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Improving Probability of Detection using CFAR and Adaptive Threshold for Cognitive Radio (CR)

Ahmed Abdulridha Thabit, Hadi T. Ziboon

***Abstract*— The electromagnetic radio spectrum is a licensed resource is carefully managed by governments. User's needs in wireless services, leads to the scarcity of available spectrum and inefficient channel utilization. The cognitive radio is the optimum solution for these requirements. The abilities to detect a primary user (PU) as well as to avoid any false alarm are of paramount importance for such a system. The Cognitive Radio has the ability to get the unlicensed user (secondary user (SU)) to use the spectrum for while according to the sensing time. In this paper increased the probability of detection (Pd) using the constant false alarm rate (CFAR) and soft decision (adaptive threshold) instead of hard decision was adapted to select the best threshold to improve the detection. The results show a good detection at variable low SNR values.**

***Index Terms*— cognitive radio, cfar, energy detector.**

I. INTRODUCTION

The demand for the radio-frequency (RF) is increasing to support the user needs in wireless communications. RF spectrum is a scarce resource and requires efficient utilization. In order to overcome this situation, it's needed to come up with a means for improved utilization of the spectrum creating opportunities for dynamic spectrum access. The issue of spectrum underutilization in wireless communication can be solved in a better way using Cognitive Radio (CR) technology, it has been proposed as a means to promote the efficient use of spectrum by exploiting the existing spectrum holes. Standard definitions of cognitive radio adopted from a number of references such as in [1, 2].

In general, the Cognitive radio is a form of wireless communication in which a transceiver can intelligently detect which RF communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones. Figure (1) represents the spectrum showing the used and unused channels.

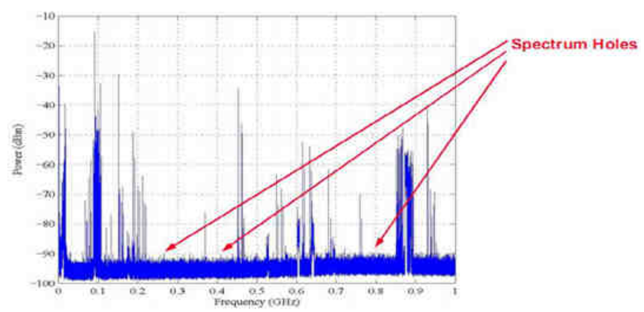

Figure (1) the radio spectrum showing the used and unused channels [6].

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Ahmed Abdulridha Thabit, Asst. Lecturer, Department of Computers Communications Engineering, Al Rafidain University College, Baghdad, Iraq.

Dr. Hadi T.Ziboon, Asst. Prof., Department of Electrical Engineering, University of Technology, Baghdad, Iraq.

This optimizes the use of available radio-frequency (RF) spectrum while minimizing interference to other users. Each CR has its steps or algorithm to reach the optimization in the detection. The cycle of cognitive radio can be represented by the figure (2) [6].

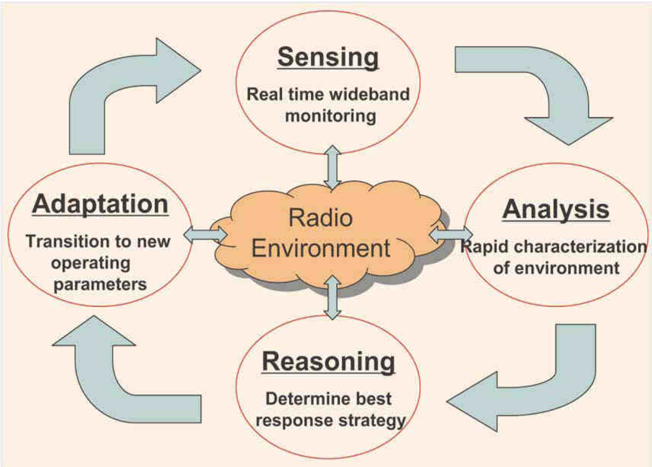

Figure (2) the cycle of cognitive radio

II. SENSING TECHNIQUES

In general, there are a number of sensing techniques [3, 4]. The first and simplest one is the energy detection (ED). An ED is a common way of spectrum sensing to decide whether unknown signals exist or not. The receiver (sensing node) does not need any knowledge of the primary users' signal. The simplest diagram of ED can be represented in fig (3) [5]

When the primary user signal is unknown or the receiver cannot gather sufficient information about the primary user signal, the energy detection method is used [6].

