Comparative Analysis of Energy Detection and Cyclostationary Feature Detection Methods for AWGN, Rayleigh and Rician Channels

[1]Aditya Raja, [2]Sabina Chaudhari, [3]Bhoomi Adroja,
[1,2,3]Students, [4]Assisstant Professor
Electronics and Communication
Marwadi Education Foundation Group Of Institute, Rajkot, India

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***Abstract* – As we know that now a days there is a huge advancement in wireless communication and its applications, efficient use of spectrum has been a great issue for researchers. Due to such issue, development in cognitive radio (the intelligent network) has been in demand which will analyze the spectrum to increase its efficiency by utilizing it properly. This paper focuses on sensing the spectrum in order to find out the licensed underutilized spectrum, to accommodate it to the secondary user without interfering the primary user. Two spectrum sensing methods, i.e. Energy Detection (ED) method and Cyclostationary feature detection (CFD) method are carried out over three fading channels (AWGN, Rayleigh, and Rician) at different SNR values were prior knowledge of the signal is not required. Similarly graph of such simulation has been resulted and compared in this paper. This simulation proves that at low SNR, CFD is used.**

***Index Terms* – Cognitive radio, Spectrum sensing, Energy detection spectrum sensing (ED), Cyclostationary feature detection spectrum sensing (CFD)**

I. INTRODUCTION

More and more number of wireless devices is being used due to which the available electromagnetic spectrum is getting overcrowded. Due to such rush in spectrum allocations some of higher frequency licensed band spectrum is getting underutilized which is observed by the Federal Communication Commission [FCC] [2]. That's why such organization is providing a guaranteed low interference to the primary users by trying to manage the spectrum efficiently and effectively. The solution to all this problems is cognitive radio [4]. Cognitive radio provides an effective way to manage such resources and allocates such underutilized spectrum i.e. licensed frequency band to the secondary users. It allows the secondary users to detect spectrum holes by the method called spectrum sensing [1].

Spectrum sensing as the name suggests is used to sense the spectrum and it also gives the information about the presence or absence of primary user [3]. Cognitive radio is such a reliable network that it can adapt any environmental condition by modifying its transmission parameters such as modulation, frequency, SNR, probability of detection etc. Main challenges of cognitive radio are to sense the spectrum and the signal should not interfere with primary users. This paper involves two spectrum sensing techniques; one is Energy detection (ED) spectrum sensing method and second is Cyclostationary feature detection (CFD)spectrum sensing method which is being executed over three fading channels (AWGN, Rayleigh and Rician) [10][11] and their comparison is carried out.

II. ENERGY DETECTION SPECTRUM SENSING METHOD

Energy detection is one of the simplest types of spectrum sensing method. It is a type of non-coherent spectrum sensing method which identifies that the signal is present or not through the signal energy [6].

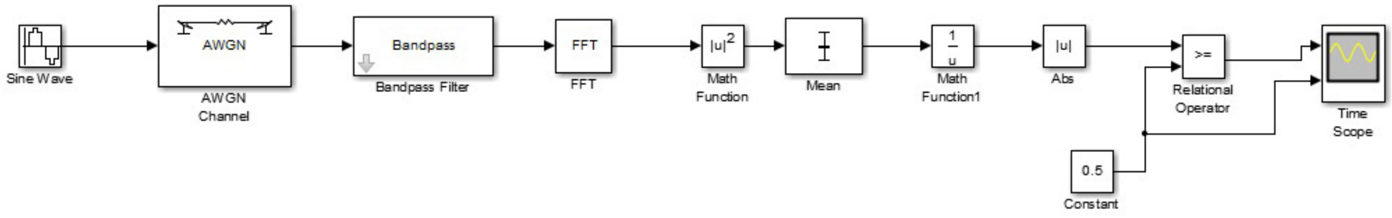


Figure 1- Energy detection spectrum sensing using Simulink

It is reliable and most common spectrum sensing method as it is less complex and can be implemented in time domain as well as frequency domain. Main advantage of using such method is that it does not require the prior information about primary user (PU) signal.

