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Editorial

Detection and False Alarm Probabilities over Non-fading and Fading Environment

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Abstract: Cognitive radio which is a low-cost communication system can choose the available frequencies and waveform so that it can restrict the interference on the unlicensed users on the premise automatically. In cognitive radio networks the spectrum sensing is considered as the key technology. On the contrary it is not only able fill voids in the wireless spectrum but also it can increase the spectral efficiency dramatically. The another issue is that sometimes users can experience deep shadowing or fading effect that time accurate detection factor will be compromised. However, we also allow the CK (cognitive Radio) users to co-operate by sharing their information so that it can detect the primary users (PU) to more accurately. Indeed, the main motive of this project is to investigate performance of Co-operative spectrum sensing scheme by upgrade using energy detection and to promote/n the sensing performance in channels such as AWGN and Rayleigh fading channels. At fusion centre (FC) hard decision is performed which is the combination of (OR rule and AND rule). That is why for this extraordinary performance CR (Cognitive Radio) can be able to make final decision about primary user present or not. Additionally, comparisons among data fusion rules have been investigated also for a vast range of average in SNR (Signal to noise ratio) values. As a result, the performance of this CR is evaluated in terms of the probability of miss detection (P_{md}) and the probability of false alarm (P_{fa}). Moreover, the report is compared between the theoretical value and the simulated result and then it describes the relationship between the signal to noise ratio (SNR) and the detections. At last, the method, energy detection and simulation and result are discussed.

Keywords: Alarm Probabilities, Fusion Rule, ROC Curve, AWGN Channel, False Alarm

1. Introduction

Modern years show an extraordinary demand for wireless communications Due to extending the field of wireless communication, this results in more spectrum resources being required to achieve our obligations. The allocation of the spectrum usually fixed for organization and Today's spectrum management is regulated by our government. However, this leads to a common problem with spectrum wastage [1]. Some licensed bands and organizations are found spectrum scarcity. The purpose of Cognitive radio has been proposed as a means to overcome spectrum scarcity and proper spectrum utilization in wireless communication. According to the Federal Communication Commission (FCC), many licensed users that are not properly utilized, remain indolent. The FCC also exposes that spectrum utilization hardly ever crosses 35% at any given time in the large populated urban areas [2]. The main concept behind the "Cognitive Radio (CR)" is to ensure the proper utilization of those underutilized spectrums without interfering with the licensed primary user (PU). This thought was first proposed by Joshep Mitola in 1999. The CR system allows the unlicensed users, also called secondary users (SUs), to use the temporarily unused spectrum that is not currently used by the licensed primary user (PU).

Spectrum sensing is a fundamental component of the CR system. The spectrum sensing enables the ability to sense the presence of PU and the parameters related to the radio channel. There are several spectrum sensing techniques that have been used to determine the existence of PU, such as feature detection, energy detection and matched filtering detection. The energy detection technique is widely used because it does not require any prior knowledge about PU. As there are some fundamental characteristics of wireless channels, such as multipath fading, shadowing, and noise uncertainty, a CR system may unable to detect the presence of the PU. To address this problem, the cooperative spectrum has been proposed [3], with the collaborative decisions of several secondary users (SU) for spectrum sensing [4], and this is done in a fusion center (FC). The FC receives signals from unlicensed SUs and combines these signals to get the final decision about the presence of PU.

There are, at present, three fusion rules to determine the availability of the free spectrum, they are: the AND-rule, OR-rule, and MAJORITY-rule. Among this three rules, energy detection gives improved sensing performance when using the OR-fusion rule.

2. Methodology

We assume that energy detection in Figure 1 is applied at each CR user. The energy detector consists of a square law device followed by a finite time integrator. The output of the integrator at any time is the energy of the input to the squaring device over the interval *T*. The noise pre-filter serves to limit the noise bandwidth; the noise at the input to the squaring device has a band-limited, flat spectral density [5, 6].

