radar uses the doppler effect to detect the moving target

→ MTI radar eliminates the clutter signals and reduces the effect of noise.

→ Delay-line cancellers are used in MTI radar to remove the effect of ~~noise~~: blind speeds.

MTI radar: A pulse radar which utilizes the doppler frequency shift for discriminating moving targets from fixed ones, appearing as clutter, is known as moving target indication (MTI) radar.

→ It usually operates with ambiguous doppler measurement but with unambiguous range measurement.

→ The opposite is generally the case for a pulse doppler radar which also discriminates moving targets from clutter by doppler frequency shift measurements.

→ The design of an MTI radar is much more challenging than a simple pulse radar or a CW radar.

→ MTI is a necessity in high quality air-surveillance in the doppler domain.

→ It determines target velocity and distinguishes moving targets from stationary targets.

Principle of operation:

→ MTI radar employs the doppler effect in its operation.

→ It eliminates clutter due to stationary objects and identifies moving targets.

→ In above fig. STALO means stable local oscillator and Coho means Coherent oscillator.

→ Coho provides refrence Signal, which has the phase of transmitter Signal.

→ The block diagram Consists of transmitter and recei-ver sections. The STALO, mixer1, modulator, microwave Signal amplifier, and duplexer are parts of transmitter

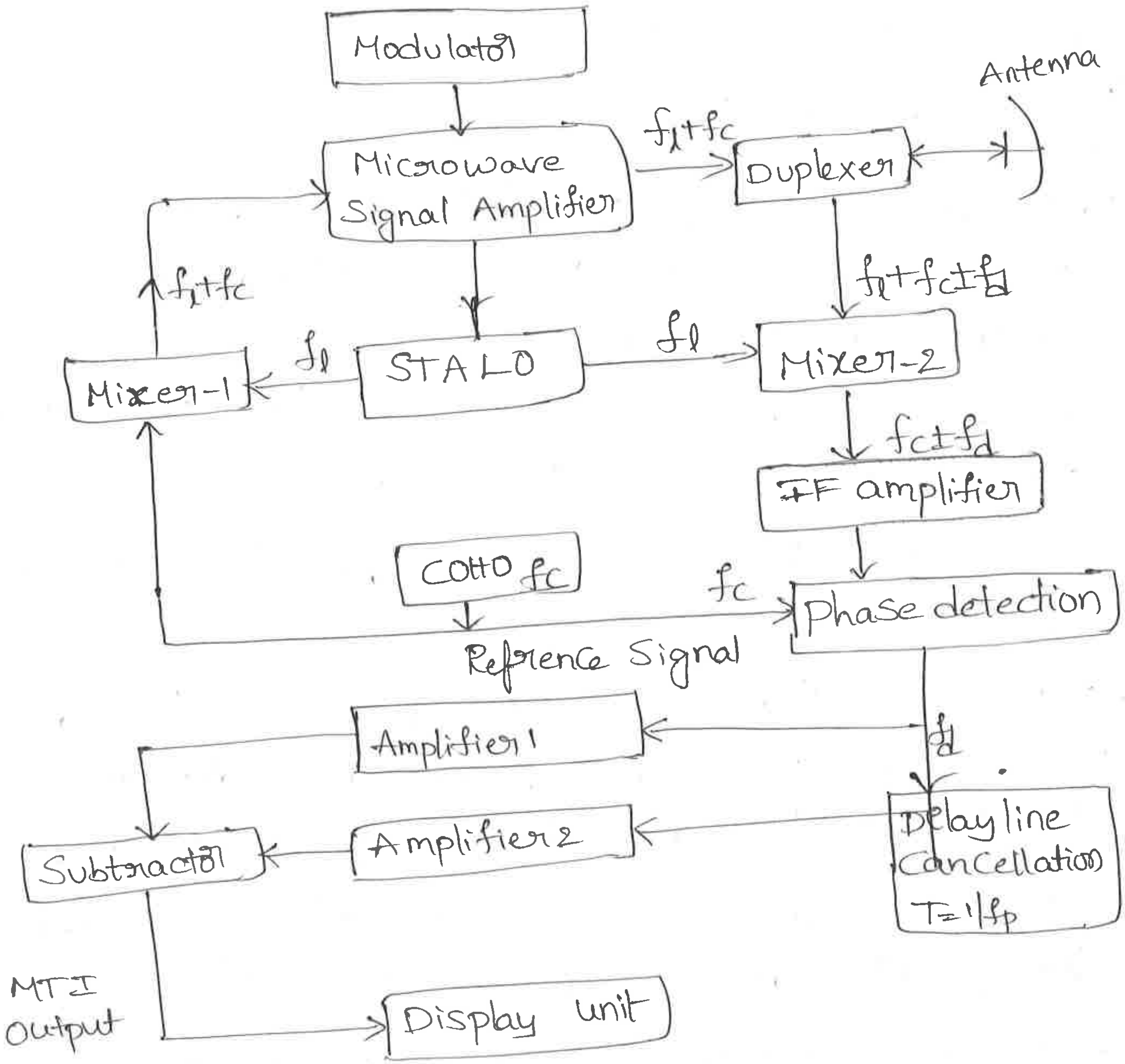
→ The duplexer, mixer2, STALO, IF amplifier2, Subtractor and display units are parts of the MTI radar.

→ MTI radar operates by Comparing a set of received echoes with those of received in the preceding Sweep. The echoes of Constant pulse are Cancelled out. This applicable to the Stationary objects. The echoes of changing phase due to moving targets are not Cancelled. The clutter due to stationary objects is removed to identify the moving objects in the display easily.

→ The input to mixer1 is from two oscillators namely STALO and Coho.

→ The

MTI Radar block diagram and principle of operation:



→ MTI radar means Moving Target Indicator radar. This is one form of pulsed radar.

→ MTI radar is characterised by its very low Prf and hence there is no range ambiguity in MTI radar.

The unambiguous range is given by

$$R_{un} = \frac{v_o}{f_p}$$

Where f_o = pulse repetition frequency

V_o = velocity of EM wave in free-space.

→ Mixer 1 and 2 use the same local oscillator, STALO and they are Identical.

→ The input to Mixer2 is $f_t + f_c \pm f_d$. This signal $f_c \pm f_d$ is given to the IF amplifier.

→ The o/p of IF amplifier is given to the phase detector whose o/p is f_d. This output goes to the delay line Canceller and also to amplifier1.

→ The o/p of the delay line Canceller is given to the ~~phase detector whose~~ amplifier2.

→ The outputs from amplifier1 and amplifier2 are given to the Subtractor. Its o/p goes to the display unit.

