Prediction of Range Performance of the Basic Pulsed Radar System

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Abstract - *This paper deals with the minimum detection change versus most signal to noise quantitative relation (SNR) for many decisions parameters like (peak power p.c, measuring system cross section (RCS), antenna gain, coherently pulses, and duty cycle) by using MATLAB simulation program, these programs are developed to create them straight forward for any user of evaluating the measuring system change and SNR equations and make them faster and a lot of convenient.*

when enter the input these parameters and the programs can calculate the detection change and SNR of a measuring system system and think about the result as graphically.

***Key Words*: pulsed radar,PAM,SNR,PRF,matched filter, Antenna.**

1.INTRODUCTION

Modern measuring system systems should give larger detection varys each against high and low altitude targets attributable to the many advances in weapon speed and range. Extended vary indicates that the facility transmitted by the measuring system should be hyperbolic. It follows, that ground come becomes a tangle even at high altitudes. Radar is for Radio Detection and move.It uses electromagnetic waves. The target's location is measured in angle, from the direction of most amplitude echo signal, the antenna points to. to measure change and the placement of moving objects, Doppler effect is used.

The RADAR system generally consists of a transmitter that produces associate degree magnetic attraction signal that is radiated into house by an antenna. once this signal strikes any object, it gets mirrored or re-radiated in several directions. This mirrored or echo signal is received by the radar antenna that delivers it to the receiver, wherever it's processed to figure out the geographical statistics of the object. The range is decided by the calculating the time taken by the signal to travel from the RADAR to the target and back.Radar systems are extremely important these days, given their applicability in target detection, Radar is a detection system that uses radio waves to figure out the range, angle and the speed of objects. It is used to detect the aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain.As long as the radar uses the same antenna for transmission and reception. The continuous wave radar has the ability to differentiate between fixed and moving targets but does not retain the time form of the information and also the continuous wave radar has practical difficulties which limit the usefulness of this system in airborne applications.

1.1 Pulsed Radar

Pulsed RADAR System sends high power signal and high frequency pulses towards the target object. It then waits for the echo signal from the object before another pulse is send. The range and decision of the RADAR depends on the pulse repetition frequency. It uses the Doppler shift method.

The principle of RADAR detecting moving objects using the Doppler shift works on the fact that echo signals from stationary objects are within the same phase and hence get canceled while echo signals from the moving object will have some changes in phase.

1.2 Types of Pulsed RADAR -

Basic Pulse RADAR :

The Radar, that operates with pulse signal for detecting stationary targets, is named as the Basic Pulse Radar or simply, Pulse Radar.It uses single Antenna for each transmittal and receiving signals with the assistance of Duplexer. Antenna can transmit a pulse signal at each clock pulse.

The duration between the two clock pulses should be chosen in such a way that the echo signal equivalent to the present clock pulse should be received before the next clock pulse.

Moving Target Indicator RADAR :

Moving target indication (MTI) is a mode of operation of a radar to discriminate a target against the muddle. Early MTI system typically used an acoustic delay line to store a single pulse of the received signal for precisely the time between broadcasts (the pulse repetition frequency).

PROCEDURE for the calculation of the range performance of a pulse radar is presented below. It takes into consideration variety of things that have an effect on the range perfomance of a radar that are frequently overlooked, and as a result has been found to give results that are very consistent with actual tests, even when applied to radars having completely different characteristics. Because of this, it is notably useful for the calculation of the relative performance of two radars or the calculation of the percentage change in range corresponding to a given change in radar parameters. Such calculations are rather much more important than the calculation of the absolute range of a radar, which at the best may be a rather indefinite number.

To present the procedure, the terms appearing in the "Radar Equation" are discussed below in detail one at a time.

The Radar Equation can be written as:

$$R^4F^2(10^{0.2\alpha R}) = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 (KT)(1.2/\tau)(NF)(S)}$$

R= Range, in meters, of which the radar is capable.

F= Propagation factor, to take into account the effect of interference of reflections from the ground surface. In effect, G/F is the resultant gain of the antenna system, including the image antenna below the ground, in the given direction.

a = Attenuation constant of the medium, in db/meter. Pt= Peak transmitter power of a pulse radar, in watts. X =Wavelength, in meters. = Cross section of equivalent isotropically re radiating target, in square meters.

KT= Boltzmann's constant X absolute temperature, =4X 10-21 watts/(cycles per second).

r = Pulse duration in seconds. 1.2/r is a frequency bandwidth in cycles per second equal to 1.2 times the reciprocal of the pulse duration r.