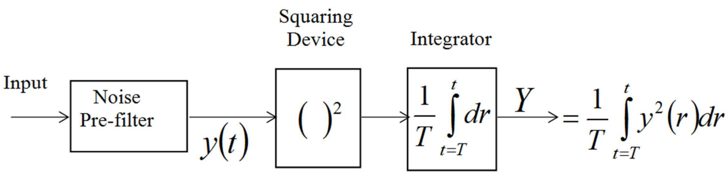

Figure 1. *Energy Detection.*

In non-fading environment the closed-form expressions for both probability of false alarm, the average probability of detection [6, 7].

$$P_d = \sum_{l=k}^{N} \binom{N}{l} P_{d,i}{}^{l} \left(1 - P_{d,i}\right)^{N-l} \tag{1}$$

$$P_f = \frac{\Gamma(u, \lambda/2)}{\Gamma(u)} \tag{2}$$

Which are defined by $P(Y > \lambda \mid H_1)$ and $P(Y > \lambda \mid H_0)$ respectively? Where λ denotes the decision threshold. Γ (.) and Γ (.) are complete and incomplete gamma functions respectively and (.) is the generalized Marcum Q-function.

The equation for probability of misdetection can obtained therefore by

$$P_m = 1 - P_d \tag{3}$$

In non-fading environment, if the signal amplitude follows a Rayleigh distribution, then the SNR γ follows an exponential PDF given by,

$$f(\gamma) = \frac{1}{\bar{\gamma}} \exp\left(-\frac{\gamma}{\bar{\gamma}}\right), \quad \gamma \geq 0 \tag{4}$$

In this case, a closed-form formula for P_d may be obtained as [10].

$$\bar{P}_{dRay} = e^{-\frac{\lambda}{2}} \sum_{k=0}^{u-2} \frac{1}{k!} \left(\frac{\lambda}{2}\right)^k + \left(\frac{1+\bar{\gamma}}{\bar{\gamma}}\right)^{u-1} \times \left(e^{-\frac{\lambda}{2(1+\bar{\gamma})}} - e^{-\frac{\lambda}{2} \sum_{k=0}^{u-2} \frac{1}{k!} \left(\frac{\lambda \bar{\lambda}}{2(1+\bar{\gamma})}\right)} \right) \tag{5}$$

2.1. Logical AND-Rule

In this rule, if all of the local decisions sent to the decision maker are one, the final decision made by the decision maker is one [11]. The fusion center's decision is calculated by logic AND of the received hard decision statistics Cooperative detection performance with this fusion rule can be evaluated by setting *k*=*N* in eq. (1).

$$P_{d,AND} = P_{d,i}^{N}\ (4.2) \tag{6}$$

2.2. Logical OR-Rule

In this rule, if any one of the local decisions sent to the decision maker is a logical one, the final decision made by the decision maker is one. Cooperative detection performance with this fusion rule can be evaluated by setting *k*=1 in eq. (1).

$$P_{d,OR} = 1 - \left(1 - P_{d,i}\right)^N \tag{7}$$

2.3. OR Fusion Rule

In this rule, if any one of the local decisions sent to the decision maker is a logical one, the final decision made by the decision maker is one. Cooperative detection performance with this fusion rule can be obtained as [9],

$$P_{d,OR} = 1 - \left(1 - P_{d,i}\right)^N \tag{8}$$

3. Simulation Results

In this simulation result, we evaluated and described performance of energy detection method where the number of used samples is set to $N = 2*u$, time bandwidth product u=5 with SNR=6dB. Following figures clearly show the performance of the energy detection i.e. detection probability increases as P_{fa} values increases from 0.01 to 1 with increasing 0.1 under AWGN and Rayleigh Fading channel [2].

