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A Double Threshold Energy Estimation Approach to Optimize Spectrum Sensing in Cognitive Radio Network

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ABSTRACT

In cognitive radio network, detection of Spectrum is a new innovation to analyses exploitation of underutilized range to overcome the issue of spectrum shortage. One of the vital Spectrum detecting strategies for cognitive radio is energy detection. In this paper, energy detection method is proposed for cooperative and non-cooperative cognitive radio. In this work we introduce new scheme for the spectrum sensing which is based on the improved double threshold method. Results demonstrate that detection probability increases whenever signal to noise ratio (SNR) and false alarm probability increases. Here, we discuss about advancement of threshold value along with energy identification for enhancing the outcome of spectrum sensing. Setting threshold value to reduce spectrum sensing fault, shrinks collision probability with primary user, enhance the value of available spectrum, hence enhancing aggregate spectrum efficiency. In any case, when deciding threshold level, spectrum sensing limitation should additionally be fulfilled since it promises least protection level of Primary User(PU) and utilization level of empty range. To minimize spectrum detecting lapse for given range detecting imperative, we determine an ideal adaptable threshold level by using the spectrum detecting lapse capacity and imperative which is given by imbalance condition. Simulation results demonstrate that the proposed plan gives better spectrum sensing results.

Keywords: Cognitive Radio; Primary user; Secondary user; Energy detection; Double threshold Algorithm.

1 Introduction

Cognitive radio is a novel methodology for enhancing the usage of one of the valuable normal resources, the radio range. The cognitive radio (CR) can be considered as another kind of software - defined radio. CR can be termed as an intelligent wireless communication [1]. In cognitive radio, PU is characterized as authorized client or licensed user who has the privilege to use a specific part of spectrum. Then again, secondary user (SU) or CR clients don't have the permit for the use of spectrum yet can use it at whatever point PU is most certainly not present. Cognitive user shifts the transmission to a distinctive frequency or modulation parameters, consequently never cause interference to PU at whatever point it is available. In this manner, SU must have the ability to sense the spectrum and check whether PU is utilizing it and at the same time make changes in the radio parameters to use the unused part of spectrum. Till now, Spectrum detecting is the most key assignment for the implementation of CRs since they have to sense hole in the spectrum band, furthermore, choose whether to utilize the range band or not. A wide range of systems were proposed for distinguishing

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proof of the PU signal transmission. Range detecting strategies can be classified to: Energy Identification, Cycle stationary Identification, and Matched Filter Identification.

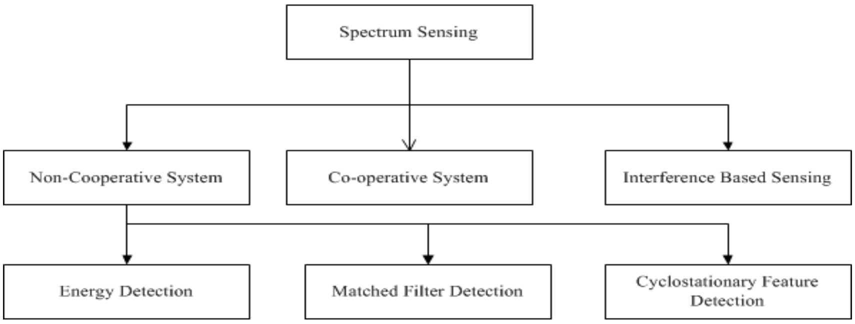

Figure 1 Classification of Energy Identification Method

Among these, energy Identification is generally used since it doesn't require the earlier information of primary signals and have less complexity contrasted with other strategies. In this paper, we have concentrated on the method of energy Identification and its uses in cognitive radio network. The fundamental function of spectrum analyzing is to identify holes in the spectrum. So the secondary user (SU) can access to the unused channel under the condition that don't cause interference to primary users (PU). In the meantime the SU handles the primary users in order to have the capacity to rapidly exit when the PU reuses the band. One of the greatest difficulties for SS is distinguishing the weak PU signaling low Signal to Noise Ratio (SNR) environment. In low SNR environment, the execution of spectrum detecting performance will be decreased [2].