NF=Noise figure of the receiver.

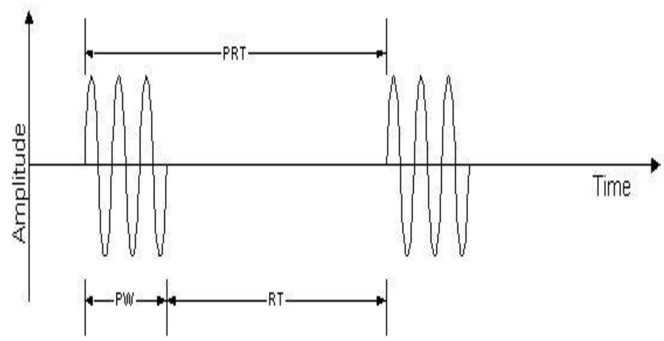
S= Integration factor; a factor to account for the effects of integration, introduction of extra noise samples, required probability of detection, etc. It is the ratio of signal power, required for detection, to noise power in the bandwidth 1.2/T. The noise power in the bandwidth 1.2/T is given by the product of terms (KT) (1.2/r) (NF). (S is sometimes quite inappropriately called Scan Loss, implying that if the antenna were not scanning, a signal precisely equal to noise could be detected).

G=Antenna gain, relative to an isotropic radiator, in the direction of the target.

Radar is a composition for Radio Detection and Ranging. The term "radio" refers to the use of electromagnetic waves with wavelengths within the questionable radio wave portion of the spectrum, which covers a wide range from 10^4 km to 1cm. Radar systems generally use wavelengths on the order of 10 cm, corresponding to frequencies of about 3 GHz. The detection and ranging part of the composition is adept by timing the delay between transmission of a pulse of radio energy and its subsequent return. If the time delay is Dt, then the range may be determined by the simple formula:

R=cDt/2
where c = 3 x 10^8 m/s, the speed of light at which all electromagnetic waves propagate.
The factor of two in the formula comes from the observation that the radar pulse must travel to the target and back before detection, or double the range.

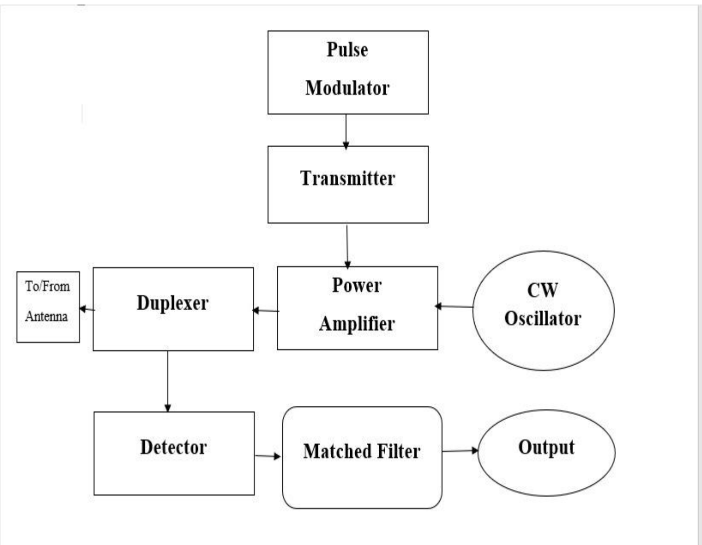
A radar pulse train is a type of amplitude modulation of the radar frequency carrier wave, similar to how carrier waves are modulated in communication systems.
In this case, the information signal or message signal is quite simple: a single pulse repeated at regular intervals.The common radar carrier modulation is known as the pulse train .



PULSE TRAIN

2. METHODOLOGY

Radar Block Diagram :



Parts :

Pulse Modulator : This produces a pulse modulated signal and it is applied to the Transmitter.

Transmitter : This can be a power amplifier like a Klystron, Travelling Wave Tube. The signal is first generated by using a waveform generator and then send it to the power amplifier.

Power Amplifier : A power amplifier is an electronic amplifier that is designed to increase or boost the magnitude of power of a given input signal.The power of the input signal is increased to a level high enough for requirement.

Antenna : The antenna used can be a parabolic reflector, planar arrays or electronically steered phased arrays.

Duplexer : A duplexer that allows the antenna to be used as a transmitter or a receiver.

Receiver : It can be a super heterodyne receiver or any other receiver that consists of a processor to process the signal and detect it.