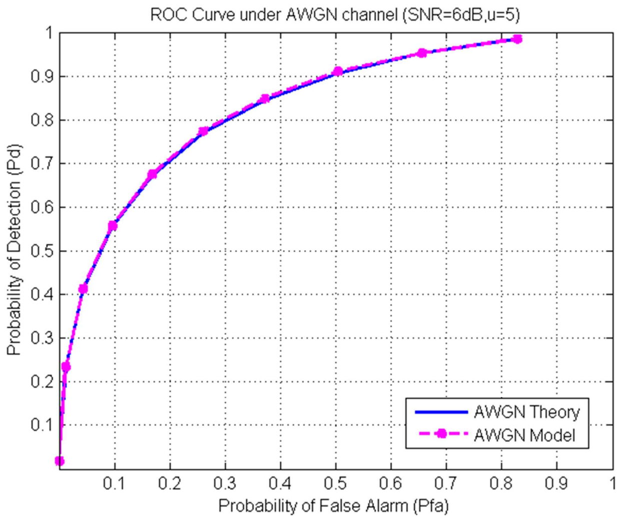

Figure 2. *ROC Curve under AWGN channel (SNR=6dB, u=5).*

Figure 2 shows ROC of spectrum sensing for different probability of false alarm under AWGN channel. The simulation was carried out for the analysis of detection probability under different number of P_{fa} . This figure shows that performance of detection varies based on P_{fa} . It also shows that with the increasing of the P_{fa} (from 0.0001to 0.8281) the detection also increased. It also shows that theory result and simulated result are almost same. Table 1 show the measurement of probability of detection based on different P_{fa} .

Table 1. *Probability of False Alarm vs. Probability of Detection for SNR = 6dB.*

Probability of False Alarm (P_{fa})	Probability of Detection (P_d)
0.0001	0.0192
0.0121	0.2347
0.0441	0.4115
0.0961	0.5552
0.1681	0.6726
0.2601	0.7682
0.3721	0.8451
0.5041	0.9058
0.6561	0.9517
0.8281	0.9839

Figure 2 shows ROC Curve under AWGN channel. In this figure we can make sure that the value of P_{fa} will influence the detections we get. So in this figure, we compare the theoretical value and the simulated result to get a suitable value for P_{fa} .

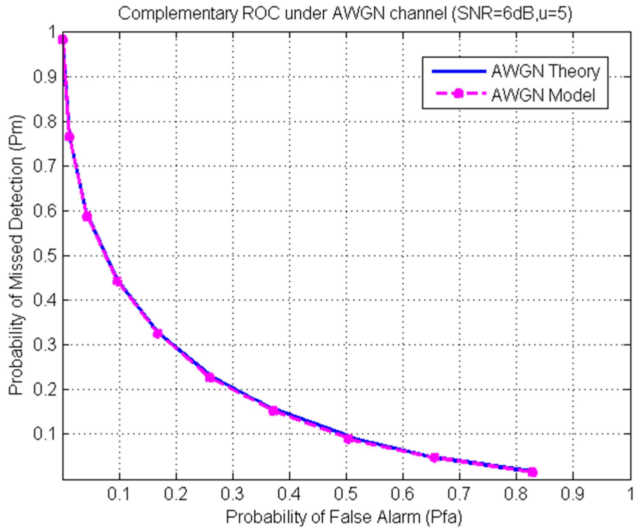

Figure 3. *Complementary ROC under AWGN channel (SNR=6dB, u=5).*

Figure 3 show Complementary ROC under AWGN channel where signal to noise ratio is 6dB and u=5. This figure shows complementary of Figure 3 where probability of missed detection is analyzed and measured which is shown in Table 2.

Table 2. *Probability of False Alarm vs. Probability of Detection for SNR = 6dB.*

Probability of False Alarm (P_{fa})	Probability of Missed Detection (P_{md})
0.0001	0.9808
0.0121	0.7653
0.0441	0.5885
0.0961	0.4448
0.1681	0.3274
0.2601	0.2318
0.3721	0.1549
0.5041	0.0942
0.6561	0.0483
0.8281	0.0161

Table 2 shows that as values of P_{fa} increases; there is drastic decrease in P_{md} .

