Analysis of Multiple Target Detectors-Review

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Abstract

Multiple target scenario is gaining importance in the recent times, thus design and analysis of Multiple Target Detectors forms the key. In this paper we first state the significance of Multiple Target detectors and then we analyse these detectors. For a given SNR, the Generalised Likelihood Ratio Test (GLRT) detectors are used to detect multiple targets but with increased Probability Of false alarm (Pfa) therefore Correlated Generalised Likelihood Ratio Test (C-GLRT) detectors are being preferred since it detects the target with reduced Pfa for a given SNR. Usually at low SNR the targets cannot be detetcted efficiently but with the use of Compressed Sensing Detectors even at low SNR the targets can be detected in an efficient way.

Index Terms— Correlated Generalised Likelihood Ratio Test (C-GLRT), Compressed Sensing (CS), Receiver Operating Characteristics (ROC), Multiple Input Multiple Output (MIMO), Probability of Detection (Pd), Probability Of False Alarm (Pfa).

I. INTRODUCTION

Radar systems use waveforms which are modulated and antennas which are of directive type to transmit electromagnetic energy into the space to search for targets. According to target detection theory, decisions about the presence or absence of targets are conventionally made at any radar in each resolution cell individually.

Radars detecting single target which are either fluctuating or non fluctuating are already in existence but design of a detector which can detect multiple targets with less computational complexity is required.

The detectors such as Algebraic Geometry Mean (AGM), Minimum-Maximum (MM), Generalised Likelihood Ratio Test (GLRT), Compressed Sensing Detectors are used to detect the multiple targets.

Considering the problem of detection for a signal whose amplitude is unknown but it is constant over a period which contains a disturbance say compound-Gaussian clutter plus additive white noise a new GLRT was presented [1].

The GLRT, proposed for the coherent radar detection against a Gaussian disturbance. This detector estimated the clutter covariance matrix on the basis of the echoes from K range cells, For a large value of K, the proposed GLRT went on to become Gaussian matched filter, which could be very far from being an optimum filter for a non-Gaussian clutter.

GLRT detectors can detect targets at a given SNR but C-GLRT detectors can detect targets with lower Pfa for the same SNR.

Radar, sonar and similar imaging systems are in high demand in many civilian, military, and biomedical applications. The resolution of these systems is limited by classical time-frequency uncertainty principles. In a simplified version of a mono static, single-pulse radar system, the assumption is that the targets are radially aligned with the transmitter and receiver. As such, the concern here is the range and velocity of the targets.[2]

Compressed Sensing (CS) Detection method is being used to reduce computational complexity. The performance of the detector is analyzed, and the receiver operating characteristic (ROC) curves are being derived [3].CS detectors are used to detect a target even at lower SNR with greater efficiency

MIMO stands for Multiple Input Multiple Output Radars often termed as Multi-static radars where there are M antennas at the input and N antennas at the output, these contain multiple spatially diverse mono-static radar [one antenna at the input and one antenna at the output] or bi-static radar[two antennas at both the input and output] components with a shared area of coverage.

The advantages of using a MIMO radar is that its diversity schemes. Diversity can be Macro diversity and Micro diversity. Micro diversity schemes include spatial diversity, frequency diversity ,temporal diversity, use of collocated antennas. Macro diversity schemes are used to overcome large scale fading like shadowing which can be executed by the use of on frequency repeaters.

In Section II Review of the detectors is discussed. In III the actual implementation is being explained. Section IV explains the results of the different detector implementation and section V gives the conclusion.

II. REVIEW OF DETECTORS

A. Generalized Likelihood Ratio Test (GLRT)

The Multiband GLRT (MBGLRT) algorithm was the multiband extension of the first GLRT detector which processed the echoes obtained using frequency agility in order to operate against a severely non-homogeneous non- Gaussian clutter background.

The multiband GLRT version had two main advantages wrt the original single band GLRT algorithm:

(i) For the adaptive implementation, it required a much smaller area of homogeneous clutter echoes in order to estimate the covariance matrix of the interference.

(ii) It provided an optimum processing of the radar echoes when the radar operates in frequency agility.[4]

A CFAR Matched Subspace Detector was a Scale Invariant GLRT which could be used for detecting a target signal in noise whose covariance structure was known but whose noise level was unknown. Now When the noise covariance matrix was unknown, the CFAR Adaptive Subspace Detector (CFAR ASD) used a sample covariance matrix based on training data.

