IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-6, Issue-5, May 2018 E-ISSN: 2347-2693

Spectrum Sensing Under Different Fading Channels Using Energy Detection Technique

R. Harikrishnan[1*], V. Padmathilgam[2]

[1]Dept of ECE, Annamalai University/Chidambaram, India
[2]Dept of EEE, Annamalai University/Chidambaram, India

[*]Corresponding Author:greenhari05@gmail.com, Tel.:+91 9043661120

Available online at: www.ijcseonline.org

Accepted: 17May/2018, Published: 31/May/2018

Abstract-- In this wireless era there is an exponential increase in wireless devices but the spectrum availability for these devices has become very less. Some additional spectrum band for these devices is required to make communication possible. To clear this spectrum demand the cognitive user access the unused licensed frequency band, when the band is free. The cognitive users may utilize unused channel till the band is occupied by primary user. In this paper, A MATLAB based simulation is carried out to appraise the detection performances of cognitive radio .The spectrum sensing in non fading Additive White Gaussian Noise (AWGN) environment and different fading scenarios such as Rayleigh, , Rican, Log normal shadowing Weibull and Hyot fading environment using energy detection technique are carried out. The performance analysis of energy detector designed for Average Signal-to-Noise Ratio (SNR) and different fading parameters are analyzed in provisions of Probability of missed detection (Pm) and Probability of false alarm (Pf).The spectrum sensing is analyzed by comparing the performances of various wireless fading channels.

Keywords: *Spectrum Sensing, Energy detection Wireless Fading channels, Receiver operating curve.*

I. INTRODUCTION

The necessity of radio spectrum for communicating devices has been observed increasing in recent years. This is primarily owing to the rising figure of clients in wireless services and development of wireless networks for high-speed networks. With the appearances of new purpose and the unavoidable nature of internet access, requirement for the spectrum is projected to rise in coming years [1].
Cognitive Radio (CR) system has been launched to crack the trouble of spectrum scarcity. By opportunistic manner of accessing the available free spectrum band, CR users divide the spectrum band in the midst of primary users (PU's). To differentiate the presences and absences of primary users accurately, spectrum sensing is the lonely indispensable tool for cognitive radio expertise. Due to shadowing and fading, spectrum sensing is a hard task to identify the state of spectrum usage. When cognitive radios fail to indentify the existences and absences of primary users in particular band it will cause obstruction to primary users. So detecting state of spectrum band must be accurate for acceptable quality of services [2].

In this paper, a simulation model to examine the performance of spectrum sensing for diverse fading wireless channels using energy detection is developed.

Figure 1.Block Diagram of Energy Detector

An energy detector is utilized to indentify the signal which is unknown in a given period of time. Fig.1 shows the block diagrammatic illustration of energy detector. The received signal is sent to band pass filter and this filter is designed to choose the required frequency. The output the of band pass filter is sent to squaring device, wherever the energy coupled with the signal is calculated. The output of squaring device inputted to an integrator. The integrator quantifies the energy over enduring phase of time window. The quantified energy is fed to threshold devices, which decides whether the licensed user's signal is present or not [3].
This paper is structured as follows: In section II, system model and important mathematical representation are explained. It also provides schemes regarding diverse wireless fading channels and measures for detection

probabilities. In section III, the results and its explanation are presented. In section IV, conclusion is provided.

II. SYSTEM MODEL

To allocate CR consumers to the unoccupied band in the spectrum, CR consumer are necessary to monitor the spectrum continuously till indentifying the spectrum is in usage or vacant. There are diverse detection techniques such as Energy detection, Cyclostationary detection and Matched filter detection are available for detecting whether the band is vacant or not. Among these three techniques, energy detection has been extensively utilized for recognize a signal because no advanced features of primary signals are needed [4].

The energy detection for the narrowband received signal follows two hypotheses as shown below

$$x(t) = \begin{cases} n(t), & Ho \\ h * s(t) + n(t), & H1 \end{cases} \quad (1)$$

H_0: Primary user(PU) is absent

H_1: Primary user(PU) is present

where, x(t) - the signal received by secondary users

S (t) - primary users transmitted signal

n (t) - noise

h - amplitude gain of the signal

The received signal is initially pre filtered by an ideal band pass filter with transfer function.

$$H(f) = \begin{cases} \frac{2}{\sqrt{N_{01}}}, & |f - f_c| \le W, \\ 0, & |f - f_c| \ge W, \end{cases} \quad (2)$$

The received signal is directed through the blocks like filter, squaring device and integrator (Fig.1) over the time interval (T).The output of the integrator block estimate the energy in the received signal .These energy value are contrasted with established in advance threshold value and after that trail statistics are decided.

