Progress In Electromagnetics Research B, Vol. 34, 367–387, 2011

A NEW ADAPTIVE LINEAR COMBINED CFAR DETECTOR IN PRESENCE OF INTERFERING TARGETS

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Abstract—In this paper, a new radar constant false alarm rate detector to perform adaptive threshold target detection in presence of interfering targets is proposed. The proposed CFAR detector, referred to as Adaptive Linear Combined CFAR, ALC-CFAR, employs an adaptive composite approach based on the well-known cell averaging CFAR, CA-CFAR, and the ordered statistics, OS-CFAR, detectors. Data in the reference window is used to compute an adaptive weighting factor employed in the fusion scheme. Based on this factor, the ALC-CFAR tailors the background estimation algorithm. The conducted Monte Carlo simulation results demonstrate that the proposed detector provides low loss CFAR performance in an homogeneous environment and also performs robustly in presence of interfering targets. The performances of the ALC-CFAR detector have been evaluated and compared with that of the CA-CFAR and the OS-CFAR detectors. The obtained results are presented and discussed in this paper.

1. INTRODUCTION

Radar is an electromagnetic system that detects, locates, and recognizes target objects. Radar transmits electromagnetic signal and then receives echoes from target objects to get their location or other information. The received signal is frequently corrupted by noise and clutter. The disturbances may cause serious performance issues with radar systems by concluding these signals as targets [1–3].

To make a right decision, the receiver is desired to achieve a constant false alarm rate (CFAR) and a maximum probability of target detection. Modern radars usually detect the targets by comparing with

Received 26 January 2011, Accepted 17 May 2011, Scheduled 2 October 2011

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adaptive thresholds based on a CFAR detector. In this detector, the threshold is determined dynamically based on the local background noise/clutter power. This threshold is set on a cell by cell basis according to the estimated noise/clutter power, which is determined by processing a group of reference cells surrounding the cell under investigation.

For example, the cell-averaging CA-CFAR detector [4] adaptively sets the threshold by estimating the mean level in a window of N range cells. The detection performance of the CA-CFAR detector is optimum in an homogeneous background when the reference cells contain independent and identically distributed (i.i.d) observations governed by an exponential distribution [5]. The assumption of an exponential distribution is justified for the square-law detector in the case of complex normally distributed noise in the video range [5]. In practice, the environment is usually non-homogeneous due to the presence of multiple targets and/or clutter edges in the reference window. However, there is a significant decrease in performance when the assumption of homogeneous environment is not met [6–10]. Modifications of the CA-CFAR schemes (such as the greatest of CFAR and the smallest of CFAR [2]) have been proposed to improve the original CA-CFAR performance for regions with either clutter transitions or multi-target situation. The order statistics, OS, detectors have been known to yield a good performance as long as the non-homogeneous background and outlying returns are properly discarded. The OS-CFAR scheme is suitable to alleviate these problems above to some degree. Its performance in a multiple target environment is clearly superior [5]. Nevertheless, the OS-CFAR detector exhibits some loss of detection power in homogenous background compared with the CA-CFAR detector. For complex environment such as anti-collision radars, where the environment changes abruptly, these conventional detectors cannot detect targets properly.

In this paper, we propose a new CFAR detector referred to as Adaptive Linear Combined CFAR detector, ALC-CFAR. The main motivation behind the development of such detector is the degradation of the CA-CFAR performance in presence of interfering targets and the additional losses involved in the OS-CFAR detector in an homogeneous background. The proposed detector reduces the CFAR detection loss and improves the detection probability in heterogenous environment. The paper is organized as follows. In Section 2, we formulate the problem and introduce the limitation of the CA-CFAR detector in multi-target radar situations and the additional detection losses of the OS-CFAR detector in an homogeneous environment. In Section 3, we present the proposed detector and the effect of the adaptive weighting factor on the detection performance. In Section 4, we show the simulation results that demonstrate the improved performance of the proposed detector versus the conventional CA-CFAR and the OS-CFAR detectors. Finally, in Section 5, we present the conclusions.

2. PROBLEM FORMULATION

In a radar system, it is needed to determine the power threshold from which any return can be considered as a target. In most radar detectors, the threshold is set in order to achieve a required probability of false alarm rate. In natural environment, unwanted clutter and interference sources change spatially and temporally. In this situation, an adaptive threshold should be employed, where the threshold level is changed to maintain a constant probability of false alarm. This property is known as constant false alarm rate (CFAR) detection [1]. A typical CFAR detector is shown in Fig. 1.

The input signals are set serially in a shift register. The content of the cells surrounding the cell under test (X_0) are processed by a CFAR detector to get the adaptive threshold. The cell under test is declared as a target if its value exceeds the threshold.

In order to analyze the detection performance, we assume, in this work, that the square law detected output for any range cell is exponentially distributed with probability density function (pdf) [5, 15]:

$$f(x) = \frac{1}{2\lambda} e^{\frac{-x}{2\lambda}} \tag{1}$$

where λ is the total background clutter plus-thermal noise power given

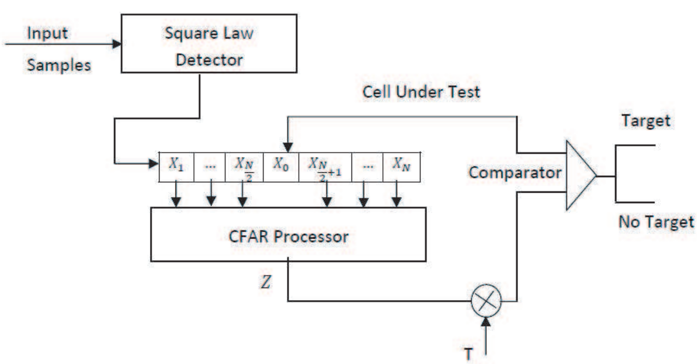

Figure 1. Bloc diagram of a typical CFAR detector.

as μ under the null hypothesis H_0 and λ is defined as $\mu(1+S)$, where S is the average signal to noise ratio, SNR, of a target.