Threshold Decision : The output of the receiver is compared with the threshold to detect the presence of any object. If the output is below any threshold, then the presence of noise is assumed.

3. PREDICTION OF RANGE PERFORMANCE

All of the parameters of the basic pulsed radar system will affect the performance in some factors :

In that some of the basic factors are -

1. Transmitter power
2. Pulse width
3. Pulse repetition frequency(PRF) and range ambiguities
4. Radar operating frequency.

Transmitter power :

In radar, the power that is transmitted from the antenna into the space. For a pulsed radar, the peak power transmitted is usually much higher than the average power transmitted by that.

The ratio of the average power to the peak power equals the duty cycle, which is the product of the pulse duration and the PRF.

Duty cycle = (PA / PP) .

where , PA = Average Power

PP = Peak Power .

Pulse Width :

The pulse width should be long enough to make sure that the radar emits sufficient energy so that the reflected pulse is detectable by its receiver. Pulse width also constrains the range discrimination, that is the capacity of the radar to differentiate between two targets that are close together.

- Minimum Range or Shortest Range of target detected by radar is given by

  Rmin = (c*width)/2.

  PW = 1 / Bheta .

Pulse repetition frequency(PRF) :

PRF is that the rate at which transmitter pulses are sent into space or air. The pulse repetition frequency is that the variety of pulses of a continuation signal in a specific time unit, normally measured in pulses per second.

PRF = 1/Tp .

where , Tp = Repetition time period.

Radar Operating Frequency :

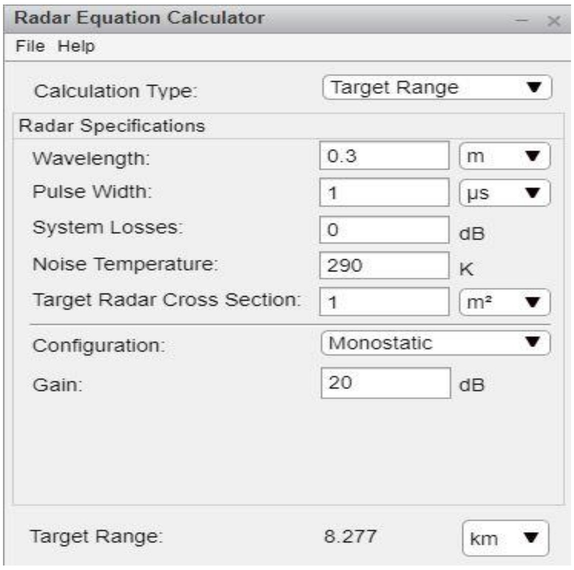
- For low frequency , the radar beam will behave much like visible light and travel in a straight line.
- At High frequency , the radar beam will suffer high losses and are not suitable for the long range systems.

PRF	Velocity ambiguity	Range ambiguity
Low (2 KHZ)	50 m/s	75 km
Medium (12KHZ)	300 m/s	12.5 km
High (200 KHZ)	5000 m/s	750 m

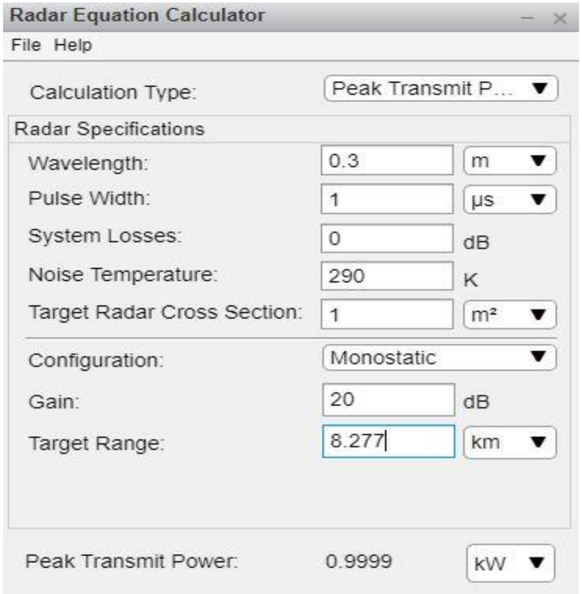
4. SIMULATION RESULTS

Here , we've got used MATLAB software to get/calculate prediction of range performance of the basic pulsed radar system.

