Evaluation of AND-CFAR and OR-CFAR Processors under Different Clutter Models

Dr.Waleed Khalid Abd-Ali
Engineering College, University of Al-Mustansiriya/Baghdad.
Najim Abd-Ullah
Engineering College, University of Al-Mustansiriya/Baghdad.
DEWK_2009@yahoo.com

Received on: 17/11/2011 & Accepted on: 4/10/2012

ABSTRACT

In this paper an evaluation the detection performances for (AND-CFAR) and (OR-CFAR) processors under different clutter models is done for pulsed radar system.

The clutter models used in this paper are three types of distribution (Exponential Clutter distribution, Rayleigh Clutter distribution and Weibull Clutter distribution).

The two detectors (AND-CFAR and OR-CFAR) are the improved conventional Cell Average-CFAR (CA-CFAR) and Order Statistics CFAR (OS-CFAR) by making full use of the cell information. The two CFAR processors combine the results of the CA-CFAR and OS-CFAR to get a better detection performance.

The mathematical equations of the probability of detection and probability of false alarm to the two detectors (AND-CFAR and OR-CFAR) for the three clutter models are founded under the assumptions that a homogenous background with a Swerling I target, and the reference cells are Independent and Identically Distributed (IID), also the detection performances of these detectors (AND-CFAR and OR-CFAR) have been evaluated for the three clutter models first and compared between them with those of CA-CFAR and OS-CFAR for Rayleigh distribution using MATLAB-Programming (M-File).

In this paper is founded that the detection performance to AND-CFAR and OR-CFAR has not been affected by changing clutter models (clutter probability density function) for fixed probability of false alarm, also for the same probability of detection (Pd=0.7) and for fixed probability of false alarm ($P_{fa}=10^{-6}$) and N=12, signal-to-ratio power ration (SNR) which ensure this Pd is equal (18dB) for AND-CFAR, but its equal (18.5dB) for OR-CFAR, this means AND-CFAR is better detection performance than OR-CFAR for different clutter models.

Keywords: AND-CFAR, OR-CFAR, OS-CFAR, CA-CFAR, Clutter

تقييم المعالجاتAND-CFAR و OR-CFAR في نماذج ضوضاء مختلفة

الخلاصة

في هذا البحث تقييم لأداء الكشف للمعالجين **(AND-CFAR)** و **(OR-CFAR)** تحت تأثير انواع مختلفة من الأشارات غير المرغوب فيها **(Clutter)** تم انجازه لمنظومة الرادار النبضي.

في هذا البحث تم دراسة تأثير ثلاثة توزيعات احتمالية مختلفة للأشارات غير المرغوب فيها **(Clutter)** وهي (**Rayleigh distribution** و **Weibull distribution** و **Exponential distribution**).

يعد المعالجان اعلاه تحسينا للأنواع التقليدية **(CA-CFAR)** و **(OS-CFAR)** باستيفاء تام لمعلومات الخلية، كما هما حصيلة بناء من **(CA-CFAR)** و **(OS-CFAR)** للحصول على افضل اداء للكشف.

المعادلات الرياضية لأحتماليات الكشف والأنذار الكاذب للمعالجين **(AND-CFAR)** و **(OR-CFAR)** تم ايجادهما للانواع الثلاثة من الأشارات غير المرغوب فيها تحت افتراض خلفية متجانسة للهدف ويتطابق مع حالة **Swerling** الأولى وجميع الخلايا مستقلة وموزعة بصورة متماثلة، كذلك تم احتساب اداء الكشف للمعالجين **(AND-CFAR)** و **(OR-CFAR)** ومقارنته مع الأنواع التقليدية **(CA-CFAR)** و **(OS-CFAR)** لحالة التوزيع **(Rayleigh)** باستخدام برنامج **MATLAB (M-File)**.

في هذا البحث وجد ان اداء الكشف للمعالجين **(AND-CFAR)** و **(OR-CFAR)** لا يتأثر بتغير شكل الأشارة غير المرغوب فيها **(clutter PDF)** عندما احتمالية الأنذار الكاذب ثابتة، كذلك لنفس احتمالية الكشف **(Pd=0.7)** عندما احتمالية الأنذار الكاذب ثابتة ($P_{fa}=10^{-6}$) و **N=12**، نسبة قدرة الأشارة الى الضوضاء المؤكدة لأحتمالية الكشف اعلاه يساوي **(18dB)** لحالة **(AND-CFAR)** لكنها تساوي **(18.5dB)** لحالة **(OR-CFAR)** مما يدل على أن اداء الكشف للمعالج **(AND-CFAR)** افضل من اداء الكشف للمعالج **(OR-CFAR)** للأنواع الثلاثة من الأشارات غير المرغوب بها **(Clutter)**.

