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Simulation Platform for Energy Detection Method of Spectrum Sensing in Cognitive Radio

Mr. Ankit Dobariya, Mr. Sagar Sodhatar

***Abstract*— An aim of this study is to focus on spectrum sensing in cognitive radio which is an introduced technology recently in order to enlarge the spectrum effectiveness. Increasing the effectiveness of the spectrum usage is a fundamental requirement as an essential result of the quickly growing number of wireless users and also the transfer of voice related applications to multimedia applications. Cognitive radio provides the important solution to overcome the problem of spectrum underutilization that's why dynamic spectrum usage is required for wireless networks instead of static spectrum allocation. The focus of this paper is to implement simulation platform for energy detection method to do comparative analysis of threshold value for predetermined probability of detection using Graphic User Interface tool in MATLAB for theoretical as well as practical values.**

***Index Terms* - Cognitive Radio, Energy Detection, Threshold, Probability of detection, Probability of miss detection, Probability of false alarm.**

I. INTRODUCTION

In a present day, wireless communication has become very much popular communication. This wireless network is categorized by a static spectrum allocation policy, means fixed frequency spectrums have been assigned to license holders on a long term basis for very large geographical area by government [1]. Due to this fixed frequency spectrum assignment this strategy faces the spectrum scarcity in some part of spectrum bands [2]. Similarly large portion of frequency bands in the spectrum are unutilized or unoccupied most of time, some other frequency bands are incompletely occupied and some frequency bands are heavily occupied. However lots of licensed spectrum bands are resulting in spectrum wastage. It has become necessary to bring in new licensing policies and organized infrastructure to facilitate dynamic and efficient spectrum utilization to meet the need of wireless users. In order to solve the disparity between lack of spectrum and spectrum underutilization a modern spectrum access strategy called cognitive radio which is promising solution to such problem.

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***Mr. Ankit Dobariya**, PG Student, Department of Electronics & Communication Engineering, Noble Group of Institutions, Junagadh.*

***Mr. Sagar Sodhatar**, Assistant professor, Department of Electronics & Communication, Noble Group of Institutions, Junagadh.*

II. CHALLENGES TO COGNITIVE RADIO

- Differentiate or identify the spectrum holes and occupied bands.
- Highly reliable communication whenever and wherever needed.
- Efficient utilization of radio spectrum.
- Do not cause any interference with the primary user.
- Giving first priority to primary user whenever they want to communicate with the other licensed users in geographical area.
- The secondary users must use the vacant frequency from the licensed band which is not utilized by primary user. Also secondary user must vacant that channel if will needed by primary user.

III. FUNCTION OF COGNITIVE RADIO

The fucntion of cognitive radio can be callsified in four catagoris for effective spectrum utilization and reduse the spectrum under utilization [3].

Spectrum Sensing: To detect the vacant spectrum from the license band

Spectrum Management: Choose the better frequency

Spectrum Sharing: Assignment of sensed frequency to valid user.

Spectrum Mobility: Vacant the detected hole if primary user requires.

IV. PROBLEM FORMULATION

Spectrum Sensing forms a very important and primary step in the setup of cognitive radio network. It helps one to fix on the vacant frequency bands in the licensed spectrum and also finds out the condition of the channel over which transmission is to take place. This is the key research area in the field of cognitive radio at the present time. At present there is no single simulator/simulation platform available for cognitive radio technology. A number of parameters to be set for checking performance of spectrum sensing using energy detection for doing comparative analysis theoretically as well as practically. As an initiative we have proposed simulation platform for doing comparative analysis for spectrum sensing using energy detection method in cognitive radio.

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V. ENERGY DETECTION BASED SPECTRUM SENSING

This method is used for deciding the absence or presence of primary user with the help of secondary user by sensing the received signal power from the primary user. To do the measurement one energy detector is used. Based on the signal strength of primary user's signal it decides that whether the channel is available for the secondary users or not. This energy detector is referred as a radio meter. For this process secondary user doesn't require the prior information regarding primary user such type of signal, modulation scheme etc. so spectrum sensing using energy detection method is called as a non-coherent detection. This method is optimal when the secondary user doesn't have any information about the primary user. Following figure 1 shows how the vacant channel is detected by secondary user based on PU signal energy level. [4]

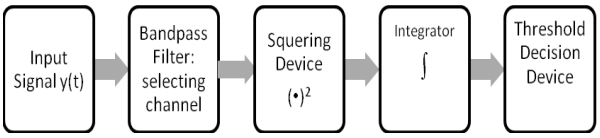

Figure 1: Block diagram of Energy detector

VI. FLOW CHART

The energy detection method is very to implement and it does require any prior information about the primary signal. It calculates the energy of received signal over L samples using monte carlo simulation. If the energy of signal founds more than energy level of threshold value then primary user is absent. Where the energy of signal founds less than the energy level of threshold value then the primary user is present.

