Multi-Target. Detection in Cutter-Edge environments using modified GO-CFAR.

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1-ABSTRACT.: Automatic target detection radar requires adaptive threshold achieved by Constant False Alarm Rate (CFAR) circuit in order to control the false alarm caused by variations in clutter background.

This work focuses on the worst radar environment that happens when abi.upt variation in clutter background merged with multi-interfering target. .to detect target in such environments, it needs robust CFAR algorithm that excises the target spikes and clutter edge's from CFAR window to give the best possible estimation to the noisy background Rickard and Dillard[1]and Weiss[2] suggested to design the modified GO-CFAR circuit using analogue technique that is very old and could not match with the speed of new computer used in radar receivers ,and also suffers from many hazard problems because of the bad component frequency response. In addition to that Rickard and Dillard[1] and Weiss[2] suggested to use rank circuit that need very long time, therefore it suggested to use new method of successive comparison circuit instead of rank circuit to speed up threshold estimation process and also using digital technology of FPGA instead of analogue technique

This new modification suggested to make the algorithm more effective in detection with less processing time , and when extended to other CA-CFAR family the modified CA-CFAR family constructed for the first time in this work .Parallel processing that shows lack of synchronization in the old model suggested by Rickard and Dillard, is an important feature in the new modified GO-CFAR algorithm since the spike selection process is working at the same time with the summing of samples process that makes this algorithm much less processing time from any other algorithm that works in same environment.

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2- Introduction.

Most CFAR processors (including other parametric and distribution-free detectors) cannot maintain the optimal performance when certain, generally held assumptions about the environment are violated. For the cell average-constant false alarm rate (CA-CFAR). the inherent assumption is that the statistics of the interference at each reference cell are the same as the statistics of the test cell. There are three common situations in which this condition is not met -:

The first problem is Edges: One common situation is step increases in the background noise level, such as that produced at clutter or chaff edges. The second problem of primary concern in a search radar is the capture effect that happens when interfering targets lie in the reference cells of the target under consideration (primary target),the threshold is raised and detection of the primary target is seriously degraded[2]. The third problem that is not considered as common problem as the other two problems mentioned above that happens when interfering targets are close to the targets are close to each other , then CFAR may record the strongest one. The consequent masking of one target by the other is called suppression effect[2. 4].

Several solutions to the problem of maintaining CFAR in multiple target situations and clutter edge environment have been proposed. They yield good performance but require more complex implementation. If there is clutter edge in some reference window that problem may be handled by using greatest of-constant false alarm rate (GO-CFAR)and for multi-target using smallest of constant false alarm rate(SO-CFAR) but if there are closely separated targets merged with clutter edge and also the clutter edge expected to be too sharp which is the worst radar environment , then GO-CFAR algorithm should be used along with some means of censoring large returns from the reference cells and for that reason the modified GO-CFAR concept was born. Modified GO-CFAR algorithm that suggested by Rickard and Dillard[1] and recommended by Weiss[2] is studied and when comparing it with other algorithms it was seen that it uses the same algorithm of order statistic-constant false alarm rate (OS-CFAR) in ranking the samples according to their magnitude when trying to excise the target from the threshold estimation. And in order to improve the response of this algorithm we proposed new approach to satisfy modified GO-CFAR algorithm by using successive comparisons instead of ranking and sorting process in order to speed up the excise of the targets samples from the estimated noise background that used in the threshold estimation .

3-Theory of CFAR.

CFAR processors were originally developed using a statistical model of uniform background noise. However , that model not representative of real situations because it is impossible to describe all radar working conditions by a single model. For that reason, test model with clutter clouds and stationary targets are chosen in different critical cases to make comparison between different CFAR procedures.

in the test model 300 echo samples generates by using mat lab from weibull CDF that represented by eq(l) [7].

If x is the amplitude of the output voltage, the Weibull CDF is[8].

$Q(x) = 1 - e^{-(\frac{x}{b})^\wedge a}$……………………………………….(1)

the Weibull probability density function PDF (which is the derivative of CDF) [9].

P(x)=$\frac{a}{b}(\frac{x}{b})^{a-1}e^{-(\frac{x}{b})^\wedge a}$…………………………………….....(2)

These samples have Weibull PDF at constant skewness(shape) parameter(which usually taken equal to 2,and it is known from eq(2) that with skewness(shape) parameter equal to 2 the Weibull PDF will take the form of Rayleigh PDF Therefore , one can use Rayleigh distributed data for calculating multiplier factor to both OS-CFAR and CA-CFAR families[4].