Introduction

In automatic radar detection, the received signal is sampled in range and frequency. Each sample is placed in an array of range and Doppler resolution cells. The clutter background in the cell under test is estimated by averaging the outputs of the nearby resolution cells (range and/or Doppler). The target detection is declared, if the signal value exceeds a preliminary determined threshold. The detection threshold is obtained by scaling the noise level estimate with a constant α to achieve a desired probability of false alarm P_{fa}[1].

The CA-CFAR processors are very efficient in case of stationary and homogenous interference. The presence of strong urban pulse interference in both, the test resolution cell and the reference cells, can cause drastic degradation in the performance of the CA-CFAR processor. Such type of interference is non-stationary and non-homogenous and it is often caused by adjacent radar or other radio-electronic devices.

In non-homogenous environment, the detection performance and the false alarm regulation properties of CA-CFAR detector may be seriously degraded. In recent years different approaches have been proposed to improve the detect ability of CFAR detectors operating in random impulse noise. One of them is the use of ordered statistics for estimating the noise level in the reference window, proposed by Rohling [2]. In Ordered Statistics CFAR (OS-CFAR)

pulse detectors, the k-th ordered sample in the reference window is an estimate of the background level in the test resolution cell. The performance of such OS-CFAR detector in the presence of multipath interference in existing communication networks is evaluated and studied in [3].

Hansen and Sawyers [4, 5] proposed the Greatest-Of selection logic in the cell averaging constant false alarm rate (GO-CFAR) detector to control the increase in the false alarm probability. A detailed analysis of the false alarm regulation capabilities of the GO-CFAR detector has been performed by Moore and Lawrence [6]. Weiss [7] has shown that if one or more interfering targets are present in the reference window, the performance of the GO-CFAR detector is very poor. He suggested the use of the smallest of selection logic in the cell averaging constant false alarm rate (SO-CFAR) detector. The SO-CFAR detector was proposed by Trunk [8] to improve the resolution of closely spaced targets.

The detection performance of CFAR processors is proposed by Hou in [9] for the case of homogenous environment and chi-square family of fluctuating target models (Swerling I, II, III, IV).

Lei Zhao, Weixian Liu, Xin Wu, and Jeffrey S. Fu. In 2001 [10], proposed two (CFAR) detectors, the AND-CFAR and OR-CFAR. The two CFAR processors are combined of the result of the CA-CFAR and –OS-CFAR to get a better detection performance in a homogenous background for Rayleigh clutter distribution.

Weixian Liu, Jeffery S. Fu. And Lei Zhao in 2001 [11], proposed a study of the performance of And-CFAR and OR-CFAR processors in a homogenous background for Weibull clutter distribution, but the mathematical models of the two detectors are not complete and their detection performance is not examined.

In this paper the behavior of CFAR statics AND-CFAR and OR-CFAR are investigated for different clutter models (Exponential Clutter distribution, Rayleigh Clutter distribution and Weibull Clutter distribution) and analyze the above statistics for different parameters like, probability of false alarm, scale parameter and number of range cells. Also comparison between performances for AND-CFAR and OR-CFAR with the CA-CFAR and OS-CFAR for Rayleigh clutter model.

The signal model

A more generic modeling of the background environments will be Weibull probability density function (PDF). The Weibull PDF has been found to apply in a large variety of real radar clutter situations, where deviation from Rayleigh PDF is encountered. It describes satisfactory many cases of land clutter as well as sea clutter for low grazing angles and horizontal polarization at high frequencies (X-band). It's a two-parameter PDF with scale and shape parameter[12].

$$p_W(x) = \frac{c}{b}\left(\frac{x}{b}\right)^{c-1} exp^{-\left(\frac{x}{b}\right)^c} \quad , x > 0 \qquad \dots (1)$$

where, c= skewness (shape) parameter of the Weibull distribution (1.2≤c≤1.8), and b=weibullscal parameter.

When c=2, the Weibull takes the form of Rayleigh pdf, and when c=1, it is the exponential pdf. With c<1, the sharp spiky clutter can be modeled with the most complicated situation in clutter-edge environment. The Weibull distributions for various values of the shape parameter c are plotted in Fig.(1) [13].

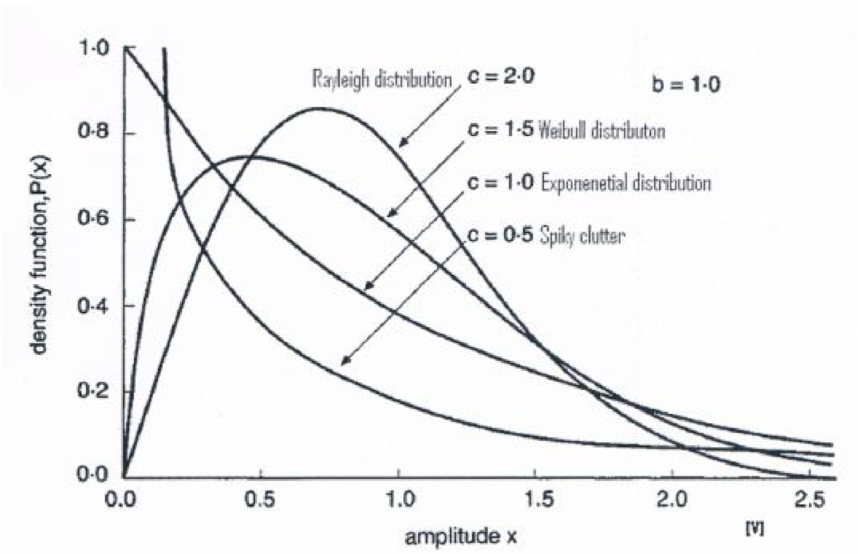

Figure (1) Weibull distribution for various values of the shape parameter c.