The test statistic concludes the received energy are matches merely to the noise energy (H_0) or to the energy of jointly to the unknown deterministic signal and noise (H_1). These H_0 /H_1 are the output of threshold detector. The test statistics in shorthand notations as shown in (3)

$$Y = \begin{cases} x_{2u}^2 & H_0 \\ x_{2u}^2\,(2\gamma) & H_1 \end{cases} \quad (3)$$

An energy detector primarily consists of a default energy threshold, λ. The threshold value is essential to measure three aspects to estimate the performance of the detector: i) false alarm probability, ii) detection probability and iii) the probability of missed detection. The primary aspects are computed by integrating (2) over the period between the energy thresholds to infinity {λ, ∞} yielding,

$$P_{d=}Pr(Y > \lambda/H_1) \quad (4)$$

$$P_{f=}\Pr(Y > \lambda/H_0\,) \quad (5)$$

Average detection probability for different wireless fading channels

A. Non-fading wireless channel (AWGN channel)

Fading factor (*h)* is equivalent to one, when the signal is gratis as of fading cause or shadowing cause. In AWGN the probability of detection and false detection probability are known by the following mathematical notations

$$P_d = \Pr(Y > \lambda/H_1) = Q_m(\sqrt{2\gamma},\ \lambda) \quad (6)$$

$$P_f = \Pr(Y > \lambda/H_0) = \Gamma\,\frac{(m,\lambda/_2)}{\Gamma(m)} \quad (7)$$

where $\Gamma(a, b)$is the incomplete gamma function and Q_m(a,b) *is* the generalized Marcum Q-function. Initially the probability of false alarm (Pf) is fixed and then by using (7) the threshold for detection value is determined. When selecting the threshold for detection (*λ)* value, the probability of detection ought be selected as large sufficient to preserve the Primary User(PU); otherwise, a high missed detection probability might consequences in unbearable obstruction to the Primary Users(PU). In this situation, the detection probability (Pd) may be obtained by normalizing (7) in fading statistics.

$$Pd = \int Q_m(\ \sqrt{2\gamma},\ \lambda) f_y(x) \quad (8)$$

Where, f_y *(x)* is *the* Probability Distribution Function (PDF) of Signal to Noise Ratio (SNR) under fading.

B.Rayleigh fading channel

Rayleigh fading is a form of signal transmission as a result of greatly built-up city surroundings over radio signals. Rayleigh fading is mainly appropriate when rejection of principal transmission beside a line of view linking the transmitter and receiver. Rayleigh distribution occurs owing to the environment consisting of few types of dispersion. Then the amplitude of the signal and the Signal to noise ratio

(γ) follows an exponential PDF given by

$$f_y(x) = \frac{1}{\bar{\gamma}}\exp\left(\frac{-\gamma}{\bar{\gamma}}\right) \quad \gamma \ge 0 \quad (9)$$

In this situation, a closed-model formula may be calculated by substituting f_y(x) in (9),

$$\overline{P_{d,Ray}} = e^{\frac{-\lambda}{2}} \sum_{k=0}^{m-2} \frac{1}{k!}\left(\frac{\lambda}{2}\right)^k + \left(\frac{1+\bar{\gamma}}{\bar{\gamma}}\right)^{m-1}\left(e^{\frac{-\lambda}{2(1+\bar{\gamma})}} - e^{\frac{-\lambda}{2}} * \sum_{k=0}^{m-2}\frac{1}{k!}\left(\frac{\lambda\bar{\gamma}}{2(1+\bar{\gamma})}\right)^k\right) \quad (10)$$

C. Log-normal shadowing channel

Log normal shadowing model is a typical model and an expansion to Friis Free space model. It is employed to guess the transmission failure for a vast range of environment. The gain of linear channel is designed by means of a log-normal random variable, e^X where X is a zero-mean Gaussian random variable through variance σ^2 .