The targets in this model are assumed to be Marcum targets(non fluctuation) the clutter cloud in each model always combines two clutter edges[4]. to test these methods radar environments will be created in a model and each algorithm is applied separately to this model to examine the behavior of each of them in the worst radar environments and other environments. There are factors of special importance when dealing with CFAR-algorithms which are size Of CFAR Window(M)that are the number of range cells used to estimate adaptive threshold and closely separated targets. When M is increased ,the CFAR loss in a stationary noise background(monotonically decreases, together with an increased hardware complexity. with increasing in M an inevitable violation will occur of the inherent assumption that the noise samples are identically distributed over the reference window which is used to estimate the noise in the cell under test. Therefore, in a non homogeneous environment CFAR penalty sometimes increases with larger M . also for large M the likelihood that An interfering' target or a 'spiky' clutter return has enterer reference window is obviously larger for larger M[2].

When another interfering target lies within the reference cells with the primary target(concerned target)the threshold is raised and detection of the primary tarp seriously degraded. Sometimes closely separated targets called dense environment ,e.g., for a radar with compressed pulse width of 1us and C window with 16-cells on each side of the test cell and if two targets are within antenna beam width and are separated in range less than 100m the described suppression effect occurs[2].

4- Simulation model.

The CFAR algorithm is tested with testing model that constructed from multi targets that have different magnitudes and to make detection procedure more complicated from the other models the multi-target are merged with clutter cloud and there is also closely separated targets which are located in different places. For more details there are from 100th to 200th cell clutter cloud which is centered by five closely targets(2-40dB,2-70dB,100dB)respectively, and there is one target 50 dB magnitude at 50th cell centered between two target with 30dB magnitude locations 40th and 60th cell respectively, and also two targets with 40dB magnitude at locations 225th and 250th as shown in fig(1).

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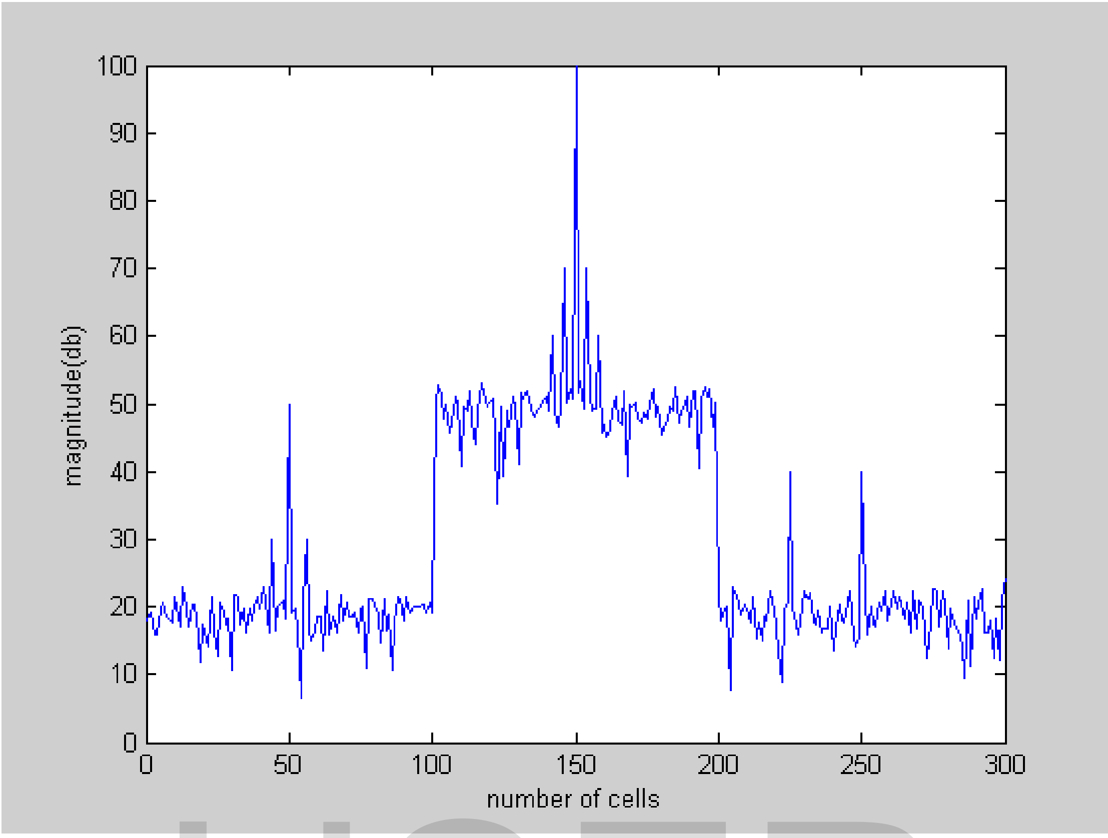

Figure(1)the testing clutter model.