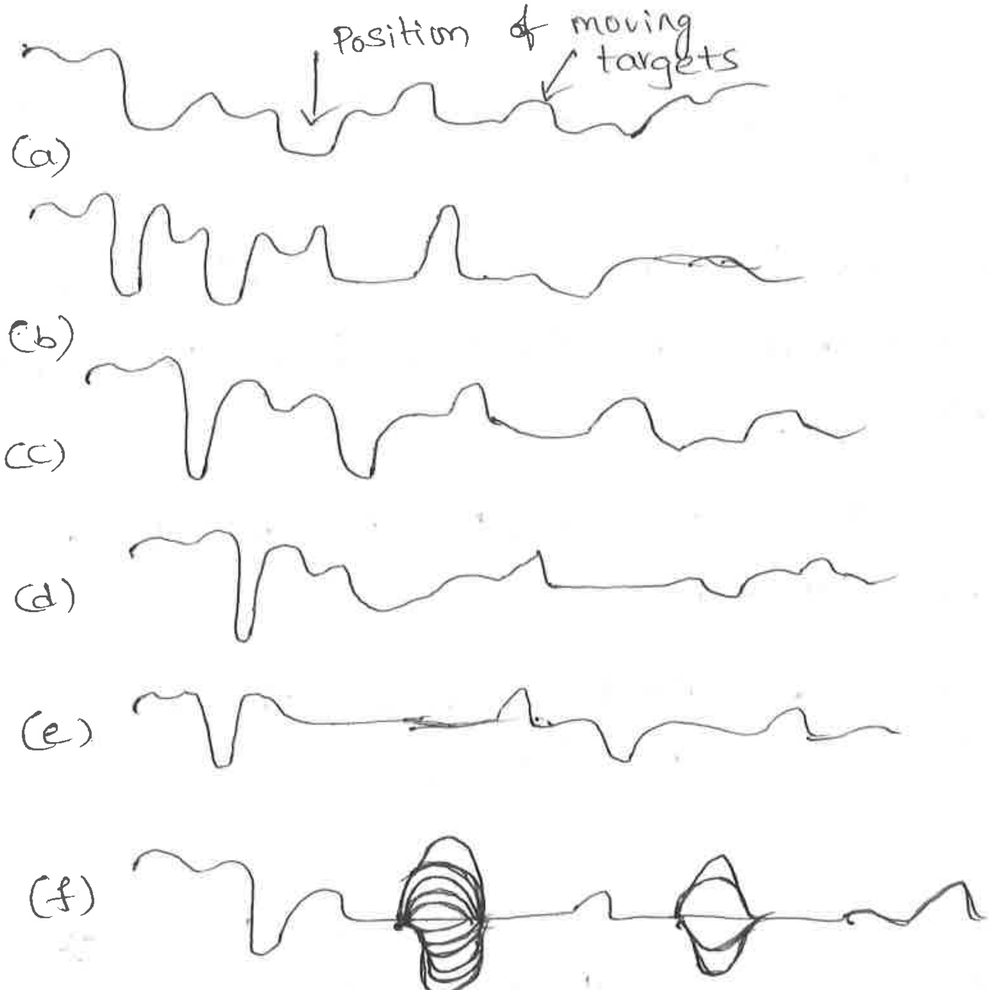
→ The delay line Canceller is a time domain filter. It rejects stationary clutter at zero frequency. Its frequency response function is derived from the signals in time domain.

Advantages of MTI radar:

The important advantages of MTI radar system are as under

1. It eliminates the clutter Signals.
2. It Can detect the echoes of much smaller moving targets Compared to clutter. Therfore moving targets that are much smaller than the stationary ones Can be observed.
3. It reduces the effect of noise.
4. For a given power the useful range is increased.

Butterfly effect :



fig② (a-e) Successive sweeps of an MTI radar A-scope display (echo amplitude as a function of time);
(f). Super position of many sweeps, arrows indicate position of moving targets.

→ Moving targets may be distinguished from stationary targets by observing the video output on an A-scope display By looks like a point target and moving target as extended target for different pulse repetition intervals A-scope display is shown in 2 as a, b, c, d and e.

→ At the rate of doppler frequency, echoes from moving targets vary in amplitude from sweep to sweep. Echoes from fixed targets remains constant. The

-> The principle of MTI radar is similar to the pulse doppler radar but the main difference is the way of generation of refrence signal.

-> In MTI radar, the refrence Signal is generated by a Stable oscillator which is Called Coho i.e Coherent oscillator

-> The Coho is a stable. Oscillator whose frequency is Same as the intermediate frequency used in the receiver.

-> In addition to providing the refrence Signal the output of the coho fc is also mixed with the local oscillator frequency fl. The local oscillator must also be 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.

-> The stalo, coho and the mixer in which they are combined plus any two-level amplification are called the receiver-exicter.

-> The Main function of stalo is to provide the necessary frequency translation from the IF to the transmitted (RF) frequency.

-> As the stalo acts as local oscillator is the receiver the stalo phase shift is Canceled.

-> Finally, the coho refrence signal and IF echo Signal are fed to a phase detector, whose o/p is Proportional to the phase difference between the input Signals.

which looks like "butterfly" shape. Therefore it is called as butterfly effect of MTI radar.

→ The moving target produce, with time, a "butterfly" effect on the A-scope.

Advantages of butterfly effect:

1. Butterfly effect helps to recognize a particular moving target from a multiple moving targets.
2. Amplitude versus range output on an A-scope helps in distinguishing the moving targets from stationary targets.