Figure 1 shows the Simulink based block diagram of spectrum sensing method. Now we have taken any random discrete signal as an input as we do not need the prior knowledge of the signal. Additive white Gaussian noise AWGN block is used to add noise to the PU signal. AWGN block measure the signal strength through signal to noise ratio (SNR) parameter [5]. Output of such signal is passed through a band pass filter. After that signal is converted from time domain to frequency domain using FFT. Now as per the definition of finding energy of signal, we have to pass the signal through a squaring block. Taking its mean and integrating it would be the next step. Now convert such signal into a real signal and compare it with a threshold value through relational operator. Required output and result would be obtained on the time scope.

$$E = \sum_{n=0}^{N} |x(n)|^2 \qquad (1)$$

Where, x(n)=received signal

This energy is now compared to a hypothesis value for the detection of primary user signal . A decision has to be taken on the basis of two hypothesis, one is null hypothesis and other is alternate hypothesis .If energy of the received signal is less than threshold, output would be H0 which means the primary user will be absent .If energy of the received signal is greater than the threshold, output would be H1 which means the primary user will be present [7].

$$E > \lambda = H1 \qquad (2)$$

$$E < \lambda = H0 \qquad (3)$$

III. CYCLOSTATIONARY FEATURE DETECTION SPECTRUM SENSING METHOD

It is one of the most important methods of spectrum sensing as it deals with the periodicity of the signal. As most of the signals are cyclic in nature, these method exhibit cyclic properties in order to accurately detect the presence of primary user signal CFD is also called spectral correlation method as it uses cyclic autocorrelation function (CAF) for detection of any signal efficiently. Using such periodic properties of the signal, it can detect any random signal in presence of any distortion [8].

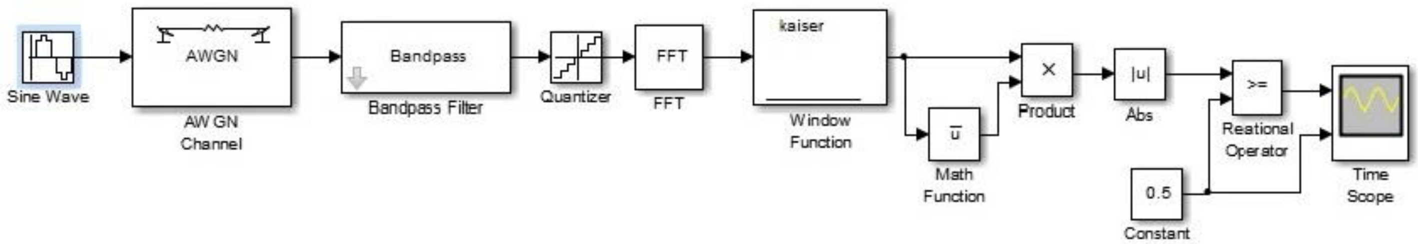


Figure 2- Cyclostationary feature detection using Simulink

Figure 2 represent block diagram of Cyclostationary feature detection using Simulink. In CFD method we do not need prior knowledge of the PU signal, and so we have taken random discrete signal. Such signal is passed through AWGN block in order to add noise to the signal. A particular band is provided to such signal through the band pass filter. Now such band limited signal is passed through a quantizer in which it converts signal into a stair step signal so that neighboring points on input axis are mapped at one point on output axis. It carries out a round to nearest method which produces an output that is symmetric about zero. Now such stair step time domain signal is converted into frequency domain through FFT. Here Kaiser Window is used which will decrease the undesired oscillation of the band limited signal. After windowing autocorrelation of such signal is carried out. Here a product is carried between the signal and its conjugate value. Now such signal is compared with a threshold value or a constant for detection of the PU signal.

$$R_x^{(\beta)}(\tau) = E[x(t)x^*(t-\tau)e^{-j2\pi\beta t}] \qquad (4)$$

E[·] is expectation operation, * is complex conjugation, and β is the cyclic frequency.

CAF can also be represented in Fourier series expansion, and it is called cyclic spectrum density (CSD) function [9]. And it is denoted as

$$S(f,\beta) = \sum_{\tau=-\infty}^{+\infty} R_x^{(\beta)}(\tau)\, e^{-j2\pi\beta t} \qquad (5)$$

IV. SIMULATIONS AND RESULTS

Energy detection simulink results over different fading channels:-

Below Table 1 shows the output values of SNR and Probability of detection (PD) of three fading channels.

Figure 3 shows the PD vs. SNR graph of Energy detection over three fading channels. Fig. 4 shows the simulation output of AWGN, Rayleigh and Rician fading channels at -60 dB SNR executed in Simulink.

