International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
SJIF (2025): 8.036

# MSSVI-CFAR for Non-Homogeneous RADAR Target Detection

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**Abstract:** ***Many algorithms have been proposed to provide constant false alarm rates (CFAR) for different RADAR conditions, including multiple interfering target situations and clutter cloud environments. However, none of these algorithms study the worst possible radar condition, the combination of multiple interfering targets within a clutter cloud. Because they lack a spike-rejecting algorithm, the variable index constant false alarm rate detector (VI-CFAR), which combines cell-averaged constant false alarm rate (CA-CFAR), greatest of (GO-CFAR), and smallest of (SO-CFAR), performs satisfactorily in homogeneous environments but is unfit with real-time radar purposes. The maximum spike subtraction variable index constant rate of false alarms is thus designed using a new technique from the maximum spike subtraction-constant false alarm rate family. The suggested approach adapts to all radar situations by using the variable index method. The proposed method uses the variable index method to adapt to all radar environments.***

**Keywords:** Clutter cloud, multiple interfering targets, VI-CFAR, MSS-CFAR, inhomogeneous

## 1.Introduction

Target detection in the radar receiver depends on the presence of a clutter cloud and multiple interfering target spikes. Therefore, eliminating the high amplitude samples (spikes) from the CFAR reference window is necessary to establish a constant rate of false alarms (CFAR) and highest target detection. Spikes originate from an unwanted clutter cloud. The ordered statistic OS-CFAR suggested solving the problem of multiple interfering targets to establish the constant rate of false alarms. This method arranges the noise samples in ascending order and chooses one sample as an estimate for the background noise; the rank of the chosen sample is found by the subtraction of the prior known number of targets from the overall number of the ordered samples [1][2][3]. The main purpose of CFAR is to tune the threshold to maintain the maximum detection in the radar receiver system while the false alarm rate remains constant. As the clutter power is variable at any place, a fixed threshold value will not work well to detect the target's signal in range cells. An adaptive threshold is automatically established by a CFAR processor that detects the input data while considering the clutter level, which helps to reduce CFAR loss in the presence of interference. These properties made the adaptive threshold widely used for CFAR processing types [1][2][6].

The OS-CFAR method cannot work efficiently with the clutter spikes. Other algorithms, such as the censored mean level detector (CMLD-CFAR), do not consider all radar environments; these algorithms show a positive response in clutter clouds with multiple interfering targets, but they require a better algorithm to extract the target when both multiple-target and clutter cloud situations appear together. The other methods that were suggested after OS-CFAR and CMLD-CFAR used very complicated hardware and therefore need high processing time. The variable indexed VI-CFAR used statistical criteria to switch among CA, GO, and SO-CFAR to deal with all radar conditions and environments [4][5]. Additionally, the MSS-CFAR family was developed to eliminate clutter spikes and interfering target spikes.

## 2.The Main Problem

There are three radar environments, which are homogeneous environments, non-homogeneous environments, and non-uniform environments. The homogeneous environments assume that all samples in the reference windows have the same statistics. When a clutter cloud appears in the reference window, it causes a sudden rise in the CFAR threshold level. This situation is referred to as a non-homogeneous environment, and when multiple interfering target spikes appear in the reference window, it causes sudden increases in the CFAR threshold value, which is known as a non-uniform environment. CFAR is designed to work effectively in homogeneous environments and needs special design to deal with other environments. The clutter edge spike samples and multiple interfering spike samples are the main reasons for not achieving an accurate threshold assumption that causes many false alarm detections of targets; therefore, the spikes must be treated and eliminated to have a favorable assumption for background noise [1][2].

## 3.CA-CFAR family

The CA-CFAR method employs the mean of nearby resolution cells to estimate the threshold, which can be in range, Doppler, or both. The smallest of (SO) CFAR is intended to enhance target detection in the existence of multiple interfering targets and take the lowest sum from the two splits, leading and lagging splits of the reference window, in order to detect the clutter cloud and multiple interfering signals when there is a clutter cloud or a non-uniform background with multiple interfering signals. However, SO-CFAR was unable to effectively handle cluttered cloud environments. The greatest of (GO) CFAR is devised by choosing the section with a bigger total sum to prevent false alarms generated by a clutter cloud [2][3].

