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Analysis of Performance of Energy Detection over Distinct Channels in Cognitive Radio

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Abstract- Due to the rapid increase in the use of wireless technologies, we require the appropriate usage of radio spectrum. For the appropriate usage of radio spectrum, one of the technique called cognitive radio come into existence. As we know number of users are increasing progressively but our available spectrum are becoming abundant. Research says that almost of the authorized spectrum persists spare for lots of the time and thus decreasing the efficiency. By using the cognitive radio we can provide this unoccupied spectrum to the unlicensed user without causing any interference to the other network. To accomplish this we need to perform the spectrum sensing and for this many spectrum sensing techniques has been proposed by the researchers. This paper will give the brief introduction about the various spectrum sensing techniques. At last the result is provided in this paper by comparing the functioning of energy detection technique on Rayleigh and AWGN channels by using Receiver Operating Characteristics Curve in MATLAB software by varying SNR and number of samples “n” values.

Keywords- cognitive radio, matched filter, energy detection, spectrum sensing.

I. INTRODUCTION

With the development of wireless applications, radio spectrum are on huge requirement. Presently, spectrum allocation is done by allocating a new service to its own rigid band. But nowadays, almost all our technologies are becoming wireless due to which need of the spectrum is increasing progressively.

As we know the primary users have their bands pre-allocated, due to which it become difficult for the new services to find the spectrum. Our present policies do not permit the unauthorized user to use spectrum of the authorized users and this leads to the scarcity of the radio spectrum. By scanning the radio spectrum, we witness that either several frequency bands in spectrum are not utilized for most of the period or some frequency bands are occupied to a great extent.

Currently, the primary users spectrum band is not utilized by the secondary user due to this spectrum scarcity problem is becoming worse day by day with the introduction of the new wireless services. Recent survey done by the Spectrum Policy Task Force (SPTF) shows that the authorized spectrum remains unoccupied for most of the time. A solution to this problem is the proper utilization of spectrum by permitting the secondary users to the usage of the authorized spectrum when primary user is not using that.

Cognitive radio technology allows the secondary user for usage of authorized spectrum when primary user is not transmitting. Cognitive radio is known to the environment of radio frequency, accordingly it chooses various communication arguments like carrier frequency, modulation type for the successful transmission and reception.

Secondary users are of two types first one is temporal secondary users and second one is partial secondary users. The temporal secondary users are those users which can use the spectrum for the transmission and throughout this period primary users are not using the spectrum. Second one, spatial secondary users are those users which uses the spectrum beyond that particular area in which primary user is using the spectrum for transmission.

By using the various spectrum sensing techniques, cognitive radio permits the secondary user to use the authorized spectrum not causing any interference to the other network:

1. Energy detection technique is a technique that helps us to determine whether the signal is available or not without any data of the primary users. This method uses a threshold value. It considers the primary signal as noise and then detect signal beingness.
2. Matched filter detection is technique when secondary user has the cognition of the primary user, because of

this matched filter detection technique necessitate fewer time detection period.

3. Cyclostationary detection uses the timely varying periodic characteristics of the signal to determine the beingness of the primary user.

For this cognitive radio has to continuously examine the spectrum to evaluate the return of primary user. As a primary user existence is found, cognitive radio has to adjourn of the spectrum immediately to avoid interference.

The following paper organizes as section 2 which describes the work that has been done till now in this field. Section 3 describes the tool used for designing of spectrum sensing technique using distinct channels. Section 4 describes the simulation outcome for distinct channels. Finally, Section 5 shows conclusion and future work that can be done.

II. RELATED WORK

Various researchers have done a lot of work on the spectrum sensing techniques used in cognitive radio.

In [1], an overview of cognitive radio system sensing techniques such as local spectrum sensing technique based on hypothesis testing criteria etc. It also include various techniques to improve the sensing performance . Further it also include various spectrum sharing technique.

In [2], review of implementation of unique characteristics of cognitive radio technology such as spectrum positioning and environmental cognizance. Also discuss the dynamic nature of cognitive radio system along with limitations, issues and mitigation techniques.

In [4], discussed about the three non-cooperative spectrum sensing technique of the cognitive radio and their implementation which is done by using the flow diagram. This paper also include the comparison between their performance.

In [8], due to the rapid increase in the wireless technology, cognitive radio is becoming very popular technology for the proper utilization of the radio spectrum. This can be done by sensing the spectrum i.e determining the existence of primary user in the authorized spectrum. It contains brief introduction of the various spectrum sensing techniques used by the cognitive radio.