Table 1- Energy Detection SNR and PD values

SNR	**Probability of detection**		
	AWGN	***Rayleigh***	***Rician***
-70	0	0	0
-60	0.021	0.01	0
-50	0.043	0.02	0.01
-40	0.077	0.04	0.02
-30	0.133	0.144	0.0667
-20	0.35	0.171	0.1556
-10	0.7	0.244	0.2
0	0.97	0.588	0.5667
10	1	1	1

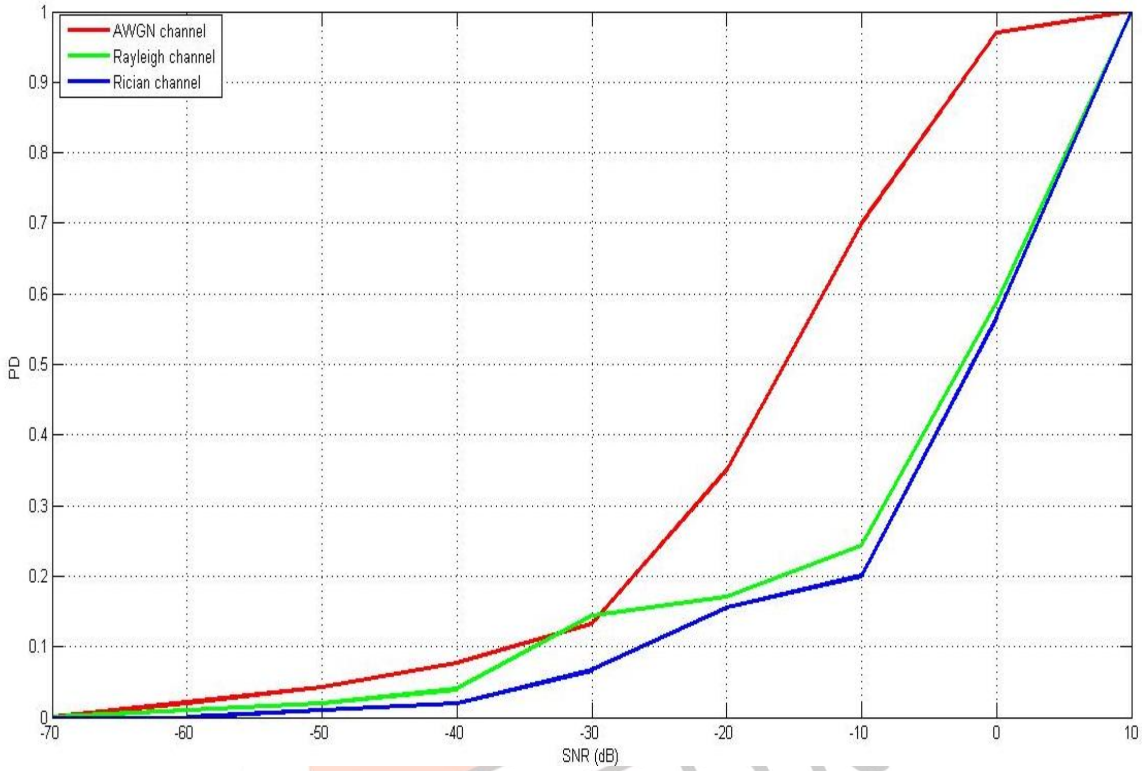
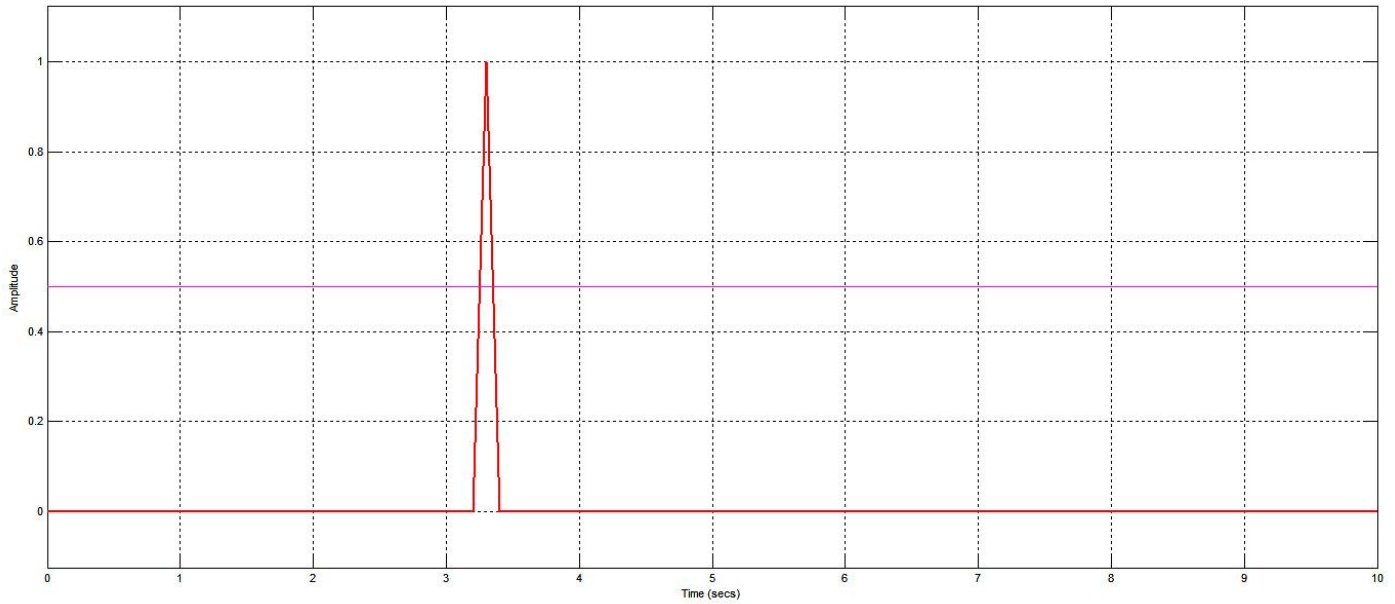
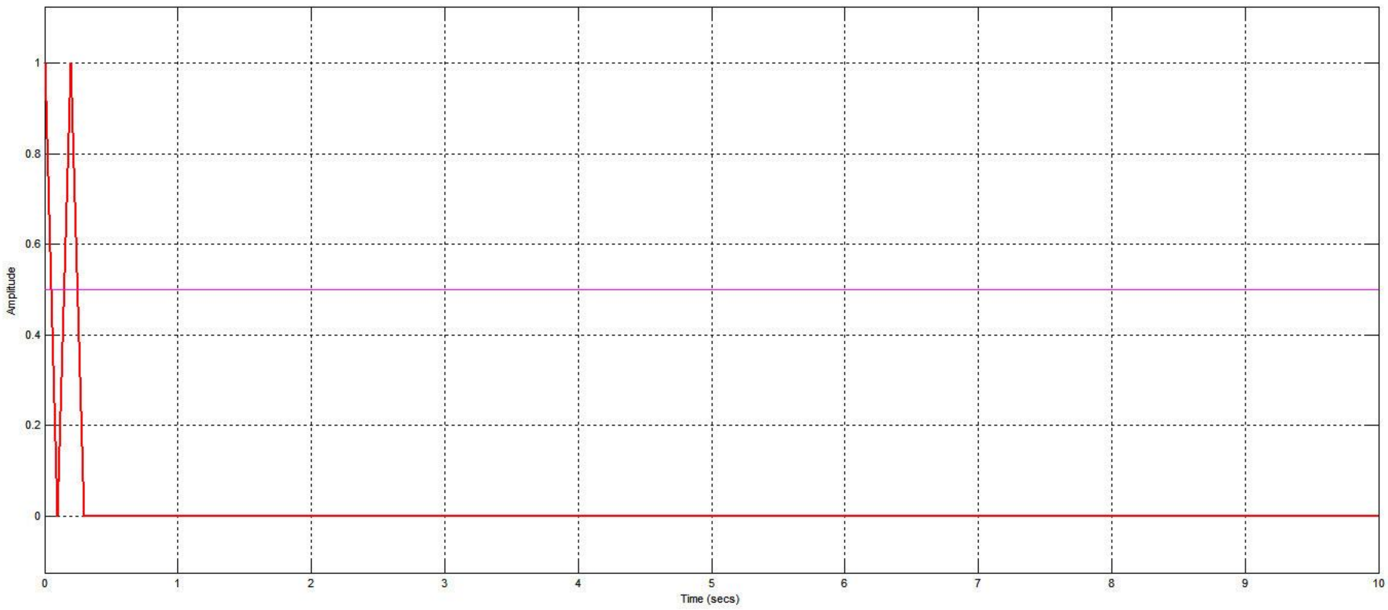


