International Journal of Electronics and Telecommunication Systems
Volume 2, Issue 02 2026

Improving ROCs of Constant False Alarm Coded Anti-collision Radar in Very Noised Cases

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Research Article

Date of Submission: 20-01-2026 **Date of Acceptance: 23-02-2026** **Date of Publication: 19-04-2026**

***Abstract*—**In the automobile industry, the use of Constant False Alarm Coded Anti-Collision Radar (CFACAR) is very intriguing. This system is the most resilient to interference from many users because of the orthogonality qualities of the utilised codes. When the input Signal to Noise Ratio (SNR) is very low, the real version of the receiver, referred to in this study as the Single Correlation Receiver (SCR), is unable to identify the targets. We introduce the Averaging Correlation Receiver (ACR), a novel receiver that calculates the average of the M subsequent correlations, as a solution to this issue. The formulation of detection and false alarm probability for the novel receiver in mono and multi-user situations was then created. The new Receiver Operating Characteristics (ROCs) are shown using these probabilities. They are shown for various input SNR and ACR length M values. According to certain equations, there is an appropriate value of M that may be assumed to have a good detection (ROCs more perfect). Additionally, we discovered that we need to significantly increase the length M for a given SNR, but this is only feasible when the target's relative velocity is low. We may reduce the SNR value to SNR = −45 dB at a velocity of 5 km/h with M = 1055.

***Keywords*—Automobile radar, detection, ROC, anti-collision, false alert, and correlation receiver**

I. Introduction

Automobile safety systems may lower the amount of traffic accidents by using collision avoidance systems. When a collision is about to occur, these systems either alert the driver or act on their own without the driver's input. In recent years, a number of automakers have created systems based on radars or other sensors. Several methods are used for radar-based systems to determine the possible obstacle's distance and speed. The safety distance and collision progress may be guaranteed by using certain algorithms [1], [2], [3], [4]. The system's alerts need to put the least amount of strain on drivers' attention. A motorist may get desensitised to repeated warnings and disregard them in the future. In dire circumstances, infrequent warnings may cause the motorist to become distracted.

Because of this, it's crucial to think carefully about how and when to alert the driver.Because they can gather more target scattering data, bistatic and multistatic antenna systems are becoming more and more common for through-wall radar imaging.To directly compare the abilities of bistatic and multistatic systems over monostatic radar alone, both human and clutter target data were measured and used to create ROC curves [5], [6].

The authors of [7], [8] have realized the first Compres- sive Sensing (CS) adaptive radar detector. They have pro- posed three novel architectures and have demonstrated how a classical Constant False Alarm Rate (CFAR) detector can be combined with l1-norm minimization. Using asymptotic arguments and the Complex Approximate Message Passing (CAMP) algorithm they have characterized the statistics of the l1-norm reconstruction error and have derived closed form expressions for both the detection and false alarm probabilities.

Target detection is one of the important functions of radar systems. In [9], [10], the authors have presented a detection method using total correlation (TC) based on information theory for noise radar systems which enables the detection of multiple targets at intermediate and low signal-to-noise ratio (SNR) regimes. The proposed method utilizes the largest eigenvalue of the sample covariance matrix to extract infor- mation from the transmitted signal replica, and outperforms the conventional TC detector when reflected signals have intermediate or low SNR values.

Based on the combination of time domain averaging and correlation, [11] proposed an effective time domain averaging and correlation based spectrum sensing (TDA-C-SS) method used in very low SNR environments. With the assumption that the received signal samples from the primary users are deterministic, the proposed TDA-C-SS method processes the received samples by a time averaging operation to improve the SNR.

The ultra-wide-band (UWB) technique is used in [12], [13] to develop the random noise radar (such as our system) for through-wall surveillance applications. They also discussed the phenomena of interference level and radar cross section (RCS) of the human target using the ROCs. Moreover, the [14] has presented an application of UWB radar in robot localization and site recognition.

In [15], [16], they have presented a signal processing tech- nique for Frequency Modulated Continuous Wave (FMCW) radar sensors. They have used chirp sequence modulation which allows the observation of slow-moving obstacles with high resolution capability in range and velocity. Also in [17], an improved FMCW radar system is introduced by including a perfect binary

sequences pairs. This system uses auto- correlation functions to determine IF (intermediate- frequency) signal, and measures distance and velocity.