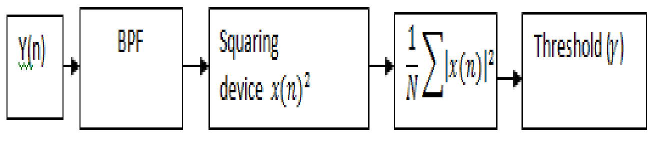

Figure (3) the block diagram of energy detection (ED)

Y(n) represents the received signal plus noise [7].

The decision problem for the energy detection scheme can be represented in a hypothesis form;-

Ho: y(n)= w(n) (only noise)

H1: y(n)= h(n) *s(n)+w(n) (signal+noise)

Ideally the spectrum sensor would select **H1** to show the presence of primary users and **Ho** otherwise. In practice spectrum sensing algorithms fall into mistakes, which are classified as missed detection and false-alarm, which may be defined as- Probability of missed detection, PMD this is the probability when a primary user is detected to be inactive while it is actually active. Higher value of PMD leads to

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higher interference, Probability of False alarm, PFA It is defined as the probability of detecting that primary user is present while it is actually inactive, and this leads to inefficient utilization of the spectrum, because even if the spectrum is free, the secondary user will assume that it is occupied by the primary user and hence will not be able to utilize the spectrum. A low value of PFA is expected to increase the channel reuse capability when it is free [8] .Probability of detection, PD is the probability that the primary users are detected to be present while they are actually present, to avoid any interference from the secondary users if they are trying to access the spectrum. A high value of PD will lead to efficient use of the spectrum without causing interference to the primary user [9].

PD= P(H1/H1), or

PD = 1- PMD

For the detection of unknown deterministic signals corrupted by the additive white Gaussian noise, an ED is derived in, which is called conventional ED. This is an easily implemented detector for the detection of unknown signals in spectrum sensing. It collects the test statistic and compares it with a threshold (λ) to decide whether the PU signal is present or absent. However, the ED suffers from noise uncertainty at low SNR [10]. Despite the aforementioned drawbacks, energy detection can provide lower sensing period than other methods and it is applicable to multiple channels for wideband sensing. Hence energy detection is the most studied technique among all sensing methods [7]. If the PU transmitter's signal is completely known, the optimal transmitter detection method is the Matched Filter. The assumption, that the signal is fully known is unreasonable; but most communication systems contain some pilot tone or synchronization codes which can be utilized by second users for detection [11]. Matched filtering is known as the optimum method for detection of primary users when the transmitted signal is known. It is known as the finest technique for detection of primary users because it maximizes the SNR of the received signal in existence with additive Gaussian noise. It is done by correlating the unknown signal with the known signal to detect the known signal in the unknown signal. Cyclostationary feature detection is another method for detecting primary user transmissions by using the Cyclostationary features of the received signal [12]. Cyclic correlation function is used for detecting signals present in a given spectrum, instead of the power spectral density (PSD). The algorithms based on Cyclostationary detections can differentiate between noise and primary users signal**.** Cyclic correlation function is used for detecting signals present in a given spectrum, instead of the PSD [8]. Pfa of cyclostationary feature detection is much smaller as compared to other two techniques. It is further seen that the "probability of false detection" for energy detection technique is inversely proportional to the SNR.

III. PROPOSED SYSTEM MODEL

In the conventional detection methods of cognitive system, a fixed threshold value (hard limiter) is used. In this case there is an uncertainty region will appear and will decreases the probability of detection (pd) because of the interference between the noise and the signal. In this system we used an adaptive threshold value (soft decision) in order to get rid of the uncertainty region and increase the detection. The system based on constant false alarm rate (CFAR) that assumes a constant value of pfa to get higher pd.