In this paper the energy detection method is applied for detecting the spectrum in cognitive radio systems. Simulation is carried out and perception demonstrates to us that energy detection is upgraded when there is an increment in the SNR or increment in likelihood of false alert increments.

2 Literature Survey

As cognitive networks are gradually developed and positioned under various high-performance networking edges, various algorithms have been planned for energy recognition and spectrum identifying. We discuss below a detail survey of these efforts.

In [1] Yonghua Wang, Pin Wan et al proposed a Stochastic Resonance (SR) spectrum detecting structure for the cognitive radio. They discussed about, an Evstigneev-type monostable stochastic resonance framework which is connected to energy detection of spectrum detecting to build the framework yield SNR, consequently upgrading the low SNR environment energy detection performance. Simulation results show that on account of steady false alert probability, the detection probability of spectrum sensing taking into account monostable SR is higher than that of the customary energy detection schemes, particularly in low SNR environment.

In [2] Sobron, I.; Diniz et al presented an adaptive method for spectrum sensing and energy detection. The detecting was performed through energy detection executed by each cognitive user. The fundamental commitments of the paper were: (i) another cost-function that characterizes another test measurement in view of a energy single parameter for single-node and community situations, (ii) another type of accumulating the data from distinctive neighboring hubs that relies on upon the standardized SNRs of the hubs.

L. Rugini, P. Banelli [3] in their work introduced energy detection technique for small sample size. By using Gaussian method, they derived a new, simple, and accurate mathematical expression for the minimum number of samples required to achieve a desired probability of detection and false alarm.

J.-g. Huang, and C.-k. Tang [4], in this paper, the detection was balanced to decrease location mistake because of clamor vulnerability. The inadequate nature of vitality change is misused to revise the judgment result. Reproduction results demonstrate that under certification the benefit of the customary vitality location, the proposed differential vitality recognition can viably enhance exact detection execution of the unmoving range for the subjective clients continuously

3 System Model

Here we are using energy detection for the use of cooperative analysis of spectrum then the secondary user pass on sensing results to fusion center by two methods which is discussed below.

3.1 Data fusion

All cognitive individuals enhance the signal received by the primary users then they pass on these signals to fusion center [3], [4]. Here secondary users do not require process of complex detection, the bandwidth of reporting channel and the bandwidth of sensing channel should be nearly same. Various fusion methods are getting applied to the fusion center for an example maximal ratio combining (MRC) and square law combining (SLC)). The information of the channel state ranging from primary to secondary user and in turn passed on to fusion center is required in MRC technique .In SLC we require information of the channel state which is passed by secondary user to fusion center considering fixed amplification at every secondary user. In case, different amplification factor is considered, information of the channel state through primary to secondary users and then from secondary to the fusion center is required. Here we are proposing a framework which is having two-user or multiple-user in cooperative spectrum analysis through data fusion [5], [6]. Here we had not discussed much about analytical study on identifying capacity in spectrum analysis.

An energy detector determines the energy used for a signal to reach the receiver from the transmitter. There are two types of energy detectors. They are the analog energy detector and the digital energy detector.

In the analog energy detector, it consists of a pre-filter, squarer, and an integrator. The prefilter reduces the noise and the integrator gives the measure of the energy the signal uses to reach the receiver from the transmitter.

3.2 Decision Fusion

Each SU settles on a decision on the PU's action and the individual decisions are accounted for to the combination focus over a reporting channel .Capacity of complex sign handling is required at every SUs. The combination guideline at the combination focus can be OR, AND, or Majority principle, which can be summed up as the "k-out of-n rule" [7]. Two principle assumptions are made:

- There is no error in reporting channel; and
- The SNR insights of the got primary signs are known at SU. In [7-8], detection performance has been researched by considering reporting errors with OR combination manages under Rayleigh fading channels.