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5-CA-CFAR Family Simulation.

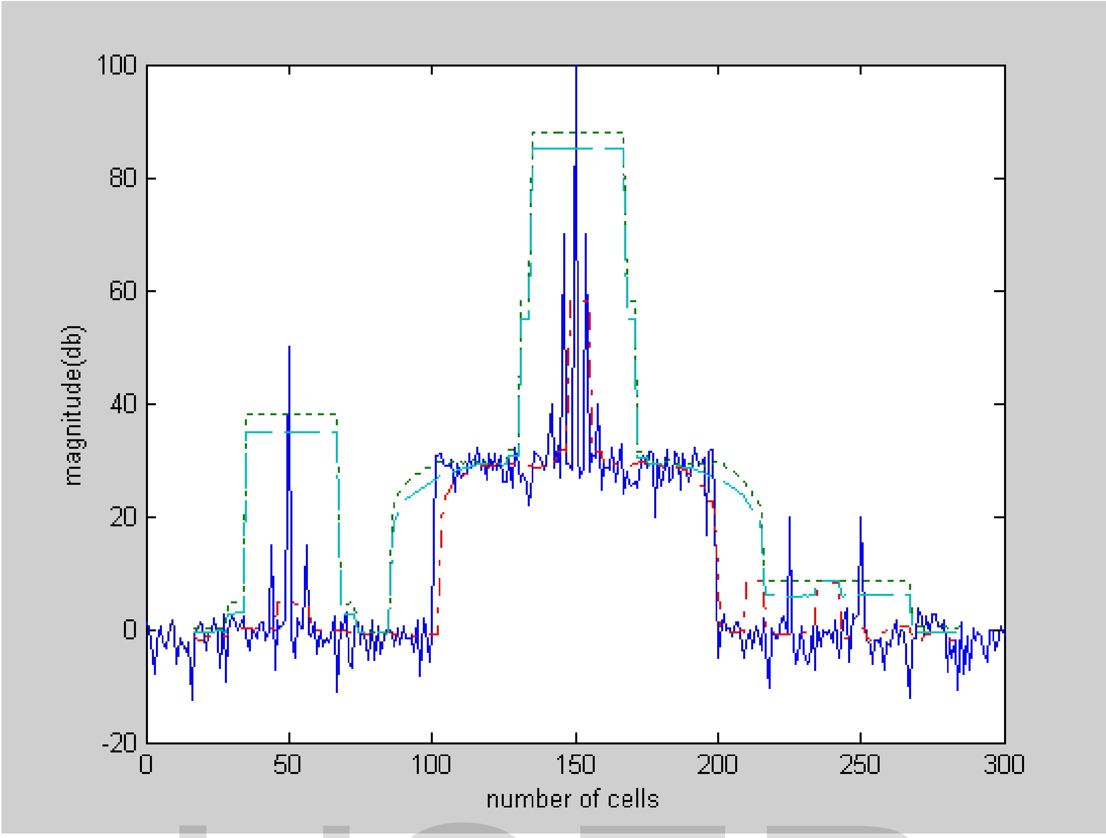
The probability of detection of The CA-CFAR is given[ ]:

$$P_D\ (SNR, \alpha, M) = (1 + \frac{\propto}{M(1+SNR)})^{-M} \qquad \text{.................................(3)}$$

M is window size .It is a scaling factor that determines the probability of false alarm (a) and SNR is the average signal-to-noise ratio The probability of false alarm of the CA-CFAR can be obtained from eq (3) by setting the average SNR to zero, thus :

$$P_{fa} = (1+\propto/M\ )^{-M} \qquad \text{.................................(4)}$$

The CA-CFAR family algorithm has been simulated using mat lab v6 and when applying CA-CFAR algorithm with GO-CFAR and SO-CFAR to the testing model and taking M=16,CA-CFAR multiplier=1.371 and SO-CFAR multiplier=5.131, and GO CFAR multiplier=2.42, so as to keep probability of false alarm 134,=10' ,the result will be, as shown in fig(2).



Figure(2)CA-CFAR Family with M=16, $P_{fa} = 10^{-6}$ applied to testing model.