1) A Monte Carlo simulation system specifications were used. The number of iterations that used are 10,… 10000 and 20000 iteration. In each case different values of samples were used from 100 to 5000. The probability of pfa was fixed for each case (from 0.002 to 0.1). Different cases were taken to show various results.
2) There are two major equations that were dependant pd and pfa they are [13]:-
3)

$$pfa = Q\left(\frac{(\gamma-\alpha^2 n)}{\sqrt[2]{\frac{2}{N}}\,\alpha^2 n}\right) \quad \ldots\ldots (1)$$

$$PD = Q\left(\frac{\gamma-(P+\alpha^2 n)}{\sqrt[2]{\frac{2}{N}}(P+\alpha^2 n)}\right) \quad \ldots.. (2)$$

The derivation of the number of samples that needed is below:-

From (1) $\Rightarrow\ Q^{-1}PFA = \left(\frac{(\gamma-\alpha^2 n)}{\sqrt[2]{\frac{2}{N}}\,\alpha^2 n}\right),$

$$\gamma - \alpha^2 n = Q^{-1}(PFA)\sqrt[2]{\frac{2}{N}}\,\alpha^2 n \quad \Rightarrow$$

$$\gamma = Q^{-1}PFA\sqrt[2]{\frac{2}{N}}\,\alpha^2 n + \alpha^2 n$$

$$\gamma = \alpha^2 n\left(Q^{-1}PFA\sqrt[2]{\frac{2}{N}}+1\right) \quad \ldots\ldots (3)$$

Then from(2)

$$PD = Q\left(\frac{\gamma-(P+\alpha^2 n)}{\sqrt[2]{\frac{2}{N}}(P+\alpha^2 n)}\right) \quad by\ division\ by\ \div\frac{\alpha^2 n}{\alpha^2 n}$$

$$Q^{-1}(PD) = \frac{\frac{\gamma}{\alpha^2 n} - (SNR+1)}{\sqrt[2]{\frac{2}{N}}(SNR+1)} \quad \text{Where} \quad SNR = P/\alpha^2 n$$

$$\frac{\gamma}{\alpha^2 n} = Q^{-1}PD\sqrt[2]{\frac{2}{N}}(SNR+1)+(SNR+1) \quad \Rightarrow$$

$$\gamma = \frac{Q^{-1}PD\sqrt[2]{\frac{2}{N}}(SNR+1)+(SNR+1)}{\frac{1}{\alpha^2 n}} \quad ..(4)$$

by equating equ. (3) and (4) :-

$$\frac{\sigma n^2}{\sigma n^2}*\sigma n^2\left(Q^{-1}PFA\sqrt{\frac{2}{N}}+1\right) = \left(\frac{Q^{-1}PD\sqrt{\frac{2}{N}}(SNR-1)+(SNR+1)}{\frac{1}{\sigma n^2}}\right)*\frac{\sigma n^2}{\sigma n^2})$$

$$\sigma n^2\left(Q^{-1}PFA\sqrt{\frac{2}{N}}+1\right) = [Q^{-1}PD\sqrt{\frac{2}{N}}(SNR-1)+(SNR+1)]*\sigma n^2$$

$$Q^{-1}PFA\sqrt{\frac{2}{N}}+1 = Q^{-1}PD\sqrt{\frac{2}{N}}(SNR+1)+(SNR+1) \quad \Rightarrow$$

$$Q^{-1}PFA\sqrt{\frac{2}{N}} - Q^{-1}PD\sqrt{\frac{2}{N}}(SNR+1) = SNR$$

$\sqrt{\frac{2}{N}}(Q^{-1}PFA - Q^{-1}PD(SNR+1) = SNR$ by squaring both sides :- $\frac{2}{N}((Q^{-1}PFA - Q^{-1}PD(SNR+1))^2 = SNR^2$

$$2*\frac{(Q^{-1}PFA-Q^{-1}PD(SNR+1))^2}{N} = SNR^2 \Rightarrow 2*\left(\frac{Q^{-1}PFA-Q^{-1}PD(SNR+1)}{SNR}\right)^2 = N$$

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$$N = 2\left(\left(Q^{-1}PFA - Q^{-1}PD(SNR+1)\right)^2 * (SNR)^{-2}\right.$$

This represents the number of samples needed to get the required probability of detection.