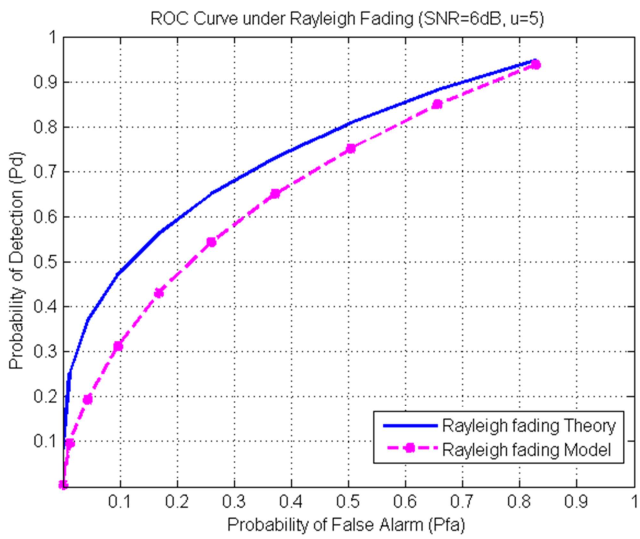

Figure 4. *ROC Curve under Rayleigh Fading (SNR=6dB, u=5).*

Figure 4 shows ROC Curve under Rayleigh Fading (SNR=6dB, u=5) like as Figure 2 but difference is that theatrical and simulated result are not same for the Rayleigh fading channel.

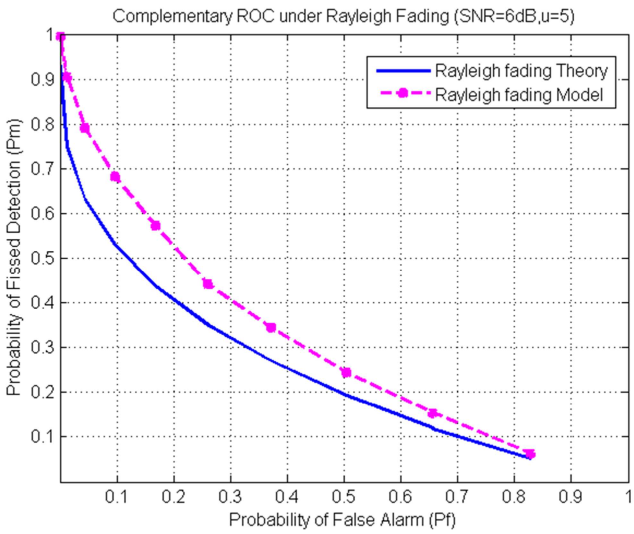

Figure 5. *Complementary ROC under Rayleigh Fading (SNR=6dB, u=5).*

Figure 5 shows complementary ROC under Rayleigh Fading (SNR=6dB, u=5) where only difference from the Figure 4 is that here probability of missed detection is measured and plotted.

