Determination of Marine Targets In The Presence of Sea Clutter for Synthetic Aperture Radar

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ABSTRACT

A new two-stage target detection method based on Constant False Alarm Rate (CFAR) is proposed in this paper. Cell Averaging CFAR is used to detect marine targets in the presence of sea clutter like birds, target-like interferences etc. K-length averaging scheme along-with CA-CFAR is applied to increase the probability of detection in marine targets. The results preliminarily verified that it is able to measure the complex degree of SAR. In our experiment, the proposed method is tested on two kinds of SAR and its effectiveness is successfully demonstrated.

Keywords: Synthetic aperture radar; Target detection; CFAR; K-length averaging.

INTRODUCTION

Radar returns are produced from nearly all surfaces when illuminated by radar. In competition with the return from a ship, there are many sources of unwanted signals. Unwanted signals in search radar are generally described as noise and clutter. Sea clutter result from the scattering of electromagnetic waves on the surface of sea waves and they move at wind speed. Clutters increase the probability of false alarm or equivalently decrease the probability of detection if false alarm rate is kept constant.

The properties of sea clutter will depend on a wide variety of parameters, some of them are:

1. The area reflectivity
2. The amplitude distribution of the clutter amplitudes
3. The spectrum of the clutter returns
4. The spatial variation of the clutter return
5. The polarisation scattering matrix
6. Discrete clutter spikes

Due to sea states and types of radars, the models of sea clutters are thought of Rayleigh, Weibull and Log-normal distribution. The type of noise present in the sea radar depends upon the state of sea and type of radar employed in the system. Some important noises are:

- Low sea state and low resolution radar: Rayleigh distribution
- Low resolution and low grazing angle radar: Weibull distribution
- High resolution radar: Log-normal distribution

In probability theory, the normal (or Gaussian) distribution is a continuous probability distribution, defined by the formula.

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \quad (1)$$

The parameter μ in this formula is the mean or expectation of the distribution (and also its median and mode). The parameter σ is its standard deviation; its variance is therefore σ^2. A random variable with a Gaussian distribution is said to be normally distributed and is called a normal deviate. In Radars the thermal noise can be significantly represented by the normal distribution.

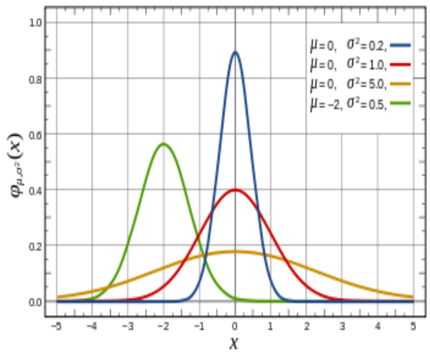

Fig.1.PDF of Normal Distribution

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Let x be an absolutely continuous random variable. Let its support be the set of positive real numbers: $R_x=[0,\infty)$ We say that x has a **Chi-square distribution** with k degrees of freedom if its probability density function is:

$$f(x,k) = \begin{cases} \frac{1}{2^{\frac{k}{2}}\varphi\left(\frac{k}{2}\right)} x^{\frac{k}{2}-1} e^{-\frac{x}{2}}, & if\ x \in \mathrm{Rx} \end{cases} \quad (2)$$

Where φ(x) denotes the Gamma function and Chi-square distribution is a special case of Gamma distribution. In Radars the clutter generated can be prominently represented by the Chi-squared distribution.

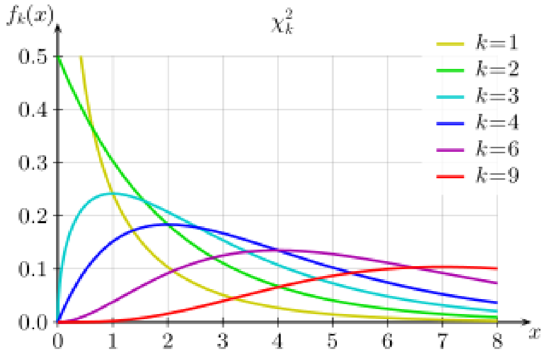

Figure.2.PDF of Chi-Square distribution

The model used to represent the observed intensity X, involves compounding two gamma distributions. In each case a re-parameterisation of the usual form of the family of gamma distributions is used, such that the parameters are:

1. The mean of the distribution, and
2. The usual shape parameter.

The model is that X has a gamma distribution with mean σ and shape parameter L, with σ being treated as a random variable having another gamma distribution, this time with mean μ and shape parameter ν. The result is that X has the following density function (x > 0):

$$f_X(x;\nu,L) = \frac{2}{x}\left(\frac{L\nu x}{\mu}\right)^{\frac{L+\nu}{2}} \frac{1}{\Gamma(L)\Gamma(\nu)} K_{\nu-L}\left(2\sqrt{\frac{L\nu x}{\mu}}\right), \quad (3)$$

Where, K is a modified Bessel function of the second kind. In this derivation, the K-distribution is a compound probability distribution.