MTI radar with Power-amplifier transmitter

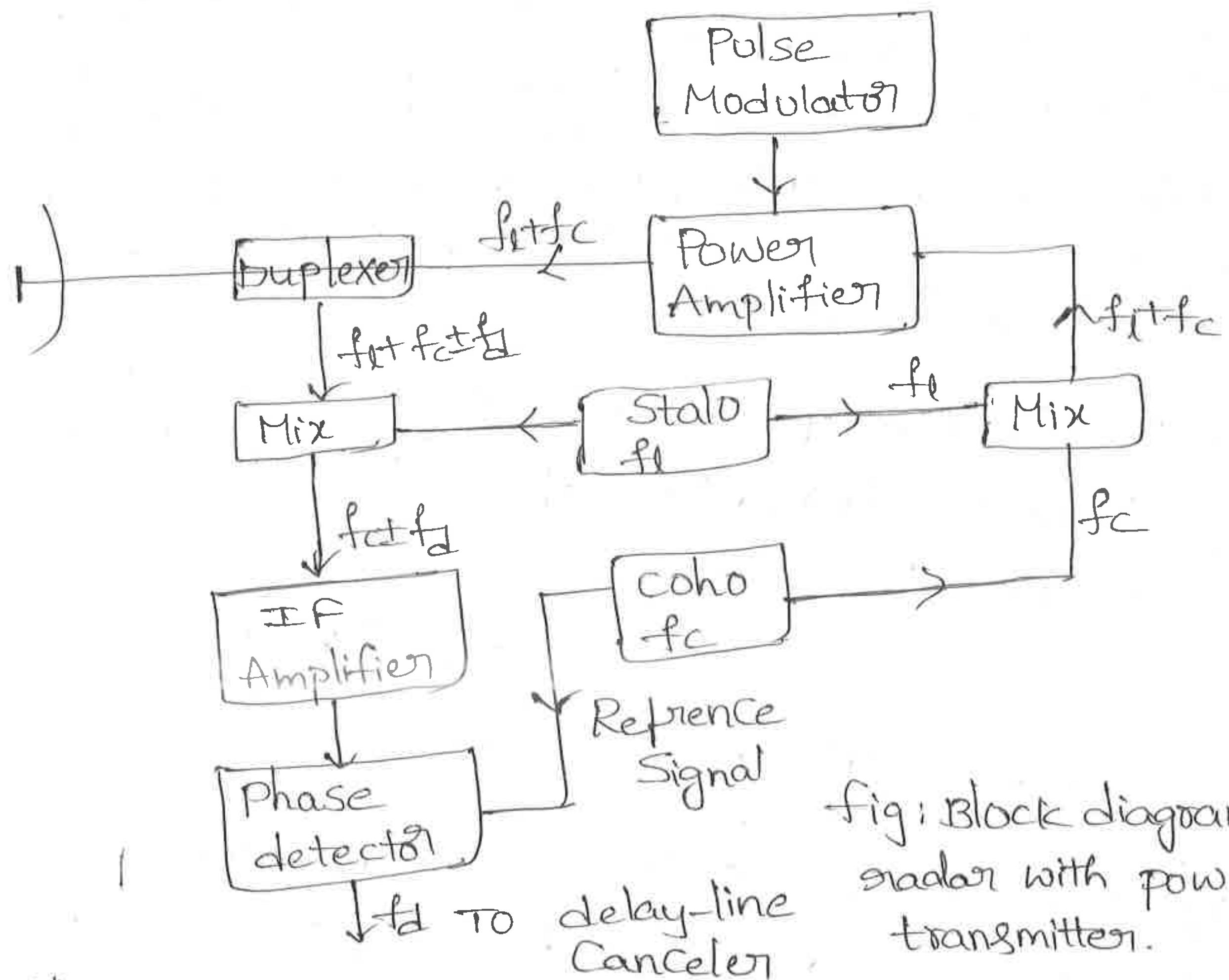


fig: Block diagram of MTI radar with power amplifier transmitter.

→ The radar which uses the concept of doppler frequency shift for distinguishing desired moving target from undesired stationary objects i.e clutter is called as moving target

MTI Radar with Power-oscillator transmitter :

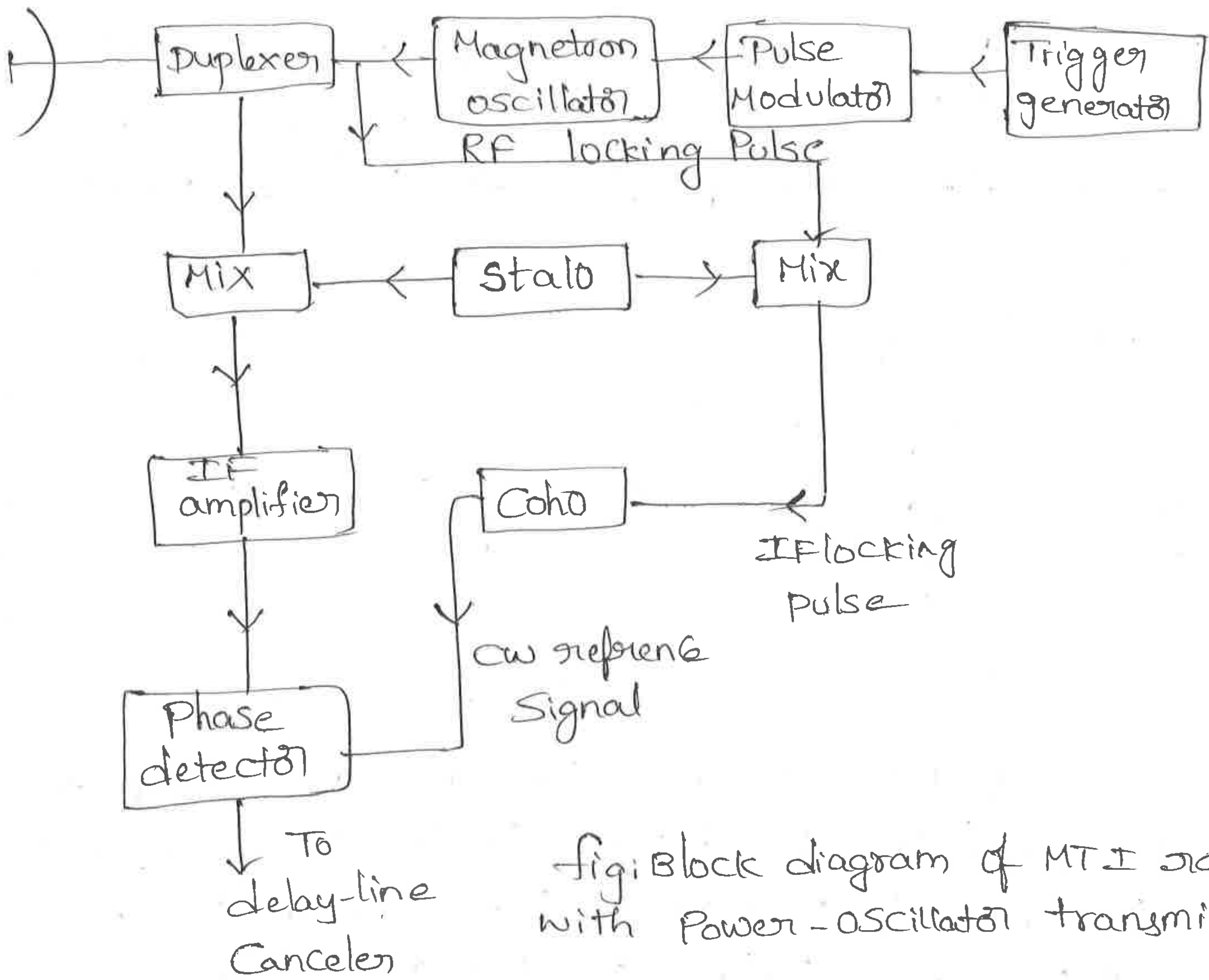


fig: Block diagram of MTI radar with Power-oscillator transmitter.

→ A block diagram of an MTI radar with a power oscillator is shown in above fig.

→ 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 refrence pulse.

→ The phase of the coho is then related to the phase of the transmitted pulse and may be used as the

Particular transmitted pulse.

-> Upon the next transmission another IF locking pulse is generated to relock the phase of the cw Coho untill the next locking pulse comes along. The type of MTI radar illustrated in above fig. has had wide application.