As shown, CA-CFAR family cannot handle this merger between clutter and multi-target since all of them miss clutter edge and CA,GO-CFARS misses six targets which are the closely separated targets inside clutter cloud while the SO-CFAR buried completely in the clutter cloud and shows the worst response in this model .

The output of GO-CFAR is larger than OSSO-CFAR and OS-CFAR which means larger loss in S/N ratio. Trading —off the behavior of the CA-CFAR family it will be seen clearly that GO-CFAR has the best behavior while the CA-CFAR has the worst response to this model since when CFAR methods are applied to the models, it can be seen from fig(3.5) that CA-CFAR family can handle only the first model, while as shown in fig(3.6) only GO-CFAR handles the second model successfully while SO-CFAR with CA-CFAR fail. In the third model as shown in fig(3.7)even GO-CFAR fails with the other CA-CFAR and SO-CFAR.

6- OS-CFAR Family Simulation.

A CFAR based on an ordered statistic technique (OS-CFAR)has some advantages over CA-CFAR especially in clutter edges or multiple target environments. Unfortunately, the large processing time required by this technique limits its use and for this reason the OS-CFAR family extends with two new OS-CFAR that require only half the processing time. One is an ordered statistic greatest of CFAR(OSGO), while the other is an ordered statistic smallest of CFAR(OSSO). The probability of detection of OS-CFAR is given :

$$p_D = \frac{(\alpha_D + M - K)!}{(\alpha_D + M)!} \frac{M!}{(M-K)!} \quad \text{...(5)}$$

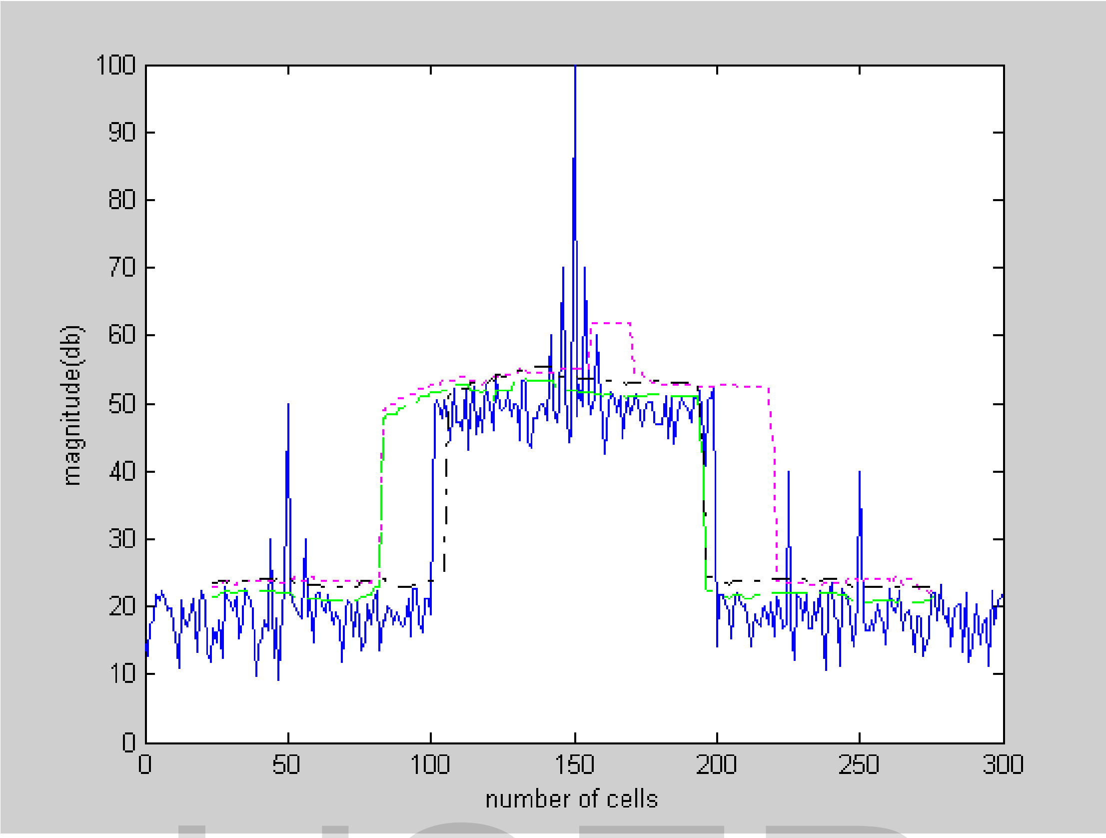
where :

$$\alpha_D = \frac{\alpha}{1+\overline{SNR}} \quad \text{...(6)}$$

That probability of detection of OS-CFAR assumed for a Rayleigh noise or clutter OS-CFAR yields a false alarm probability that is function of the number of the Reference cells M, the rank of the representive cell k, and the scaling factor ∝ . The probability of false alarm of the CA-CFAR can be obtained from eq(5) by setting the average SNR to zero, thus

$$p_{fa} = \frac{(\alpha + M - K)!}{(\alpha + M)!} \frac{M!}{(M-K)!} \quad \text{..(7)}$$