Model description and basic assumptions

AND-CFAR and OR-CFAR processors are the combined result of the CA-CFAR and OS-CFAR to get a better detection performance; by making full use of the cell information. The modified CFAR structure makes use of the two threshold settings of the CA-CFAR and OS-CFAR processors compared with the cell under test to make the judgment.

For the AND-CFAR algorithm, when the cell under test is greater than both of the two CA-CFAR and OS-CFAR thresholds, a target present will be declared. Otherwise, no target will be declared see Figure (2) [10].

$$X_o \underset{H_0}{\overset{H_1}{\gtrless}} \alpha_{Z_{and}} = \mathrm{Max}\,(Z_{CA}.\,\alpha,\ Z_{OS}.\,\alpha) \qquad \ldots (2)$$

where:

x_o represents the cell under test. $\alpha_{Z_{and}}$ is the AND-CFAR adaptive threshold.

Z_{CA} and Z_{OS} are the CA-CFAR and OS-CFAR estimated noise levels.

The PDF of the new threshold $\alpha_{Z_{and}}$ is given by:

$$f_{\alpha_{Z_{and}}} = f_p(\alpha_{Z_{and}}).F_q(\alpha_{Z_{and}}) + f_q(\alpha_{Z_{and}}).F_p(\alpha_{Z_{and}}) \qquad \ldots (3)$$

where;

$f_p(\alpha_{Z_{and}})$ and $F_p(\alpha_{Z_{and}})$ **are the PDF and CDF of the AND-CFAR respectively.**
$f_q(\alpha_{Z_{and}})$ and $F_q(\alpha_{Z_{and}})$ **are the PDF and CDF of the AND-CFAR respectively.**
For the OR-CFAR algorithm, when the cell under test is greater than any of the two thresholds, a target will be declared. Otherwise a no target declaration will be made see Figure (2) [10].

$$X_o \underset{H_0}{\overset{H_1}{\gtrless}} \alpha_{Z_{or}} = \mathrm{Min}(Z_{CA}.\,\alpha, Z_{OS}.\,\alpha) \qquad \dots (4)$$

Where: $\alpha_{Z_{or}}$ **is the OR-CFAR adaptive threshold?**
The difference in the derivation of OR-CFAR false alarm probability and detection probability with the AND-CFAR starts from the PDF representing the new threshold setting.
The PDF of $\alpha_{Z_{or}}$ **is given by [10]:**

$$f_{\alpha_{Z_{or}}} = f_p(\alpha_{Z_{or}})[1 - F_q(\alpha_{Z_{or}})] + f_q(\alpha_{Z_{or}})[1 - F_p(\alpha_{Z_{or}})]$$
$$= f_p(\alpha_{Z_{or}}) + f_q(\alpha_{Z_{or}}) - [f_p(\alpha_{Z_{or}})F_q(\alpha_{Z_{or}}) + f_q(\alpha_{Z_{or}})F_p(\alpha_{Z_{or}})] \quad \dots (5)$$

Where;
$f_p(\alpha_{Z_{or}})$ and $F_p(\alpha_{Z_{or}})$ **are the PDF and CDF of the OR-CFAR respectively.**
$f_q(\alpha_{Z_{or}})$ and $F_q(\alpha_{Z_{or}})$ **are the PDF and CDF of the OR-CFAR respectively.**