Delay line Cancelers:

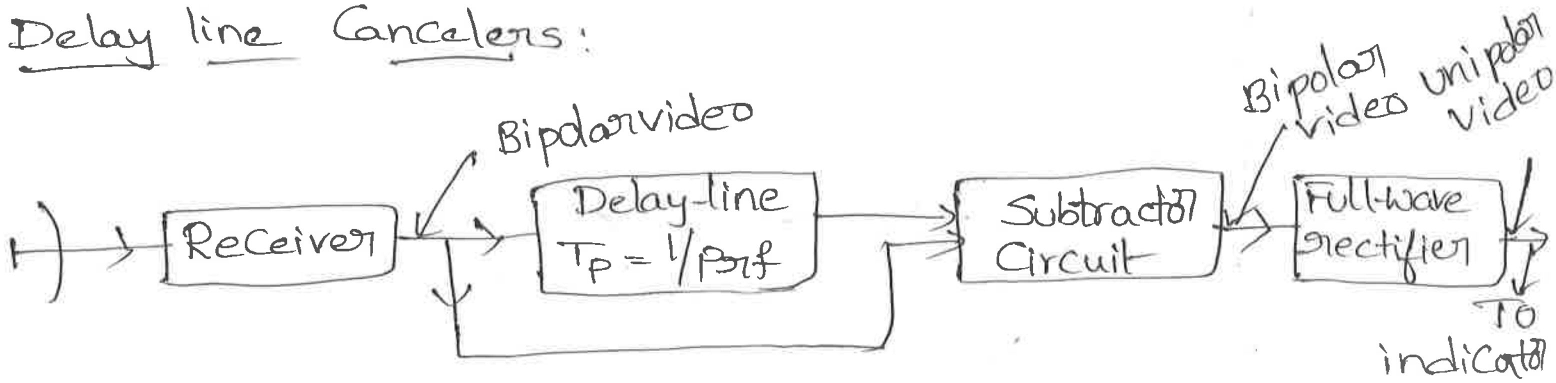


fig: MTI receiver with delay-line Canceler.

-> In case of MTI radars, Sometimes phase shift effect 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 Canceler shown in fig above.

-> The delay line canceler is a time domain filter. It rejects Stationary clutter at zero frequency. Its frequency respo-nse function is derived from the Signals in time domain.

-> The delay line Canceler 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 equal to one pulse repetition period.

-> 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 pulse and subtraction results in an uncanceled 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.

Filter characteristics of the delay-line canceler:

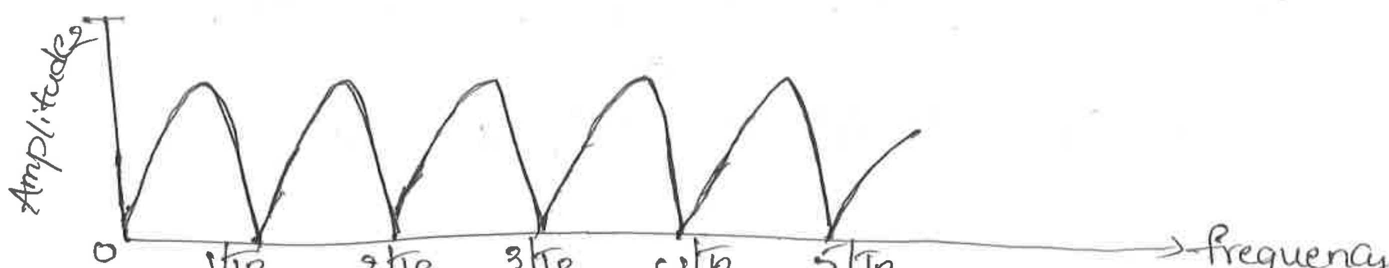


fig: frequency response of the single delay line canceler

-> The simple delay-line canceler is an example of time domain filter. The capability of this device depends on the quality of medium used as delay line.

-> The delay line canceler acts as a filter which rejects the dc component of clutter (unwanted target)

-> Because of its periodic nature, the filter also rejects energy in the vicinity of the pulse repeti-

→ The video signal received from a particular target at range R_0 is

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

where ϕ_0 = phase shift

k = amplitude of video signal

→ The signal which is delayed by a time T_p = pulse repetition interval is

$$V_2 = k\sin(2\pi f_d (t - T_p) - \phi_0)$$

→ The output from the subtractor circuit is

$$V = V_1 - V_2$$

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

$$V = k\left[\sin(2\pi f_d t - \phi_0) - \sin(2\pi f_d (t - T_p) - \phi_0)\right]$$

$$\sin C - \sin D = 2\cos\frac{(C+D)}{2} \cdot \sin\frac{(C-D)}{2}$$

$$V = k\, 2\cos\frac{[2\pi f_d t - \phi_0 + 2\pi f_d (t - T_p) - \phi_0]}{2} \times \sin\frac{[2\pi f_d t - \phi_0 - 2\pi f_d (t - T_p) + \phi_0]}{2}$$

$$= 2k\cos\frac{(2\pi f_d t - \phi_0 + 2\pi f_d t - 2\pi f_d T_p - \phi_0)}{2} \times \sin\frac{(2\pi f_d t - 2\pi f_d t + 2\pi f_d T_p)}{2}$$

$$= 2k\cos\frac{(4\pi f_d t - 2\phi_0 - 2\pi f_d T_p)}{2}\sin\frac{(2\pi f_d T_p)}{2}$$

$$= 2k\cos(2\pi f_d t - \phi_0 - \pi f_d T)\sin(\pi f_d T_p)$$

$$V = 2k\sin(\pi f_d T_p)\cos\left[\left(2\pi f_d \left(t - \frac{T_p}{2}\right) - \phi_0\right]\right. \longrightarrow (1)$$

→ It is assumed that the gain through the delay line canceler is unity. The output from the canceler. Consists of cosine wave at the doppler frequency f_d with an amplitude $2K\sin\pi f_d T_p$.

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 is shown in above fig.

→ The frequency response of delay line canceler is the ratio of the amplitude of the output from the delay line canceler to the amplitude of the normal radar video

→ When two delay line cancelers are used in cascaded form then it is called double delay line canceler.

→ Double delay line canceler is used when single delay line does not detect the target properly.

Blind Speeds:

Def: Blind speed is defined as the radial velocity (or relative velocity) of the target at which the MTI response is zero.

Def: It is also defined as the radial velocity of the target which results in a phase difference of exactly 2π radians between successive pulses.

Def: Blind speed is defined as the radial velocity of the target at which no shift appears making the target appearing stationary and echoes from the target were cancelled.