IV. SIMULATION RESULTS

Matlab simulation program was used to implement the system. Figure (4) represents the results when the number of iteration is 10 with pfa=0.1 and number of samples is 1000. As shown there is a big similarity between the theory and simulation

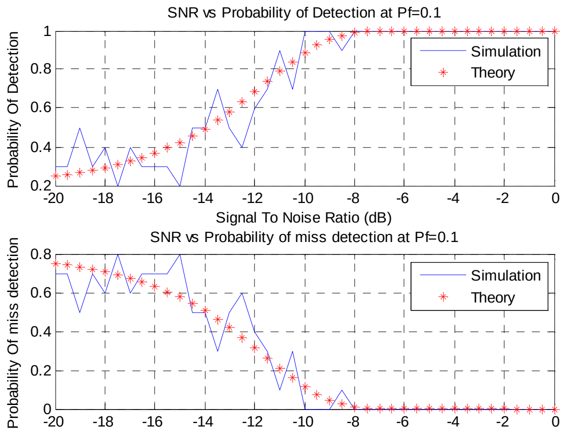

Figure (4) represents the results when number of iteration is 10, pfa=0.1 and N= 1000

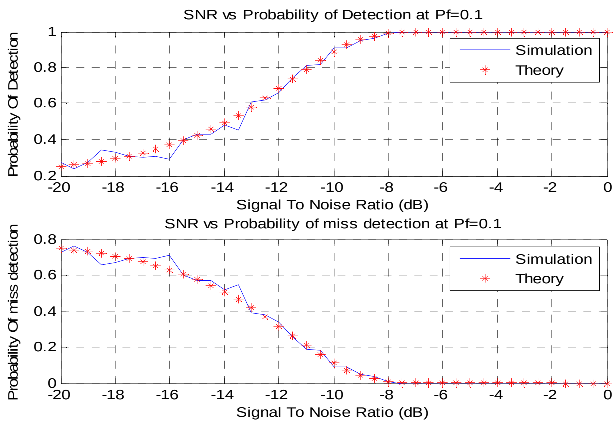

Figure (5) represents the results when number of iteration is 100, pfa=0.1 and N= 1000.

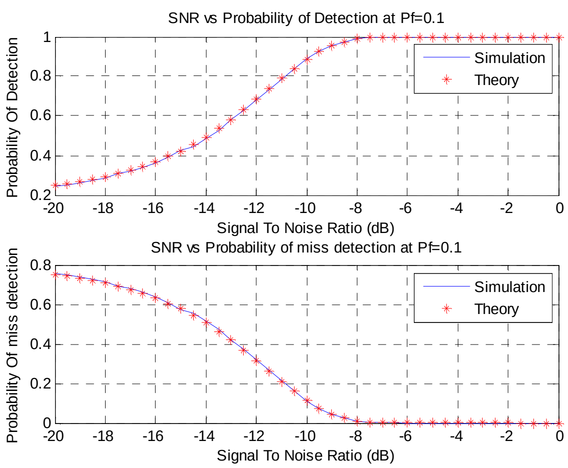

Figure (6) represents the results when number of iteration is 10000, pfa=0.1 and N= 1000.

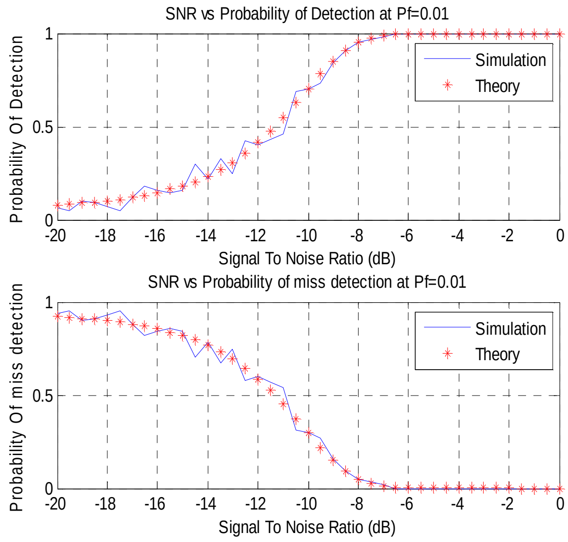

Figure (7) represents the results when number of iteration is 10000, pfa=0.01 and N= 1000.