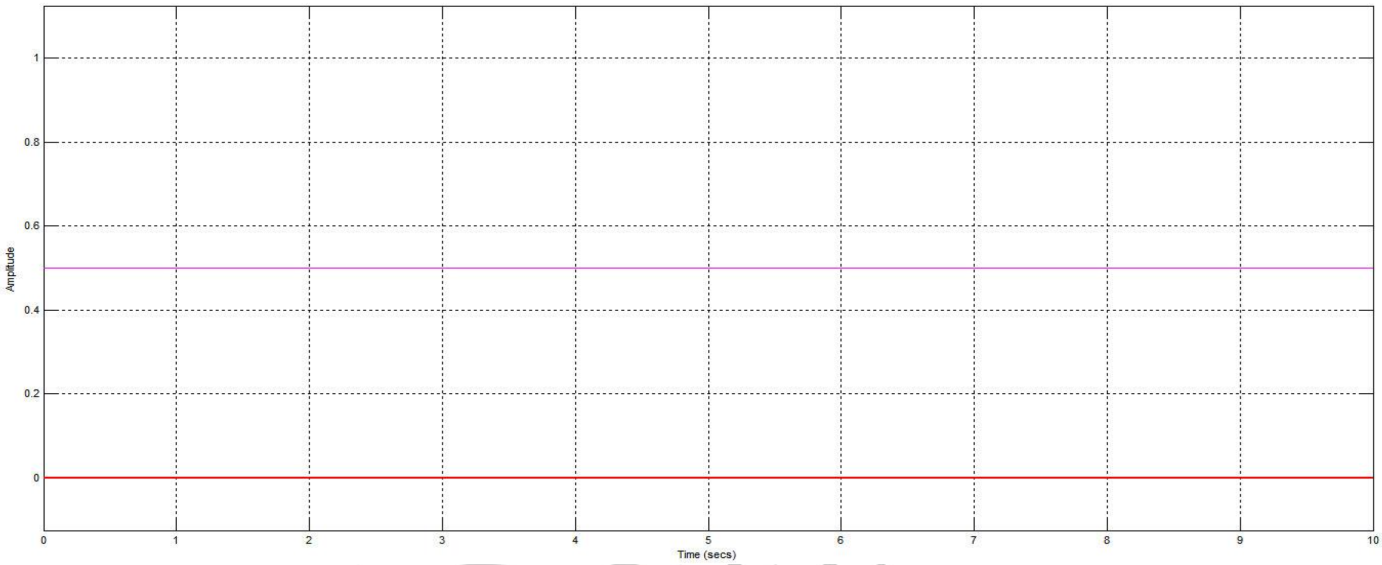
Figure 3- Graph of Energy detection over fading channels