Target Range :



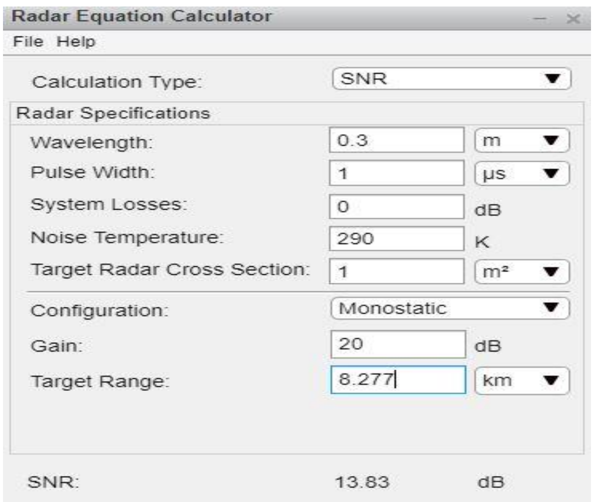
Peak power Transmitter :



Receiver Output SNR :

$$\frac{Pr}{N} = \frac{(Pt\tau GtGr(\lambda\text{^}2)\sigma)}{((4\pi\text{^}3)kTs(Rt\text{^}2)(Rr\text{^}2)L)}$$

SNR :



ROC CURVES OUTPUTS :

ROC curves are typically used to assess the performance of a radar or sonar detector. ROC curves are plots of the probability of detection (Pd) vs. the probability of false alarm (Pfa) for a given signal-to-noise ratio (SNR).

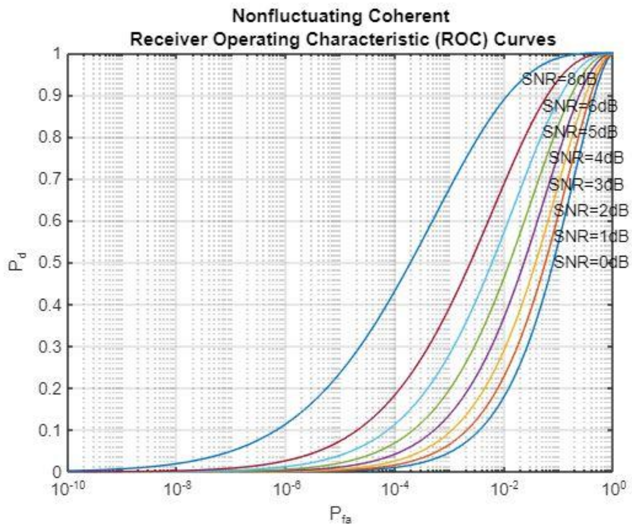
The probability of detection (Pd) is that the probability of saying that "1" is true on condition that the "1" occurred. The probability of false alarm (Pfa) is the probability of saying that "1" is true on condition that the "0" event occurred.

A detector's performance is measured by its ability to achieve a certain probability of detection and probability of false alarm for a given SNR.

Assuming we have an SNR value of 8 dB and our requirements dictate a Pfa value of at most 1%

Pfa = 0.01.

And we get , Pd = 0.8899.

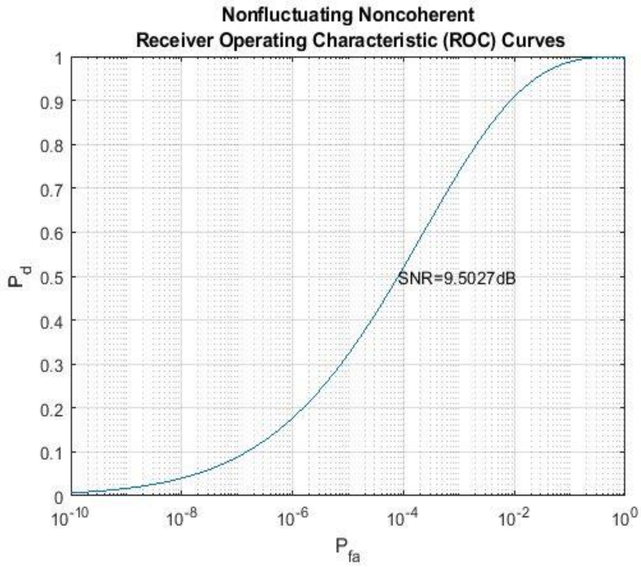


In the plot we can select the data cursor button in the toolbar (or in the Tools menu) and then select the SNR = 8 dB curve at the point where Pd = 0.9 to verify that Pfa is approximately 0.01.

we need a higher SNR to achieve the same Pd for a given Pfa. For noncoherent linear detectors, we can use the Albersheim's equation to determine what value of SNR will achieve our desired Pd and Pfa.