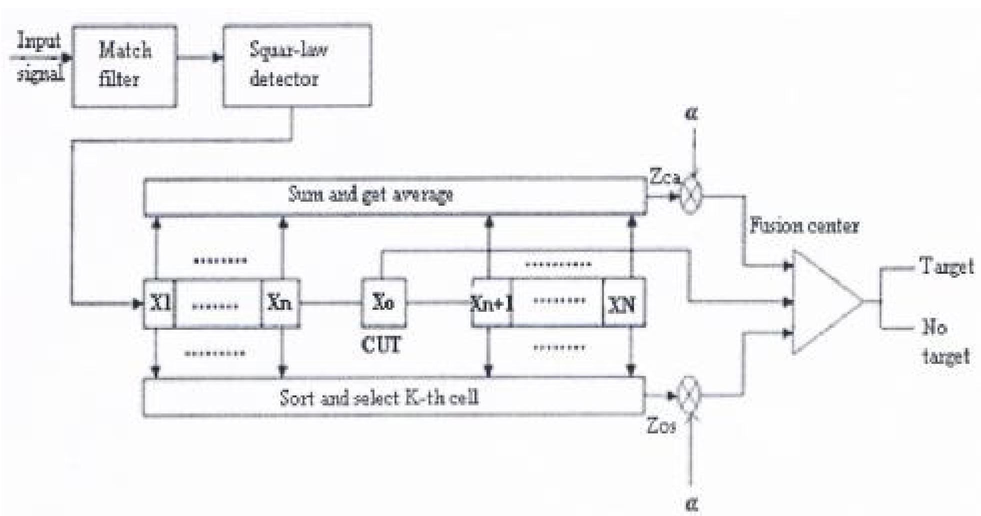

Figure (2) Generalized block diagram AND-CFAR and OR-CFAR detector.

Note; the block diagram in Figure (2) presents AND-CFAR processor according to Eq.(2) and on the other hand present OR-CFAR processor according to Eq.(4).

The formulas were derived under the assumptions that the receiver noise is Weibull distributed and with a Swerling I target. X_0 represents the cell under test. α is the scaling factor and the cells are Independent, Identically Distributed (IID).

AND-CFAR

For AND-CFAR, the target must be greater than both the CA-CFAR threshold and the OS-CFAR threshold to declare a target present, which is equivalent as choosing the maximum value of the CA-CFAR and the OS-CFAR thresholds compared with the target. The decision criterion for this algorithm is [10];

In homogenous background, with all the cells Independent and Identically Distributed (IID), the false alarm probability for AND-CFAR in Weibull background is defined and calculated as;

$$p_{fa}(AND) = k\binom{N}{k}\left[\frac{\Gamma\left(N-k+v^{c}/_{2}+1\right)\Gamma(k)}{\Gamma\left(N+v^{c}/_{2}+1\right)} - \frac{1}{N}\sum_{i=0}^{N-1}\sum_{j=0}^{k-1}\binom{k-1}{j}(-1)^{j}\left(\frac{N}{2N-k+j+v^{c}/_{2}+1}\right)^{(i+1)}\right] + \sum_{i=k}^{N}\binom{N}{i}\sum_{j=0}^{i}\binom{i}{j}(-1)^{i}\left(\frac{N}{2N+j-i+v^{c}/_{2}}\right)^{N} \quad \textbf{... (6)}$$

The detection probability for AND-CFAR is defined and calculated as;

$$p_{d}(AND) = k\binom{N}{k}\left[\frac{\Gamma\left(N-k+\frac{v^{c}/_{2}}{(1+SNR)}+1\right)\Gamma(k)}{\Gamma\left(N+\frac{v^{c}/_{2}}{(1+SNR)}+1\right)} - \frac{1}{N}\sum_{i=0}^{N-1}\sum_{j=0}^{k-1}\binom{k-1}{j}(-1)^{j}\left(\frac{N}{2N-k+j+\frac{v^{c}/_{2}}{(1+SNR)}+1}\right)^{(i+1)}\right] + \sum_{i=k}^{N}\binom{N}{i}\sum_{j=0}^{i}\binom{i}{j}(-1)^{i}\left(\frac{N}{2N+j-i+\frac{v^{c}/_{2}}{(1+SNR)}}\right)^{N} \quad \textbf{...(7)}$$

where; SNR=signal-to-noise power ratio, N=Number of Cells that are used in the detection, k=Rank of the cell and v=Constant scale factor.

OR-CFAR

As the case of OR-CFAR, the target should be greater than any of the CA-CFAR threshold and the OS-CFAR threshold to declare a present target,

which is equivalent to choosing the minimum value of the CA-CFAR and the OS-CFAR thresholds compared with the target.
In homogenous background, with all the cells Independent and Identically Distributed (IID), the false alarm probability for OR-CFAR in Weibull background is defined and calculated as;

$$p_{fa}(OR) = \frac{1}{\left(1+v^{c/2}/_{N}\right)^{N}} - k\binom{N}{k}\frac{1}{N}\sum_{i=0}^{N-1}\sum_{j=0}^{k-1}\binom{k-1}{j}(-1)^{j}\left(\frac{N}{2N-k+j+v^{c/2}+1}\right)^{(i+1)} - \sum_{i=k}^{N}\binom{N}{i}\sum_{j=0}^{i}\binom{i}{j}(-1)^{i}\left(\frac{N}{2N+j-i+v^{c/2}}\right)^{N} \quad \ldots (8)$$

$$p_{d}(OR) = \frac{1}{\left(1+v^{c/2}/_{\frac{(1+SNR)}{N}}\right)^{N}} - k\binom{N}{k}\frac{1}{N}\sum_{i=0}^{N-1}\sum_{j=0}^{k-1}\binom{k-1}{j}(-1)^{j}\left(\frac{N}{2N-k+j+\frac{v^{c/2}}{(1+SNR)}+1}\right)^{(i+1)} - \sum_{i=k}^{N}\binom{N}{i}\sum_{j=0}^{i}\binom{i}{j}(-1)^{i}\left(\frac{N}{2N+j-i+\frac{v^{c/2}}{(1+SNR)}}\right)^{N} \quad \ldots (9)$$