In proposed model, it is assumed that the energy detection is implemented at every SU. Energy detector is consisting of a finite time integrator and a squaring law device. Output of the integrator at any time instant is input energy to squaring device over the time interval 'T'. Noise pre-filter limits noise bandwidth, input noise to the squaring device has the spectral density as flat and band-limited

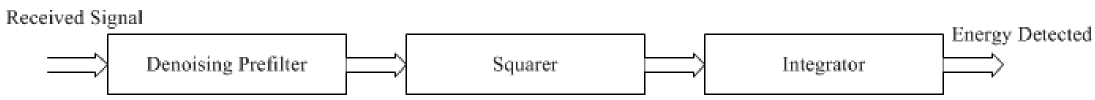

Figure 2 Analog Energy Detection Technique

Analog energy detector contains the denoising filter, squarer and integrator whereas the digital energy detector is same as the analog energy detector except that it contains an additional analog to digital converter. Figure 2 shows the architecture of Analog detector and figure 3 digital energy detector

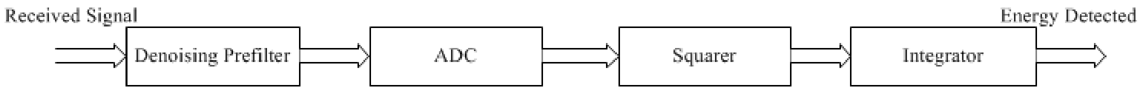

Figure 3 Digital energy detection technique

Energy detection method is one of the sub-optimal Signal detecting procedures which have been massively utilized as a part of radio interchanges. The recognition strategy can be performed in time area and additionally in frequency domain. Figure1 demonstrates the energy detection process with the theories as take after

$$\mathrm{H_0} = \mathrm{Y[m]} = \mathrm{W[m]} \quad \text{; Absence of signal} \tag{1}$$

$$\mathrm{H_1}: \mathrm{Y[m]} = \mathrm{X[m]} + \mathrm{W[m]} \text{ ; Presence of signal} \tag{2}$$

Here, $\mathrm{m} = 1, 2, \ldots, \mathrm{M}$; where M is the window under surveillance Here $\mathrm{X[m]}$ represent sample of target signal which is having definite power $'\mathrm{u}'$ and $\mathrm{W[m]}$ is a sample noise that is considered to be additive white Gaussian noise (AWGN) which is having 0 mean and change same to the signal power. Hypothesis 'H0' shows nonappearance of the primary user and the frequency band of interest only has noise whereas 'H1' points for existence of primary user. So for the both state hypotheses numbers of significant cases are:-

- $\mathrm{H1}$ would be TRUE in case of existence of primary user i.e. $\mathrm{P(H1/H1)}$ is considered as possibility of detection
- $\mathrm{H0}$ would be TRUE in case of existence of primary user i.e. $\mathrm{P(H0/H1)}$ is considered as possibility of misdetection
- $\mathrm{H1}$ would be TRUE in case of existence of primary user i.e. $\mathrm{P(H1/H0)}$ is considered as possibility of false alarm

The possibility of detection is of main worry as it provides the possibility of suitably sensing the occurrence of primary users in frequency band. Possibility of non-detection is the accompaniment of detection possibility. The aim of the analyzing schemes is to optimize the detection possibility for a low possibility of wrong alarm. There is a trade-off among these two possibilities in general. Receiver Operating Characteristics (ROC) provides much vital information with regards to the behavior of recognition possibility with varying false alarm possibility $(\mathrm{Pd\ v/s\ Pf})$ or non-detection possibility $(\mathrm{Pm\ v/s\ Pf})$.

The energy is estimated by:

$$\mathrm{E} = \sum_{\mathrm{n}=0}^{\mathrm{N}} |\mathrm{x(n)}|^2 \tag{3}$$

Now the Energy is matched to a threshold for examination which hypothesis would be true.

$$\mathrm{E} > \lambda \implies \mathrm{H_1}$$
$$\mathrm{E} < \lambda \implies \mathrm{H_0} \tag{4}$$

The detecting is accomplished to make definite if any action of the primary user for a particular band of frequency occurs, as suggested by binary hypothesis testing, and that can be mapped as:

H_0: The idle primary user

H_1: The working primary user

Missed detection senses busy channel as an idle channel and selects the hypothesis $H0$, which causes harmful interference to the primary user whereas false alarm senses idle channel as busy channel and selects the hypothesis $H1$, which cases the secondary user to miss the opportunity for efficient spectrum utilization[9].