When ordered statistics OS-CFAR family are simulated with predetermined umber of targets equal to ten and applied to testing model as shown in fig (3). [t is shown clearly that OSGO-CFAR handles testing model successfully and only misses one small target, but OS-CFAR and OSSO-CFAR fail in this model .the output of OSGO-CFAR is larger than OSSO-CFAR and OS-CFAR which means larger loss in S/N ratio



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figure(3)OS —CFAR family applied to testing model , M=48, $P_{fa} = 10^{-6}$

he window is taken M=48 for comparison with CA-CFAR family because the nature of excising the spikes of this method needs larger windows.

The OS-CFAR was proposed as the most robust algorithm in clutter edge and multi-target environment by R.R1FKIN [10]. On the other hand, OSGO-CFAR needs very high processing time and because of sorting process for the samples, it is very hard to implement in an electronic circuit. From practical view, the problem involve searching for another method that handles testing model but needs less hardware than OSGO-CFAR. Therefore, it may implemented successfully, and it can function adequately in a complex non homogeneous environment consisting of both clutter edges and closely separated targets, and that it can minimize both excessive false alarms and detection suppression effects.

7-Construction of Modified CA-CFAR Family.

The new algorithm combine ordinary CA-CFAR family detectors with spike selection lock circuit in leading and lagging windows which select the maximum sample in each window which will be subtracted from that window as shown in fig(7) . Two reference windows ,upper and lower(U,L)are formed from the sum of M/2 cell outputs on the leading and lagging side after spike subtraction process. If the average of (U,L)is taken then modified CA-CFAR is constructed. On the other hand if the greatest or the smallest of (U,L)is taken, then the modified GO-CFAR and modified SO-CFAR is constructed respectively. The modified CA-CFAR family structure is divided in to three stages as shown in fig(7) The first stage ,is the same general CFAR detection scheme as the square law detected video range samples are sent serially in to a shift register of length M+1 window which contain M/2 leading reference cells and M/2 lagging reference

The second stage ,contain two parallel processing circuits that is work on the cell samples at the same time. The first process is summing process circuit for the leading and the lagging windows. This process is synchronized with the second processing circuit which is the maximum sample lock process circuit which is done by the two lock circuits in the leading and the lagging window. The maximum sample selected from leading and lagging window will be subtracted from the sum of samples in each window. The lock circuit works under the assumption that the target echo signal is always greater than the noise echo in magnitude, therefore, when excising the target sample from the window sample this may lead to a better estimation of the background noise in determining the adaptive threshold and increasing the probability of detection and decreasing the probability of false alarm since this excising process make robust scheme that could not be affected easily with multi-target and clutter-edge environments. After the subtraction process in the second stage subtracts the maximum sample from the summing process result in the leading and lagging windows ,the result is averaged by neglecting the three least significant bits for M=16 which means dividing by 8 . The third stage , is the selection logic stage that select either the mean of the

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leading and lagging window to construct the modified CA-CFAR, or minimum or maximum of the leading and lagging to construct the modified SO-CFAR and the modified GO-CFAR respectively.

8- Theory of proposed method of Modified CA-CFAR.

For M=16 and number of targets J=2(or could be maximum noise target condition) are excised from window the new sample in no window size that used for threshold estimation will be:-

S=M-J ……………………………………………………………………..(8)

As J=2 always for modified CA-CFAR family then:-

S=M-2 ……………………………………………………………………..(9)

Recalling the eq(4) from CA-CFAR theory

$$P_{fa}(\alpha, M) = \left(1 + \frac{\alpha}{M}\right)^{-M} \quad \text{……………………………………………………..(10)}$$