In our previous work [18], we have proposed the analytical expression of detection and false alarm probabilities and validated them by numerical simulations in different situations. Then, the ROCs performances of CFACAR (Constant False Alarm Coded Anti-collision Radar) system had been given and compared in term of used codes. We concluded that the Kasami codes of type 2 guarantee a good ROCs and many users can share the same channel like CDMA technique. But, the ROCs are bad for $SNR <= 15\,dB$. To improve them in this very noisy case, we propose a new scheme version of the receiver.

This paper is organized as follows: In section II, we recall the principle of actual version of the receiver called SCR (Single Correlation Receiver). Then, we discuss the time aspect of moving a target compared to the time needed to computing of one correlation. In section III, we describe the proposed version of the receiver called Averaging Correlation Receiver (ACR). Then, in section IV ROCs numerical results of both SCR and ACR considered in different situations are given and in section V, a conclusion is drawn.

II. Principle of CFACAR

The principle of the CFACAR system is to generate a pseudo random code $c(i)$ of length N as described in the Figure 1. This pseudo random code modulates a microwave carrier in BPSK (Bi Phase Shift Keying) at $76\,77\,GHz$ and is transmitted towards the potential targets. After reflection on an obstacle, the reflected wave is demodulated, amplified and filtered by a low pass filter. The obtained signal is sampled at transmitted code frequency and converted to a digital signal using an Analog to Digital Converter (ADC). Then, the correlation between the reference code $c(i)$ and the received signal $r(i)$ is computed. The detection unit is added to decide if the peak exceeds or not the detection threshold. The latter is adjusted to have some desired Constant False Alarm probability values. If the decision is true, the distance from the target can be deduced using the following formula:

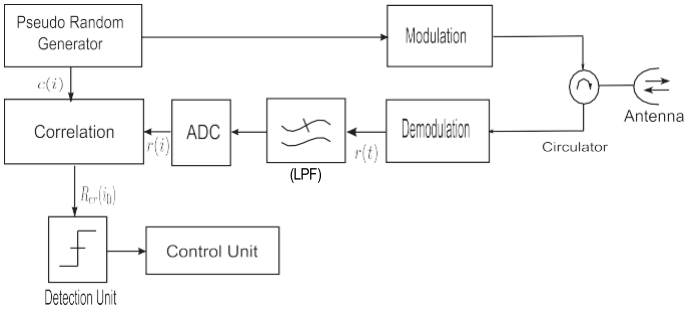


Figure 1. Coded Anti-collision Radar.

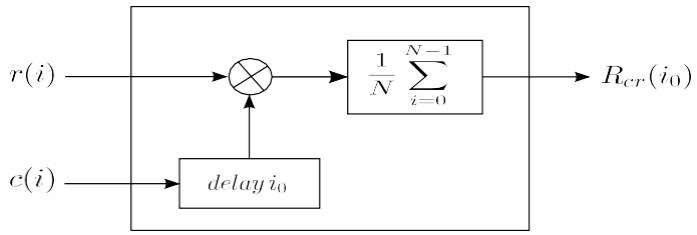


Figure 2. Single Correlation Receiver (SCR).

$$R_{cr}(i_0) = \sum_{i=0}^{N-1} c(i - i_0)r(i) = AR_{cc}(i_0 - k) + R_{cn}(i_0) \quad (3)$$

Then this signal is compared to the threshold at decision time ($i_0 = k$). The main specification of our system is to generate the reference code and to perform computation at $100\,MHz$.

It is shown in [2], [20] that the SNR gain is equal to code length N:

$$G = \frac{SNR_{out}}{SNR_{in}} = N \quad (4)$$

Where SNR_{in} and SNR_{out} are respectively input and output SNR of correlation receiver.

$$D = k.\frac{c}{2f_h}$$

In dB this gain can be written as:

Where D is the distance to the target (in m), f_h is the radar code frequency (in Hz), c is the propagation speed of light and $P = \frac{c}{2f_h}$ is the distance precision.
The estimated distance is communicated to the Control Unit (CU) which decides how to accelerate or decelerate in order to maintain a safety distance between the vehicle and the target [19].