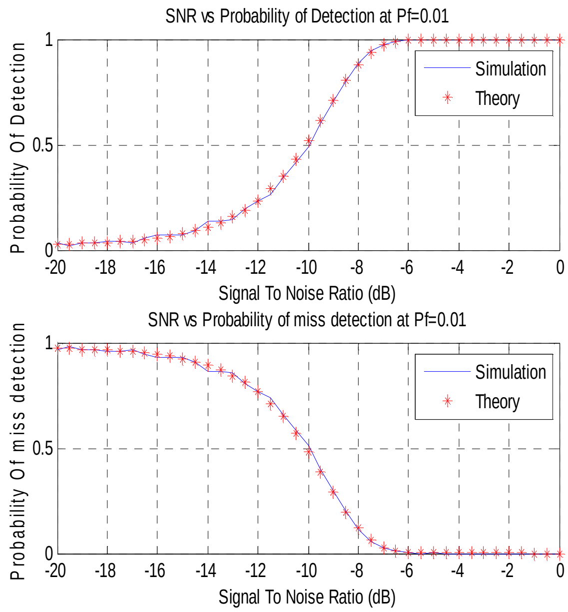

Figure (8) represents the results when number of iteration is 10000, pfa=0.001 and N= 1000.

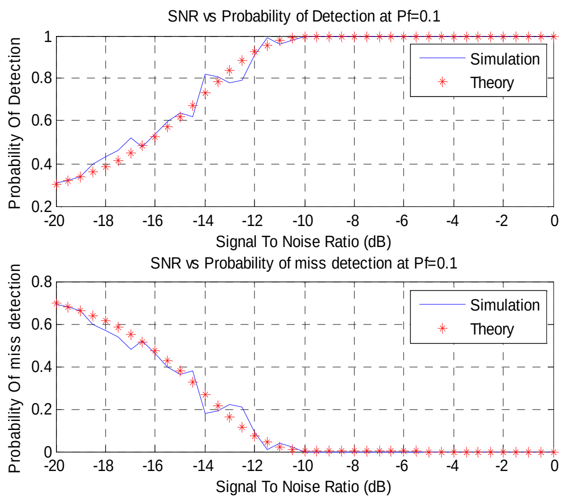

Figure (9) represents the results when number of iteration is 10000, pfa=0.001 and N= 3000.

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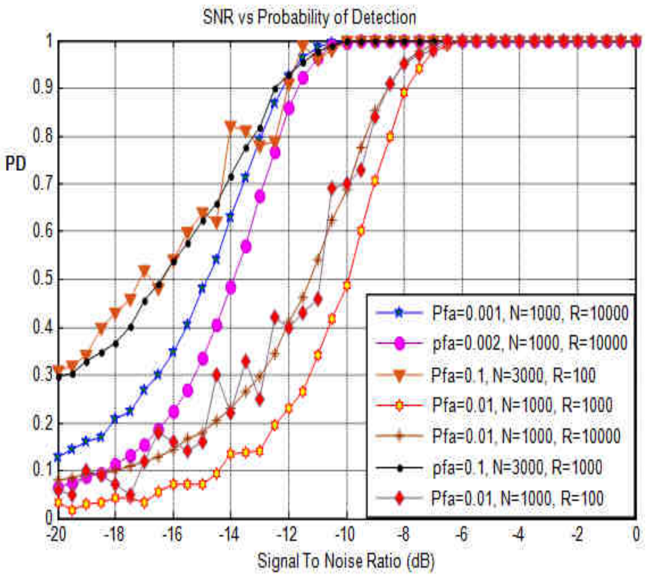

Figure (10) represents the Pd vs SNR for various cases

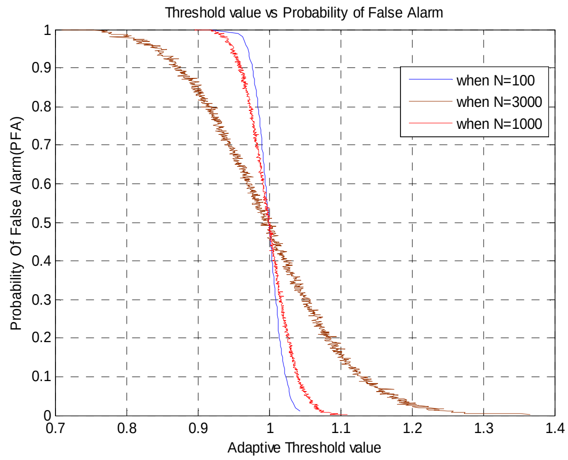

Figure (11) represents the adaptive threshold vs Pfa for various cases

V. CONCLUSION

As result from the above figures, it's seen that the proposed system has good results as compared with the available results in references. Numerical results shows that the proposed approach can guarantee a reliable sensing while enhancing the spectrum utilization greatly. The simulated system with soft decision and variable SNR values with different cases of **Pfa** and variable number of samples show good results.

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