→ The response of the single delay-line canceler will be zero whenever the $\pi f_d T_0$ is the ai - factor of eq①

M, 0, π, 2π, 3π . . . etc.

$$\pi f_d T_p = n\pi$$

$$f_d T_p = n$$

$$f_d = \frac{n}{T_p} = n f_p$$

where $n = 0, 1, 2 \ldots\ldots$ and f_p = Pulse repetition frequency

→ The delay-line canceler not only eliminates the d.c component caused by clutter ($n=0$), but it also rejects any moving target whose doppler frequency happens to be the same as the pulse repetition frequency which causes the effect of blind speed and is given by

Blind speed of the target is given by

$$V_n = \frac{n\lambda}{2T_p} = f_p \cdot \frac{n\lambda}{2} \quad , n = 1, 2, 3$$

where V_n is the n^{th} blind speed

f_p = pulse repetition frequency (Hz)

n = Any integer $= 1, 2, 3$

λ = wavelength (m)

T_p = pulse repetition interval $= 1/f_p$ or $1/\text{Prf}$

→ If λ is measured in meters, f_p in Hz and the relative velocity is in knots, the blind speeds are given by

$$V_n = \frac{n\lambda f_p}{1.02} \simeq n\lambda f_p$$

→ If λ is in meters f_p in Hz and radial velocity

→ The blind speeds are one of the limitations of pulse MTI radar which do not occur with CW radar. Usually only the first blind speed v_1 is considered since others are integer multiples of v_1.

Problem:

(1) For an MTI radar what are first three blind speeds at 2 GHz when the PRF is 1 KHz

Sol: $f = 2\,GHz$, $\lambda = \frac{c}{f} = \frac{3\times10^8}{2\times10^9} = 0.15\,m$

$$f_p = PRF = 1\,KHz$$

Blind speed are given by

$$v_n = f_p \frac{n\lambda}{2} \text{ (or) } PRF\left(\frac{n\lambda}{2}\right)$$

For first blind speed $n=1$

$$V_1 = 10^3 \frac{(1\times0.15)}{2} = 75\,m/s = 270\,km/hr$$

For second blind speed $n=2$

$$V_2 = 10^3\left(\frac{2\times0.15}{2}\right) = 150\,m/s = 540\,km/hr$$

For third blind speed, $n=3$

$$V_3 = 10^3\left(\frac{3\times0.15}{2}\right) = 225\,m/s = 810\,km/hr$$

(2) An MTI radar operates at a PRF of 1.5 KHz. Its operating wavelength is 3 cm. Determine lowest blind speed

Sol: $PRF = 1.5\,KHz$

$$\lambda = 3\,cm = 3\times10^{-2}\,m$$

$$V_n = Prf\left(\frac{n\lambda}{2}\right)$$

- $n=1$ gives the lowest blined speed

$$V_1 = 1.5\times10^3\left(\frac{1\times3\times10^{-2}}{2}\right) = 22.5\ m/s.$$

(3) What are the three lowest blind frequencies of the radar when it is operating at 10GHz with a PRF of 1KHz.

Sol: $PRF = 1KHz$

$f = 10GHz$

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{10\times10^9} = 0.03m$$

The blind frequencies are given by

$$f_n = n\times PRF$$

For $n = 1, 2, 3$

$$f_1 = 1\times1\times10^3 = 1KHz$$

$$f_2 = 2\times1\times10^3 = 2KHz$$

$$f_3 = 3\times1\times10^3 = 3KHz$$

∴ The lowest three blind frequencies are 1kHz, 2kHz, 3KHz.

(4) If an MTI radar operates at 10GHz with PRF of 0.8KHz, then find the three lowest blind speeds.

Sol: $f = 10GHz$, $\lambda = \frac{c}{f} = \frac{3\times10^8}{10\times10^9} = 0.03\ m$

$PRF = 0.8KHz$

The blind speed is given by

$$V_n = PRF\left(\frac{n\lambda}{2}\right)$$

The first lowest blind speed is given by $(n=1)$.

$$V_1 = 0.8\times10^3\left(\frac{1\times0.03}{2}\right) = 12\ m/s.$$

The second lowest blind speed is given by (n=2)

$$V_2 = 0.8\times10^3\left(\frac{2\times0.03}{2}\right) = 24\ m/s$$

The third lowest blind speed is given by (n=3)

$$V_3 = 0.8\times10^3\left(\frac{3\times0.03}{2}\right) = 48\ m/s.$$

Limitation of MTI radar:

The blind speeds can be a serious limitation in MTI radar since they cause some desired moving targets to be canceled along with the undesired clutter at zero frequency.

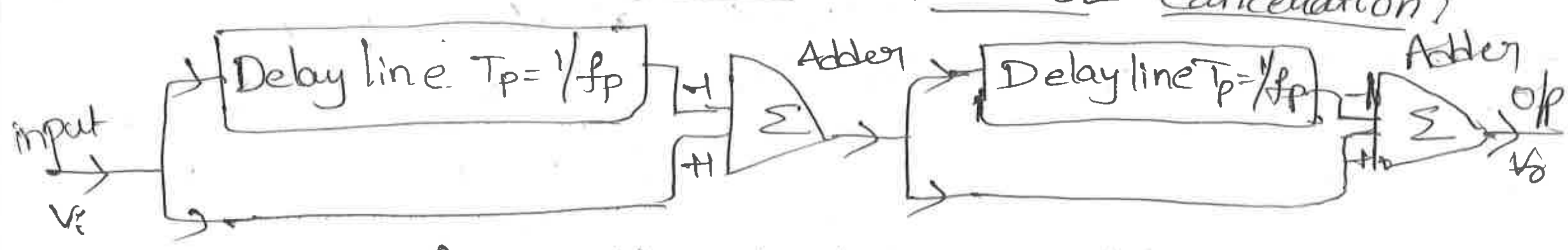
There are four methods to reduce the effect of blind speeds by operating the radar at

1. Long wavelengths (Low frequencies)
2. high pulse repetition frequency
3. more than one pulse repetition frequency and
4. More than one wavelength (or more than one RF frequency)

Notes: The presence of blind speeds with in the doppler frequency band reduces the detection capabilities of the of the radar

Notes: The effect of blind speeds can be reduced by operating with more than one pulse repetition frequency. This is called as staggered Prf MTI. operating at more than one PRF frequency can also reduce the effect of blind speeds.