In Baseband, we can model the received signal by the following expression:

$$r(i) = Ac(i - k) + n(i) \qquad (2)$$

Where k is the unknown delay, A is the attenuation factor and $n(i)$ is the additive white gaussian noise. At the output of the correlation receiver (Figure 2) we have: $G_{dB} = 10log(G) = 10log(N)$ (5)

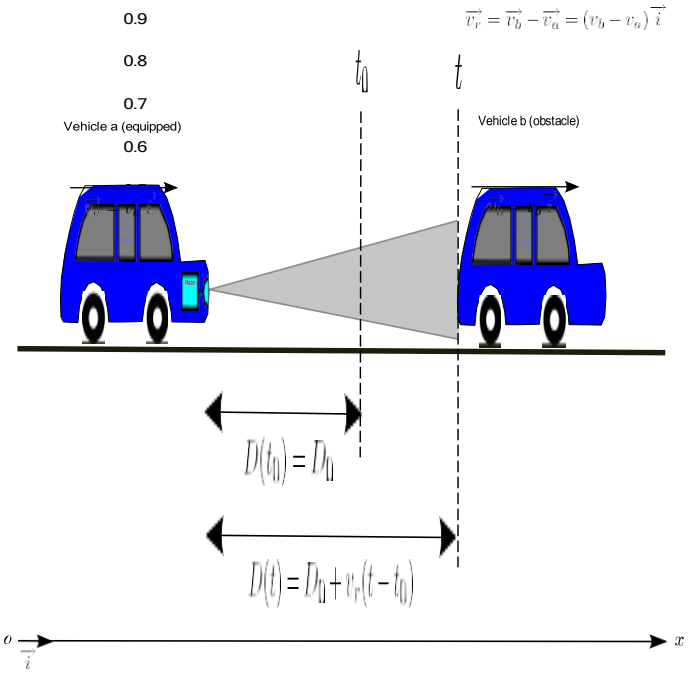
As long as the code is the longest this gain increases. In our study we take $N = 1023$ that represents the compromise between good performances and less complexity. In fact, this length ensures a high SNR gain ($G_{dB} = 30\ dB$), the corre- lation complexity is fairly reasonable for an implementation in real time [21]. Also, if we increase the code frequency, we get a good precision in distance. The frequency of $100\,MHz$ give a precision in distance $P = 1.5\,m$ and maximum range is equal to $D_{max} = N \quad P = 1534\,m$.

Assuming that one obstacle vehicle moves at constant relative speed v_r compared to an other vehicle equipped by the radar (Figure 3).

The distance is expressed as:

$$D(t) = D_0 + v_r(t - t_0) \qquad (6)$$

*



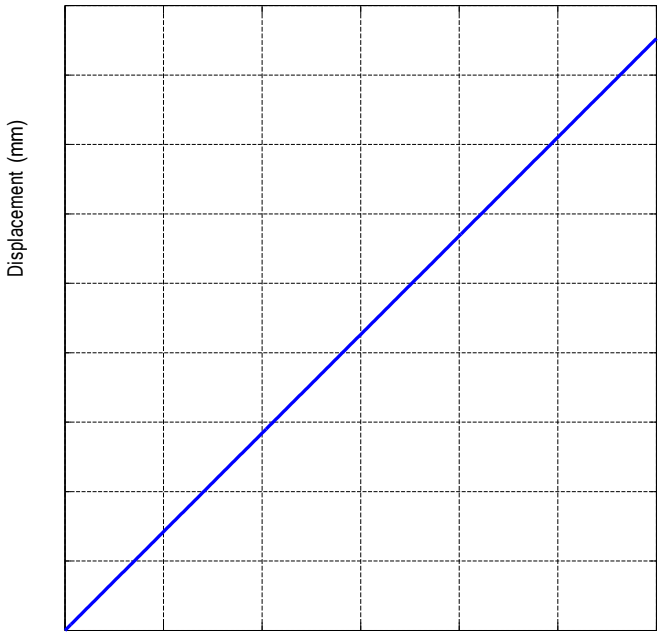
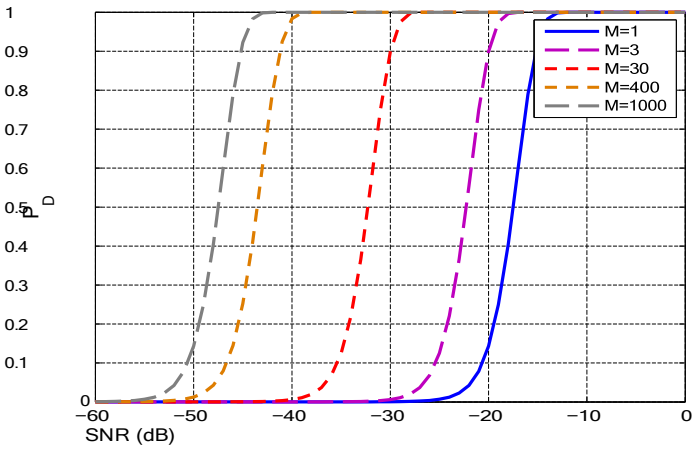


