

# UWB SRR System Performance in Weibull Clutter environment

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**Abstract.** The objective of this paper is to analyze the detection performance of non-coherent detectors such as square law detector, linear detector and logarithmic detector in weibull clutter environment for Ultra Wide Band Short Range Radar in Automotive applications. The detection performance of the detectors is analyzed and simulation has been done in order to verify it.

**Keywords:** UWB SRR, Coherent Integration, Non-coherent integration, Clutter.

## 1 Introduction

UWB Automotive Radar technology is a key enabling technology for innovative driver assistance systems and safety systems. Intelligent Transportation System uses UWB SRR system for driver's safety and convenience. Ultra wideband (UWB) offers many applications to vehicle such as pre-crash warning system, stop and go operation, spot assist and lane change assist. Clutter is generally distributed in spatial extent in that it is much larger in physical size than the radar resolution cell [1]. The ability to determine range by measuring the time for the radar signal to propagate to the target and back is probably the distinguishing and most important characteristic of radar. In order to suppress the clutter, a pulse integration and Constant False Alarm Rate (CFAR) has been employed. It is therefore important to investigate the more appropriate clutter model to resemble the clutters in automobile applications. In high resolution radars, the log normal and weibull clutters are proved to be better suited for clutter model in automobile applications. The road clutter resembles weibull distribution for 100 MHz bandwidth.

The frequency band of 21.625-26.625 GHz is allocated for the use of UWB short range radar in automotive applications [1]-[2]. Sea clutter measured by means of low-resolution radar on L and X-band has been studied and reported [3]. Recently, ground clutter data has been measured by Ka-band radar [4].

In this paper, we analyze the detection performance of non-coherent detectors such as square law detector, linear detector and logarithmic detector in weibull clutter

environment. The performance of non-coherent detector is analyzed in Weibull environment by using Monte Carlo simulation for automobile applications.

The organization of this paper is as follows. In Section II, the non-coherent detectors are described. In Section III, the simulation results are shown. Finally, conclusion is presented in section IV.

## 2 UWB SRR Detector

In this section, we present the non-coherent detector which consists of coherent integrator and non-coherent integrator. The coherent and non-coherent range gate memory size ( $K$ ) is less than the maximum range and indicates the total number of target range to be tested. These range gates are used as buffer to integrate the values coherently and non-coherently. Therefore, at every  $T_{pRi}$ , we use the samples as much as the range gate's memory size ( $K$ ).

The sampling frequency of ADC is same to the pulse width ( $T_v$ ). Thus each sampled values of the in-phase (I) and quadrature (Q) channel are shifted at every  $T_p$  during one  $T_{pRi}$ . At every  $T_{pRi}$ , we use the samples only as much as the range gate's memory size ( $K$ ). The coherent integrator integrates the sample values at each range gate during  $r \cdot c \cdot T_{pRi}$  (where  $N$ , is the number of coherent integration). If the round trip delay (T) from target is equal to the time position of the  $k$ -th range gate ( $k \cdot T_p$ ), then the target maximum range can be expressed as  $k \cdot T_p \cdot 2 = k \cdot AR$ . And then the range resolution is given by  $AR = c \cdot T_p / 2$ .

The transmitted signal can be written as follows

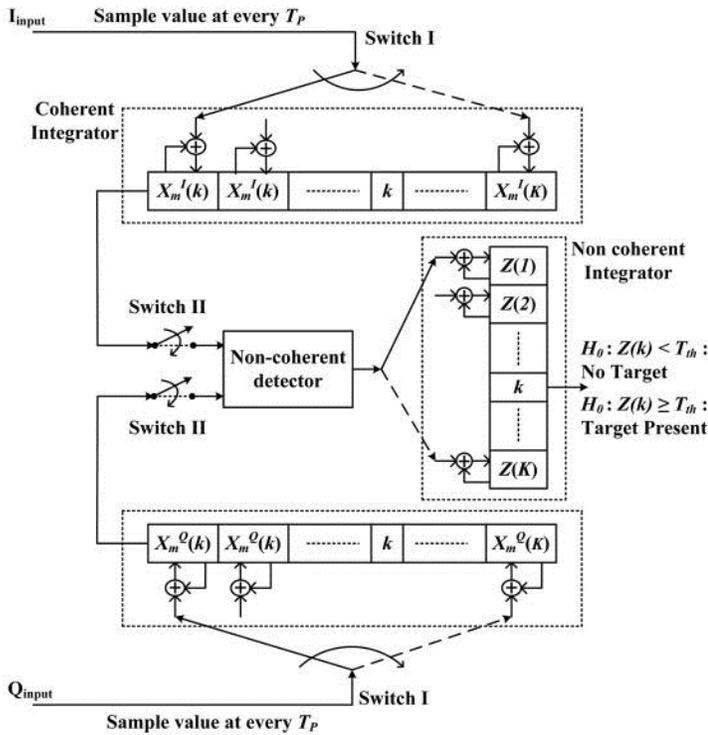
$$s(t) = A_T \cdot \sin(2\pi f_c t + \phi_0) \cdot M(t) \quad (1)$$

where  $M(t)$  is the Gaussian pulse train;  $A_T$  is the amplitude of single transmit pulse,  $\phi_0$  is the phase of the transmit signal,  $f_c$  is the carrier frequency [11].