The CFAR ASD is a GLRT when the test measurement has a different noise level than the training data. But this GLRT differd from the well-known GLRT in two respects:

(i) The hypothesis testing problems,

(ii) Their group- transformation invariances.[5]

GLRT can be implemented in two steps. This implementation provides better performance with the reduction in the computational savings. The advantages of this implementation is that for a given PFA [Probability of False Alarm] the two-step GLRT's performance is constant for a wide range of threshold pairs.

The two-step GLRT provided side lobe target rejection compared with the regular GLRT[6].

B. CS-GLRT

The signal processing/mathematics community has seen a paradigmatic shift in the way information is represented, stored, transmitted and recovered. This area was often referred to as Sparse Representations and Compressed Sensing.[2]

Considering the problem of target detection from a set of Compressed Sensing (CS) radar measurements corrupted by additive white Gaussian noise. Using asymptotic arguments and the Complex Approximate Message Passing (CAMP) algorithm, characterization of the statistics of the -norm reconstruction error was done and closed form expressions for both the detection and false alarm probabilities of both schemes were derived. [7]

III. IMPLEMENTATION

Here first GLRT concept is being exploited and a new detector called C-GLRT is developed and its parameter Pfa is being compared with eigenvalue based detectors. Later CS-GLRT is being formulated and its performance is compared with C-GLRT and the inferences are drawn.

A. IMPLEMENTATION OF C-GLRT and CS-GLRT

Here first a parameter for correlated case and independent case is defined, then number of signals is generalized, this signal maybe any waveform defined such as Stepped FM, Rectangular or a Sinusoidal waveform with its intial properties, later samples received for sensing is assumed and finally transmitted power is assumed as 1. The noise considered is Additive White Guassian Noise (AWGN) with mean 0 and variance 1. Here the estimates are taken and they are estimated and generalized.

The spectrum sensing problem is essentially the binary hypothesis test as follows.[10]:

$$H0 : xi(n) = wi(n), \quad i = 1, 2, . . . ,M \quad (1)$$
$$H1 : xi(n) = hi(n)s(n) + wi(n), \quad n = 1, 2, . . . , N \quad (2)$$

where s(n) is the complex phase shift keying (PSK) modulated signal with averagetransmitted power P. The signal is transmitted over a Rayleigh fading channel, w(n) is the AWGN. x(n) is M X n vector of nth sample of the received signal. X = [x(1)……x(N)].[10]

The Likelihood functions H0 and H1 are implemented. The decision statistic is made by:

$$Lg(x)=p(X|H1, \theta 1)/ p(X|H0, \theta 0) \quad (3)$$

Were L(x) is the likelihood ratio test (LRT) which is given as L(x) = p(x/H1) / p(x/H0). This step is followed by Matrix inversion and eigen decomposition given by

$$ln\ L(x)=\sum_{n=1}^{j} x(n)\ (p\sigma_w^2 A + p\sigma_h^2 I)V^H x(n) (4)$$

Implementation of compressed sensing [CS] detectors requires comparison of threshold with received energy. The received signal is the AWGN noise combined with input signal which is a sawtooth waveform of a given sampling frequency and multiple targets at different location.

Signal-to-Noise Ratio (SNR) is specified and its corresponding SNR in db is calculated. Thus a plot of Pd vs Pfa is obtained. The MIMO system efficiently aquires and reconstructs a signal which follows the definition of compressed sensing.[11]

The energy of the received signal is calculated in the beginning which is given by

$$energy = abs\ (received\ signal)^2 \quad (5)$$

The test static of this calculated energy is given by

$$energy\ test\ static = \frac{1}{Number\ \ of\ samples}(energy) \quad (6)$$

The theoretical plot of Pd Vs Pfa is obtained by calculating the threshold followed by finding the Q-function of this threshold.

Later this theoretical plot is compared with the plot obtained previously and the inferences are drawn.

These two architectures are proposed and their performance are compared by means of Receiver Operating Characteristic (ROC) curves.

IV. RESULTS

A. Analysis of C-GLRT

The power transmitted Tp of the input signal is normalised to 1, the number of samples was 20, the required probability of detection was 0.99. The C-GLRT plot with the above specification is as follows. The Input has M number of signals and N number of samples. The output is a plot of Pfa Vs SNR in MATLAB.