The probabilities of false alarm and detection to AND-CFAR and OR-CFAR for Weibull distribution can be obtained from Eqs.(6), (7), (8) and (9) by substituting any value of shape parameter in the range ($1.2 \leq c \leq 1.8$), also, the probabilities of false alarm and detection to AND-CFAR and OR-CFAR for Exponential distribution can be obtained from Eqs.(6), (7), (8) and (9) by substituting c=1, and the probabilities of false alarm and detection to AND-CFAR and OR-CFAR for Rayleigh distribution can be obtained from Eqs.(6), (7), (8) and (9) by substituting c=2.

Performance of AND-CFAR and OR-CFAR

This section presents the detection performance for (AND-CFAR and OR-CFAR) for three types of clutters distribution (Exponential distribution, Rayleigh distribution and Weibull distribution), and then a comparison is made between them and with that of the CA-CFAR detector and OS-CFAR detector for fixed probability of false alarm (P_{fa}) for Rayleigh clutter distribution.

Detection Performance of AND-CFAR and OR-CFAR Processors for Rayleigh Clutter Distribution c=2

As false alarm probability is fixed, the scaling constant α can be calculated from Equation (6) for c=2 to AND-CFAR and Equation (8) for c=2 to OR-CFAR so that the performances can be evaluated.

Table (1) Scale Factor (α) for AND-CFAR for Rayleigh Clutter Distribution. c=2.

P_{fa}(AND-CFAR)	α(N=8, k=7)	α(N=12, k=11)	α(N=16, k=14)
10^{-4}	7.8564	6.3786	6.2929
10^{-6}	14.5922	11.2363	11.0624
10^{-8}	23.5055	17.3358	16.5456

Table (2) Scale Factor (α) for OR-CFAR for Rayleigh Clutter Distribution c=2.

P_{fa}(OR-CFAR)	α(N=8, k=7)	α(N=12, k=11)	α(N=16, k=14)
10^{-4}	17.7416	13.886	12.486
10^{-6}	37.92	25.978	21.971
10^{-8}	74.323	43.738	34.62907

From the above tables, founded that the value of α increase is the value of P_{fa} decrease for fixed value of N and k, but the value of α decrease if the value of N and k increase for fixed value of P_{fa}.

Equations. (7) and (9) at shape parameter (c=2) are used to calculate the Pd of the AND-CFAR and OR-CFAR for Rayleigh Clutter Distribution respectively, plotted as a function of the primary target (SNR in dB) for $P_{fa}=10^{-8}$, different window sizes N=8, 12 and 16 and with k=7, 11 and 14, where k=0.875N[14], see Figure (s) (3) and (4).

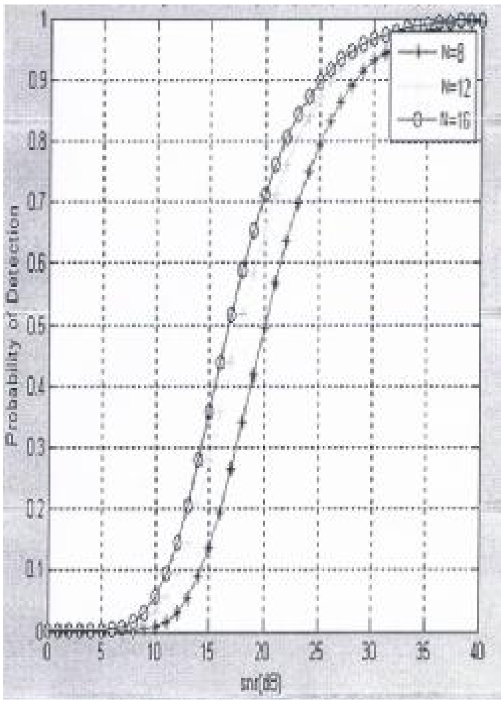

Figure (3)
Detection Performance of AND-CFAR for$P_{fa}=10^{-8}$, c=2, N=(8,12,16).

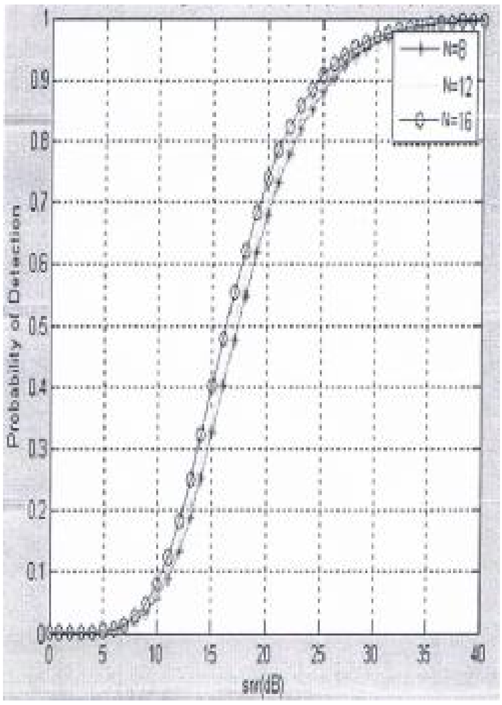

Figure (4)
Detection Performance of OR-CFAR for$P_{fa}=10^{-8}$, c=2, N=(8,12,16).