Double Delay line Canceler (or) Double Cancellation:



Here, two single delay-line Cancelers are cascaded with the help of adders. The delay is given by $T_P = (T_P = 1/f_P)$ where f_P is the pulse repetion frequency and T is Pulse repetition period

The O/P of delay line canceler is given by

$$V_i = V_i(t) - V_2(t+T_0) - V_2(t+T_0) + V_2(t+2T_0)$$

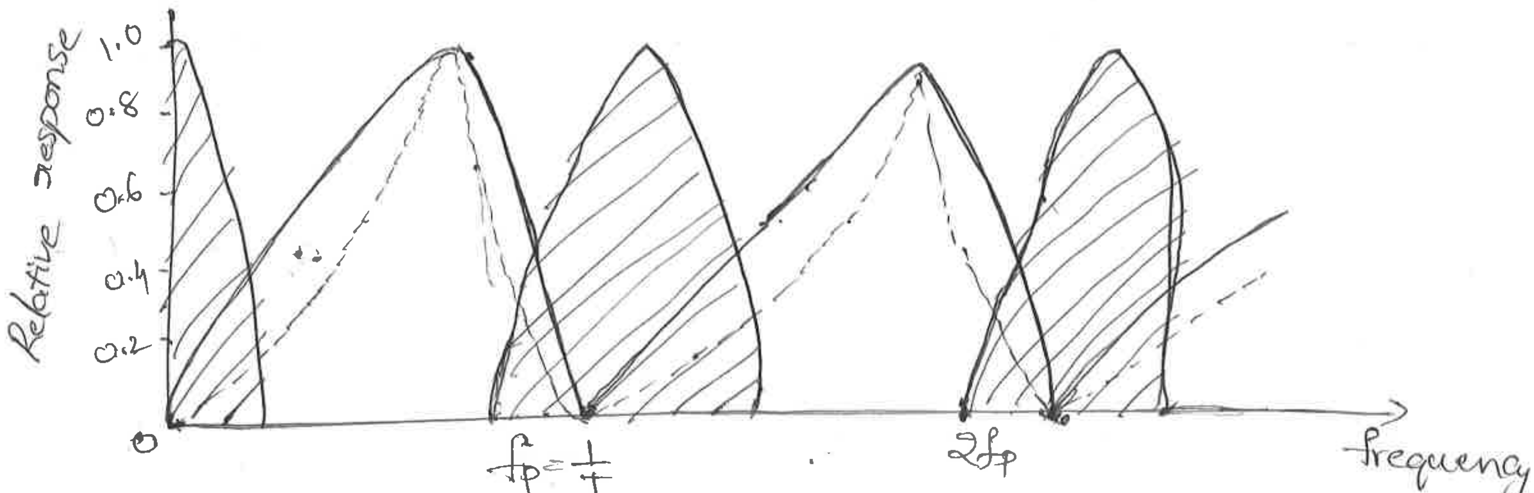


fig (2): Relative frequency response of the single delay-line canceler (solid curve) and the double delay-line Canceler (dashed curve). Shaded area represents the clutter Spectrum.

→ The frequency response of a single delay line Canceler does not always have as broad a clutter-rejection null as might be desired in the vicinity of d.c.

→ The clutter rejection matches may be widened by Passing the output of the delay line Canceler through a Second delay line Canceler as shown in fig(1).

→ The output of the two-single delay-line Cancelers cascade in the square of that from a single Canceler. Thus the frequency response is $4\sin^2 \pi f_d T_0$

→ The Configuration of fig(i) is called a "double-delay line" Canceler (or) simply a double Canceler.

→ The relative response of the double Canceler Compared with that of a single delay-line Canceler is shown in fig (2).

→ The finite width of the clutter spectrum is also shown in this figure so as to illustrate the additional Cancellation of clutter offered by the double Canceler

Multiple or Staggered PRFs :

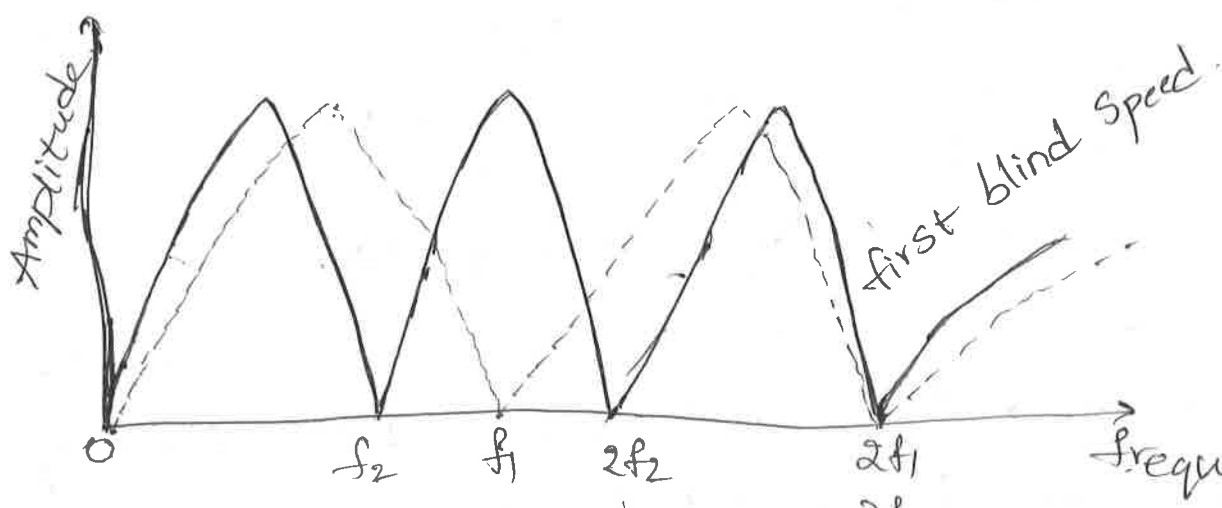


fig : frequency response of a single delay-line Canceler with two different Prfs, f_1 (dash curve) and f_2 (solid curve)

→ The use of multiple wave-forms with different pulse repetition frequencies allows the detection of Moving targets that can be eliminated with a Constant Prf waveform if their radial velocities were at or in the vicinity of a blind speed.

→ A simple illustration is shown in above fig. which graphs the frequency response of a single delay line Canceler with two diffrent Prfs

→ At Prf, f_1 blind Speeds (nulls) occur when the doppler frequency is f_1 or $2f_1$ (other integer multiples are not shown).

→ with Prf $f_2 = 2f_1/3$, blind Speeds occur when the doppler frequency equals f_2, $2f_2$ or $3f_2$.

→ It Can be Seen in fig(1) that targets not detectable because of a blind Speed in the frequency response of one prf will be detectable with the other Prf.

→ A target is lost on both Prfs, however, when the blind Speeds occur Simultaneously, as when $2f_1 = 3f_2$.

→ The above illustrates the benifit of using more than One Prf to reduce the effects of blind Speeds, but it might be Cautioned that it is not usual to use Prfs with the relatively large ratio of 3/2.

→ There are Several methods for employing multiple Prfs to avoid losing target echoes due to blind Speeds. The Prfs Can be Changed ① scan to scan ② dwell to dwell ③ pulse to pulse usually Called staggered Prfs.

→ Staggered Prfs have been popular for air traffic Control radars.

→ An example of the lower intervals of a staggered Prf waveform is given in below fig(2). The four interval Sequence is then repeated.

fig(2): Staggered Pulse-train with four different Pulse Periods or intervals.

-> In pulse-to-pulse staggered Prfs, as in fig(2), the time between pulses is an interval or a period

-> Multiple staggered Prfs can be processed with a transversal filter.