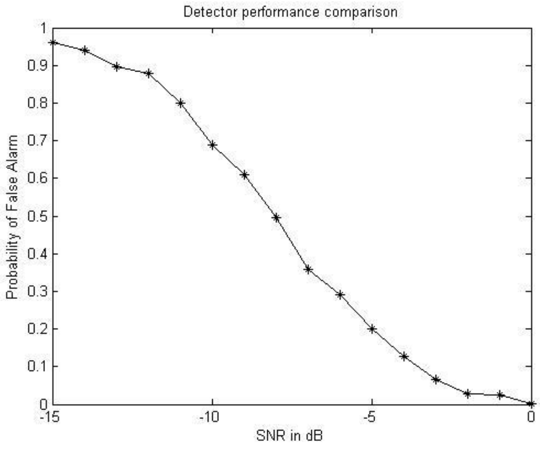

Fig.1 Probability of False Alarm vs Signal-Noise-Ratio

For a given parameter M (no.of pulses)=15 and N (no. of samples)=10 we can see the proposed algorithm denoted in black performs better. Here in fig 2 as the SNR increases the Probability of false alarm (Pfa) of the proposed algorithm decreases at a faster rate when compared to the previous algoritm.

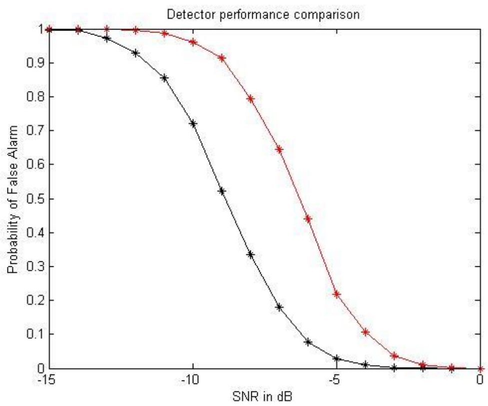

Fig .2 Comparison of C-GLRT and Other generalised Detectors

Different plots have been checked with M=25 and N=10 in fig 2 and M=17 and N=17 in fig 3

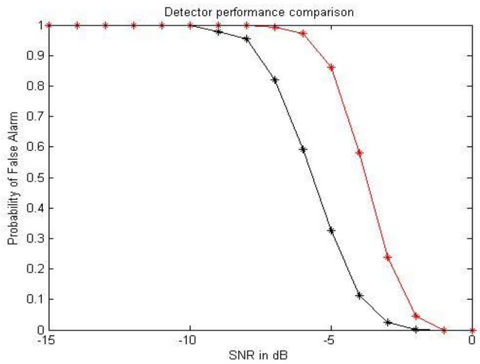

Fig .3 Comparison of C-GLRT and Other generalised Detectors

B. Analysis of CS based detectors

CS based detectors track the signal and retransmit it when the energy becomes lower than a specified threshold forming the basis of Compressed Sensing.SNR is the Input and the output is a plot of Pd Vs Pfa. The plot is obtained in MATLAB.

Here as SNR decreases Pd also decreases, Thus capability of detecting a target at lower SNR increases when compared to Non CS detection strategy

Considering SNR as 2e-05 in fig. 4 its corresponding value in DB is -46.897 thus a plot of Pd Vs Pfa is obtained. Here we can note that theoretical plot denoted in red initialises at 0.0145 but CS based plot initialises at 0.0186.

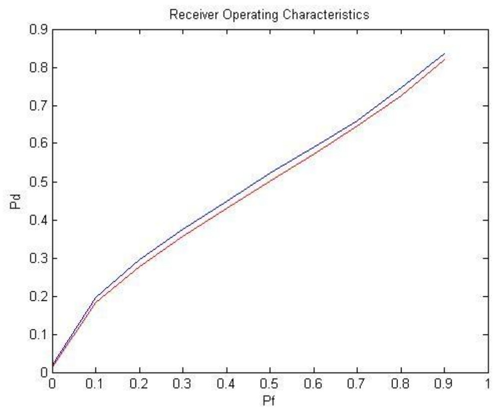

Fig. 4 Receiver operating Characteristics

Given SNR as 0.21 and its value in DB corresponds to -6 we can note that Pd value is initialized from 0.3120 in fig 5 and when SNR is 0.15 and its value in DB as -8.2391 its clear that Pd value initilises from 0.17 which is denoted in fig 6