For performance assessment, we consider two environments.

The early CFAR detector called cell-averaging CFAR (CA-CFAR) was proposed by Finn and Johnson in [4]. In this detector, the adaptive threshold is the arithmetic mean of its reference cells according to Eq. (2).

$$Z_{CA} = \frac{1}{N}\sum_{i=1}^{N} X_i \tag{2}$$

The threshold level is obtained by multiplying the estimate, Z_{CA}, by a given constant, T_{CA}, chosen as a function of the desired false alarm probability, P_{fa}, and the number of reference cells, N. T_{CA} is given in Eq. (3) [4].

$$T_{CA} = P_{fa}^{\frac{-1}{N}} - 1 \tag{3}$$

The detection probability, P_D is given by Eq. (4).

$$P_D = \left(1 + \frac{T_{CA}}{1+SNR}\right)^{-N} \tag{4}$$

The CA-CFAR performs well under an homogeneous environment, however, in presence of interfering targets it presents a serious performance degradation. The order statistics detector, OS-CFAR, has been introduced to overcome some of the problems in the CA-CFAR detector [5].

The adaptive threshold of the OS-CFAR detector is formally defined by selecting the Kth largest sample in the reference window, $X(K)$, as shown in Eq. (5).

$$X(1) \leq X(2) \leq \ldots \leq X(K) \leq \ldots \leq X(N) \tag{5}$$

The indices in parentheses indicate the rank order number. $X(1)$ denotes the minimum and $X(N)$ the maximum value.

The threshold level is computed according to Eq. (6).

$$T_{OS}Z_{OS} = T_{OS}X(K); \quad K \in \{1,2,3,\ldots,N\} \tag{6}$$

where T_{OS} is a scale factor chosen according to the desired P_{fa} and N, $X(K)$ is the Kth ordered sample in the reference window. T_{OS} can be derived from Eq. (7) [5].

$$P_{fa} = K \binom{K}{N} \frac{(K-1)!(T_{OS}+N-K)!}{(T_{OS}+N)!} \tag{7}$$

The estimate Z_{OS} is then multiplied by T_{OS} to get the threshold level. The result is compared with the sample level in the cell under test, X_0. After comparison, if the cell under test is greater than the threshold level, hypothesis H_1 (presence of target in the cell under test) is declared true; else the alternative hypothesis H_0 (absence of target) is declared true.

The detection probability is given by:

$$P_D = K \binom{K}{N} \frac{\left(\frac{T_{OS}}{1+S} + N - K\right)!(K-1)!}{\left(\frac{T_{OS}}{1+S} + N\right)!} \tag{8}$$

The performances of the CA-CFAR and the OS-CFAR detectors have been examined by means of computer simulations under an homogeneous and non homogeneous (presence of interfering targets) environments.

2.1. An Homogeneous Environment

We consider the detection of separate targets using the conventional CA-CFAR and OS-CFAR detectors. In Fig. 2, we show the detection thresholds for the CA-CFAR and the OS-CFAR detectors for $P_{fa} = 10^{-5}$, $N = 16$ and $K = 12$. Both detectors distinguish easily the four targets present at cells range 10, 40, 60 and 80. Nevertheless, the OS-CFAR processor exhibits some additional losses in detection

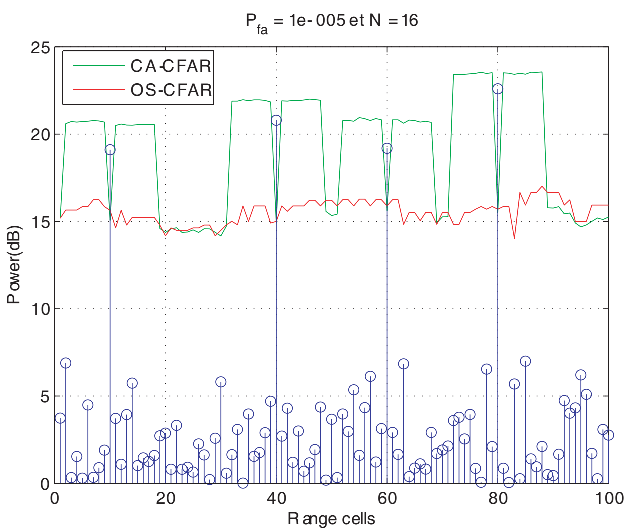

Figure 2. OS-CFAR and CA-CFAR detection thresholds in an homogeneous environment, $P_{fa} = 10^{-5}$, $N = 16$ and $K = 12$.