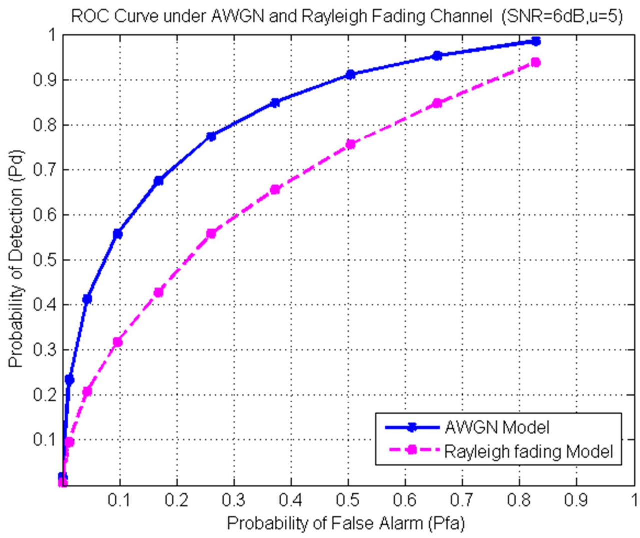

Figure 6. *ROC Curve under AWGN and Rayleigh Fading Channel (SNR=6dB, u=5).*

Figure 6 shows ROC Curve under AWGN and Rayleigh Fading Channel (SNR=6dB, u=5) where probability of detection is analyzed based on probability of false alarm. Here Energy detection is calculated both AWGN channel and Rayleigh fading channel based on the theatrical equation from fig. it shows that probability of detection in AWGN channel is better than Rayleigh fading channel. Where Rayleigh fading channel is more degraded.

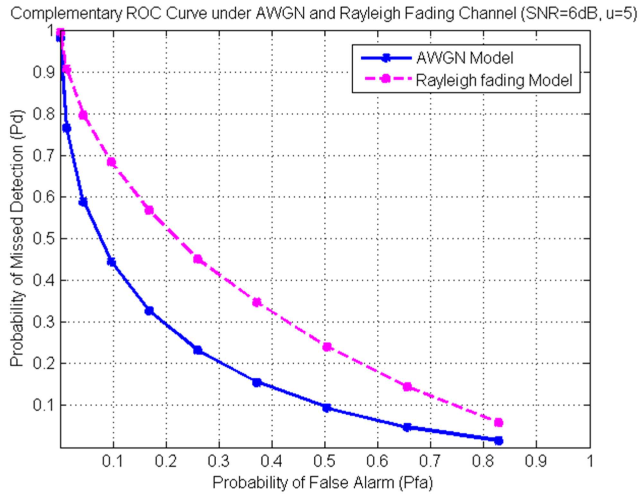

Figure 7. *Complementary ROC Curve under AWGN and Rayleigh Fading Channel (SNR=6dB, u=5).*

Figure 7 shows Complementary ROC Curve under AWGN and Rayleigh Fading Channel (SNR=6dB, u=5) and this is as like as Figure 7 only with difference is that probability of missed probability of missed detection is measured.

4. Discussion

We have discussed about a radio or system that senses and is aware of its operational environment and can be trained to dynamically and autonomously adjust its radio operating parameters accordingly. This radio is known as cognitive radio. However, a common assumption regarding cognitive radios is that they are unlicensed spectrum users that should avoid interference with the licensed primary users. Effective detection of primary users is the major issue of cognitive radio was to use the existing traditionally allocated spectrum in an opportunistic way. Thus, one of the important elements of the cognitive radio is detecting the available spectrum opportunities. In general, we have discussed about cognitive radio and the issues in spectrum detection performance of detector algorithms under both AWGN and Rayleigh fading channel in order to minimize interference between primary users and cognitive users [13].

Spectrum is a very precious resource in wireless systems and applications, and it has been a central point for research over the last several decades. Cognitive Radio is a novel technology that can potentially improve the utilization efficiency of the radio spectrum. In this project, several spectrum sensing techniques have been reviewed and a comparison is made. But, special attention has been given to Energy Detection because of its low computational complexity, it does not require any prior knowledge of PU signal and Cooperative Spectrum Sensing (CSS) as it improves the detection performance under severe fading and hidden terminal problem. Cooperative spectrum sensing is better than classical spectrum sensing techniques as it overcomes the hidden node problem, reduces false alarm and gives more accurate signal detection. To analyze the performance of energy detection algorithm for spectrum sensing in cognitive radio by drawing the ROC (Receiver Operating Characteristics) and complementary ROC curves between probability of false alarm vs. probability of detection, SNR vs. probability of detection, Probability of error vs. Threshold in cognitive radio systems. We have analyzed the performance of energy detection over AWGN channel and over fading environment (Rayleigh). We considered the challenges of multipath fading and hidden terminal problem. To overcome it we studied and presented cooperative spectrum sensing with hard combination over AWGN channel and Rayleigh fading channel. Finally cooperative Energy spectrum sensing (CESS) detection based on hard decision with AND rule evaluated which shows better results in different situations.