In [9], paper contains the brief introduction of cognitive radio and various spectrum sensing techniques used in the cognitive radio. It gives functional analysis of the energy detection spectrum sensing technique.

In [11], due to the rapid growth in the wireless services, there is the need for the proper usage of the radio spectrum. This problem is solved by cognitive radio by allocating the unoccupied spectrum to the secondary user in absence of the primary user. For this there is requirement of continuous sensing of the spectrum using the various spectrum sensing technique. One of the technique called energy detection is being discussed in this paper over the different fading channel by using the various parameters such as probability of false alarm, probability of detection, signal to noise ratio.

In [12], maximum threshold level for the energy detection is determined. This maximum threshold value is chosen such that it minimizes the sensing error and increases the overall spectrum efficiency. To minimize the sensing error, maximum adaptive threshold value is calculated. The result shows that this strategy gives the better than the already existing scheme.

In [14], discussed the solution of energy detection problem of the unknown signal by considering the different channels. Firstly it starts with no-diversity case and then it find probability of detection having some closed form expressions. After that by using the various diversity scheme it increases the probability of detection.

Table 1. Literature Review Summary

S.NO	AUTHOR NAME	DESCRIPTION	METHOD USED
1	Lu et al (2012)	Overview of cognitive radio technology.	
4	Nazar Radhi (2011)	Discussed various non-cooperative spectrum sensing technique. Their implementation using the flow diagram and performance comparison was also being discussed.	Non-cooperative spectrum sensing method
5	Sajjad Ahmad Ghauri, I M Qureshi, M. Farhan Sohail, SherazAlam, M. Anas Ashraf (2013)	By considering performance arguments such as probability of detection, probability of false alarm, signal to noise ratio(SNR), the performance analysis was done under the different channels for the energy detection and matched filter detection method.	Energy detection and matched filter detection method
6	Mr. Pradeep Kumar Verma, Mr. Sachin Taluja, Prof. Rajeshwar Lal Dua (2012)	Functionality comparison between the various spectrum sensing techniques i.e energy detection, matched filter detection, cyclostationary feature detection is being illustrated.	Energy detection, matched filter detection, cyclostationary feature detection method
7	J Ma, GD Zhao, YG Li (2008)	Cooperative spectrum sensing based on energy detection in cognitive radio networks is being studied.. Using the Neyman-Pearson standard, favorable soft combination scheme is obtained that optimizes the	Cooperative spectrum sensing technique

		probability of detection for a particular probability of false alarm.	
8	Tulika Mehta, Naresh Kumar, Surender S Saini, (2013)	This paper contains the brief introduction and comparison between the various spectrum sensing techniques used by the cognitive radio for the proper utilization of the radio spectrum.	Energy detection, matched filter detection, cyclostationary feature detection method
2	H. Celebi, Ismail Guvenc, S. Gezici and H. Arslan (2010)	Implementation of unique characteristics of cognitive radio technology such as spectrum positioning and environmental cognizance. Also the dynamic nature of cognitive radio system along with limitations, issues and mitigation techniques is being discussed.	
9	Garima Nautiyal, Rajesh Kumar (2013)	Paper contains the brief introduction of the cognitive radio and the various spectrum sensing techniques. This paper gives the functionality synthesis of energy detection spectrum sensing technique.	Energy detection technique
10	Md. Shamim Hossain, Md. Ibrahim Abdullah, and Mohammad Alamgir Hossain (2012)	Paper shows how the change in the probability of detection effects with the change in signal to noise ratio and bandwidth factor in the energy detection technique.	Energy detection technique
11	Omkar S. Vaidya, Vijaya M. Kulkarni (2013)	One of the technique called energy detection is being discussed in this paper over the different fading channel by using the various parameters such as probability of false alarm, probability of detection, signal to noise ratio.	Energy detection method
3	Y-C Liang, K-C Chen, G. Ye Li and P. Mahonen (2011)	Paper focuses on overview of cognitive radio technology that solves the problem of spectrum scarcity and functions of three layers.	
12	Dong-Chan Oh and Yong-Hwan Lee (2009)	Maximum threshold level for the energy detection is determined such that it minimizes the sensing error and increases the overall spectrum efficiency. The result shows that this strategy gives the better than the already existing scheme.	Energy detection method
13	Sajjad Ahmad Ghauri, et al (2103)	Functioning of the energy detection and matched filter detection method by using the various arguments such as probability of false alarm, probability of detection and signal to noise ratio over the different fading channels is being discussed.	Energy detection and matched filter detection method

III. RESEARCH METHOD AND DESIGNING

MATLAB tool is used for the analysis of energy detection. Energy detection helps us to determine whether the signal is available or not without any data of the primary users. This method uses a threshold value. It considers the primary signal as noise and then detect signal beingness. Following is the diagram for energy detector.