Detection Performance of AND-CFAR and OR-CFAR Processors for Exponential Clutter Distribution c=1

As false alarm probability is fixed, the scaling constant α can be calculated from Equation (6) for c=1 to AND-CFAR and Equation (8) for c=1 to OR-CFAR so that the performance can be evaluated.

Table (3) Scale Factor (α) for AND-CFAR for Exponential Clutter Distribution c=1.

P_{fa}(AND-CFAR)	α(N=8, k=7)	α(N=12, k=11)	α(N=16, k=14)
10^{-4}	61.723	40.686	40.159
10^{-6}	212.93	126.25	122.38
10^{-8}	552.53	300.533	273.728

Table (4) Scale Factor (α) for OR-CFAR for Exponential Clutter Distribution c=1.

P_{fa}(OR-CFAR)	α(N=8, k=7)	α(N=12, k=11)	α(N=16, k=14)
10^{-4}	314.78	192.83	155.905
10^{-6}	1437.9	674.882	482.74
10^{-8}	5523.7	1913.05	1199.1

Equations. (7) and (9) at shape parameter (c=1) are used to calculate the Pd of the AND-CFAR and OR-CFAR for Exponential Distribution Clutter respectively, see Figure (s) (5) and (6).

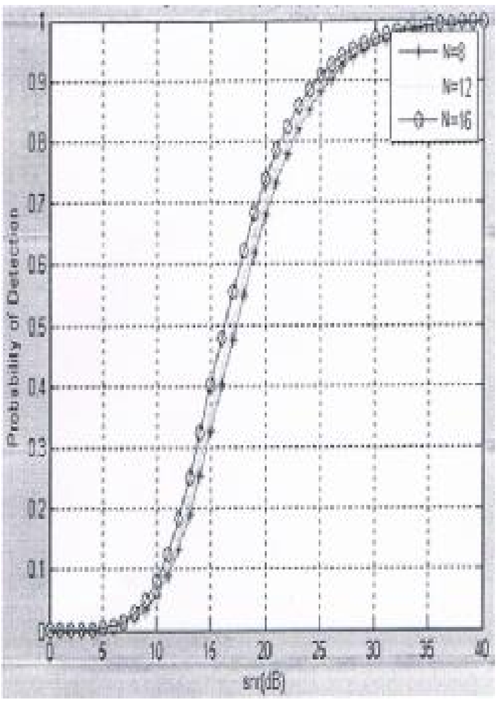

Figure (5)
Detection Performance of AND-CFAR for $P_{fa}=10^{-8}$, c=1, N=(8,12,16).

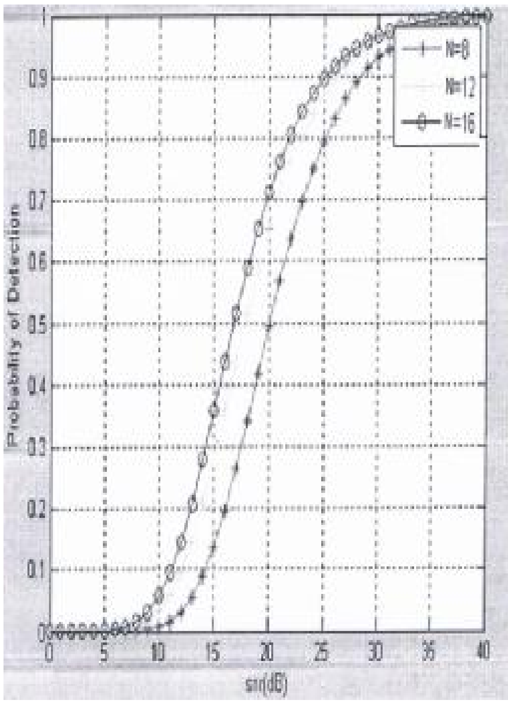

Figure (6)
Detection Performance of OR-CFAR for $P_{fa}=10^{-8}$, c=1, N=(8,12,16).

Detection Performance of AND-CFAR and OR-CFAR Processors for Weibull Clutter Distribution c=1.5

As false alarm probability is fixed, the scaling constant α can be calculated from Equation (6) for c=1.5 to AND-CFAR and Equation (8) for c=1.5 to OR-CFAR so that the performance can be evaluated.

Table (5) Scale Factor (α) for AND-CFAR for Weibull Clutter Distribution c=1.5.