MATERIALS AND METHODS

Detection refers to a common form of adaptive algorithm used in radar systems to detect target returns against a background of noise, clutter and interference. Conversely, if the threshold is too high, then fewer targets will be detected, but the number of false alarms will also be low. A changing threshold can be used, where the threshold level is raised and lowered to maintain a constant probability of false alarm. This is known as constant false alarm rate (CFAR) detection.

Cell-averaging CFAR: In most simple CFAR detection schemes, the threshold level is calculated by estimating the level of the noise floor around the cell under test (CUT). This can be found by taking a block of cells around the cell under test (CUT) and calculating the average power level. To avoid corrupting this estimate with power from the CUT itself, cells immediately adjacent to the CUT are normally ignored (and referred to as "guard cells"). The noise estimate can be computed as

$$P_n = \frac{1}{N}\sum_{m=1}^{N} X_m \quad (4)$$

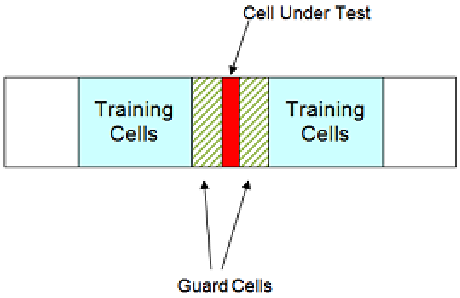

Figure.3.CFAR Test Cells

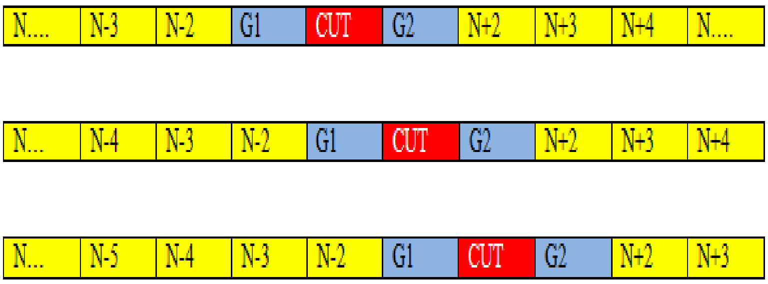

Figure.4.MATLAB processing of CFAR

Formulae used in programming:

$$T_h = \frac{\left(\sum_{i=1}^{16} RC_L + \sum_{i=1}^{16} RC_R\right) \times K}{16} \quad (5)$$

Here it is also known as Binary Moving Window Detector. Over the N scans the algorithm is run such that, if the number of spikes exceed or equals to M we say target is detected (1) otherwise result is null (0). The role of the constant false alarm rate circuitry is to determine the power threshold above which any return can be considered to probably originate from a target. If this threshold is too low, then more targets will be detected at the expense of increased numbers of false alarms.

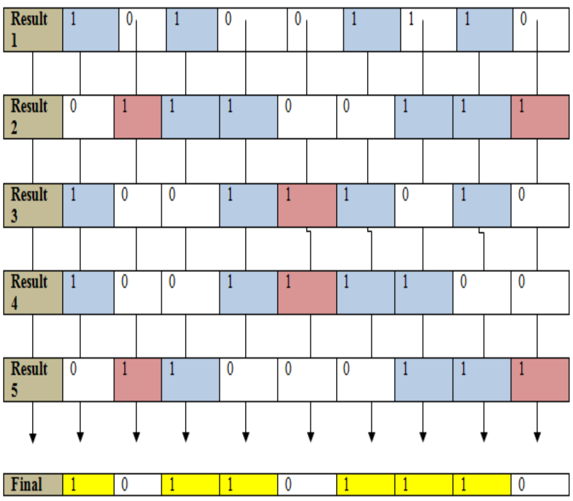

Fig.5.CFAR Results

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K-Length Averaging: This technique provides us with Space-persistence of marine targets over a predefined range 'k'. There are '5' range cell length moving average. The algorithm records and sums the first 5 cell in a row. The resulting value is rounded to either 0 or 1, thereby indicating the presence of a range extended target (Moving). This happens if 50% of the range cells exceed the threshold. Example:

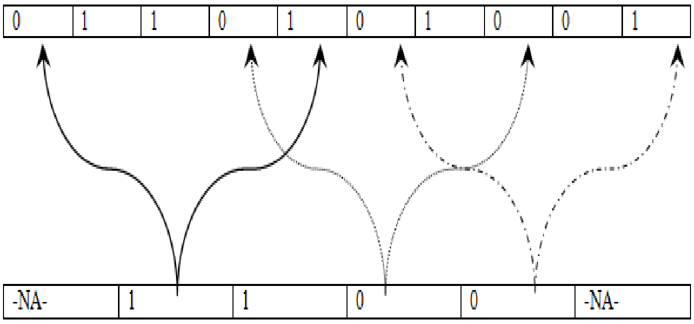

Figure.5a.K-Length Averaging

RESULTS AND DISCUSSION

The 'False spikes' are automatically removed from the data, giving us crisp location of our desired marine targets. T_h is the Adaptive threshold using CFAR technique. RC_L and RC_R are the Row Cells on the right, & Row Cells on the left of the guard cells respectively. K is the Multiplication Factor whose value depends on the RADAR parameters. User can choose the value of K as per his requirement in the program.

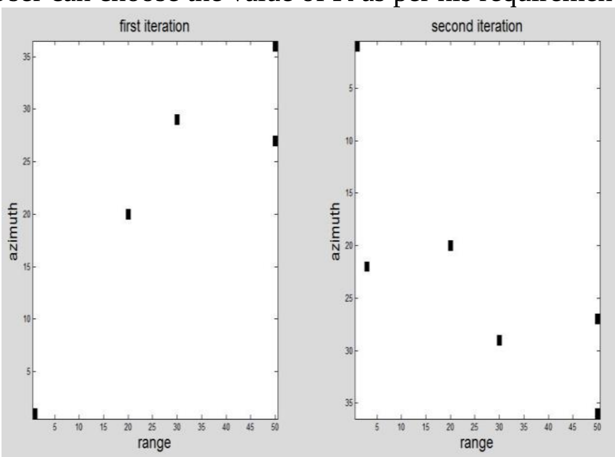

Figure.6. Result after first and second iteration

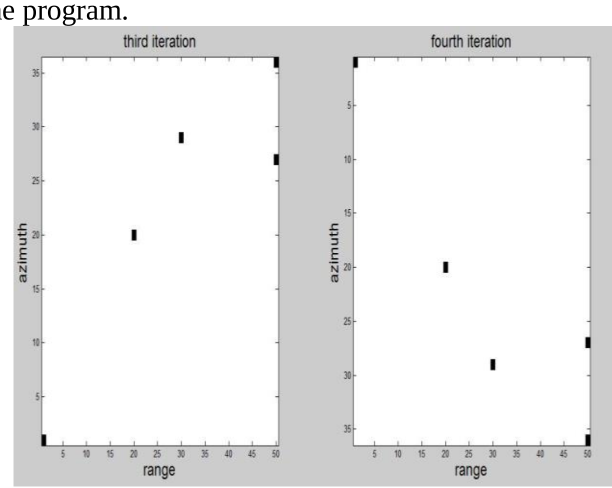

Figure.7.Result after third and fourth iteration

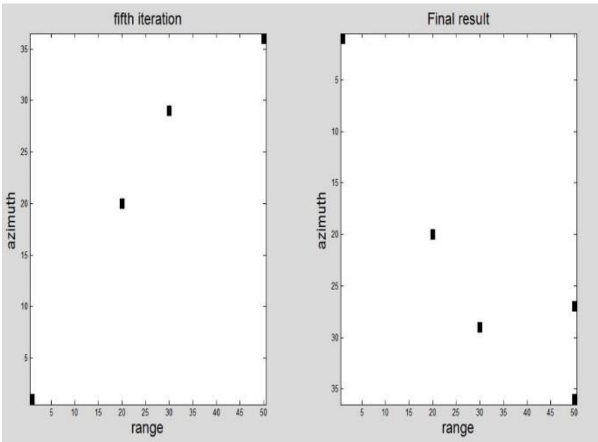

Figure.8.Result after fifth and Final Detection result

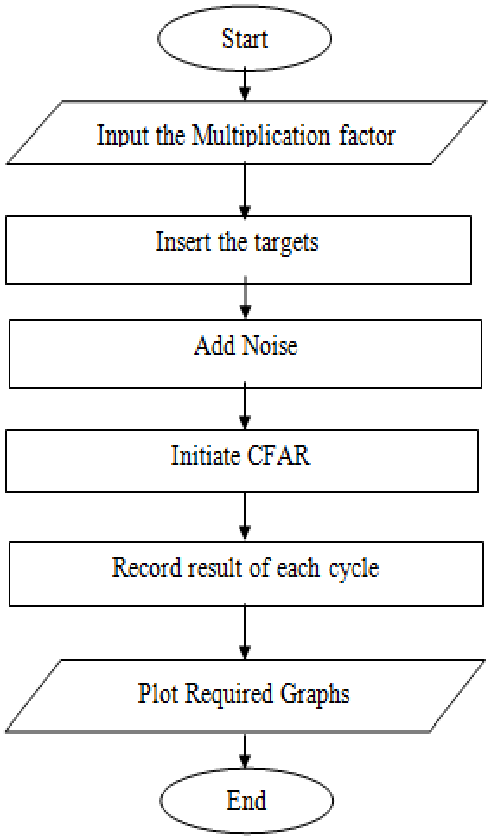

Figure.10.Comparison of Rayleigh and Normal Distribution

A target is declared present in the CUT if it is both greater than all its adjacent cells and greater than the local average power level. The estimate of the local power level may sometimes be increased slightly to allow for the limited sample size. This simple approach is called a cell-averaging CFAR (CA-CFAR).