-> The use of more than one pulse repetition frequency offers additional complexity in the design of MTI doppler filters.

-> The blind speeds of two independent radars operating at the same frequency will be different if their pulse repetition frequencies are different Therfore, if one radar were "blind" to moving targets, it would be unlikely that the other radar would be "blind" also. Instead of using two different radars the same result can be obtained with one radar which time-shares its Prf between two or more different values.

-> The pulse repetition frequency might be switched every other half beam width, or the period might be altered on every other pulse. when the switching is pulse-to-pulse it is known as staggered Prf.

Range Gated Doppler filters

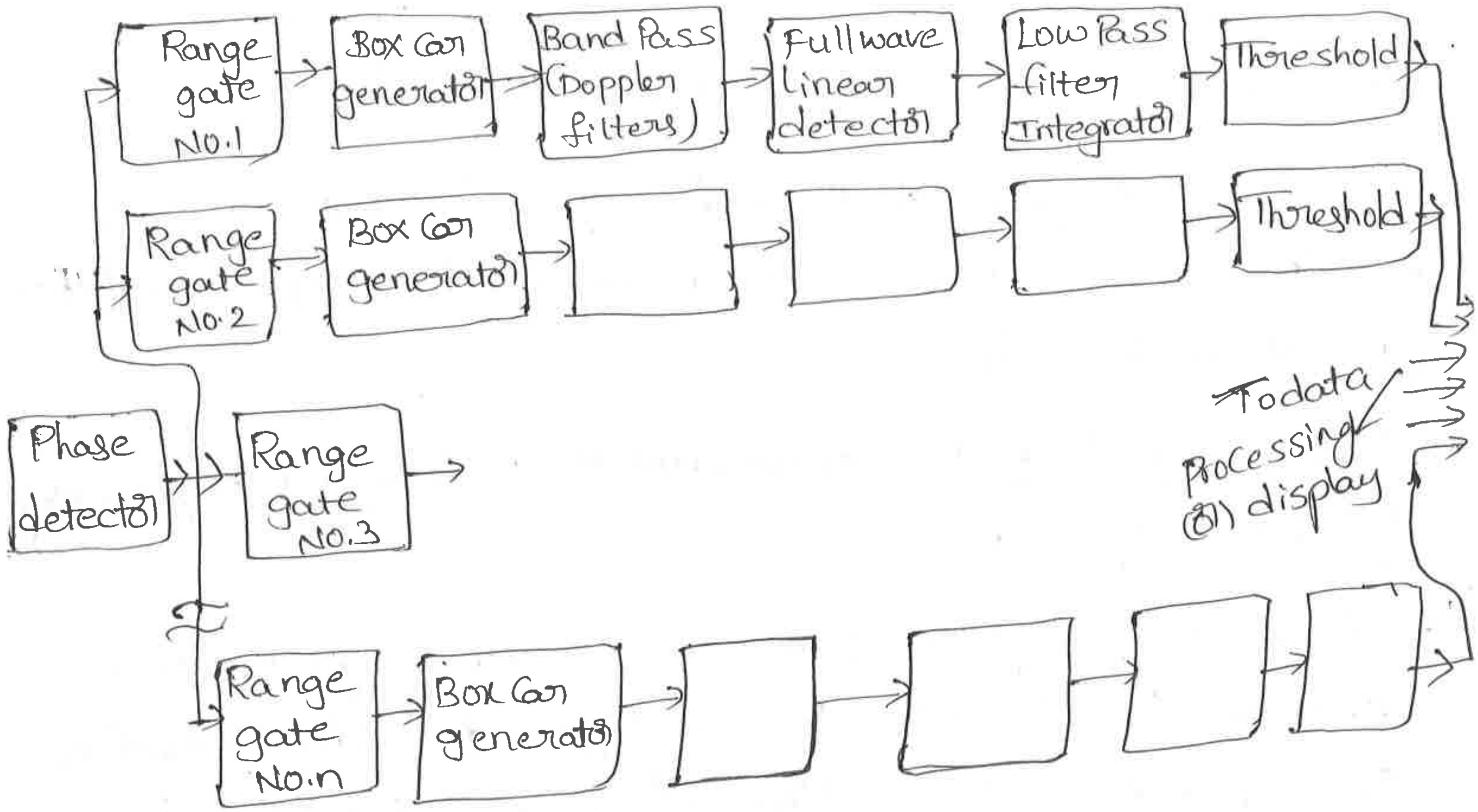
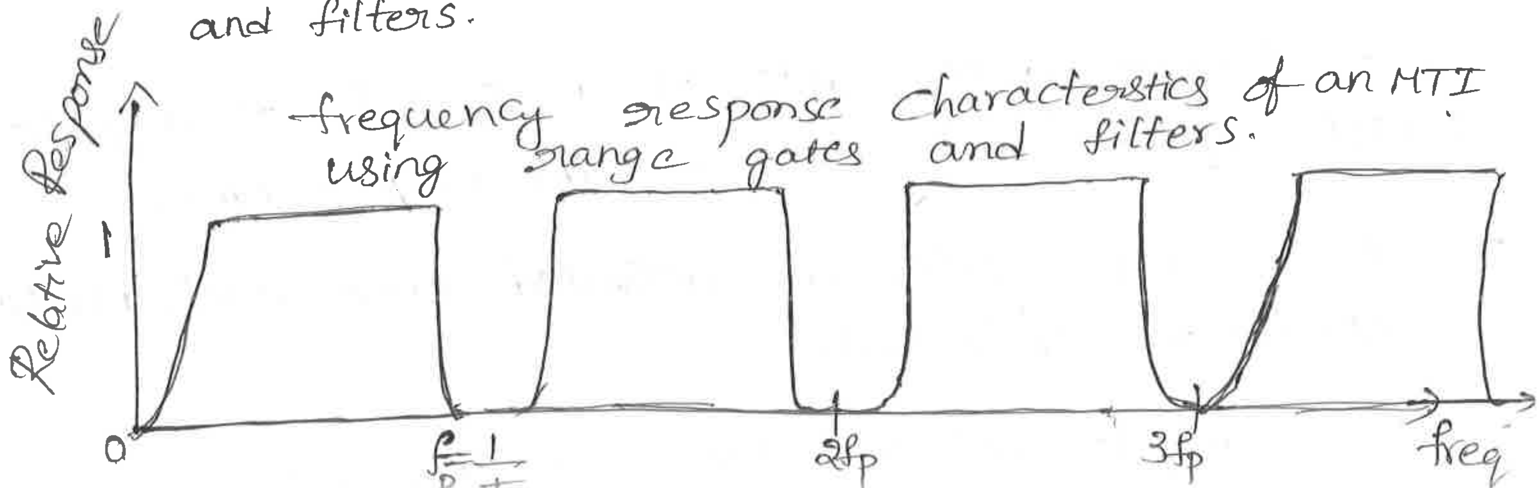


fig (1): Block diagram of MTI radar using range gates and filters.

frequency response Characteristics of an MTI using range gates and filters.