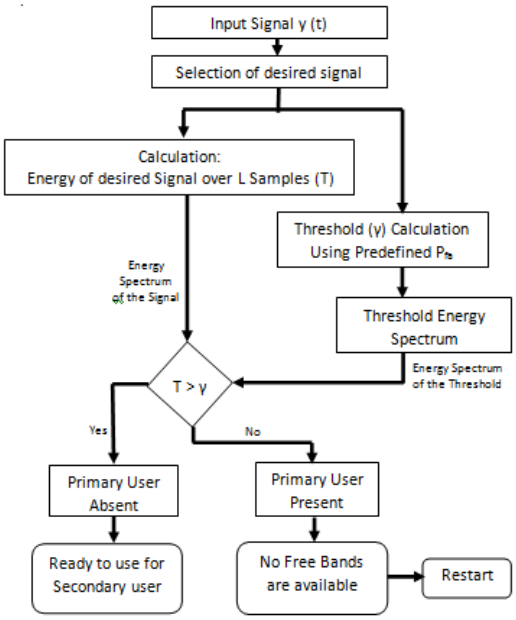

Figure 2: Flow Chart for Energy Detection method

The decision statistic for the energy detector is as follows [5].

$$T = \frac{1}{L}\sum_{n=1}^{L}[y\ (t)]^2$$

The decision static has a central chi square distribution with L number of freedom while primary user is absent. The decision statistic has a non- central chi square distribution with the same degree of freedom. So, T is random variable. It is a probability distribution function (PDF) under H0 and H1 respectively.The noise has the random distribution with zero mean and its variance is given by σ_n^2 and the signal can also represented by zero mean and its variance is σ_s^2.

Using this variance of noise and signal we can define a signal to noise ratio by,

$$SNR = \frac{\sigma_s^2}{\sigma_n^2}$$

The test statistic used for energy detection model is shown as under [6].

$$T = \frac{1}{L}\sum_{n=1}^{L}[y\ (t)]^2 \gtrless \gamma$$

Here L is number of samples taken to compute the spectrum estimation of received signal $y(t)$ and the value of L is very large (L >> 1). In this case noise parameter is unknown in real situation. γ is the threshold value which can decide between the real time noise and available primary user signal. When the number of sample is large enough, the probability distribution function of T represent as a test statistic as a Gaussian distribution with mean and variance as shown here [6].

$$f(T) = \begin{cases} L\left(\sigma_{n,}^2\ \frac{2\sigma_n^2}{L}\right) & \textit{Under H0} \\ L\left(\sigma_t^2\ ,\frac{2\sigma_t^2}{L}\right) & \textit{Under H1} \end{cases}$$

The threshold value can be found by taking certain amount of probability of false alarm for detection of the received signal [7].

$$P_{fa} = prob(T > \gamma/Ho)$$

$$= \dot{Q}\left(\frac{\gamma - \sigma_n^2}{\sigma_n^2/\sqrt{N/2}}\right)$$

The Q function is related to complementary error function which is given by

$$Q(\cdot) = \frac{1}{2}\ erfc\left(\frac{x}{\sqrt{2}}\right)$$

Now, the error function erfc is a complementary error function

$$erfc(x) \triangleq \frac{2}{\sqrt{\pi}}\int_x^{\infty} e^{-t^2}\ d(t)$$

The theoretical value of threshold for energy detector in the presence of additive Gaussian noise for the desired probability of false alarm P_{fa} [7].