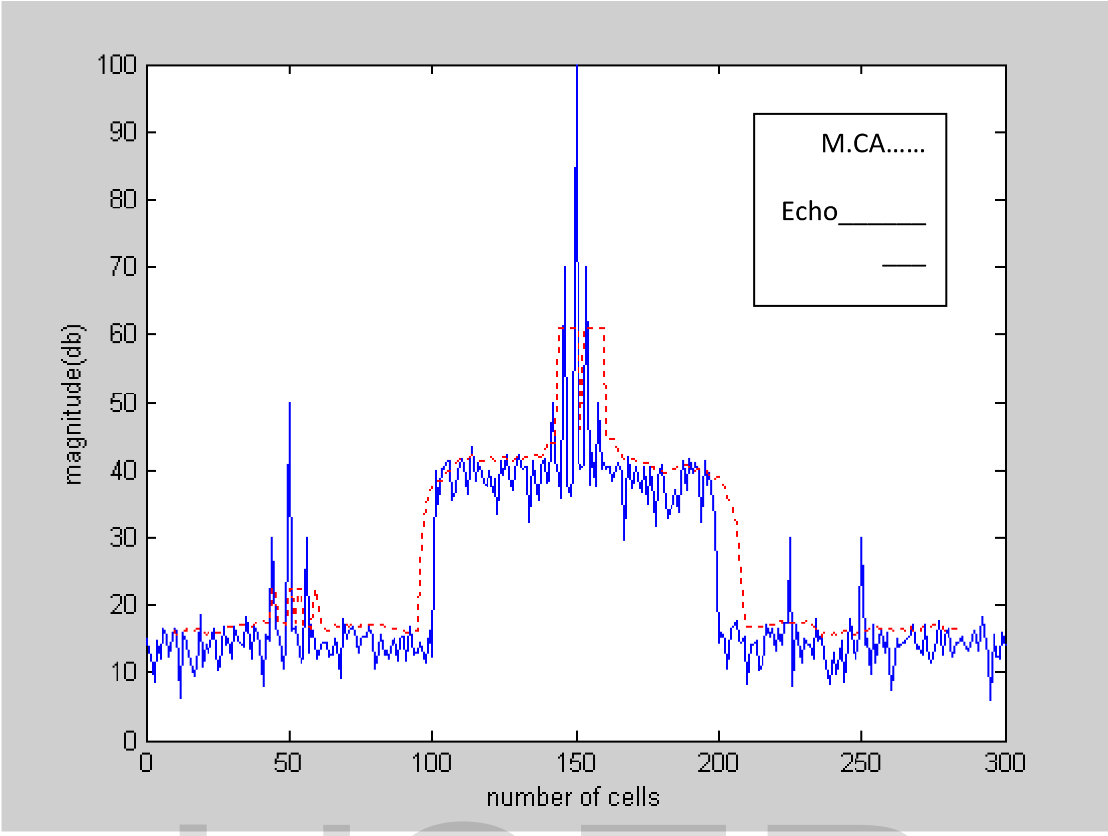
the equation of probability of false alarm for modified CA-CFAR will be in terms of S instead of M.

$$P_{fa}(\alpha, M) = \left(1 + \frac{\alpha}{S}\right)^{-S} \quad \text{……………………………………………..(11)}$$

since S<M that means the multiplier value will increase for modified CA-CFAR as a result for excising the spikes. Also the probability of detection of modified CA-CFAR is -:

$$P_D(SNR, \alpha, M) = \left(1 + \frac{\alpha}{S(1 + \overline{SNR})}\right)^{-S} \quad \text{……………………………………………..(12)}$$

the same procedure applied for modified GO-CFAR and modified SO-CFAR.the simulation result for the family as shown in fig.(4,5,6)respectively .



Figure(4) modified CA-CFAR threshold response , M=16, $P_{fa} = 10^{-6}$ modified CA-show bad response to clutter edge and miss one target,