Log-normal shadowing is typically illustrated in the expression of its dB-spread, σ_{db} which is associated to σ by σ = 0.1ln (10) σ_{db}

D. Rican fading channel

Rican fading is a form for radio transmission irregularity sourced by incomplete termination of a radio signal. It also occurs when the signal incoming at the receiver as a result of numerous diverse paths. Consequently they are showing multipath obstruction, and at slightest one of the paths is altering and reduction. Rican fading also arises while one of the paths, normally a line of view signal is to a large extent of stronger than the other signal. In this case, the received signal's amplitude has a Rican distribution.

Then PDF in mathematical equation given as

$$f_y(x) = \frac{1+K}{\bar{\gamma}} \exp\left(-K\frac{(1+K)\gamma}{\bar{\gamma}}\right) * I_0\left(2\sqrt{\frac{K(1+K)}{\bar{\gamma}}}\right) \quad (11)$$

Where K is the Rican factor. The average probability of detection calculated by averaging (7) .

$$\overline{P_{d,Ric}} = Q\left(\sqrt{\frac{2K\bar{\gamma}}{K+1+\bar{\gamma}}}, \sqrt{\frac{\lambda(1+K)}{K+1+\bar{\gamma}}}\right)_{u=1} \quad (12)$$

If K = 0, then the given equation is reduces to the Rayleigh expression with u = 1.

E. Weibull fading channel

Weibull fading model is uncomplicated model of fading used in wireless communications and this fading model follows Weibull distribution..The Empirical study have shown it to be an efficient form in both indoor and outdoor environment.

The equivalent PDF of the immediate SNR per symbol is known by

$$f_y(x) = \frac{a}{2}\left(\frac{\Gamma\left(1+\frac{2}{a}\right)}{\bar{\gamma}}\right)^{\frac{a}{2}} \gamma^{\frac{a}{2}-1} e^{-}\left[\frac{\gamma}{\bar{\gamma}}\Gamma(1+\frac{2}{a})\right]^{a/2} \quad (13)$$

Where $\bar{\gamma}$ is stand for the average SNR per symbol.

The overall probability of detection equation for (Pd) in case of a weibull channel acquired by (6) over (13) , then Pd is given by

$$\overline{P_{d,weib}} = \sum_{l=0}^{u-1} \frac{\lambda^l e^{\frac{-\lambda}{2}}}{l!2^l} + \sum_{l=0}^{\infty} \frac{(-1)^l A^l \lambda^u}{1!u!2^u e^{\frac{\lambda}{2}} \gamma^{-la/2}} \left(\Gamma\frac{la}{2} + 1\right)_1 F_1\left(\frac{la}{2}+1, u+1, \frac{\lambda}{2}\right) \quad (14)$$

where, ${}_1F_1(a,b,X) \triangleq \sum_{l=0}^{\infty} \frac{(a)_l x^l}{(b)_l\, l!}$

F1 is the Kummer's confluent hyper geometric function.

F.Hoyt fading Channel

Hoyt fading distribution is commonly employed to differentiate the fading scenarios which are more rigorous than Rayleigh fading.

The PDF of Hoyt distribution is put forward by

$$f_\gamma(\gamma) = \frac{1}{\sqrt{p\bar{\gamma}}} exp\left(-\frac{\gamma}{p\bar{\gamma}}\right) I_0\left(\frac{\gamma\sqrt{1-p}}{p\bar{\gamma}}\right); \gamma \geq 0 \quad (15)$$

$$p = \frac{4q^2}{(1+q^2)^2}\ ; 0 \leq p \leq 1$$

Where q is fading severity parameter.

Then average detection probability of Hoyt fading obtained by replace with the value of $f_\gamma(\gamma)$ in (15)

III. RESULTS AND DISCUSSION

The simulation is designed in MATLAB by means of the following system parameters: Time-bandwidth product, m = 5, average SNR, $\bar{\gamma}$ =7dB. The Receiver Operating Characteristics (ROC) curves of missing probability (Pm) vs False alarm probability (Pf) is plotted for the system parameters. This simulation set up is conceded for different fading channels. Then simulated results of different fading wireless channel are contrasted with non fading AWGN.