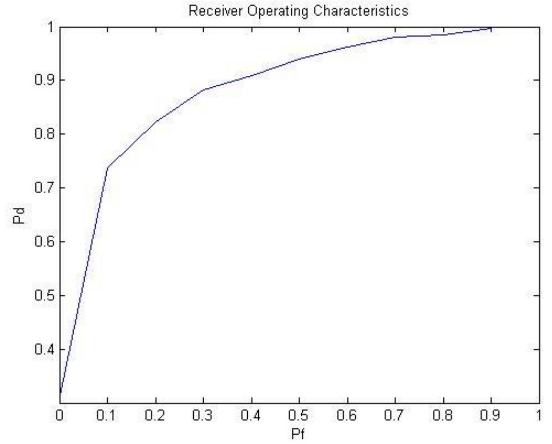

Fig .5 Plot of probability of detection Vs Probability of false alarm with SNR=0.3120

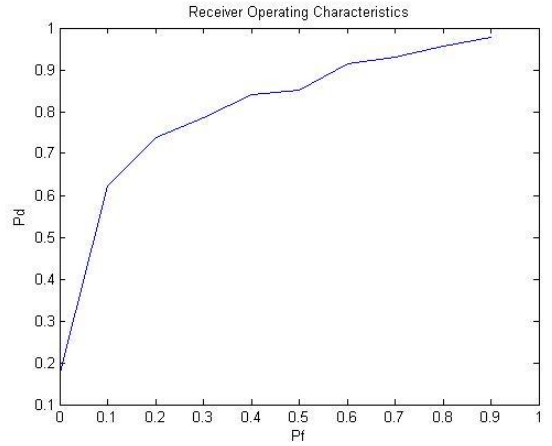

Fig .6 Plot of probability of detection Vs Probability of false alarm with SNR=0.15

The plots of Input waveform with sampling frequency 1000 and multiple target locations is given in fig 7 and fig 8

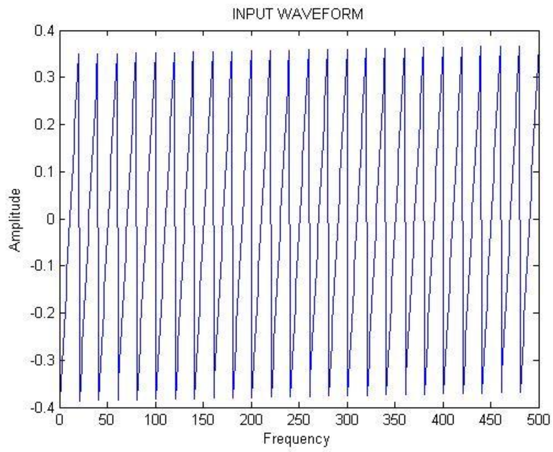

Fig. 7 Plot of input waveform of a given sampling frequency 1000 samples/seconds

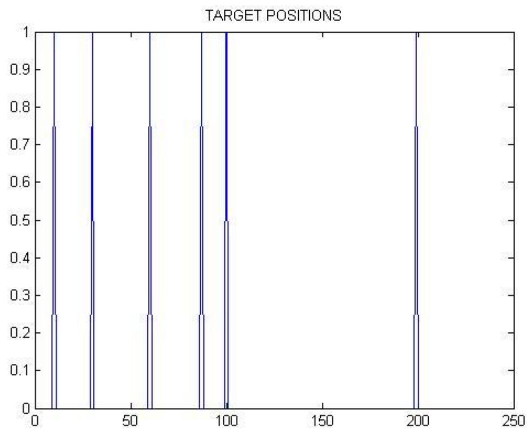

Fig. 8 Plot of Multiple Target positions

Considering SNR as 0.4 whose SNR in DB is -3.97, 0.25 whose SNR in DB is -6.02 and 0.02 whose SNR in DB is -16.98 we can note that as the SNR decreases the Receiver Operating Characteristics (ROC) curves drops shown in fig 9.