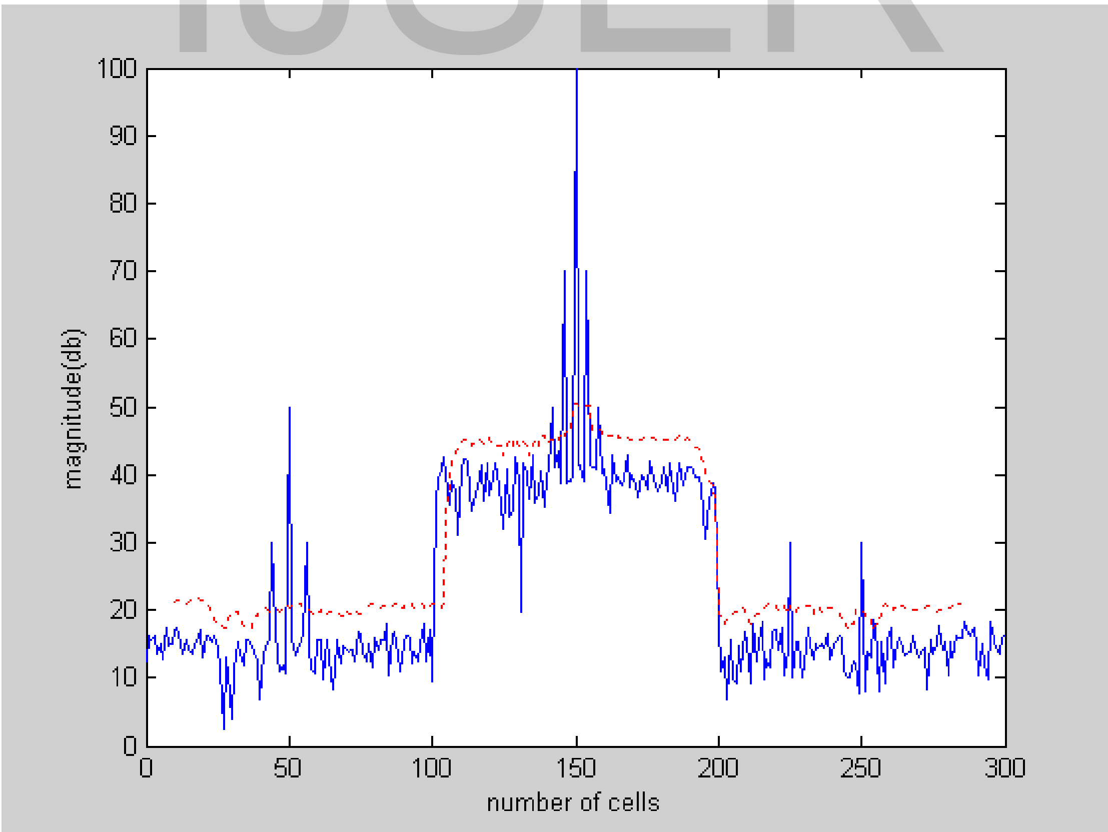


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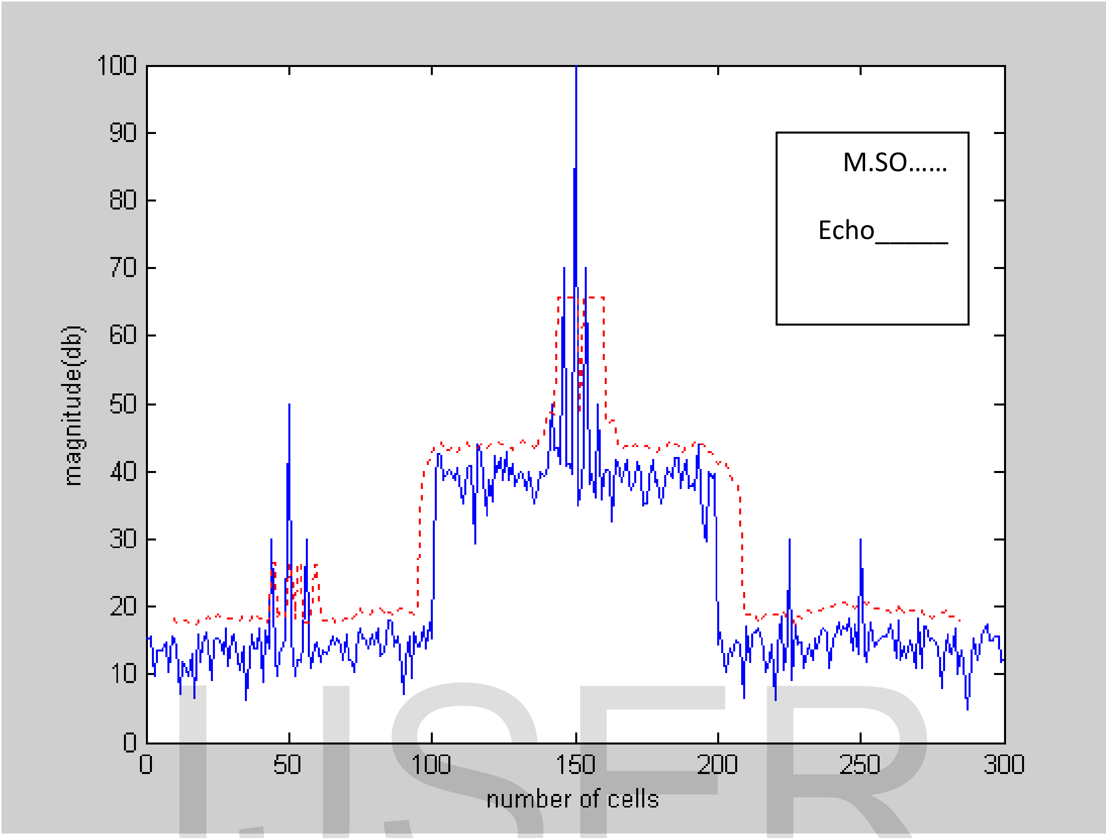
Figure (5)modified SO-CFAR threshold response , M=16, $P_{fa} = 10^{-6}$ modified SO-CFAR shows bad response to clutter edge but miss no target