A simulation comparison of AND & OR cooperative decision fusion rules was undertaken and results show that OR rule (corresponding to considering the decision of at least one detector out of k available detectors) out-performs the AND & OR rule combining rules [14].

5. Conclusion

We have studied the spectrum sensing performance in cooperative and non-cooperative environment in both non fading AWGN channel and Rayleigh fading channel. We have used energy detection method to detect the PU. We also used OR fusion rule here. We have seen that the energy detection performs better in the non-fading channel over fading channel in non-cooperative environment. We also observed that, when CSS was considered, sensing performance improved over a Rayleigh fading channel compared to AWGN channel.

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References

[1] Federal Communications Commission, November 2002, "Spectrum policy task force report. ET Docket 02- 135".

[2] FCC, ET. "Docket No 03-222 "Notice of proposed rulemaking and order." (2003): 1-21.

[3] Cabric, Danijela, Shridhar Mubaraq Mishra, and Robert W. Brodersen, 2004, "Implementation issues in spectrum sensing for cognitive radios." Signals, systems and computers. Conference record of the thirty-eighth Asilomar conference on. Vol. 1. IEEE.

[4] Lu, et al.,"Ten years of research in spectrum sensing and sharing in cognitive radio." *EURASIP* Journal on Wireless Communications and Networking 2012.1 (2012): 28.

[5] Urkowitz, Harry. "Energy detection of unknown_deterministic_signals." Proceedings of the IEEE 55.4 (1967): 523-531.

[6] Hossain, Mohammad Alamgir, Md Shamim Hossain, and Md Ibrahim Abdullah, 2012 "Cooperative spectrum sensing over fading channel in cognitive radio." International Journal of Innovation and Applied Studies 1.1: 84-93.

[7] Digham, Fadel F., Mohamed-Slim Alouini, and Marvin K. Simon. 2007, "On the energy detection of unknown signals over fading channels." IEEE transactions on communications 55.1: 21-24.

[8] P. Verma, B. Singh (24–27 September, 2014), "Throughput analysis in cognitive radio_networks", International Conferen_On Advances in Computing, Communications and Informatics (ICACCI), New Delhi, India.

[9] Z. Shi, K. The (2013), "Energy-efficient joint design of sensing and transmission durations for protection of primary user in cognitive radio systems", IEEE Communications Letters, Volume 17, Issue 3, pp. 565–568, DOI: 10.1109/LCOMM.2013.012313.122442.

[10] C. Sun, W. Zhang, K. B. Letaief (11–15 March, 2007), "Cooperative spectrum sensing for cognitive radios under bandwidth constraints", Wireless Communications and Networking Conference, Kowloon, China.

[11] Ma, J., Zhao, G., & Li, Y. (2008). Soft combination and detection for cooperative spectrum sensing in cognitive radio networks. IEEE Transactions on Wireless Communications, 7 (11), 4502-4507.

[12] Quan, Z., Cui, S., & Sayed, A. H. (2008). Optimal linear cooperation for spectrum sensing in cognitive radio networks. IEEE Journal of selected topics in signal processing, 2 (1), 28-40.

[13] Taricco, G. (2011). Optimization of linear cooperative spectrum sensing for cognitive radio networks. IEEE Journal of Selected Topics in Signal Processing, 5 (1), 77-86.

[14] S. Haykin,, Feb 2005, "Cognitive radio: brain- empowered wireless communications," IEEE Journal on Selected Areas in Communications, vol. 23, no. 2, pp. 201-220.

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

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