P_{fa}(AND-CFAR)	α(N=8, k=7)	α(N=12, k=11)	α(N=16, k=14)
10^{-4}	15.6177	11.8293	12.113
10^{-6}	35.659	25.1668	24.6486
10^{-8}	67.334	44.8673	42.157

Table (6) Scale Factor (α) for OR-CFAR for Weibull Clutter Distribution c=1.5.

P_{fa}(OR-CFAR)	α(N=8, k=7)	α(N=12, k=11)	α(N=16, k=14)
10^{-4}	46.274	33.3777	28.967
10^{-6}	127.394	76.942	61.538
10^{-8}	312.48	154.105	112.8806

Equations. (7) and (9) at shape parameter (c=1.5) are used to calculate the Pd of the AND-CFAR and OR-CFAR for Exponential Distribution Clutter respectively, see Figure (s) (7) and (8).

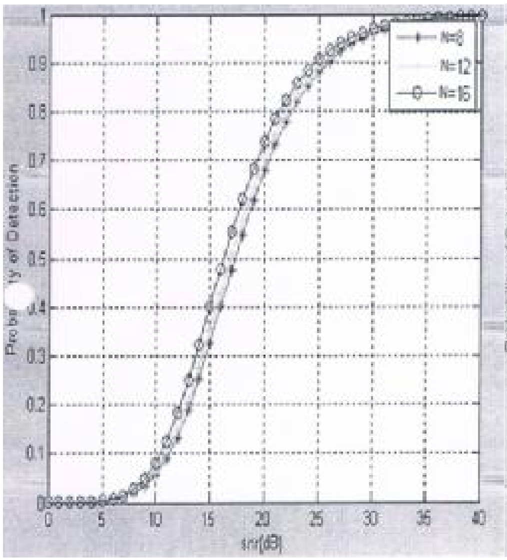

Figure.(7)
Detection Performance of AND-CFAR forP_{fa}=10^{-8}, c=1.5, N=(8,12,16).

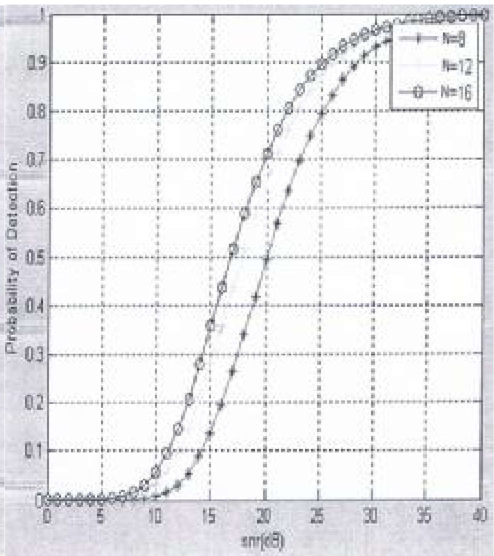

Figure.(8)
Detection Performance of OR-CFAR forP_{fa}=10^{-8}, c=1.5, N=(8,12,16).

Performance Comparison

The detection probability under different SNR is actually compared for the four detectors (CA-CFAR, OS-CFAR, AND-CFAR and OR-CFAR). In Fig. (9), the number of reference cells is N=12, a designed probability of false alarm $P_{fa}=10^{-8}$and the ordered sample k=11. It can be seen that, the AND-CFAR achieves better detection probability than both OS-CFAR, CA-CFAR and OR-CFAR is of very close performance to CA-CFAR but better than OS-CFAR. Furthermore, AND-CFAR is better than OR-CFAR and the best among the four.

To see the effect of k change value on the Pd of four detector in Figure (10), the k setting is changed to (7) and keeps the other factors unchanged.

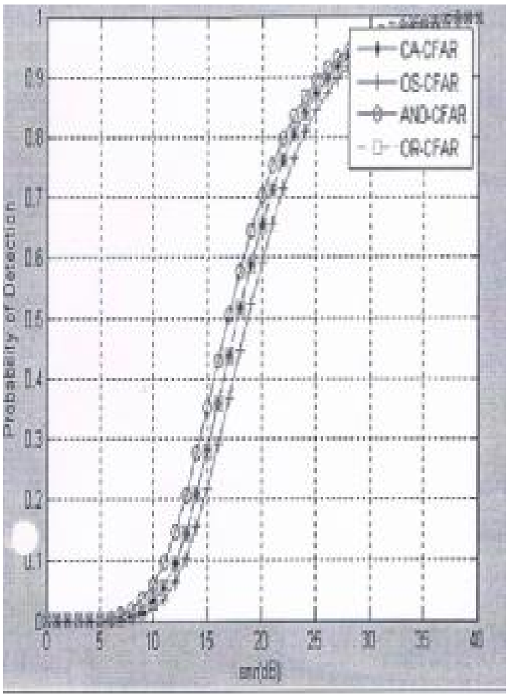

Figure.(9)
Comparison of Pdamong the four CFAR detectors with $P_{fa}=10^{-8}$, c=2, N=12, k=11.