— Range gating: The loss of the range information and the Collapsing loss may be eliminated by first quantizing the range (time) into small intervals. This process is Called range gating.

-> The width of the range gates depends upon the range accuracy desired and the Complexity which Can be tolerated

-> Range resolution is established by gating.

-> A collapsing loss does not take place since noise from the other range intervals is excluded.

-> A block diagram of the video of an MTI radar with multiple range gates followed by clutter-rejection filters is shown in fig (1).

-> The output of the phase detector is sampled sequentially by the range gates.

-> Each range gate opens in sequence just long enough to sample the voltage of video waveform corresponding to a different range interval in space.

-> The range gate acts as a switch or a gate which opens and closes at the proper time.

-> The range gates are activated once each pulse repetition interval.

-> The output for a stationary target is a series of pulses of constant amplitude.

-> An echo from a moving target produces a series of pulses which vary in amplitude according to the doppler frequency.

-> The output of the range gates is stretched in a circuit called the boxcar generator and detection process by emphasizing the fundamental of the modulation frequency and eliminating harmonics of the pulse repetition frequency.

-> The clutter rejection filter is a bandpass filter whose bandwidth depends upon the extent of the expected clutter spectrum.

-> Following the doppler filter is a full wave linear detector and an integrator (a LPF)

-> The purpose of the detector is to convert the bipolar video to unipolar video.

-> The output of the integrator is applied to a threshold detection circuit.

-> Only those signals which cross the threshold are reported as targets.

-> Following the threshold detector the outputs from each of the range channels must be properly combined for display on the PPI or A-scope or for any other appropriate indicating or data-processing device.

-> The shape of the rejection band is determined primarily by the shape of the bandpass filter.

-> The frequency response characteristic of an MTI using range gates and filters is shown in fig (2)

Limitation to MTI Performance:

-> An improvement in the Signal-to-noise ratio of an MTI is affected by several factors other than the design of the doppler signal processor.

-> The performance of MTI radars degraded because of the following reasons.

1. equipment instabilities.
2. Internal fluctuation of clutter
3. Antenna Scanning modulation.
4. Limiting in MTI radar.

Equipment Instabilities: pulse-to-pulse changes in the amplitude, frequency or phase of the transmitter signal lower the improvement factor of an MTI radar.

-> If the Coho from stationary clutter on the first pulse is $A\cos\omega t$ and from the second pulse $A\cos(\omega t+\Delta\phi)$. Then the difference between the two is

$$A\cos\omega t - A\cos(\omega t+\Delta\phi) = A - 2\sin\left(\frac{\omega t+\omega t+\Delta\phi}{2}\right)\sin\left(\frac{\omega t-\omega t-\Delta\phi}{2}\right)$$

$$= (A)-2\sin\left(\frac{2\omega t+\Delta\phi}{2}\right)\sin\left(\frac{-\Delta\phi}{2}\right)$$

Notes:

$$\sin C-\sin D = -2\sin\frac{(C+D)}{2}.\sin\frac{(C-D)}{2}$$

$$= 2A\sin\left(\omega t+\frac{\Delta\phi}{2}\right)\sin\left(\frac{\Delta\phi}{2}\right)$$

→ For small phase errors the amplitude of the resultant difference

$$2A \sin\left(\frac{\Delta\phi}{2}\right) \approx 2A \frac{\Delta\phi}{2} = A\Delta\phi$$

→ So, the limitation on the improvement factor due to oscillator instability is $I =$

→ This would apply to the Coho locking or to the phase change which is introduced by a power amplifier.

Internal fluctuation of clutter: There are many types of clutter which are not absolutely stationary like that due to buildings, water, towers hills, mountaines etc. echoes from these limit the performance of MTI radar.

→ Most of the fluctuating clutter targets situated within the resoluation cell of the radar.

→ Experimentally measured power spectra of clutter signals may be approximately written as.

$$W(f) = |g(f)|^2 = |g_0|^2 \exp\left[-a\left(\frac{f}{f_0}\right)^2\right]$$

where $W(f)$ = clutter power spectrum as a function of frequency

$g(f)$ = fourier transform of the input waveform

f_0 = radar carrier frequency

a = Parameter which depends on the clutter

→ The expression for improvement factor for an N-Pulse canceler with $N_i = N-1$ delay lines can be written as

$$I_{NC} = \frac{2^{N_i}}{\ldots}\left(\frac{f_p}{\ldots}\right)^{2N_i}$$

Antenna Scanning Modulation:

→ As the antenna Scans by a target, it observes the target for a finite time to

where $t_0 = \frac{n_B}{f_p} = \frac{\theta_B}{\theta_s}$

Here -

n_B = number of hits received

f_p = pulse repitition frequency

θ_B = antenna beam width

θ_s = antenna Scanning rate.

→ The received pulse train of duration to has a frequency Spectrum whose width is propotional to $1/t_0$

→ Therfore, 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.

→ when the clutter Spectrum is too wide, it affects the improvement factor. This limitation is also called Scanning modulation or Scanning fluctuations.

→ The limitation to the improvement factor caused by antenna Scanning are.

$$I_{1S} = \frac{n_B^2}{1.388}$$

$$I_{2S} = \frac{n_B^4}{3.853}$$

Limiting in MTI radar: Before the MTI processor, a limiter is generally employed in the IF amplifier for preventing the residue from large clutter echoes. An ideal MTI radar should reduce the clutter to a level comparable to receiver noise.

-> If the limit level relative to noise is set higher than the improvement factor clutter residue obscures part of the display, while if it is set too low there may be a "black hole" effect on the display.

-> The limiter provides a Constant false alarm rate and thus it serves a very essential part to obtain usable MTI Performance.

-> The use of the limiter eliminates the amplitude information of the IF output holding it Constant to the limiting level and, therefore, such an MTI radar may be called a phase processing MTI, since only the phase information is retained after limiting.

<u>MTI radar versus pulse doppler radar:</u>

MTI radar	Pulse doppler radar
1. In this, range ambiguities are avoided with low Pulse repetition frequencies	1. In this doppler frequency ambiguities are avoided with high pulse repetition frequencies.
2. It has blind speed effect	2. There is no chance of blind Speed effect.
3. MTI radar has unambiguous range	3. pulse doppler radar has ambiguous range
4. MTI radars use Magnetron Clutter	4. They use range gate doppler filters for Separating the Moving targets from
5. These are more widely used in radar applications.	
6. It operates at low duty	

7. They use delay-line Cancelers for separating the Moving targets from Stationary Clutter.	5. pulse doppler radars are klystron oscillators 6. These are rarely used in radar applications 7. It operates at high duty Cycle.