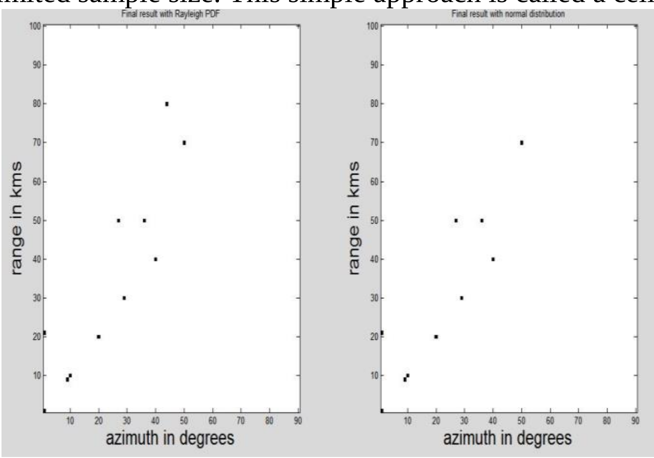

Figure.10.Comparison of Rayleigh and Normal Distribution

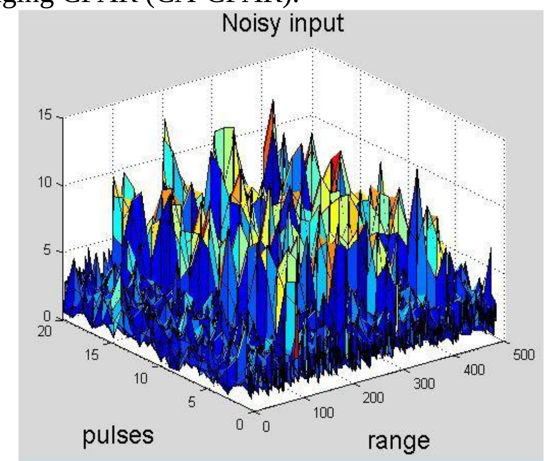

Figure.11.Targets Supressed by clutter

In the radar receiver the returning echoes are typically received by the antenna, amplified, down-converted and then passed through detector circuitry that extracts the envelope of the signal (known as the video signal).

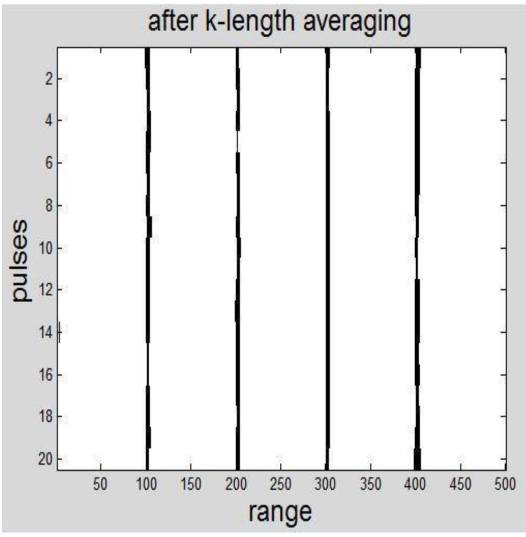

Figure.12.Detection of targets in the presence of clutter

CONCLUSIONS

This paper gives an overview of basic and significant Signal Processing techniques used in Radar Systems. The algorithm and programming simulates the virtual user programmed clutter, over which various methods are used to detect the actual targets. The program graphically illustrates the detection of a marine target. Further work can be carried out over detection of speed of the target, its size, and direction in space utilizing real time data.

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