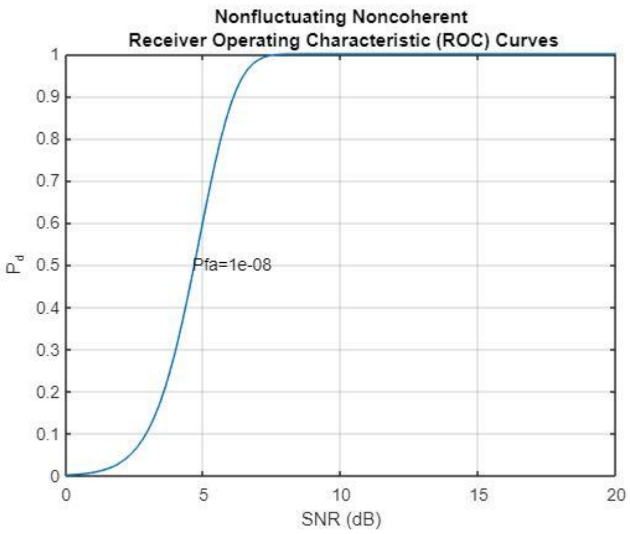
Plotting the ROC curve for the SNR value is approximated by the Albersheim's equation, we can see that the detector will achieve Pd = 0.9 and Pfa = 0.01. Note that the Albersheim's technique applies only to noncoherent detectors.

SNR_valdB = 9.5027

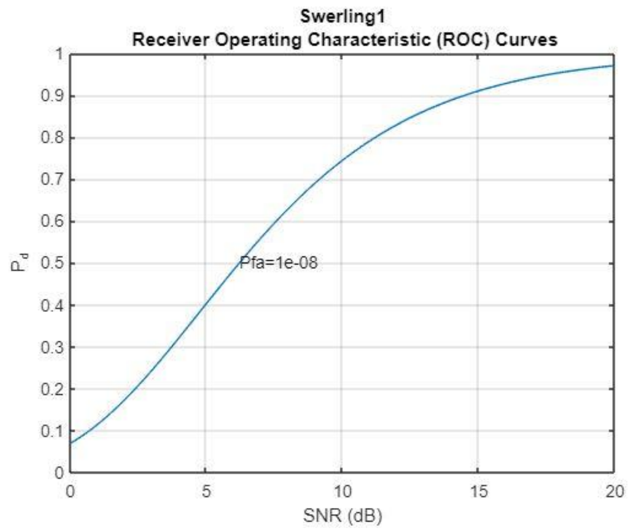


Detection of Fluctuating Targets

Let us assume that we are doing noncoherent detection with 10 integrated pulses, with the desired Pfa being at most 1e-8. We first plot the ROC curve for a nonfluctuating target.



We then plot the ROC curve for a Swerling 1 target for comparison.



After swerling1,the SNR value is 14.7131 .

Range Detection :

The most critical parameter of a transmitter is that the peak transmit power. The required peak power is related to several factors including the maximum explicit range, the required SNR at the receiver, and the pulse width of the waveform. Among these factors, the required SNR at the receiver is determined by the design goal of Pd and Pfa, as well as the detection scheme implemented at the receiver.

The relation between Pd, Pfa and SNR can be represented by a receiver operating characteristics (ROC) curve.

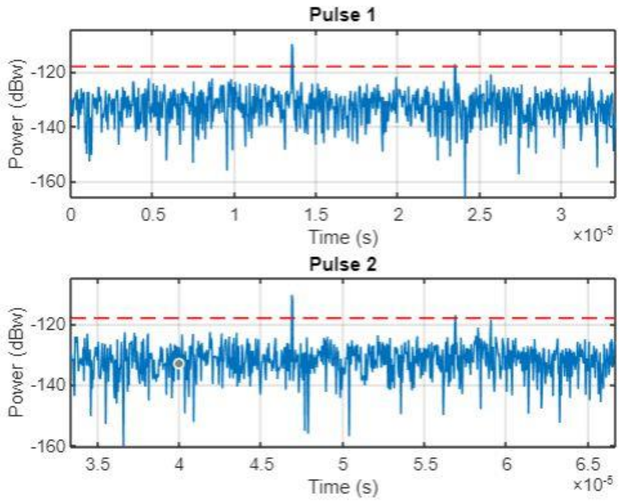
snr_min = 4.9904

Once we obtain the required SNR value at the receiver, the peak power at the transmitter can be calculated by using the radar equation. Here we assume that the transmitter has a gain of 20 dB.

peak_power = 2.0906e+04

The detector compares the signal power to a given threshold. In radar applications, the threshold is commonly chosen in order that the Pfa is below the certain level. In this case, we can assume that the noise is white Gaussian and also the detection is non coherent.