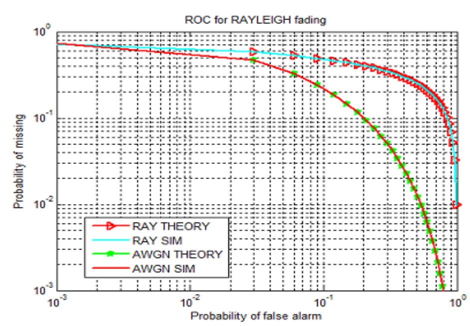

Figure 2.ROC curve under Rayleigh fading ($\overline{\gamma}$ =7dB, m= 5)

Fig.2. shows the ROC curve over Rayleigh fading. The simulated results are compared with analytical results obtained from equation which perfectly matches. It is observed that when compared to AWGN, the Rayleigh fading has less detection probability due to fading.

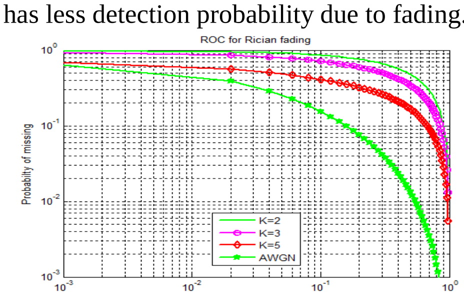

Figure 3.ROC curve under Rican fading ($\overline{\gamma}$ =7dB, m= 5)

Fig.3 shows the ROC curve for Rican fading channel. Three values of fading parameters are measured, viz., K=2, 3 and 5. The overall performance of energy detector in Rican fading channel is less when fading parameter k=2 and high when fading parameter k=5.

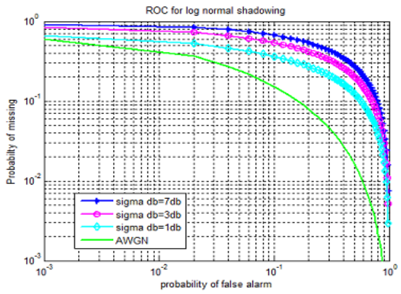

Figure 4.ROC curve under log normal shadowing with different db spreads ($\overline{\gamma}$ =7dB, m= 5)

Fig.4.shows the ROC curve for log normal shadowing. When evaluating the AWGN curve related to shadowing, it is observe that, detection probability is more when db spread is less. Spectrum sensing is hard in occurrence of shadowing.

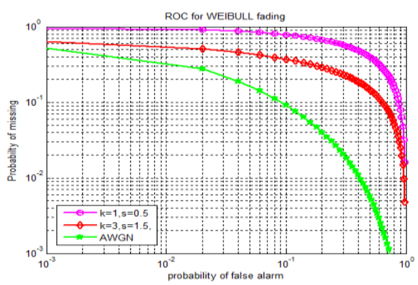

Figure 5.ROC curve under Weibull fading ($\overline{\gamma}$ =7dB, m= 5)

Fig.5 shows the ROC curve in Weibull fading channel. Here two values of fading shape and scale parameters are considered, viz., K=1, S=0.5 and k=3, S=1.5. From figures it is noticed that the performance of energy detector in Weibull fading channel is less when shape parameter k=1 and scale parameter s=0.5 and high when shape parameter k=3 and scale parameter s=1.5.

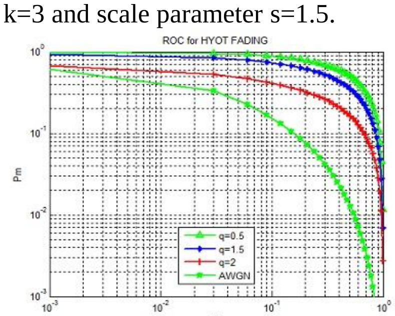

Figure 6. ROC curve under Hyot fading ($\overline{\gamma}$ =7dB, m= 5)

Fig.6. shows the ROC curve under Hyot fading channel. Here three values of fading severity q parameters are considered, viz., q=0.5 ,1.5 and 2 .The performance of energy detector in Hyot fading channel is less when q=0.5 and high when q=2.