## 4.Structure of MSS-CFAR algorithm

Maximum spike subtraction-constant false alarm rate (MSS-CFAR) is designed to remove these spikes from CFAR


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reference windows, improving noise background estimation and enhancing primary target detection; it includes a lock circuit that selects the highest sample from both split of the reference windows. The highest sample will be cancelled from each section of window. If the average of the leading and lagging samples is taken to construct the cell-averaged maximum spike subtraction (MSSCA-CFAR), or the greater of the two section of windows, is taken to construct the greatest of maximum spike subtraction constant false alarm rate (MSSGO-CFAR), or the smallest of the two is taken to construct the minimum of maximum spike subtraction (MSS SO-CFAR) [1][7].

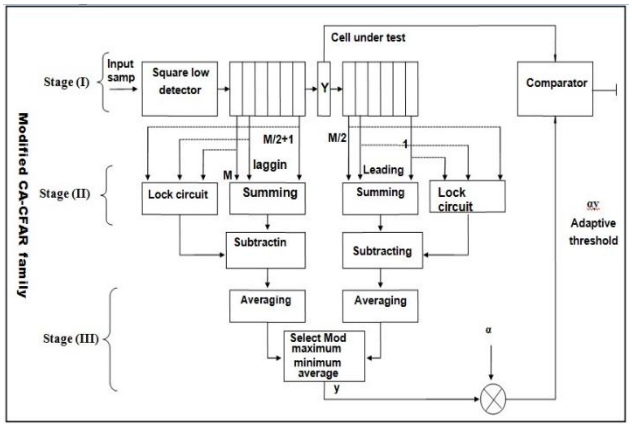


Figure 1 MSS-CFAR family [1][7]

## 5.Theory of VI-CFAR

This method automatically alternates between the CA-CFAR, SO-CFAR, and GO-CFAR with respect to the average and variability of the cells in the leading or lagging portion of the reference windows [4][5][8]. The benefits of each of the three CFAR approaches are incorporated into this new method. To switch the appropriate CFAR method for the leading and trailing windows, the mean and variability index are calculated. The variability in relation to the reference cells' magnitude increases with the variability index. If there are high-power targets, the leading window will be more variable than the lagging window.

**Table 1:** VI-CFAR decision logic

| Leading Variable? | Lagging Variable? | Different Mean? | Adaptive threshold | CFAR Method |
|---|---|---|---|---|
| No | No | No | $\alpha_N.\Sigma AB$ | CA |
| No | No | Yes | $\alpha_N \cdot \max(\Sigma A, \Sigma B)$ | GO |
| Yes | Yes | ---- | $\alpha_N \Sigma B$ | CA |
| No | Yes | ---- | $\alpha_N \Sigma A$ | CA |
| Yes | Yes | ---- | $\alpha_N . \min(\Sigma A, \Sigma B)$ | SO |

The variability index equation measured by [5]:

$$VI = N \frac{\sum_{i=1}^{N} X_i^2}{(\sum_{i=1}^{N} X_i)^2} \quad (1)$$

Here, $X_i$ is a sample of the resolution cell with rank i; the summation is taken from cells Xi of either the leading or lagging window [4][5]. The algorithm determines whether the leading, lagging, or both windows are variables after computing VI. The window is considered non-variable if its variability index is less than the constant $K_{VI}$and regarded as variable when the variability index is greater than $K_{VI}$.

$$VI \leq K_{VI}: \text{Homogeneous}$$
$$VI > K_{VI}: \text{Non-homogeneous} \quad (2)$$

where $K_{VI}$ is a threshold. The difference between the leading (A) and lagging (B) window means is measured by the mean ratio (MR). It is calculated as a ratio of each window's reference cell summations.

$$MR = \frac{\sum_A X_i}{\sum_B X_i} \quad (3)$$

If MR within the range defined by the mean ratio constant, $K_{MR}$, then the means of leading and lagging window are assumed to be equal [4][5][8]. The decision-making procedure to select the proper method for every calculated environment is shown clearly in Table 1.