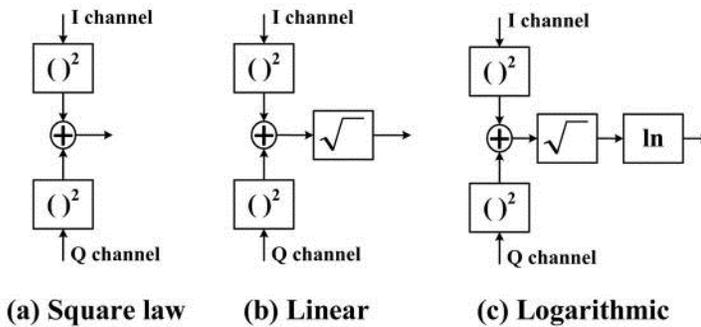
In this paper, we assume one reflected signal from single stationary target against a background of weibull clutter environment, and then the baseband complex received signal can be described as

$$r(t) = A_T E a \cdot e^{j(\omega t + \phi)} p(t - nT, \dots, -z) + C(t), \quad (2)$$

where the amplitude of the scatter  $a$ , the time delays of the scatters  $r$  and the arbitrary phase  $\phi - 2\pi f_c z + 0$  are all unknown. Also,  $c(t)$  is the reflected clutter signal from unwanted object. Doppler shift is denoted as  $\omega_d = \pm 4\pi v / \lambda = \pm 4\pi v / c \cdot f_c$  where the wavelength  $\lambda$  is  $c / f_c$  and  $c$  is the velocity of light. In the Doppler shift, the positive sign (+) indicates the closing target and the negative sign (-) means the receding target.



**Fig. 1 Block Diagram of receiver**



**Fig. 2 Non-coherent detector**

The output of the coherent integrator can be distinguished in to two hypotheses,

$$H_1 = \overline{X}_k(m) = \frac{A_r \alpha}{N_c} \sum_{n=mN_c}^{(m+1)N_c-1} e^{j(\omega_r t + \theta)} p(t - nT_{PRI} - \tau) + \overline{C}(n),$$

$$H_0 = \overline{X}_k(m) = \frac{1}{N_c} \sum_{n=mN_c}^{(m+1)N_c-1} \overline{C}(n),$$

where  $m$  indicates the  $m$ -th coherent integration and  $H_1$  is for  $T=k7p$  and  $H_0$  is for  $j^*k \cdot Tp$ . Also, the sampling rate of the ADC is equal to the pulse width. The baseband received signal is sampled at peak point of  $p(t)$ . Therefore, we get the coherently integrated values as  $(j(m), k=1, \dots, K)$ . The sample value received from the coherent integration is squared and operates at every  $Ar_c \cdot Tp_{Ri}$ . The squared range gate samples are combined and then both I and Q branch values are summed as shown in Fig. 2(a). The  $k$ -th range gate value after squaring can be represented as

$$Y_k(m) = \{X_f(m)\}^2 \cdot \{X_f(m)\}^2 \quad (5)$$

In the case of linear detector the squared range gate samples are combined and square root is applied to the combined values as shown in Fig. 2(b). The output of the linear detector can be represented as

$$y_k(n) = \sqrt{\{X_f(m)\}^2 \pm \{X_f(m)\}^2} \quad (6)$$

In the case of logarithmic detector the squared range gate samples are summed, square root and natural logarithmic is applied to the combined values as shown in Fig. 2(c). The output of the linear detector can be represented as

$$y_k(m) = \sqrt{\{X_f(m)\}^2 + \{X_f(m)\}^2} \quad (7)$$

The value  $Y_k(m)$  is stored in the  $k$ -th memory of the non-coherent integration at every  $N_c \cdot Tp_{Ri}$ . The output of the non-coherent integration  $Z(k)$  can be written as

$$Z(k) = \frac{1}{N} \sum_{m=1}^N Y_k(m) \quad (8)$$

If the above result is greater than the defined threshold, then we can determine that a target is present. And the index  $k$  represents the position of the target; the target range indicates  $k \cdot 30$  cm. It takes  $N_c \cdot N_{ne} \cdot T_{pRI}$  to decide the target range.

## 4 Simulation Results

The purpose of the simulation is to assess the detection performance of the non-coherent detectors in weibull clutter environment. The various optimized parameters used in the simulation are as follows; the coherent integration number ( $NJ$ ) and the non-coherent integration number ( $Ar_n$ ) [10]. The percentage of total energy reflected from the target is assumed to be 1. The signal-to-clutter ratio (SCR) is defined as  $E/C_o$ , where  $E$  represents the total average energy reflected from a target.