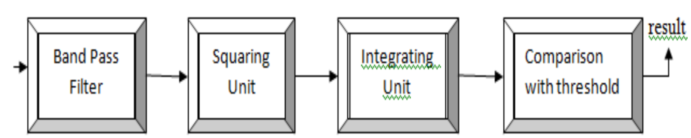

Figure 1. Block Diagram of Energy Detection Based Spectrum Sensing technique

The input signal is passed through the band pass filter to filter the signal by decreasing the noise in the signal. Next, the signal is sent through the squaring unit which squares the signal over the time period and further passed through the integrating unit. The output of the Integrating unit is the energy of the signal passed in the squaring unit which is further compared against the threshold value to determine the beingness of the primary signal.

Assume Z be energy output from the integrating unit which is as follows:

$$W=\frac{1}{k}\int_0^T Z^2(t)\,dt \qquad (1)$$

Then the decision is made by comparing Z with the threshold value ϒ:

$$R= \begin{cases} B1, & Z > \Upsilon \\ B0, & Z < \Upsilon \end{cases} \qquad (2)$$

Where ϒ indicates the threshold

When B_0=1, designates the non existence of primary user

When B_1=1, designates the existence of primary user

A. Mathematical Model For Performance Measurement

The performance of the signal existence is calculated by using some parameters: probability of Detection (P_{de}), probability of false alarm (P_{fa}) and probability of missed detection (P_{md}). P_{de} determines the signal existence to avoid interference. As large as P_{de} value, less chances of interference. False Alarm indicates the chances of the free spectrum used by the secondary user. Value of P_{fa} should be kept small so that chances of usage of free spectrum by the secondary user are high. Miss detection occurs when the existence of primary signal is not detected and secondary user starts transmission which leads to interference. Higher the value of P_{md}, more the chances of interference. So a good spectrum sensing technique should have a higher P_{de} , lower P_{fa} and lower P_{md} .

ROC (Receiver Operating Characteristics) curve is used to describe and measure the performance of the received signal. In these curves, one argument is constant and other argument is inconsistent. This curve depicts the relation between P_{md} and P_{fa} therefore results in the evaluation of threshold value.

Considered channel Result Statistics (W) is calculated for k no of samples by passing the signal through energy detection technique:

$$W=\frac{1}{k}\int_0^T Z^2(t)\,dt \qquad (3)$$

Signal To Noise Ratio (SNR), β is calculated using non-central parameter distribution as in [14]:

$$\beta = \frac{E_{si}}{2k} = \frac{\mu}{2} \qquad (4)$$

where μ is the non-central parameter and E_{si} is the energy of the signal.

B. Calculation of P_{de} for Additive White Gaussian Noise (AWGN) channel:

Probability of false alarm (P_{fa}) and probability of detection (P_{de}) is calculated by [14] as follows:

$$P_{de}=P(W > \Upsilon|B_1) \qquad (5)$$

$$P_{fa}=P(W > \Upsilon|B_0) \qquad (6)$$

Where ϒ= threshold value

Probability of False Alarm (P_{fa}) can also be scripted using the probability density function as in [15]:

$$P_{fa}=\int_{\Upsilon}^{\infty} f_{z'}(y)\,dy \qquad (7)$$

From (6), we obtain,

$$P_{fa}=\frac{1}{2^d\Gamma(d)}\int_{\Upsilon}^{\infty}\left(\frac{y}{2}\right)^{d-1} e^{-\left(\frac{y}{2}\right)}dy \qquad (8)$$

Now multiplying and dividing the above equation by 2^{d-1} and then substituting the equation by $\frac{y}{2}$ = t and representing the equation by using $\Gamma(d,x)=\int_x^{\infty} t^{d-1}\, e^{-t}dt$, P_{fa} is shown as [14],

$$P_{fa}= \frac{\Gamma(d,\Upsilon/2)}{\Gamma(d)} \qquad (9)$$

By using the cumulative distribution function, we can write probability of detection (P_{de}) as follows as in [15]:

$$P_{de}=1- F_W(\Upsilon) \qquad (10)$$

The CDF of W can be evaluated as [16]:

$$F_{W(y)}=1- Q_d(\sqrt{\mu},\sqrt{\Upsilon}) \qquad (11)$$

Using above two equations (10) and (11), P_{de} for AWGN channel is as follows as in [14]:

$$P_{de}= Q_d(\sqrt{\mu},\sqrt{\Upsilon}) \qquad (12)$$

Using (4),

$$P_{de}= Q_d(\sqrt{2\beta},\sqrt{\Upsilon}) \qquad (13)$$

Here Q(….) = generalized Marcum-Q function

Hence by using the above equation we can calculate probability P_{de} for the Additive White Gaussian Noise Channel.