## 6.mss-cfar theory

The MSS-CFAR family improves target detection that exists in the clutter cloud environments by removing the largest spike from each reference-window half before estimating the detection threshold. If a total of M reference cells is used, one maximum sample is excised from each section of the window. Therefore, J = 2 samples are removed; these may represent interfering targets or, when no target is present, the largest noise samples. The effective window size for threshold estimation is

$$S = M - J \quad (4)$$

Because J = 2 for the modified CA-CFAR family:

$$S = M - 2 \quad (5)$$

## 7.MSSVI-CFAR

The VI statistic is useful in discriminating between homogeneity and non-homogeneity in a given non-Gaussian environment. There are some weak points in this idea, despite the complicated mathematical approach, which is very difficult to implement. It is based on the assumption that there will be one strongest interfering target or clutter cloud spike in each split of the reference window. If there are equal interfering targets and clutter edges in the two splits of the leading and lagging windows, the whole algorithm will be less effective [4][7]. Modification on VI-CFAR is suggested to use the maximum spike subtraction CFAR (MSS-CFAR) family to construct a new maximum spike subtraction variable index MSSVI-CFAR processor that employs a dynamic background estimation by using the VI predicting criteria and use the suitable method from MSS-CFAR family. before estimating an adaptive threshold by measuring the cleaned background and computing the variability index for each spike-suppressed half-window and comparing their means. These tests identify whether the local background is homogeneous, uneven, or affected by a clutter edge. Select the threshold rule dynamically.


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i. If both halves are stable with similar means**, use** MSSCA-CFAR.
ii. If both halves are stable but with different means**, use** MSSGO-CFAR, which is appropriate near a clutter-cloud edge.
iii. One-half variable**:** use the univariable half through MSSCA-CFAR.
iv. Both halves are variable**:** use MSSSO-CFAR to limit the influence of infected reference data.

To make the target decision. Compare the cell-under-test amplitude with the selected adaptive threshold. A target is declared when it exceeds that threshold.

**Table 2:** MSSVI-CFAR decision logic

| Leading Variable? | Lagging Variable? | Different Mean? | Adaptive threshold | CFAR Method |
|---|---|---|---|---|
| No | No | No | $\alpha_N.\Sigma AB$ | MSSCA |
| No | No | Yes | $\alpha_N \cdot \max(\Sigma A, \Sigma B)$ | MSSGO |
| Yes | Yes | ---- | $\alpha_N \Sigma B$ | MSSCA |
| No | Yes | ---- | $\alpha_N \Sigma A$ | MSSCA |
| Yes | Yes | ---- | $\alpha_N . \min(\Sigma A, \Sigma B)$ | MSSSO |

## 8.Matlab Test Model

The test model in Figure 2 shows there are five multi-targets inside the clutter cloud. The clutter cloud has 15 dB and many targets located in many locations. dB, and 50 dB at 40th and 50th and at 45th and 55th, and have 30 dB, a clutter cloud which includes five targets, two dB, two 40 dB, and one 70 dB at cell locations from the 100th to the 200th cell, and also one target 40 dB at the 230th cell between two targets with 20 dB in locations 225th and 235th cell, respectively [1][7].

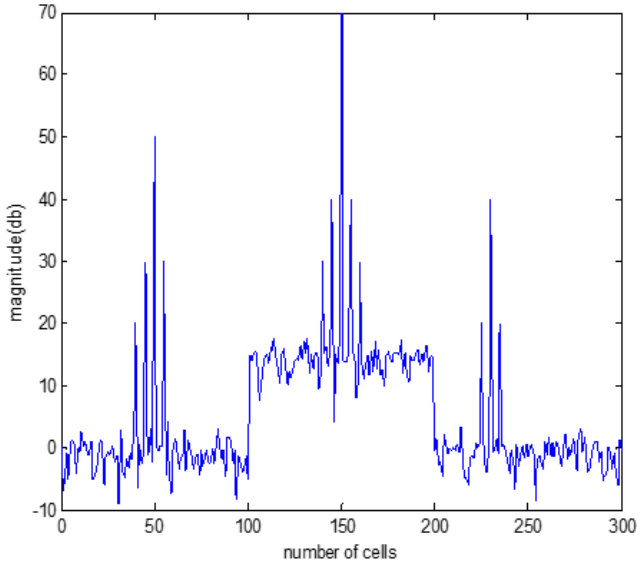


**Figure 2 :** Test model

When applied to the test model, both CA-CFAR and VI-CFAR will respond as shown in Figure 3, clearly indicating that they miss all targets except for the strongest one.