Matched filter stage

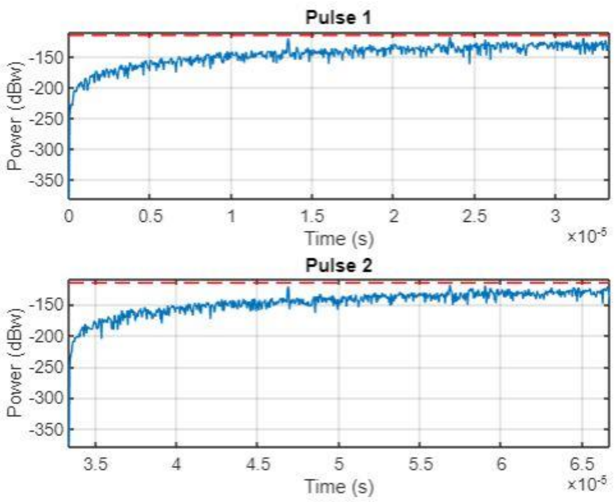


The matched filter offers a processing gain which improves the detection threshold. It involves the received signal with a local, time-reversed, and unite copy of the transmitted waveform. Therefore, we must specify the transmitted waveform when creating our matched filter. The received pulses are first passed through a matched filter to improve the SNR before doing pulse integration, threshold detection, etc.

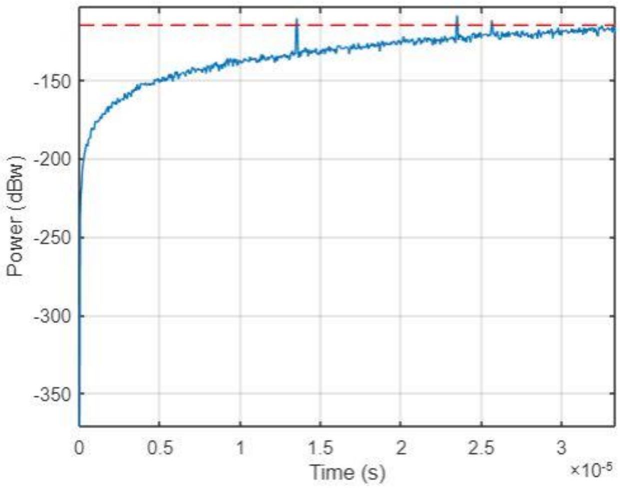
The matched filter introduces an intrinsic filter delay so that the locations of the peak (the maximum SNR output sample) are no longer coordinate with the true target locations. To compensate for this delay, in this example, we will move the output of the matched filter forward and pad the zeros at the end. Note that in real systems, as a result of the information or data is collected continuously, there is really no end of it.

The threshold is then increased by the matched filter processing gain.

After the matched filter stage, the SNR is improved. However,as a result of the received signal power is reliant on the range, the return of a close target is still much stronger than the return of a target longer away. Therefore, as the above figure shows, that the noise from a close range bin also has a important chance of surpassing the threshold and shadowing a target longer away. To ensure the threshold is fair to all the targets within the detectable range, we can use a time varying gain to compensate for the range dependent loss within the received echo.



We can further improve the SNR by noncoherently integrating (video integration) the received pulses.



For practical and theoritical values of SNR is having small difference.for theoritical, SNR value is 13.83dB. and for practical,the SNR value is 14.7131dB.

After the video integration stage,the data is ready for the final detection stage.

true_range = 2025 3519 3845

range_estimates = 2025 3519 3844

3. CONCLUSIONS

Basic Pulsed Radar system for prediction of range performance is designed and verified in MATLAB. By using matched filter stage we have improved the signal to noise ratio and we have used further Non-coherent Integration to improve SNR. and in this there is an small difference of SNR in theoretical and practical calculation. All the parameters of the basic pulsed radar system will affect the performance in some factors :

In that some of the basic factors are -

1.Transmitter power, 2. Pulse width, 3. Pulse repetition frequency (PRF) and range ambiguities, 4. ROF. Finally we have calculated all the parameters of the radar using MATLAB.

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BIOGRAPHIES

I have been working as a Associate Professor of Dept. Of Electronics and Communication in VelTech university, Chennai, Tamil Nadu , India.

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