$$\gamma = L\,\sigma_n^2\left(1+\frac{\sqrt{2}Q^{-1}(P_{fa})}{\sqrt{L}}\right)$$

From the above equation we have to take number of sample is very high. So the multiplication term can be neglect for finding a threshold value theoretically to determine perfect value for the same. Modified equation as under:

$$\gamma = \sigma_n^2\left(1+\frac{\sqrt{2}Q^{-1}(P_{fa})}{\sqrt{L}}\right)$$

First of all input signal y(t) is filtered by band pass filter. Here the function of Band pass filter (BPF) is in order to reduce the noise and choose the significance bandwidth. It also selects the center frequency. The output of band pass filter is given as an input to the squaring device. In this stage measurement of received signal is take place. The output of squaring device is followed by the input to integrator device which can decide the observation interval. At final stage the output of the integrator is compared with a threshold to determine the availability of primary user. Now the threshold value can be set either fix or variable depending upon the condition of channel. In this method, it does not identify the formation of the signal and determine the presence of user by only comparing the known threshold value with received energy of primary signal.

VII. PROPOSED SIMULATION PLATFORM

This section describe the MATLAB-based simulation platform that provides interactive access to check the performance and comparative analysis of threshold value for energy detection method theoretically as well as practically. The platform GUI (Graphic User Interface) is shown in below figure.

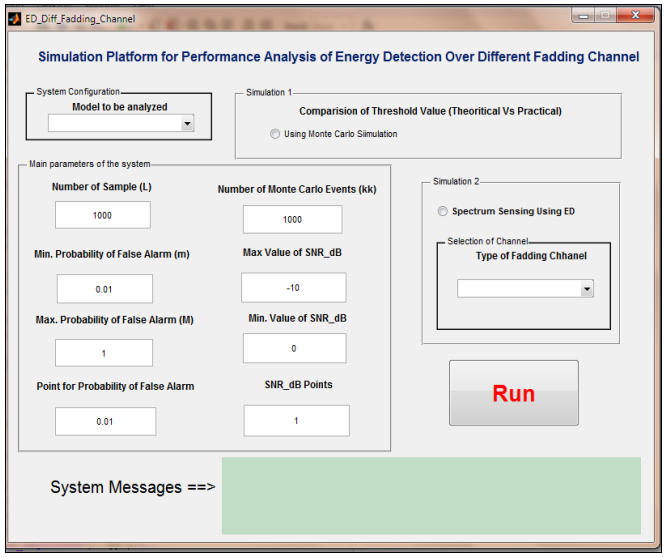

Figure 3: MATLAB based Simulation Platform

In order to deal with GUI, we must have to run the file (ED_Diff_Fadding_Channel.m") in MATLAB. As explain in previous section, there are a large number of parameters to be set for different simulation. Using GUI tool it minimize the easy way to analyze the simulation result in less time. First it is necessary to configure the system configuration, where the model is to be select and which are Calculation of threshold and performance analysis of energy detection.