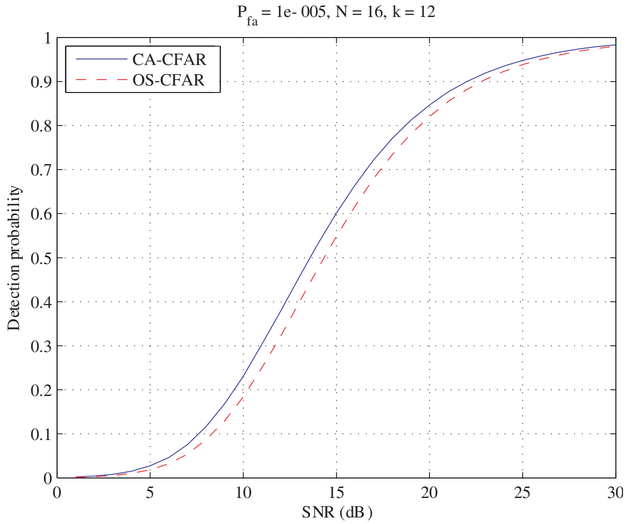

Figure 3. OS-CFAR detection loss versus the CA-CFAR detector in an homogeneous environment, $P_{fa} = 10^{-5}$, $N = 16$ and $K = 12$.

power under an homogenous background compared with the CA-CFAR detector. We observe clearly in Fig. 3 that the detection curve of the OS-CFAR detector differs from that of the CA-CFAR detector with some detection loss and we note that the detection performance of the OS-CFAR detector depends on the order parameter K.

The corresponding curves have been obtained by Monte Carlo experiments. A trial of 10000 experiments is used.

2.2. Non-homogeneous Environment

In Fig. 4, we consider radar signal detection in a non-homogeneous environment, presence of interfering targets, using the CA-CFAR and OS-CFAR detectors for $N = 16$, $K = \frac{3N}{4} = 12$ and $P_{fa} = 10^{-5}$, in presence of two groups of targets and a separate target present at cell range 80. The first one contains two targets (cells 15 and 16), while the second one contains four targets (from cell 40 to 43) with different signal to noise ratios.

The application of the CA-CFAR detector allows the detection of the separate target and only the target with higher SNR of the first group, while all the targets of the second group are missed. The OS-CFAR detector detects all the targets of the two groups.

In order to apply different CFAR techniques in a non-homogenous

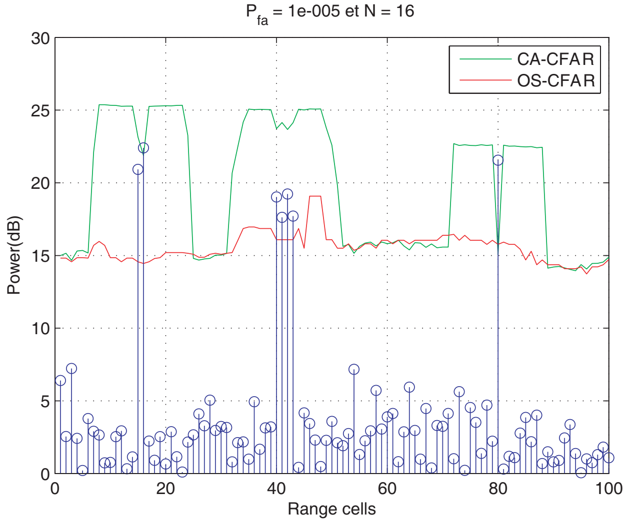

Figure 4. The OS-CFAR and CA-CFAR thresholds in presence of interfering targets, $P_{fa} = 10^{-5}$, $N = 16$ and $K = 12$.

and an homogeneous environment simultaneously, setting a fusion criterion is necessary in order to discriminate the local homogenous character from the non-homogeneous one. Therefore, the ALC-CFAR detector has an attractive feature by adding to the available conventional detectors the potential to perform the detection procedure with a better detection quality in heterogenous radar environment.

3. THE PROPOSED DETECTOR

In Section 2, we have presented some limitations of the CFAR detection especially for the conventional CA-CFAR and OS-CFAR detectors by comparison of their performances in different radar situations. In this section, we introduce a new CFAR detector which has the capability to present detection performance close to the CA-CFAR detector with less detection losses than the OS-CFAR detector in homogenous environment, and very close to the OS-CFAR in presence of interfering targets to overcome the CA-CFAR detector performance degradation in this kind of situation [10]. The performances of the proposed detector are compared with both the CA-CFAR and the OS-CFAR detectors.

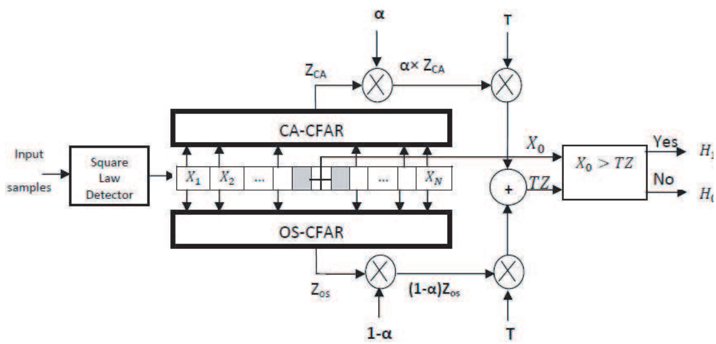

Figure 5. The proposed adaptive linear combined CFAR detector.

3.1. The ALC-CFAR Principle

The proposed detector referred to as ALC-CFAR (Adaptive Linear Combined CFAR), is depicted in Fig. 5.

The ALC-CFAR detector is an adaptive linear combination of the CA-CFAR and the OS-CFAR threshold estimates using an adaptive weighting factor according to the environment changes.