Figure 3. Displacement of obstacle vehicle compared to the vehicle equipped by the radar.

Where D_0 is the distance at instant $t = t_0$.
According to the sign of the velocity v_r, positive or negative,

Figure 4. Displacement of the obstacle vehicle during computation time.

6000
$t_c = NT_h$
$= N/f_h$



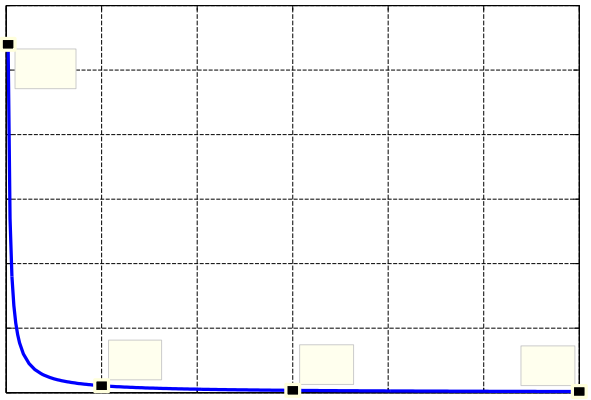


Figure 14. P_D as function as SNR.

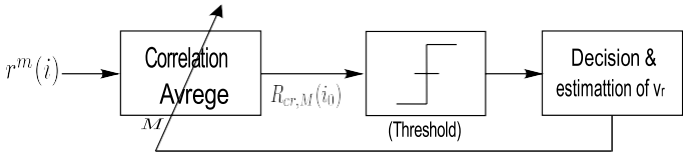


Figure 15. Adaptive averaging correlation receiver.

FMCW and MFSK [23], [24], [25]. This can be done as a future improvement in future work.

III. Conclusion

The phrasing of detection and false alarm probability for CFACAR has been suggested by us in earlier publications. We plotted the ROCs for each of the three situations we handled. We found that these latter are excellent for high SNR and extremely poor for low SNR (less than 15 dB). In this study, we present the ACR receiver, which consists of calculating the average of the M later correlation findings, to enhance the performances in extremely low SNR scenarios. This is made achievable by the obstacle's insufficient movement in relation to the system's accuracy. Following the derivation of the detection and false alarm probability, the updated ROCs are shown. By selecting an appropriate number for the duration of the ACR, we can guarantee a decent detection in very noisy cases, such as when the SNR is 40 dB. This length fluctuates between a big value for low velocity and a low value for high velocity, depending on the relative velocity. For instance, we may decrease to SNR = 45 dB for a velocity of 5 km/h with M = 1055 and to SNR = 27 dB at a velocity of 300 km/h with M = 17. We suggest using adaptive length selection. However, our sensor does not provide a reliable estimate of velocity. In the future, we will concentrate on figuring out how to employ alternative methods, like as FMCW, to get an accurate velocity estimate while preserving the CDMA properties of the possible new system.

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