The weibull distribution can be expressed as follows

$$f(x) = \frac{a}{b} \left(\frac{x}{b}\right)^{a-1} e^{-\left(\frac{x}{b}\right)^a} \quad (9)$$

where  $b$  is the scale parameter ( $b > 0$ ),  $a$  is the shape parameter ( $a > 0$ ) and  $x$  is the random variable of the weibull distribution.

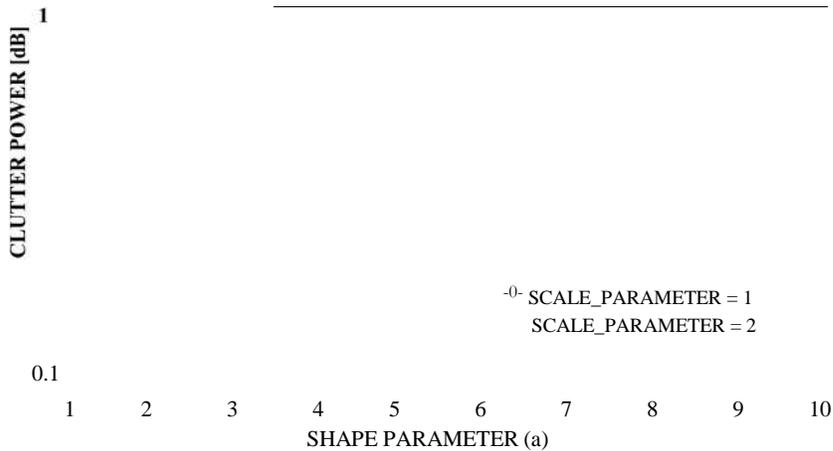


Fig. 3 Weibull Clutter power for various scale parameters.

The clutter power ( $C_0$ ) for weibull environment can be expressed as follows

$$C_0 = \frac{x_n^2 F(1 + (2/a))}{(n-2)} \quad (10)$$

where  $a$  is the shape parameter and indicates the degree of skewness,  $x_n$ , is the median of weibull distribution [8]. From Fig. 3, we can predict that the clutter power is approximately 1 dB for shape parameter greater than 3. Also, we know that the weibull scale and shape parameter for 24 GHz automobile short range radar is 1.6 and 6.9 for traffic road clutter [2]. Thus, we use the maximum scale and shape parameter value as 2 and 7 in the simulation.

Fig. 4 shows the detection probability versus weibull skewness parameter at  $PFA = 0.01$ . The simulation result shows that the probability of detection is approximately 1 for optimized non-coherent integration number of 8 [10]. Finally, we can predict that the probability of detection is almost 1 for skewness ( $a$ ) and scale parameter ( $b$ ) greater than 4 and 2. Also, the detection performance of non-coherent detectors is almost same for the optimized parameters in weibull clutter environment.

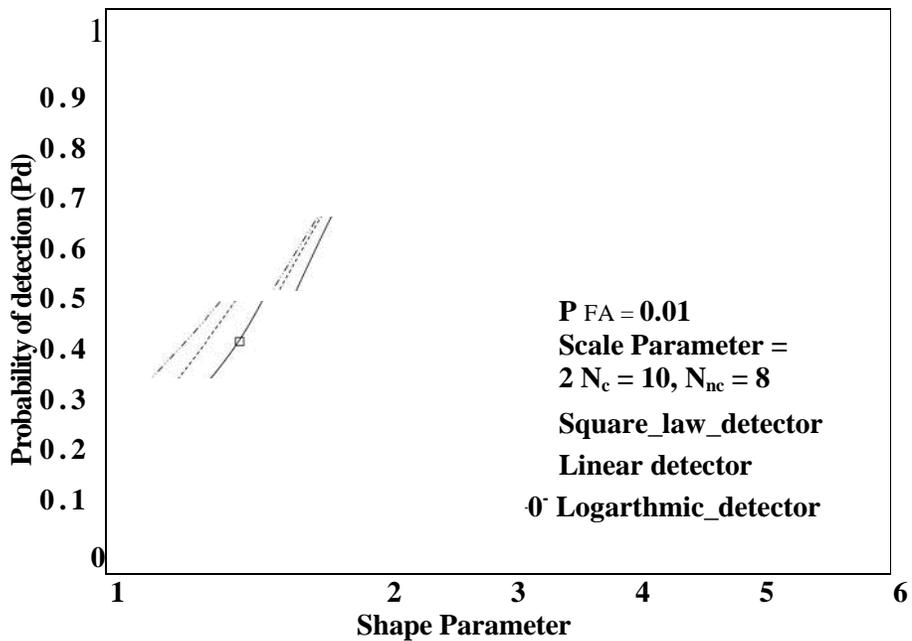


Fig. 4 Probability of detection Vs False alarm probability.

## 5 Conclusion

In this paper, we have analyzed the detection performance of non-coherent detectors for UWB-SRR in automotive applications. The detection probability is found to be same for all the non-coherent detectors such as square law detector, linear detector and logarithmic detector. Finally, in order to get the detection probability of more than 0.9 for  $P_{FA}=0.01$ , the coherent and non-coherent integration number of approximately 10 and 8 is required for non-coherent detectors in weibull clutter environment.

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