Based on this the performance of the detection technique can be defined by the following two possibilities. The possibility of unused detection,

$$P_{md} = P(H_0 = H_1) \tag{5}$$

And the possibility of false alarm

$$P_{fa} = P(H_1 = H_0) \tag{6}$$

Possibility of Recognition for AWGN Channel

Possibility of recognition Pd and false alarm Pf can be assessed respectively by

$$P_d = P(V > \frac{V_{th}}{H_1})$$
$$P_f = P(V > \frac{V_{th}}{H_0}) \tag{7}$$

Where Vth is the threshold

Conventional Single-Threshold Power Recognition Alogorith

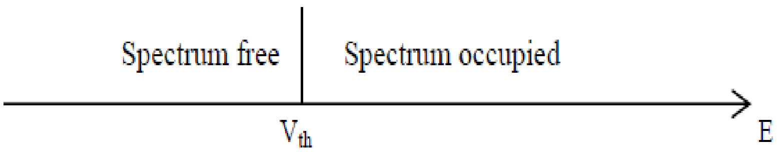

Figure 1 Single threshold method

Neyman-Pearson criterion [10] is mostly used in traditional single-threshold energy estimation algorithm. In Figure. 4, we have single detection threshold. The received signal energy defined as V is higher than the estimation threshold Vth then it is assumed the presence of primary user, represented as$H1$, on the contrary, here primary user represented as $H0$.

The estimation possibility, false alarm possibility, and miss possibility can be evaluated [11], respectively:

$$p_d = \Pr\left(V > \frac{V_{th}}{H_1}\right) = Q_u(\sqrt{2\gamma}, \sqrt{V_{th1}}) \tag{8}$$

$$p_f = \Pr\left(V > \frac{V_{th}}{H_0}\right) = \frac{\Gamma(u, \frac{V_{th}}{2})}{\Gamma(u)} \tag{9}$$

$$p_m = \Pr\left(V \le \frac{V_{th}}{H_1}\right) = 1 - p_d \tag{10}$$

Here is the SNR (Signal-Noise Ratio) received by cognitive user, Vth is the detection threshold, Qu (a, b) is normalized Marcum function with the order u . $\Gamma(a, b)$ is a non-complete gamma function; $\Gamma(a)$is complete gamma function.

4 Improved Double-Threshold Energy Detection Algorithm

We add another detection threshold within the conventional single-threshold energy detection algorithm, and it becomes a double-threshold energy detection algorithm with two detection thresholds (V_{th0} and V_{th1}).

The primary user will be detected if and only if $V > V_{th1}$, and will not be presented if and only if $V < V_{th0}$, corresponding to H1 and H0, respectively.

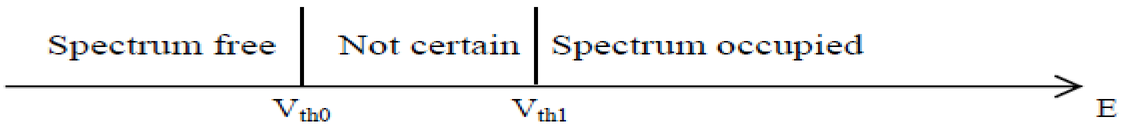

Figure 5 Double threshold methods

In this model, two thresholds V_{th0} and V_{th1} are used to help the decision of the secondary user.

- If energy value exceeds V_{th1}, then this user reports H1, which means that it 'sees' the primary user. If E is less than V_{th0}, decision H0 will be made.

Otherwise, if E is between V_{th0} and V_{th1}, then we also allow the secondary user reporting its observational energy value[12].

- So in our model, the fusion center receives two kinds of information: local decisions and observational values of the secondary users, i.e. local energy values.