C. P_{de} for the Rayleigh channel:

Probability of detection P_{de} can be calculated by taking average of f(β) which is the probability density function of the channel over the P_{de} of the AWGN channel as in [17]:

$$f(\beta)=\frac{1}{\bar{\beta}}\, exp^{(-\frac{\beta}{\bar{\beta}})}, \beta>=0 \quad (14)$$

Now P_{deR} for the Rayleigh channel can be shown as follows as in [14]:

$$P_{deR}=e^{(-\frac{\Upsilon}{2})}\sum_0^{d-2}\frac{1}{n!}\left(\frac{\Upsilon}{2}\right)^n+\left(\frac{1+\bar{\beta}}{\bar{\beta}}\right)\left[exp^{(-\frac{\Upsilon}{2(1+\bar{\beta})})}-exp^{(-\frac{\Upsilon}{2})}\sum_0^{d-2}\frac{1}{n!}\left(\frac{\Upsilon\bar{\beta}}{2(1+\bar{\beta})}\right)^n\right] \quad (15)$$

IV. SIMULATION AND RESULT

Simulation is done using MATLAB (R2016a) tool over Rayleigh fading channel and AWGN channel. Receiver Operating Characteristics(ROC) curve shows the functioning of the spectrum sensing technique on various fading channels by plotting P_{de} v/s P_{fa} and P_{md} v/s P_{fa} . Simulation is done in MATLAB using MC (Monte Carlo) technique.

Fig 2. And Fig 3. Shows the ROC graph P_{de} v/s P_{fa} for two distinct values of SNR i.e SNR = -18db and SNR= -8db with number of samples 900 over the AWGN channel. From the curves we can conclude that as the value of SNR increases, theoretical and simulation values become identical which shows the better performance.