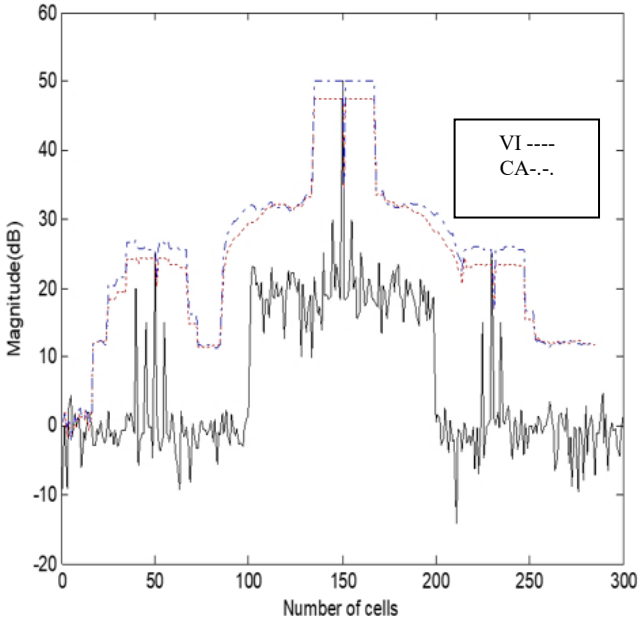


**Figure 3 :** VI-CFAR and CA-CFAR response to test model M=32.

## 9.MSSVI-CFAR algorithm response

By applying the MATLAB simulation of MSSVI-CFAR to the MATLAB test model, the response shows that it can easily detect all targets and also successfully detect the two edges of the clutter cloud, as shown in Figure 4, while VI-CFAR could not detect all targets, as shown in Figure 3.

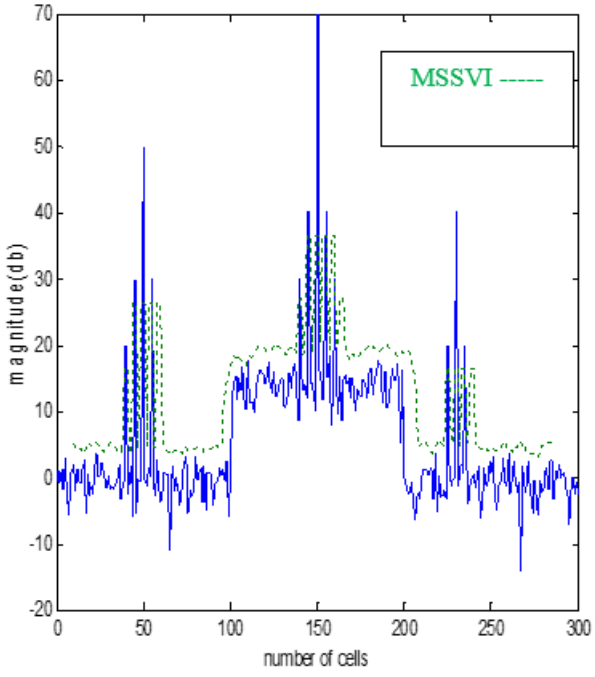


**Figure 4:** MSSVI-CFAR response, M=32

## 10. Result and discussion

Simulation results indicate that all targets detected by MSSVI-CFAR, which is part of the MSS-CFAR family, exhibit a more efficient response compared to those detected by VI-CFAR, which relies on the CA-CFAR family.


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Additionally, the simulation indicates that MSSVI-CFAR adapts easily to all possible radar environments.

## 11. Conclusion

The spike excise circuit used to construct the new MSSVI-CFAR algorithm is another method to improve VI-CFAR by using the ordered statistics OS-CFAR family and choosing the greater of ordered statistics OSGO-CFAR to avoid the clutter effect [8], but that method is impractical due to its high computational time to sort samples, requires complicated hardware, is more expensive, and still allows the clutter effect [8].

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