Following are the performing schemes of the double threshold energy detection cooperative spectrum sensing method. When the detected energy V is in (V_{th0}, V_{th1}), this result is invalid because of easy to mistaken. It needs redetection.

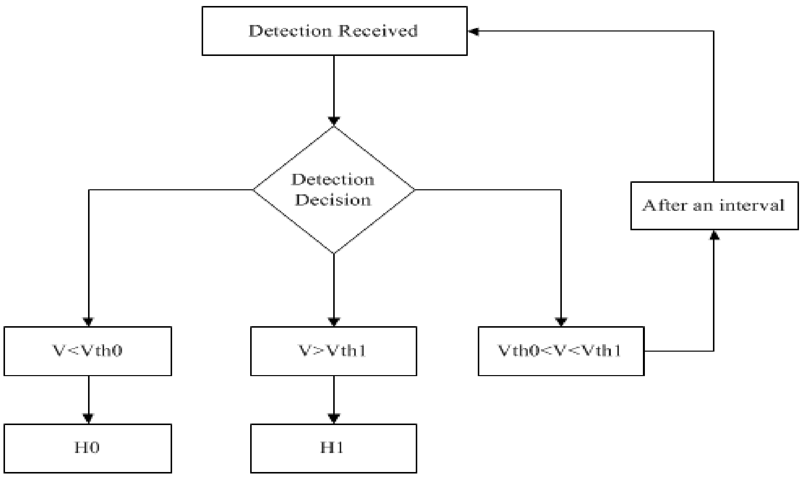

Figure 6: Double threshold energy detection

From our discussion the performance indicator for the detection probability, false alarm probability and missing probability for double threshold method can be calculated using

$$p'_d = \Pr(V' > V_{th1}/H_1) = Q_u(\sqrt{2\gamma'}, \sqrt{V_{th1}}) \quad (11)$$

$$p'_f = \Pr\left(V' > \frac{V_{th1}}{H_0}\right) = \frac{\Gamma(u, \frac{V_{th1}}{2})}{\Gamma(u)} \quad (12)$$

$$p'_m = \Pr\left(V' \leq \frac{V_{th0}}{H_1}\right) = 1 - p'_d \quad (13)$$

Here p'_d is the correct detection probability when the primary user presents.

$p'_f$is the probability of the primary user detected presently, but in fact it does not present.

p'_m is the probability of the primary user perhaps may not be detected, but in fact it does present. According to our proposed Improved Double Threshold Energy Detector we are using two thresholds values (V_{th0}, V_{th1}) in improved energy detector. Here by adding the advantage of less probability of collision of Double threshold algorithm ,with advantage of better Detection of Improved Energy detection of spectrum sensing , we are getting the better performance in the Energy detection method of spectrum sensing .Expressions for detection probability, false alarm, collision probability and spectrum non-available probability are

$$P_c = \Pr\left(V < \frac{V_{th0}}{H_0}\right) \quad (14)$$

$$P_{na} = \Pr\left(V > \frac{V_{th0}}{H_0}\right) \quad (15)$$

$$P_f = \Pr\left(V > \frac{V_{th1}}{H_0}\right) \quad (16)$$

$$P_d = \Pr\left(V > \frac{V_{th1}}{H_1}\right) \quad (17)$$

5 Results and Discussion

Receiver operating characteristics(ROC) plot for energy detector based spectrum sensing:

Pm=probability of missed detection

Pd= probability of detection

Pf= probability of false alarm

Pc= probability of collision

Detection probability (Pd), False alarm probability (Pf) and missed detection probability (Pm) are the key measurement metrics that are used to analyze the performance of spectrum sensing techniques. The performance of a spectrum sensing technique is illustrated by the receiver operating characteristics (ROC) curve which is a plot of Pd versus Pf (or) Pd versus Pm.

The performance of energy detector is analysed using ROC curves. Monte-Carlo method is used for simulation. The plot of Probability of false alarm versus Probability of detection for different values of probability of false alarm is illustrated in Figure.7 and it can be interpreted from Figure.8 that the performance of energy detector improves with increase in SNR and increase in probability of false alarm respectively.