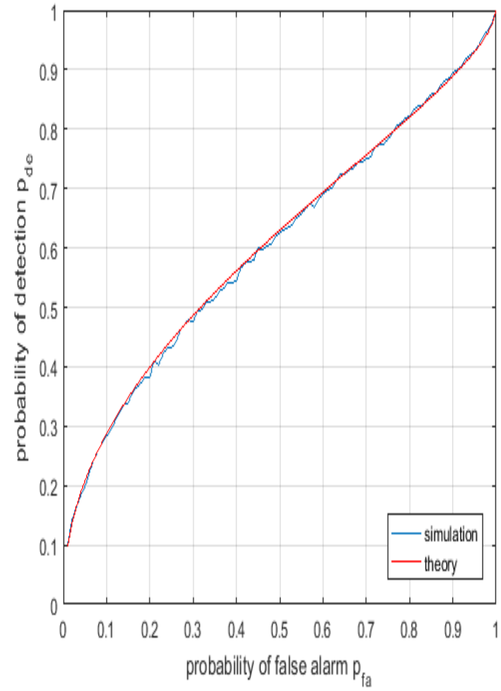

Figure 2. ROC curve showing P_{de} v/s P_{fa} for SNR = -18db

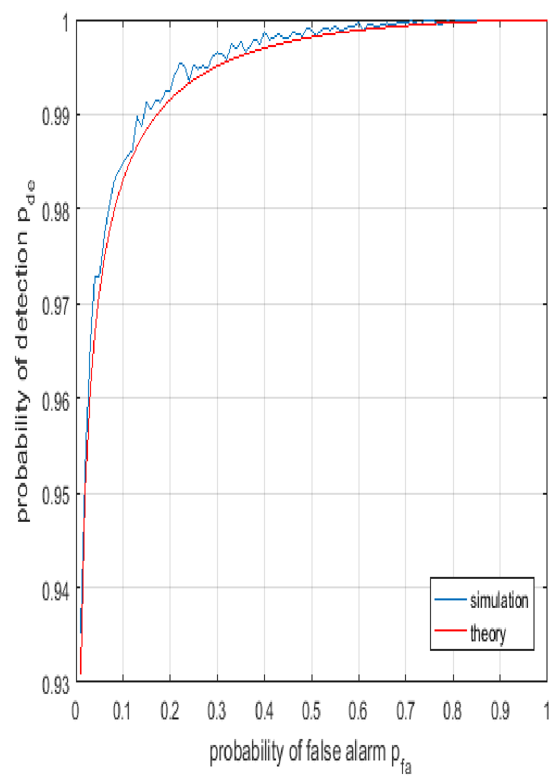

Figure 3. ROC curve showing P_{de} v/s P_{fa} for SNR = -8db

Fig 4 shows the graph P_{de} v/s P_{fa} for distinct values of number of samples ( ) . Lower the value of number of samples, higher the value of performance.

Fig 5 shows the graph P_{de} v/s P_{fa} for distinct SNR values(8db,18db and 28db) over the Rayleigh Channel with the number of samples taken as 900. In case of Rayleigh channel the fading of the channel is higher than the AWGN channel. From the graph we can conclude that as the value of SNR becomes higher, the value of P_{de} also get increased.

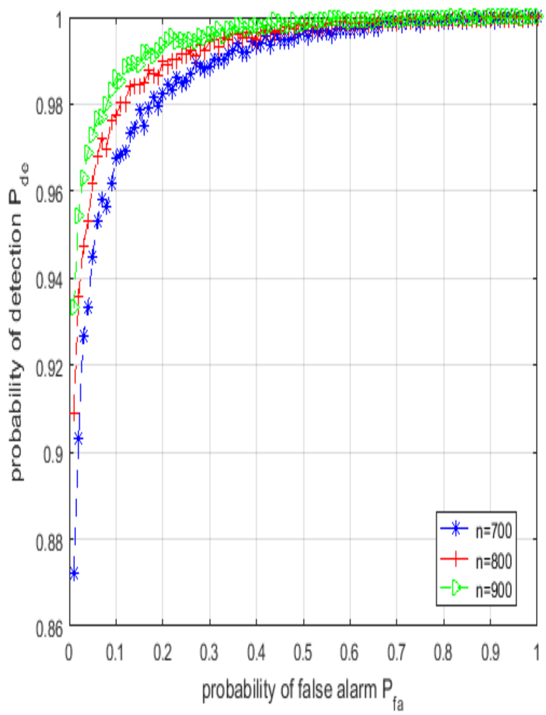

Figure 4. ROC curve showing P_{de} v/s P_{fa} for SNR = -8db for different 'n'

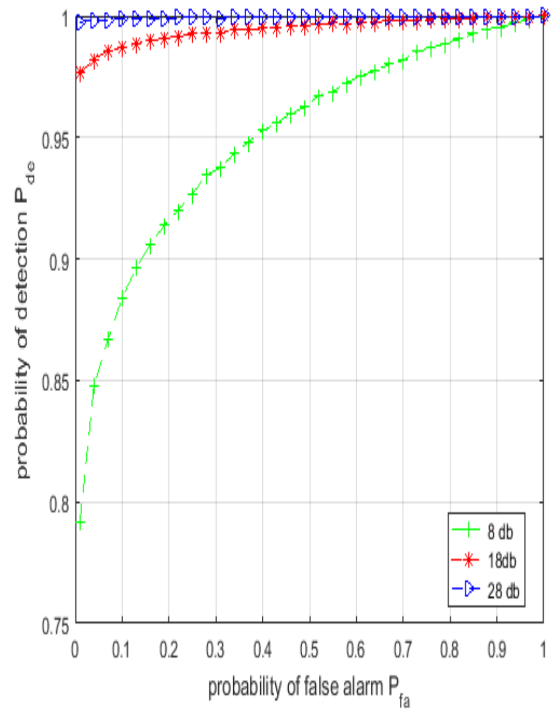

Figure 5. ROC curve showing P_{de} v/s P_{fa} on Rayleigh channel for distinct SNR values

Following ROC curves(Fig 6,7,8) shows the comparison over the two channels at distinct SNR values. A better spectrum sensing technique must have a higher P_{de}, lower P_{fa} and lower $P_{md.}$ From the following graphs we can see that as high is the value of P_{de} , low is the value of P_{fa} which leads to the better performance.