The ALC-CFAR detector estimates the noise level, Z, in the CFAR reference window according to Eq. (9).

$$Z = \alpha Z_{CA} + (1 - \alpha) Z_{OS} \tag{9}$$

where Z_{CA} and Z_{OS} are the noise level estimates for the CA-CFAR and the OS-CFAR detectors respectively and α is a measure of homogeneity of the reference window samples and belongs to the interval [0,1]. The estimate Z is then multiplied by the scale factor T to form the threshold. The result is compared with the sample level in the cell under test, X_0. After comparison, if the cell under test is greater than the threshold level, hypothesis H_1 (presence of target in the cell under test) is declared true; else the alternative hypothesis H_0 (absence of target) is declared true.

3.2. The Adaptive Weighting Factor

The parameter α, is computed according to the following steps:

Step1: The CFAR reference window samples are sorted to form a new window W which will be subdivided in two sub-windows W_0 and W_1 according to the rule:

$$k \gtrless^{W_1}_{W_0} \beta \tag{10}$$

where β is an integer threshold. The reference cell $Z_k \in W$, $k = 1, 2, \ldots, N$, is in the sub-window W_1 if $k > \beta$ and in the sub-window W_0 if $k \leq \beta$.
The principal of this selection is illustrated in Fig. 6.

Step2: The two sub-windows W_0 and W_1 are used to compute α according to expression 11.

$$\alpha = \frac{1}{\beta Z_N} \sum_{k=1}^{\beta} Z_k \tag{11}$$

where Z_N is the largest sample in the CFAR reference window, so in the sub-window W_1, and Z_k is the kth largest sample in the sub-window W_0.

We agree that Z_{CA} defined in Equation (9) is the arithmetic mean of the reference window samples. The use of the mean instead of the sum is to make Z_{CA} and Z_{OS} similar.

The expressions of Z_{CA} and Z_{OS} are given by Eq. (12) and Eq. (13) respectively:

$$Z_{CA} = \frac{1}{N} \sum_{i=1}^{N} Z_k \tag{12}$$

$$Z_{OS} = Z_{K_{OS}} \tag{13}$$

In the rest of the paper, we consider $K_{OS} = \frac{3}{4}N$, which is known to be the optimum value [5], to protect against interfering targets in the OS-CFAR detection. The integer threshold β defined in Eq. (10) is also equals to K_{OS}. The objective of this preference is to have only

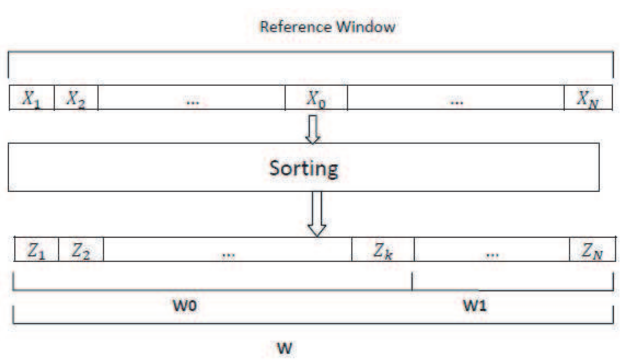

Figure 6. Illustration of step 1 for the adaptive weighting factor estimation.

the noise samples in W_0 with as great number of cells as possible. The advantage of this choice is developed above.

From Equation (11), one can observe that α is the arithmetic mean of W_0 divided by the largest sample in the reference window. According to the value of the parameter α, the ALC-CFAR uses either the CA-CFAR threshold (for $\alpha = 1$) or the OS-CFAR threshold (for $\alpha = 0$).

To show that Z is adapted to the environment changes, several experimental situations are conducted.

In an homogeneous environment, no interfering targets, if the reference window samples have close magnitudes, α tends to 1 and the CA-CFAR detector is favorable in the threshold level estimation.

In presence of one interfering target, α becomes lower than that in the previous case, because the largest sample in the reference window corresponds, probably, to the interfering target sample. In this case, the OS-CFAR detector which is adapted to this kind of situation has a greater weighting factor than that of the CA-CFAR detector.

In multiple targets situations, α remains closer to zero and practically only the OS-CFAR estimate, Z_{OS}, is used in the ALC-CFAR threshold estimation. So, the ALC-CFAR uses, in limit cases, either the CA-CFAR or the OS-CFAR detectors according to the environment homogeneity level.

3.3. Analysis of the Adaptive Weighting Factor

In this sub-section, we study the effect of α on the estimation of the noise level, Z, in the reference window given by Eq. (9), and the influence of the environment changes on the value of α.

We consider two environments. An homogeneous environment, presence of noise only, and heterogenous environment, presence of interfering targets.

We suppose that the magnitudes of the noise samples in the reference window are independent and identically distributed (i.i.d) random variables and governed by an exponential distribution.

In the first case, the reference cells contain noise only, the parameter α becomes a random variable because it is formed by a combination of random variables, so, we can compute its expectation.

The computation of the expectation of α is done by Monte Carlo experimentations. The number of experiments is taken equal to 10^4. The obtained results are presented in Table 1, where $E(\alpha)$ is the expectation of α.

Table 1 presents the expectation of the adaptive weighting factor versus N. It shows that α is not very close to one in an homogeneous environment, the observed value of $E(\alpha)$ for $N = 4$ is 0.351. It can

Table 1. The expectation of the parameter α, in an homogeneous environment for different N.

N	4	8	16	24	32
$E(\alpha)$	0.351	0.244	0.185	0.160	0.147

Table 2. The expectation of the parameter α, in nonhomogeneous environment for different, N, in presence of one interfering target with $SNR = 15\,\text{dB}$.