(a)



(b)



(c)

Figure 4 (a), (b) and (c) shows Energy detection over AWGN, Rayleigh and Rician channel at (-60db) respectively.

Cyclostationary feature detection simulink results over different fading channels

Below Table 2 shows the output values of SNR and Probability of detection (PD) of three fading channels.

Figure 5 shows the PD vs. SNR graph of Cyclostationary Feature detection over three fading channels. Fig. 6 shows the simulation output of AWGN, Rayleigh and Rician fading channels at -60 dB SNR executed in Simulink.

Table 2- Cyclostationary feature detection SNR and PD values

SNR	**Probability of detection**		
	AWGN	***Rayleigh***	***Rician***
-70	1	1	1
-60	1	1	1
-50	0.96	0.98	0.98
-40	0.95	0.94	0.96
-30	0.88	0.92	0.92
-20	0.6	0.811	0.855
-10	0.46	0.633	0.7667
0	0.06	0.06	0.411
10	0.03	0.01	0.02
20	0	0	0

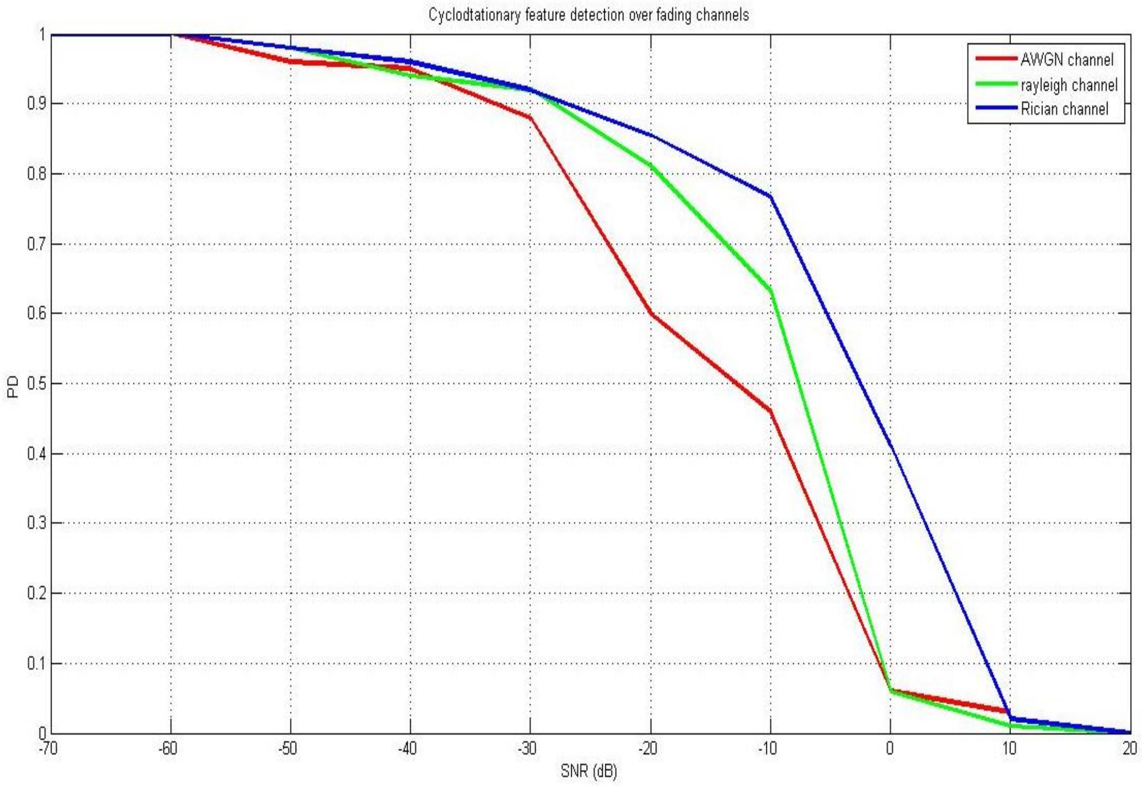
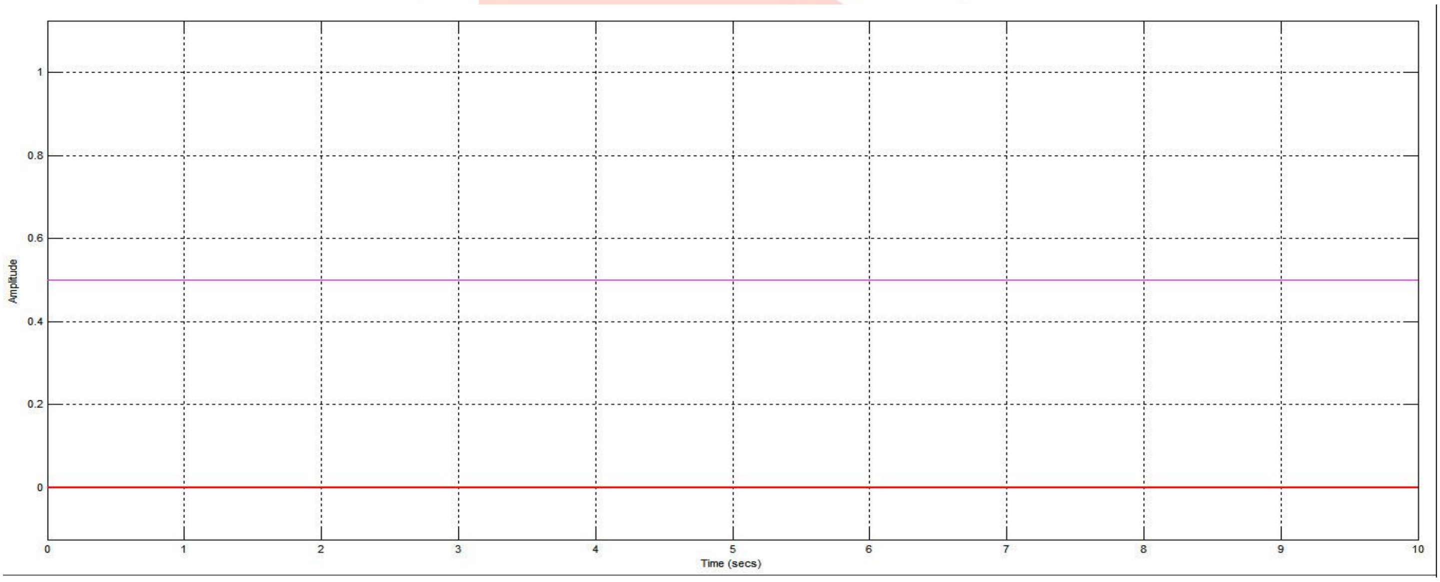
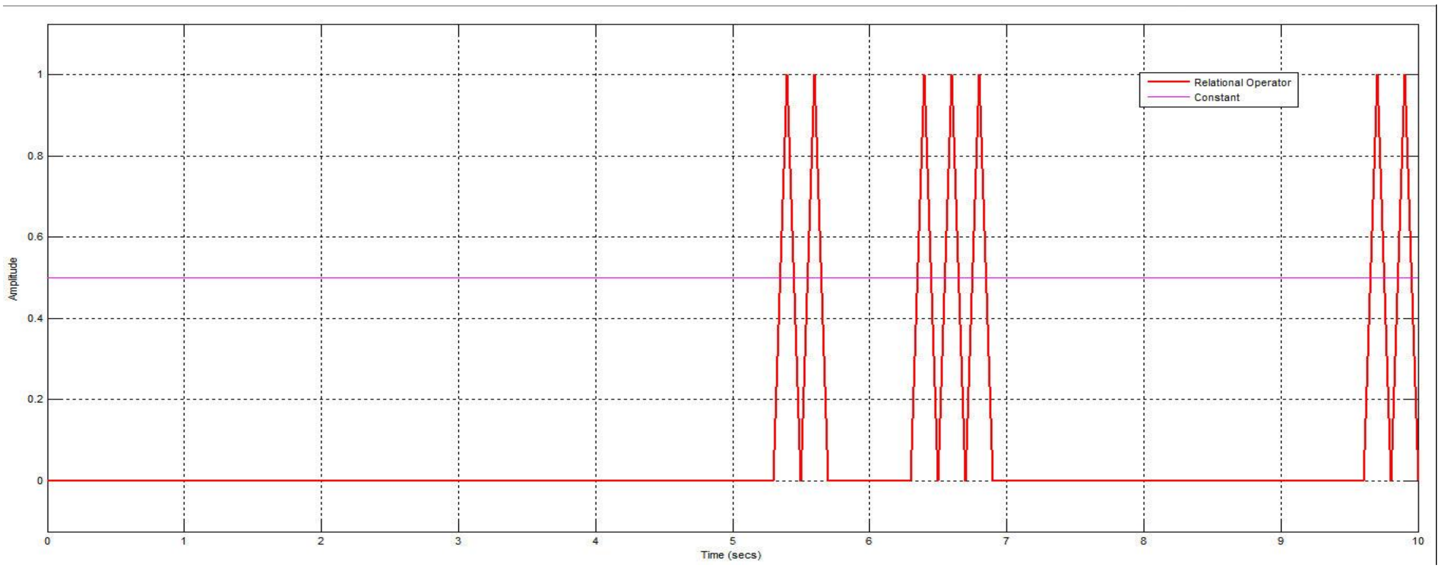