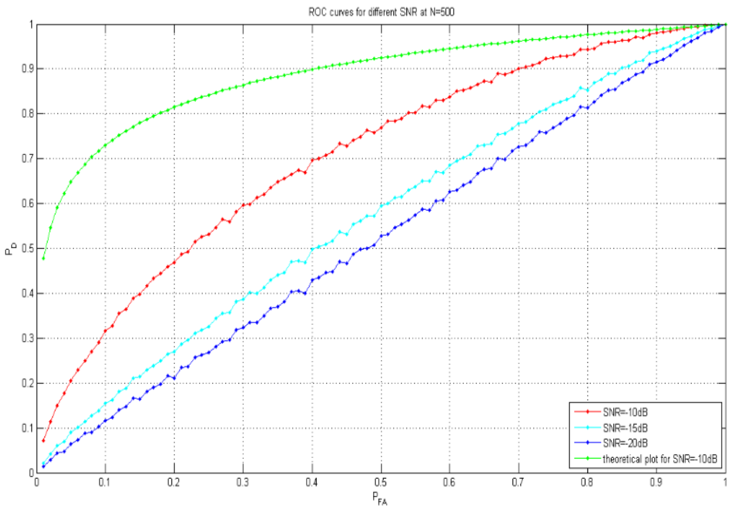

Figure 7 ROC curve for different SNR

Here we have taken probability of false alarm is (0, 1), N=500 and the SNR at three different values -10dB,-15dB,-20dB.from the Figure.7 it is observed that detection performance improved by increasing SNR value.

Table 1 PD, PF and Threshold values for SNR Variation

PD	PF	TH1
0.7107	0.001 -0.9	0.8901
0.5723	0.001 -0.9	0.8901
0.5248	0.001 -0.9	0.8901

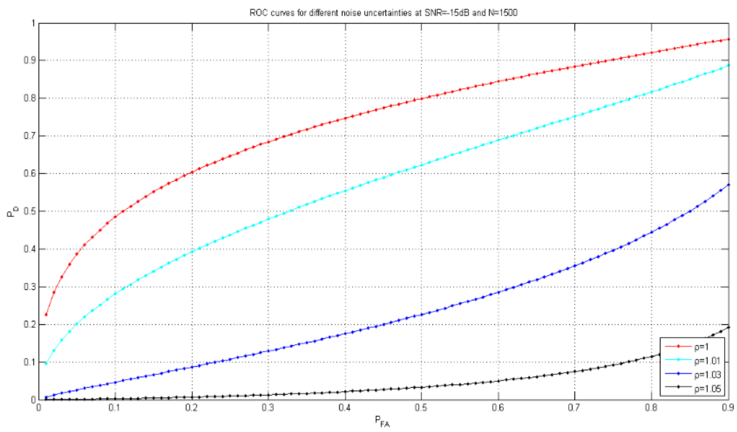

Figure 8 ROC CURVE FOR NOISE VARIATION OVER AWGN

Figure.8. above illustrates the ROC (Receiver Operating Characteristics) curves i.e. PD versus PFA using Energy detection method for spectrum sensing. This conventional method uses squaring operation. The graph is plotted for different SNR values over AWGN channel and it shows that with increase in SNR (Signal to Noise Ratio), the probability of detection increases