N	4	8	16	24	32
$E(\alpha)$	0.078	0.066	0.054	0.049	0.047

be seen also that when the number of reference cells increases, the expectation of α decreases. As a consequence, in presence of noise only, the weighting factor of the CA-CFAR is about 0.351, while the OS-CFAR achieves 0.649 for $N = 4$.

In the second case, presence of interfering targets, the expectation of α is depicted in Table 2.

Table 2 shows that $E(\alpha)$ falls to 0.079 for $N = 4$ in presence of one interfering target with $SNR = 15\,\text{dB}$. The value of $E(\alpha)$ decreases if the SNR of the interfering target increases more. In these conditions, the weighting factor of the CA-CFAR detector is about 20 percent and the OS-CFAR detector is 80 percent. The ALC-CFAR detector is effectively very close to the OS-CFAR detector in presence of one interfering target. Table 2 shows also that when N increases the ALC-CFAR performance tends to that of the OS-CFAR detector.

In presence of two (or more) interfering targets, the results are the same as for one interfering target because the second interfering target does not contribute to the computation of α. The study of the effect of α in presence of a number greater than $\frac{3N}{4}$ is not interesting because both the CA-CFAR and the OS-CFAR performances are degraded [5].

3.4. The Threshold Multiplier

The threshold multiplier of the ALC-CFAR detector is determined using Monte Carlo simulations. The number of experiments is taken to be $\frac{100}{P_{fa}}$ [12].

Figure 7 presents the variation of the threshold multiplier, T, of the ALC-CFAR detector versus the desired P_{fa}, for different number of the reference range cells. It can be shown that when N increases, T decreases, and when the P_{fa} increases T decreases. For a given P_{fa}

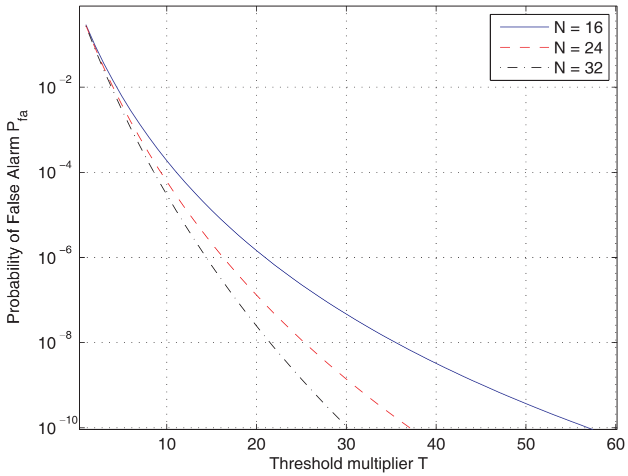

Figure 7. The threshold multiplier of the ALC-CFAR detector versus Pfa for different N.

and a fixed N, the threshold multiplier can be deduced directly from Fig. 7.

4. PERFORMANCE ASSESSMENT

In this section, the performances of the ALC-CFAR detector are analyzed and compared with the CA-CFAR and the OS-CFAR detectors in different radar situations. The comparison is based on the evaluation of the probability of detection, P_d, versus SNR and the effective P_{fa} using intensive Monte Carlo simulations. The gain in the detection probability of the ALC-CFAR compared with the OS-CFAR is also investigated. The number of experimentations is taken equal to 10^4 for P_d and $\frac{100}{P_{fa}}$ for P_{fa}.

4.1. The Detection Probability

The simulations are conducted for different N and P_{fa}. Two environments are considered; an homogeneous environment and non-homogeneous environment (presence of interfering targets).

Figures 8, 9 and 10 show the detection probabilities of the CA-CFAR, the OS-CFAR and the ALC-CFAR detectors for $N = 16$ and different values of P_{fa}, 10^{-4}, 10^{-5} and 10^{-6} respectively. It can be seen from the presented curves that the performance of the

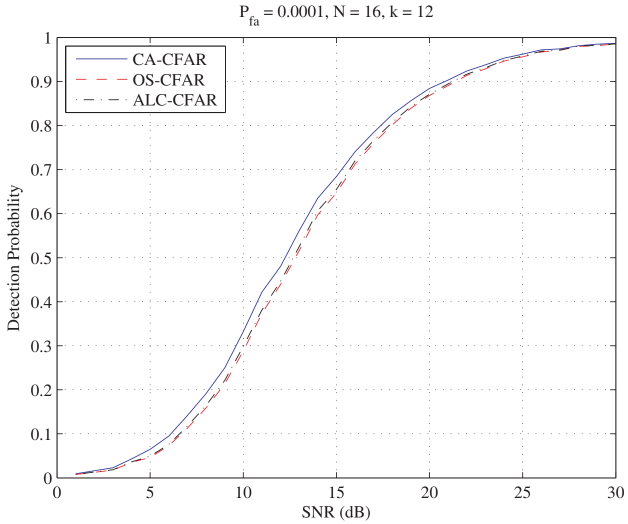

Figure 8. Detection probabilities of the ALC-CFAR, OS-CFAR and CA-CFAR detectors in homogenous environment, $P_{fa} = 10^{-4}$ and $N = 16$.