Figure(6)modified GO-CFAR threshold response , M=16, $P_{fa} = 10^{-6}$ The modified GO-CFAR showed good response for clutter edge and multi-target.

9-simulation results(discussion)

as shown in fig(6) only modified GO-CFAR could handle both Clutter edge and multi target successfully and the same result is obtained when modified CA-CFAR family applied separately to test model. The two algorithm that succeeded in overcoming the problem of model three which represent the worst radar environment was OSGO-CFAR and modified GO-CFAR, and trading off between the two ,it will be seen clearly that modified GO-CFAR need much less processing time , although , that OSGO-CFAR that recommended by RIFKIN[10].

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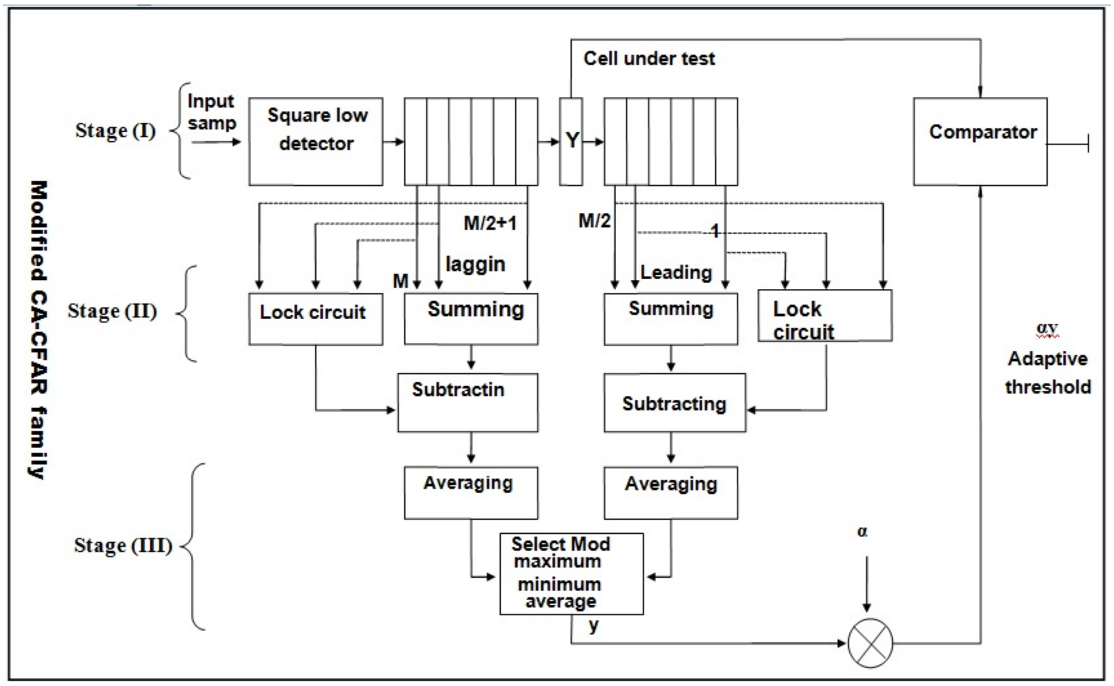

Fig(7) construction of modified CA-CFAR family

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10-conclutions (future work)

finally ,the new modified CA-CFAR family algorithm, that have robust algorithm for excising one strongest sample from leading window and one strongest sample from lagging window.

Also , the competition between OSGO-CFAR algorithm that recommended by Rifkin[10] and succeeded in the models test which has sorting algorithm similar as that of old modified GO-CFAR that recommended by Weiss [2].

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