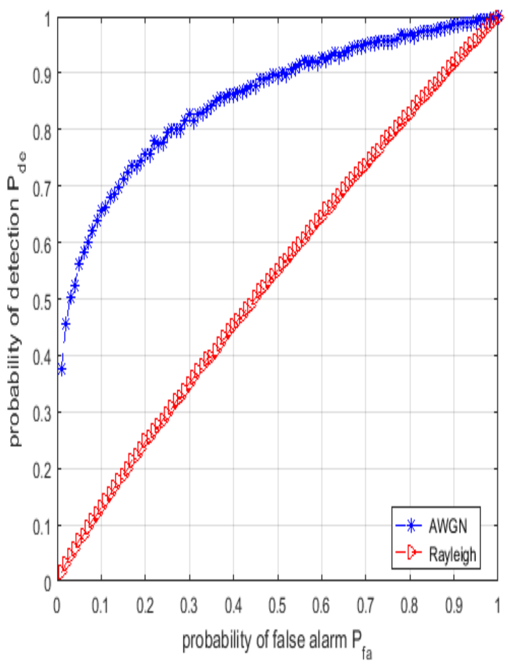

Figure 6. ROC curve showing comparison on SNR = -12db

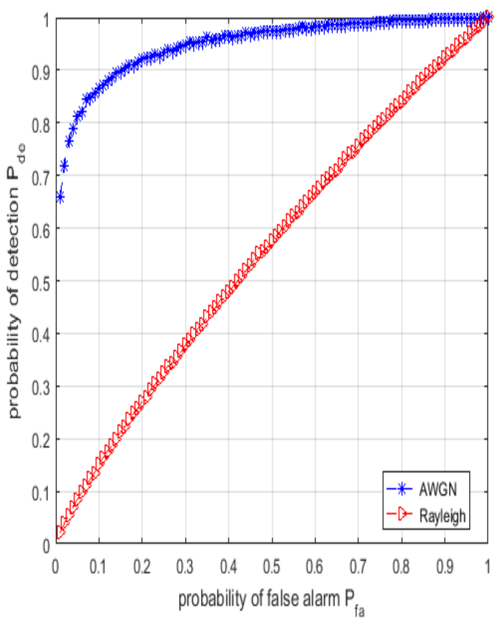

Figure 7. ROC curve showing comparison on SNR = -10db

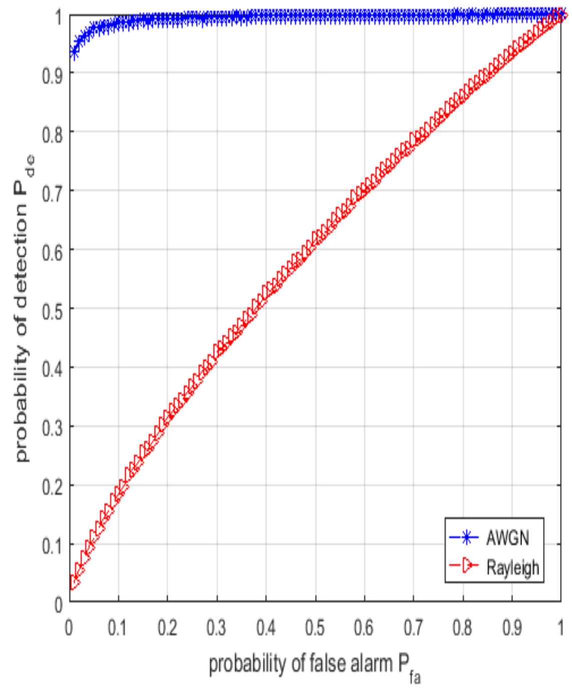

Figure 8. ROC curve showing comparison on SNR = -8db

From the above curves we can conclude that best performance is shown over AWGN channel as the value of P_{de} is higher in this case than the Rayleigh channel. As the value of P_{fa} varies from 0 to 1, the value of P_{de} for AWGN channel is more than Rayleigh channel and also the value of P_{de} gets increased in a single channel too.

V. CONCLUSION

In this paper a technique that reduces the underutilization of band , called Cognitive Radio has been talked about. Performance of the spectrum is evaluated over distinct channels i.e AWGN and Rayleigh channels. Performance parameters which are P_{de} , P_{fa} and P_{md} have been assessed and taken for finding out the performance of the channel. Various ROC curves have been plotted on different channels taking different signal to noise ratio values. As the value of false alarm probability (P_{fa}) gets more and more, value of detection probability (P_{de}) gets more and more over AWGN channel. Hence, among the two channels, the performance of AWGN channel is better than the Rayleigh channel.

VI. FUTURE SCOPE

In this paper, fixed threshold value is taken to check the functioning which depends on noise of the signal. In future, a varying threshold value can be taken and also performance can be detected by taking other channels for achieving better performance.

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