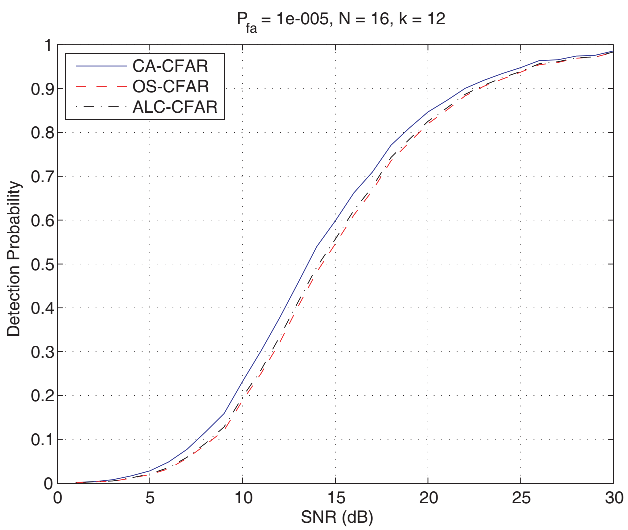

Figure 9. Detection probabilities of the ALC-CFAR, OS-CFAR and CA-CFAR detectors in homogenous environment, $P_{fa} = 10^{-5}$ and $N = 16$.

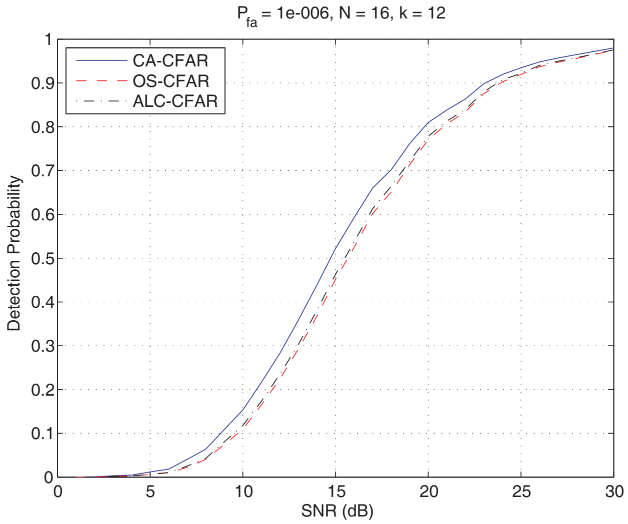

Figure 10. Detection probabilities of the ALC-CFAR, OS-CFAR and CA-CFAR detectors in homogenous environment, $P_{fa} = 10^{-6}$ and $N = 16$.

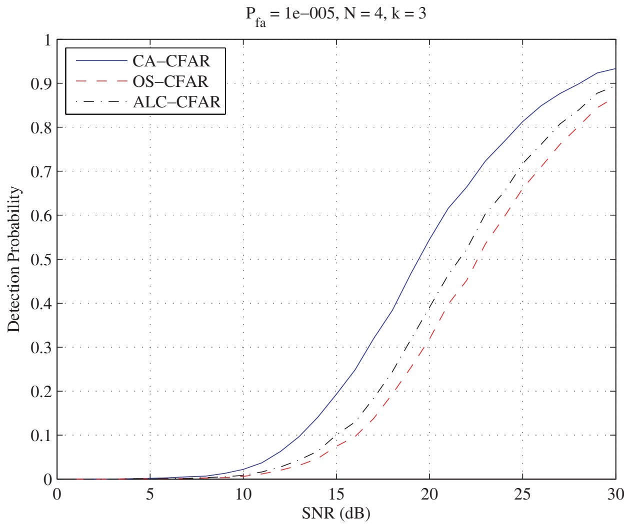

Figure 11. Detection probabilities of the ALC-CFAR, OS-CFAR and CA-CFAR detectors in homogenous environment, $P_{fa} = 10^{-5}$ and $N = 4$.

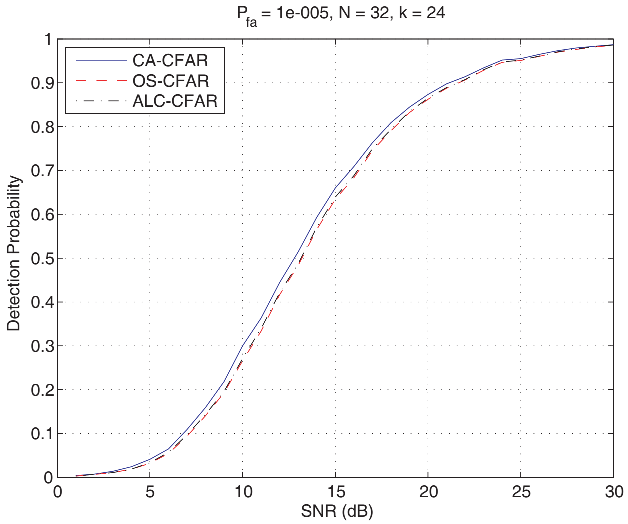

Figure 12. Detection probabilities of the ALC-CFAR, OS-CFAR and CA-CFAR detectors in homogenous environment, $P_{fa} = 10^{-5}$ and $N = 32$.

ALC-CFAR belongs always between the CA-CFAR and the OS-CFAR for different P_{fa}. The difference between the ALC-CFAR and the OS-CFAR detectors increases for lower P_{fa}. The proposed detector performs better than the OS-CFAR detector in this kind of environment whatever the P_{fa} value.

Figures 11 and 12 present the detection probabilities of the CFAR detectors for $N = 4$ and $N = 32$ respectively. The desired false alarm rate is fixed to $P_{fa} = 10^{-5}$. From this figures, it returns out that the gain of the ALC-CFAR detector compared with the OS-CFAR detector is greater for lower N. For higher N, the ALC-CFAR converges to the OS-CFAR performances.