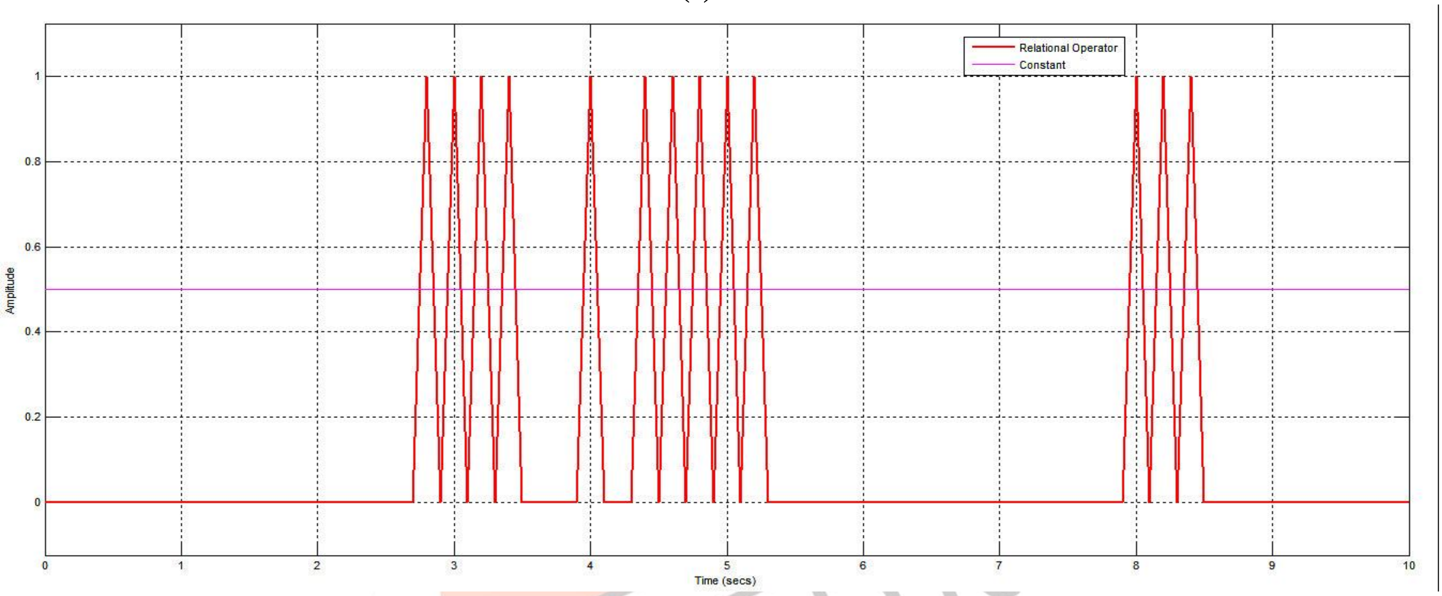
Figure 5- Graph of Cyclostationary feature detection over fading channels