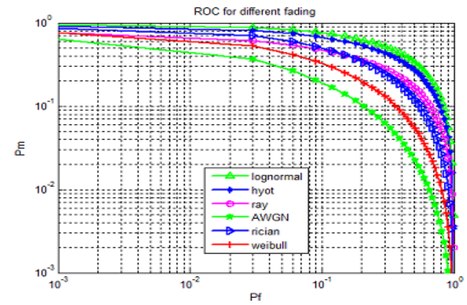

Figure 7. ROC curve under different channels ($\overline{\gamma}$ =7dB, m= 5)

Fig.7.shows ROC curve of the energy detection foundation on spectrum sensing in the existence of Rayleigh, Log normal shadowing, Rican, Weibull and Hyot fading under same SNR condition. When contrasting the AWGN to other fading channel, the performance of energy detector is finest in Weibull fading amid all other fading channels.

IV. CONCLUSION

In this paper, the performances of energy detection under different wireless fading channels are evaluated. When comparing probability of detection of all these fading channels (Rayleigh, Log normal shadowing, Rician, weibull and Hyot), it is noted that the weibull fading channel gives best detection performance. It is observed that the performance of the detector is influenced by the value of parameters like different fading parameters and average SNR values. This is obvious that even minor changes of the fading parameter outcome to considerable deviation in the detection probability.

REFERENCES

[1] Federal Communications Commission, "*Spectrum policy task force report*, (ET Docket No. 02-135)," Nov. 2002. [Online]. Available: hraunfoss. fcc.gov/edocspublic/attachmatch/DOC-228542A1.pdf.

[2] S. Haykin, "*Cognitive radio: brain-empowered wireless communications*," IEEE J. Select. Areas Communication, vol. 23, pp. 201-220, Feb. 2005.

[3] Mahmood A. Abdulsattar and Zahir A. Hussein, "*Energy detection technique for spectrum sensing in cognitive radio": A survey,* in International journal of computer networks & communications (IJCNC) vol.4, no.5, September 2012.

[4] S D. Cabric, S. M. Mishra, and R. W. Brodersen, "*Implementation issues in spectrum sensing for cognitive radios,*" in Proc. of Asilomar Conf. on Signals, Systems, and Computers, Nov. 7-10, 2004, vol. 1, pp. 772–776.

[5] F. F. Digham, M.-S. Alouini and M. K. Simon, "*On the energy detection of unknown signals over fading channels,*" *in Proc. of IEEE International Conference on Communications (ICC'03)*, pp. 3575– 3579, May 2003.

[6] H. Urkowitz, "*Energy detection of unknown deterministic signals," Proceedings of IEEE*, vol. 55, pp. 523–231, April 1967.

[7] C.E. Shannon, "*Communication in the presence of noise*," proc. IRE, vol. 37, pp. 10-21, January 1949.

[8] A. Ghasemi and E. S. Sousa, "*Collaborative spectrum sensing for opportunistic access in fading environments*," in Proc. of 1st IEEE Symp. New Frontiers in Dynamic Spectrum Access Networks, Baltimore, USA, Nov. 8-11, 2005, pp. 131-136.

[9] Jiaqi Duan and Yong Li, "*Performance analysis of cooperative spectrum sensing in different fading channels*," in Proc. IEEE Interantional conference on Computer Engineering and Technology (ICCET'10), pp.v3-64-v3-68, June 2010.

[10] S. Nallagonda, S. Suraparaju, S. D. Roy, and S. Kundu, "*Performance of energy detection based spectrum sensing in fading channels*," in Proceedings of the 2nd International Conference on Computer and Communication Technology (ICCCT '11), pp. 575–580, Allahabad, India, September 2011.

Authors Profile

R.Harikrishnan pursed Bachelor of Engineering from Vel High Tech Engineering,chennai,Tamil Nadu in 2011 and Master of Engineering from KSR College Of Engineering in year 2015 . He is currently pursuing Ph.D.in Department of Electronics and Communication Engineering. ,Annamalai university, chidambaram since 2015. His main research work focuses on cognitive radio network,spectrum sensing and wireless communication based application.

V.Padmathilagam pursed Bachelor of Engineering and Master of Engineering from Annamalai university, chidamabaram in year 1993 and 2005. And Ph.D. in Electrical Engineering, Annamalai university in 2011.she is currently working as Assistant professor in Electrical Engineering in Annamalai university.Her main research work focuses on power Electronics and control system.