It is known that the OS-CFAR detector has an additional detection losses than the CA-CFAR detector in an homogeneous environment [5], so, the ALC-CFAR reduces these losses in this kind of environment.

In non homogeneous environment, Fig. 13 depicts the detection probabilities of the ALC-CFAR, the CA-CFAR and the OS-CFAR detectors in presence of one interfering target. The interference to noise ratio, INR, of the interfering target is taken equal to the SNR of the target in the cell under test. It can be seen that the detection probability of the CA-CFAR decreases, while that of the OS-CFAR

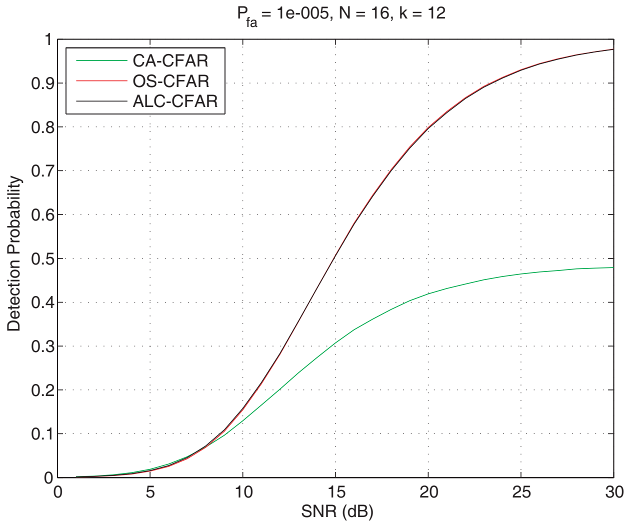

Figure 13. Detection probabilities of the ALC-CFAR, OS-CFAR and CA-CFAR detectors in presence of one interfering target.

is maintained and the ALC-CFAR performance remains very close to that of the OS-CFAR detector.

When the number of interfering targets increases, and remains less than the tolerable number in the OS-CFAR detector (four interfering targets are tolerable for $N = 16$), the performance degradation of the CA-CFAR decreases, the OS-CFAR is not affected and the ALC-CFAR remains very close to the OS-CFAR detector.

Figure 14 shows the detection probabilities of the ALC-CFAR, the OS-CFAR and the CA-CFAR detectors in presence of five interfering targets.

It can be seen that when the interfering targets number is greater than the tolerable one, the behavior of the ALC-CFAR is similar to the OS-CFAR. As the performance of the OS-CFAR detector is affected in this case, the ALC-CFAR performance is also degraded.

The ALC-CFAR detector offers a compromise between the CA-CFAR and the OS-CFAR detectors. In an homogeneous environment, the ALC-CFAR performs better than the OS-CFAR detector by reducing the detection losses. In presence of interfering targets, the ALC-CFAR is very close to the OS-CFAR detector which is designed to support interfering targets and prevents the performance degradation of the CA-CFAR detector in this kind of situation.

Figure 15 shows the detection thresholds of the CA-CFAR, the OS-

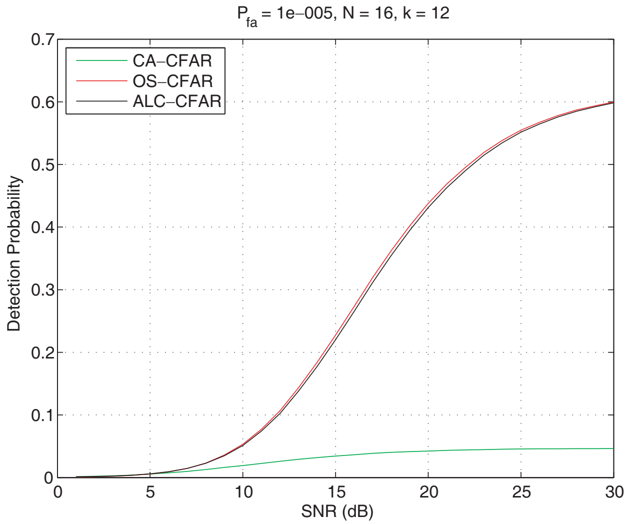

Figure 14. Detection probabilities of the ALC-CFAR, OS-CFAR and CA-CFAR detectors in presence of five interfering targets.

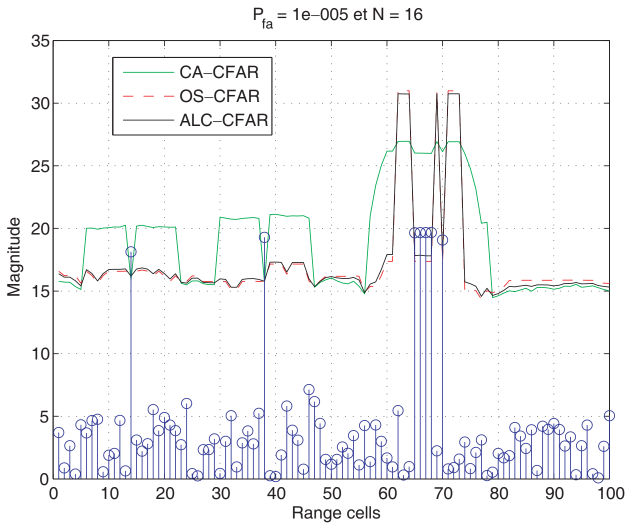

Figure 15. Detection thresholds for the ALC-CFAR, the CA-CFAR and the OS-CFAR detectors for $N = 16$ and $P_{fa} = 10^{-5}$.