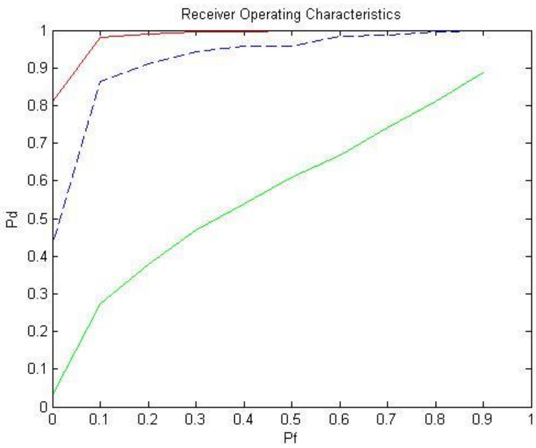

Fig .9 SNR COMPARISON

V. CONCLUSION

The Analysis of C-GLRT will show that as the Probability of detection increases the Probability of false alarm decreases comparatively in C-GLRT with respect to other generalized eigen based detectors thus a target can be successfully detected by employing C-GLRT with reduced Probability of False Alarm.[10]

The Analysis Of CS based detectors shows that as the SNR decreases, the Probability of detection also decreases and targets can be detected at low SNR efficiently when compared to theoretical approach of detection.

REFERENCES

[1] LAURA ANITORI, ARIAN MALEKI, MATERNOTTEN, RICHARD G. BARANIUK, PETER HOOGEBOOM: 'DESIGN AND ANALYSIS OF COMPRESSED SENSING RADAR DETECTORS', IEEE TRANS. ON SIGNAL PROCESSING., VOL 61, (4), [2013],PP. 813–827

[2] M. DERAKHTIAN Z. KHALILIAZAD M.A. MASNADISHIRAZI M. NEINAVAIE: 'GENERALISED LIKELIHOOD RATIO TEST-BASED MULTIPLE-TARGET DETECTION FOR FLUCTUATING TARGETS WITH UNKNOWN PARAMETERS', IET RADAR SONAR NAVIG. ON SIGNAL., VOL 5, (6), [2011],PP. 613–625

[3] BIN LIU, BIAO CHEN JAMES H. MICHELS: 'A GLRT FOR RADAR DETECTION IN THE PRESENCE OF COMPOUND-GAUSSIAN CLUTTER AND ADDITIVE WHITE GAUSSIAN', IEEE, [2002],PP. 81–91

[4] CHAORAN DU, JOHN S. THOMPSON, YVAN R. PETILLOT: 'DETECTOR AND WAVEFORM DESIGN FOR MIMO RADAR SYSTEM WITH NOISY CHANNEL ESTIMATION', IEEE TRANS. ON SIGNAL PROCESSING., VOL 48, (3), [2012],PP. 2332–2348

[5] C. HAO J. YANG X. MA C. HOUD. ORLANDO: 'ADAPTIVE DETECTION OF DISTRIBUTED TARGETS WITHORTHOGONAL REJECTION', IET RADAR SONAR NAVIG. ON SIGNAL., VOL 6, (6), [2012],PP. 483–493

[6] T. JIAN Y. HE F. SU C. QU: 'ADAPTIVE RANGE-SPREAD TARGET DETECTION BASED ON MODIFIED GENERALISED LIKELIHOOD RATIO TEST IN NON-GAUSSIAN CLUTTER', IET RADAR SONAR NAVIG. ON SIGNAL., VOL 5, (9), [2011],PP. 470–477

[7] G. CUI L. KONG X. YANG: 'MULTIPLE-INPUT MULTIPLE-OUTPUT RADAR DETECTORS DESIGN IN NON-GAUSSIAN CLUTTER', IET RADAR SONAR NAVIG. ON SIGNAL., VOL 4, (5), [2010],PP. 724–732

[8] NICHOLAS PULSONE AND MICHAEL ZATMAN: 'A COMPUTATIONALLY-EFFICIENT TWO-STEP IMPLEMENTATION OF THE GLRT DETECTOR, IEEE, [2002],PP. 1161–1164

[9] MATTHEW HERMAN AND THOMAS STROHMER: 'COMPRESSED SENSING RADAR', IEEE, [2008],PP. 1509–1512

[10] L.P. LUO, P. ZHANG, G.C. ZHANG AND J.Y. QIN: 'SPECTRUM SENSING FOR COGNITIVE RADIO NETWORKS WITH CORRELATED MULTIPLE ANTENNAS',ELECTRONIC LETTERS., VOL 47, (23), [2011],PP. 2332–2334

[11]Shuangling Wang, Qian He, and Zishu He: 'Compressed Sensing Moving Target Detection forMIMO Radar with Widely Spaced Antennas',ISPACS 2010.