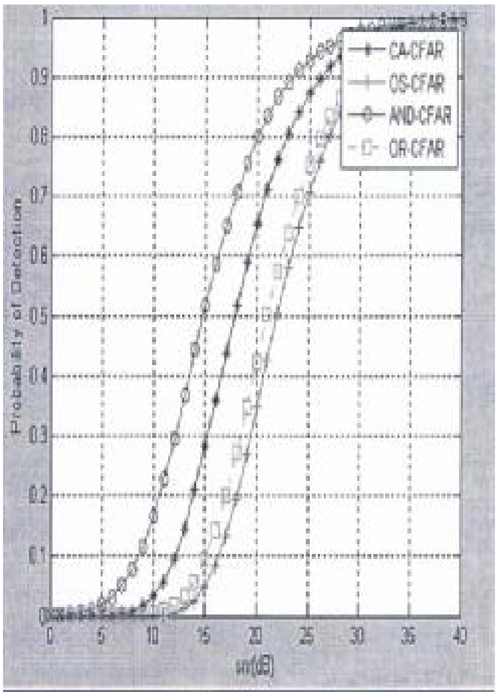

Figure.(10)
Comparison of Pd among the four CFAR detectors with $P_{fa}=10^{-8}$, c=2, N=12, k=7.

CONCLUSIONS

- **The detection performance for the AND-CFAR and OR-CFAR has been not affected by changing clutter models (clutter PDF).**
- **The AND-CFAR has better detection performance than OR-CFAR for the three types of clutters (Rayleigh distribution, Exponential distribution, Weibull distribution).**
- **The AND-CFAR achieves better detection probability than both OS-CFAR and CA-CFAR.**

- **The OR-CFAR is very close to the CA-CFARperformance, but better than the OS-CFAR for the (Rayleigh distribution) if the ordered sample k=0.875N, but better than the OS-CFAR only for other values of "k".**

REFERENCES

[1]Finn, H. M., R. S. Johnson. "Adaptive Detection Mode with Threshold Control as a Function of Spatially Samples Clutter Estimation". RCA Review, Vol. 29, No. 3, 414-464, 1968.

[2]Rohling, H. "Radar CFAR Thresholding in Clutter and Multiple Target Situaitons". –In: IEEE Trans., Vol. AES-19, No. 4, 608-621, 1983.

[3]Kabakchiev, Chr., V. Kyovtorov, I. Garvanov. "OS CFAR Detector for PN Signal Processing in Multipath Interference". –In: Proc. Of IEEE – International Radar Conference "Radar 2004", Toulouse, France, CD-6P-SP-121, Vol. 6, 2004.

[4]Hansen, V. G. "Constant False Alarm Rate Processing in Search Radars". – In: IEE International Radar Conference, London, England, 325-332, 1973.

[5]Hansen, V. G., J. H. Sawyers. "Detectability Loss Due to Greatest-Of-Selection in a Cell-Averaging CFAR". –In: IEEE Trans., Vol. AES-16, 115-118, 1980.

[6]Moore, J. D., N. B. Lawrence. "Comparison of Two CFAR Methods Used with Square Law Detection of Swerling I Targets". In: Proc. Of IEEE International Radar Conference, Arlington, VA, USA, 403-409, 1980.

[7]Weiss, M. "Analysis of Some Modified Cell-Averaging CFAR Processors in Multiple Target Situations". In: IEEE Trans., Vol. AES-18, No. 1, 102-114, 1982.

[8]Trunk, G. V. "Range Resolution of Targets Using Automatic Detectors". In: IEEE Trans., Vol. AES-14, No. 5, 750-755, 1987.

[9]Hou, X., N. Morinaga, T. Namekawa. "Direct Evaluation of Radar Detection Probabilities". In: IEEE Trans., Vol. AES, 418-423, 1987.

[10]Lie Zhao, Weixian Liu, Xin Wu and Jeffrey S Fu.: "A Novel Approach for CFAR Processors Design". IEEE Radar Laboratory, School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore, pp. (284-288), (639798), 2001.

[11]Weixian Liu, Jeffrey S. Fu. And Lei Zhao: "A Novel Approach for CFAR Detector Design in Weibull Background". IEEE Radar Laboratory, School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore, pp. (338-340), (639798). 2001.

[12]Matsuo, S. and Yuhai, M. "Weibull Radar Clutter", 1st edition, Peter Peregrinus LTD., London, United Kingdom, 1990.

[13]Gaspar Galati, "Advanced Radar Techniques and Systems", 1st edition, Peter Peregrinus Ltd., on behalf of the Institution of Electrical Engineers, London, United Kingdom 1993.

[14]Gandhi, P.P., and Kassam, S. A.: "Analysis of CFAR Processor in Non-Homogenous Background", IEEE Trans. On Aerospace and Electronic System, Vol. AES-24, No. 4, pp.(427-445), July 1988.