(a)



(b)



(c)

Figure 6 (a), (b) and (c) shows the Cyclostationary feature detection over AWGN, Rayleigh and Rician channel at (10db) respectively.

V. CONCLUSION

After implementing Energy detection and Cyclostationary feature detection in Simulink, it can be concluded that ED works well for AWGN in comparison with Rician and Rayleigh channels. Similarly CFD works well for Rician channel when compared to AWGN and Rayleigh channel. From the results of Energy Detection and Cyclostationary feature Detection, it shows that ED performs well at high SNR and CFD performs well at low SNR.

VI. ACKNOWLEDGMENT

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REFERENCES

[1] Wenjing Yue, Baoyu Zheng Nanjing, Jiangsu,” Spectrum sensing algorithms for primary detection based on reliability in cognitive radio systems,” Nanjing University of Posts and Telecommunications, 210003, and China.
[2] Garima Nautiyal, Rajesh Kumar, “Spectrum Sensing In Cognitive Radio Using Matlab,” International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-5, June 2013.
[3] Aravind.Hb, R.Gandhiraja, K.P.Somanb, M.Sabarimalai Manikandanb, Rakesh Peterb, “Spectrum Sensing Implementations for Software Defined Radio in Simulink,” Coimbatore, India.
[4] Ashfaque Ahmed Khan, S.M. Imrat Rahman, Mohiuddin Ahmed, “Research Challenges of Cognitive Radio,” Islamic university of Technology, Green University of Bangladesh ISSN: 2278-0181 Vol. 1 Issue 3, May – 2012.

[5] Waleed Ejaz, Najam ul Hasan and Hyung Seok, "SNR-Based Adaptive Spectrum Sensing For Cognitive Radio Networks," Sejong University, Kim International Journal of Innovative Computing, Information and Control ICIC International c 2012 ISSN 1349-4198 Volume **8**, Number **9**, September 2012 pp. 6095-6105.
[6] Pawan Yadav, Rita Mahajan, " Energy Detection for Spectrum Sensing in Cognitive Radio Using Simulink," PEC University of Technology, Vol. 3, Issue 5, may 2014.
[7] Md. Shamim Hossain Md. Ibrahim Abdullah Mohammad Alamgir Hossain, "Energy Detection Performance of Spectrum Sensing in Cognitive Radio," DOI: 10.5815/ijitcs.2012.11.02.
[8] Shital Vachhani, Arjav Bavarva, "Cyclostationary Based Detection Method of Spectrum Sensing for Cognitive Radio," Computer Science and Engineering, Islamic University, Bangladesh, Volume 7 – April 2014.
[9] Kulbir Singh, Rita Mahajan Chandigarh, "Comparative Analysis of Energy Detection and Cyclostationary Feature Detection using Simulink," INDIA Volume 5, Issue 5, May-2014.
[10] Sajjad Ahmad Ghauri1, I M Qureshi, M. Farhan Sohail, Sherazalam, M. Anas Ashraf , "Spectrum Sensing For Cognitive Radio Networks Over Fading Channels," National University of Modern Languages (NUML), Islamabad, Pakistan Air University, Islamabad, Pakistan Volume 2, Issue 1, February 2013.
[11] Omkar S. Vaidya, Vijaya M. Kulkarni, "Analysis of Energy Detection based Spectrum Sensing over Wireless Fading Channels in Cognitive Radio Network," M.I.T., Aurangabad, Volume 3, Issue 3, and March 2013.