VIII. SIMULATION RESULTS

Case -1: L=1000, Pfa = 0.01:0.01:1, Nevents = 10

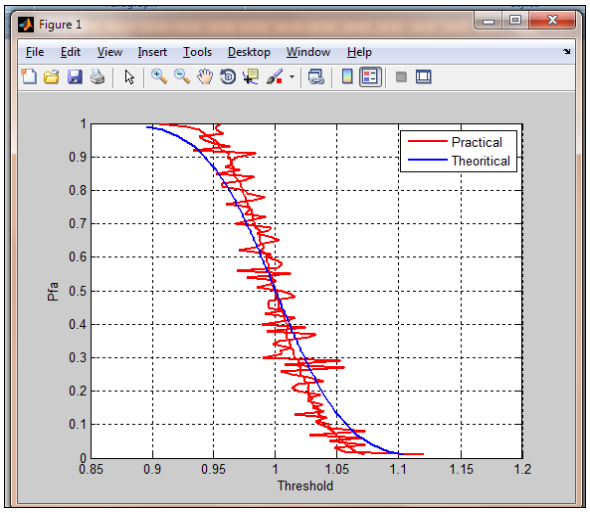

Figure 4 : Probability of False alarm Vs Threshold

Case -2: L=1000, Pfa = 0.01:0.01:1, Nevents = 10000

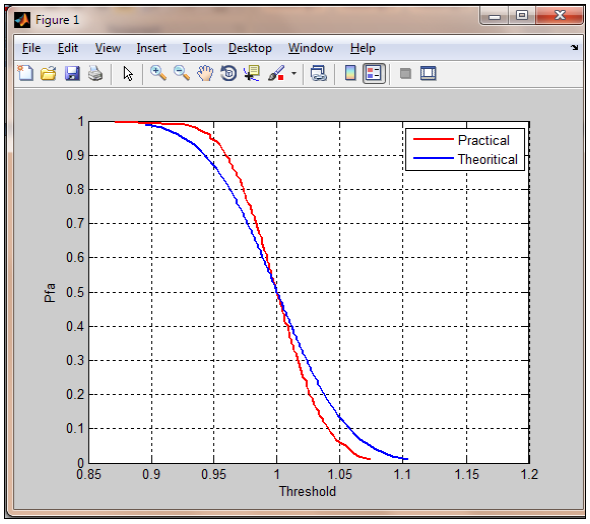

Figure 5 : Probability of False alarm Vs Threshold

From the above simulation result and analysis we can say that the if we take the number of monte carlo events larger than theoretical and practical calculation of threshold value will be almost same. Also we can say that for a particular value of probability of false alarm we can get fixed value of threshold.

Value of Pfa	Value of Threshold	
	Nevents=10	Nevents=10000
0.03	1.093	1.06
0.1	1.05	1.041
0.2	1.039	1.026
0.3	1.018	1.016
0.4	1.017	1.008
0.5	1.027	0.9996
0.6	0.9976	0.9921
0.7	0.9964	0.9824
0.8	0.9889	0.9733
0.9	0.9486	0.9599
0.99	0.9475	0.9286

Table 1: Comparative Analysis of Threshold Vs P_{fa}

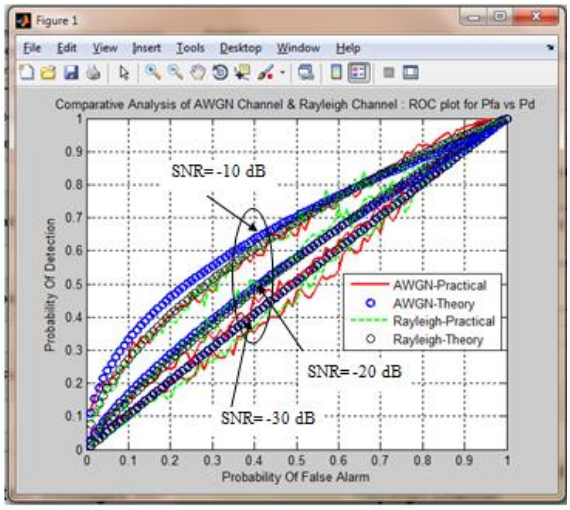

Figure 6: Comparative analysis of AWGN channel & Rayleigh channel

CONCLUSION

Spectrum band is a very precious resource in wireless communication systems, and it has been crucial point for explore and expansion efforts over the last several decades. The spectrum sensing using energy detector is very easy to implement and computational cost is very low. For doing comparative analysis we have designed Graphic User Interface simulation platform in MATLAB which can reduce a time for setting the parameters every time while doing simulation for new parameter. By analyzing the performance of threshold value for different value of probability of false alarm using monte carlo simulation we can conclude that if we take more number of monte carlo events than we get theoretical and practical values are almost same. From the comparative analysis of simulation result for AWGN channel and Rayleigh channel, we get some improvement in Rayleigh channel when we take number of monte carlo event is larger and as the values of SNR varies from -30 dB to -10 dB the probability of detection improves in Rayleigh channel.

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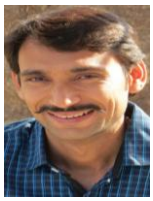
Ankit D. Dobariya, pursuing Master of Engineering in Electronics and Communication, Noble Group of Institutions, Junagadh, Gujarat, India. He is currently working as research scholar in Department of Electronics and Communication under GTU. His research interest includes wireless communication and Digital Communication. He has over 3.0 years of industrial experience in Telecommunication field.



Mr. Sagar Sodhatar, Assistant Professor, Department of Electronics and Communication, Noble group of Institutions, Junagadh, Gujarat, India. Did his Masters of Engineering from L.D. Engineering College, Ahmadabad. He has over 3.0 years of teaching experience and guided several Master's Projects.