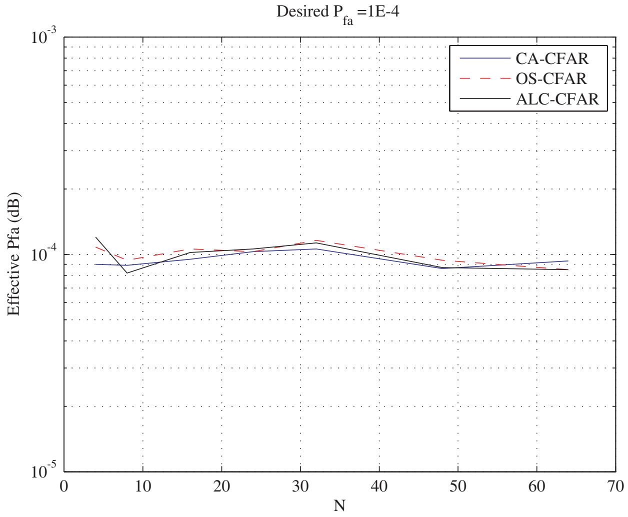

Figure 16. The false alarm regulation performance for different N. The desired $P_{fa} = 10^{-4}$.

CFAR and the ALC-CFAR detectors for $N = 16$ and $P_{fa} = 10^{-5}$. It is clear that the ALC-CFAR threshold is adapted to the environment by means of the parameter, α, to detect targets in clear areas and prevent the target masking effect in presence of interfering targets and consequently it ensures less losses compared with the OS-CFAR detector.

We observe that the CA-CFAR detects only the two targets present in the clear area, while the OS-CFAR detects the six targets. The ALC-CFAR guarantees also the detection of the six targets with less detection losses compared with the OS-CFAR detector. Other radar situation scenarios are considered to validate the performance of the proposed detector.

The false alarm regulation performance of the proposed detector versus the CA-CFAR and the OS-CFAR detectors for different N under an homogeneous environment is evaluated. The obtained results for a desired $P_{fa} = 10^{-4}$, by Monte Carlo experimentations using a total of 10^6 independent trials, are presented in Fig. 16. It can be seen that the effective P_{fa} of the proposed detector is relatively maintained close to the desired one.

4.2. The Gain of the Proposed Detector

The obtained gain, defined as the difference between the corresponding SNRs to yield $P_D = 0.5$, of the ALC-CFAR compared with the OS-CFAR detector for different P_{fa} and N is given in Table 3. It can be seen from this table that the gain is higher for lower N and P_{fa}. It achieves more than one dB for $N = 4$ and $P_{fa} = 10^{-6}$. For higher N and P_{fa}, the gain is reduced and the ALC-CFAR detector performs like the OS-CFAR detector.

From Table 3, it returns out that, by carefully selecting N as well as P_{fa}, it is possible to achieve satisfactory performance in both an homogeneous and non homogeneous situations and make up for losses of the OS-CFAR detector. According to the obtained results, it is also very interesting to note that the proposed detector is particularly suitable for low resolution radars which use low number of reference cells to ensure the minimum homogeneity range†.

Table 3. Gain of the ALC-CFAR v.s the OS-CFAR for different values of P_{fa} and N.

	N	4	8	16	24	32	64
Gain (dB)	$P_{fa} = 10^{-4}$	0.813	0.312	0.145	0.081	0.043	0.024
	$P_{fa} = 10^{-5}$	1.251	0.327	0.214	0.115	0.062	0.031
	$P_{fa} = 10^{-6}$	1.316	0.415	0.223	0.132	0.091	0.035

For practical application in radar detection, it is clear, however, that the computation burden is greater for the proposed detector than the OS-CFAR. In order to overcome this limitation, a solution to this problem is to take the advantages of the optimized implementation architectures for the CA-CFAR and the OS-CFAR detectors developed in [14] and [13] respectively. For the CA-CFAR detector, the computational load is reduced to only two additions and two subtractions whatever the reference window size. For the OS-CFAR detector, the computational load is reduced about 75 percent compared with the classical configuration. The proposed architecture is based on an efficient procedure for real time implementation of the OS-CFAR detector, based on the $(N - K + 1)$-th maximum determination. By showing that the determination of the K-th order out of N reference cells is equivalent to selecting the $(N + 1 - K)$-th maximum, the detector that uses N reference cells can be implemented using only $(N - 1)$ comparators and $(N - 1)$ inverters. The combination of these

† This range is about 1 nmi for S band radars [1].

two approaches improves significantly the computational burden of the proposed detector for real time applications [11].

5. CONCLUSION

In this paper, a new CFAR detector referred to as Adaptive Linear Combined CFAR, ALC-CFAR, is proposed. The proposed detector principle is to wisely combine the threshold estimates of the CA-CFAR and OS-CFAR detectors, based upon the observed characteristics of the environment. This detector requires sensing the CFAR reference window cells, and applying an appropriate adaptive weighting factor in the fusion scheme to produce an efficient detection decision and ensure a reduced CFAR loss. The application of the ALC-CFAR detector in presence of interfering targets is demonstrated using an adaptive weighting factor. Simulations based on Monte Carlo experiments show that the ALC-CFAR detector performs much better than the CA-CFAR detector in non-homogenous environment, and has a very close detection performance to the OS-CFAR detector in presence of interfering targets with less CFAR detection loss compared with that of the OS-CFAR detector in homogenous environment.

For practical application in radar detection, it is very interesting to note that the proposed detector is particularly suitable for low resolution radars which use low number of reference cells to ensure the minimum homogeneity range.

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