Table 2 PD, PF and Threshold values for SNR variation over AWGN

PD	PF	TH1
0.6829	0.001 -0.9	0.9669
0.8961	0.001 -0.9	0.9669
0.9346	0.001 -0.9	0.9669

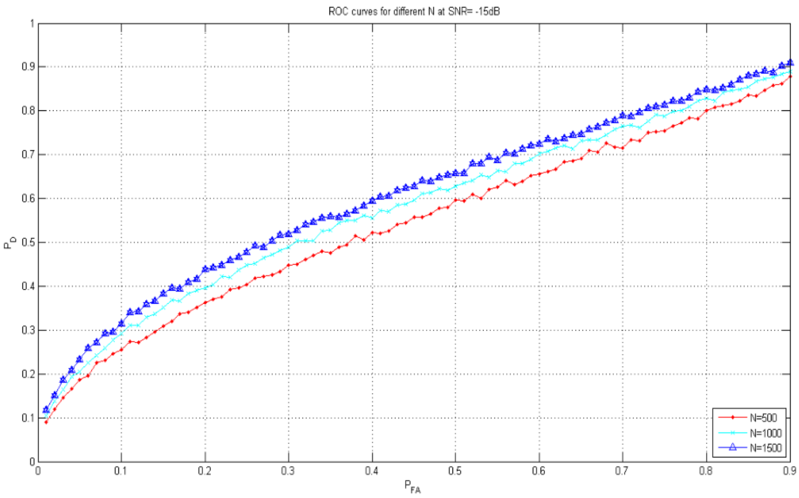

Figure 9 ROC Curve For Varied Samples

From figure 9 shown for varied number of samples, we can observe that the detection performance of Improved Double Threshold Energy detector is improved compared to Energy detector algorithm in double threshold Energy detection, as the number of samples increases the probability of detection also increases.

Table 3 PD, PF and Threshold values for sample variation

PD	PF	TH1
0.8750	0.001 -0.9	0.9556
0.8942	0.001 -0.9	0.9806
0.900	0.001 -0.9	1.0351

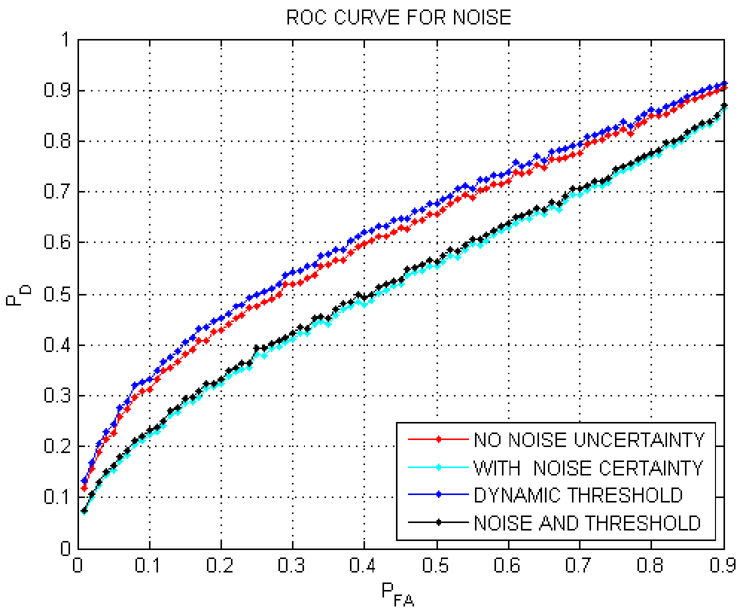

Figure 10 ROC Cure for No Noise Uncertainty, Noise Certainty, Dynamic Threshold, Noise and Threshold Variation.

From the plot shown above noise variation, we can observe that the detection performance of Improved Double Threshold Energy detector is improved compared to Energy detector algorithm, with this improvement the enhancement of this Hybrid detector gives better detection performance

Table 4 PD PF and Threshold Values For No Noise Uncertainty, Noise Certainty, Dynamic Threshold, Noise and Threshold Variation noise Certainty, and uncertainty and Threshold Variation

PD	PF	TH1
0.1155	0.001 -0.9	0.9669
0.0698	0.001 -0.9	0.9862
0.1267	0.001 -0.9	0.9650

6 Conclusion

In this work, an improved double threshold energy detection method is applied for spectrum sensing to improve the SNR and detection probability in cognitive radio. It can be seen by the simulation results that by keeping the false alarm probability as constant the energy detection performance is greater compared to other techniques. Simulation results are carried out under various parameters i.e. varied number of samples, noise and threshold. Our main aim of the work is to sense the spectrum when the SNR of PU is less, here in the simulation results for SNR = -10 dB, the probability of detection is achieved 1. In the same manner, when the number of samples are increased the PD is also increased.

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