Cognitive Radio: Energy Detection Spectrum Sensing Under Awgn And Rayleigh Channel

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ABSTRACT:
Cognitive Radio (CR) is a paradigm to enhance the spectrum utilization by allowing opportunistic spectrum sharing. The objective of the CR is to utilize licensed spectrum without creating intervention to the Primary User (PU).Spectrum sensing permits the CR users to sense the unused band of the spectrum. In this paper, Energy Detection(ED) based spectrum sensing is considered, and the performance is evaluated under different fading conditions. We derive probability of detection over Additive White Gaussian Noise (AWGN) and Rayleigh channel with simulation results under different signal to noise ratio (SNR) values, fading parameters using ED spectrum sensing.

KEY WORDS: Cognitive radio, energy detection, spectrum sensing, rayleigh, AWGN

INTRODUCTION

The Rapid increase in the number of wireless products in last decade causing a scarcity of available frequency spectrum. According to FCC more than 80% of spectrum is underutilized at any given time resulting in spectral inefficiency [3]. These studies reveal that extensive spectrum utilisation takes place in unlicensed band (example: ISM band), wireless utilisation in the licensed band (example: TV band & cellular band) [6][9].

To counter this problem and other challenges we use cognitive radio technology that allows wireless devices to sense the empty band and use it for transmission when the licensed user is not active, thus improving the spectrum utilisation [10].

There are various methods that have been proposed for example cyclostationary feature detection, which can distinguish between noise and primary signal, but the computational cost is very high. It also requires prior knowledge of primary signal parameters for the identification of cyclic frequencies. Matched filter sensing maximizes the signal to noise ratio (SNR) at the output but requires prior information of PU signal [1].

ED is easy to implement, because it does not require any initial information of the primary user. It compares, the received signal with the estimated threshold, which is largely dependent on the noise power [5] [7]. ED is widely used due to its simplicity [4].

MATERIAL AND METHODS

In energy detection, as shown in fig.1 block diagram [5]. The received signal x(t) is passed through the band pass filter [BPF] which selects the required bandwidth of interest B. The output of the BPF is passed through the A/D block where the signal is sampled and quantized. The signal is then passed through the squaring device, which senses the signal energy over the time duration T using the integrator. Finally, the output is compared with the predefined threshold λ to check whether primary user is present or absent.

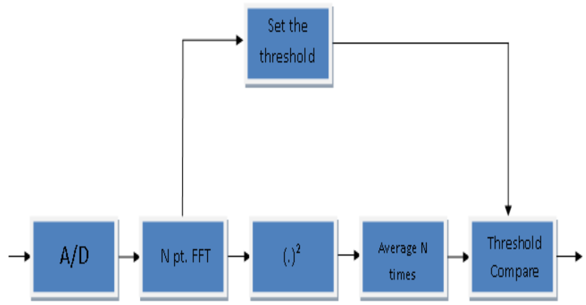

Fig. 6 Energy Detection block diagram

$$x(n) = \begin{cases} s[n] & h0 \\ hr[n] + s[n] & h1 \end{cases} \qquad (1)$$

Where r(n) corresponds to the primary user signal, s[n] corresponds to the noise component and h is amplitude gain of the channel, which is assumed to be constant over a duration of observation (N samples).

The energy collected is denoted by Y which is shown as following distribution [2]

$$Y = \sum_{N} (x[n])^2 \qquad (2)$$

In Energy detection spectrum sensing, the received signal can be modelled as a binary hypothesis problem defined as [8]

$$Y \sim \begin{cases} x_0^2, & H_0 \\ x_0^2, & H_1 \end{cases} \qquad (3)$$

y

Then Y will be central chi square under h_0 and non central chi square under h_1.

The performance is characterized by the following metrics:

Probability of false alarm (P_{fa})

The output of the decision device is h_1 while h_0 is true denoted as

Pfa =P ($h1$; $h0$) = P (Y > λ : h_1) (4)

Probability of missed detection (Pmd)

The output of the decision device is h_0 while h_1 is true; this represents the probability of misdetection.

Pmd =P (h_0 ; h_1) (5)

Probability of detection (Pdt)

The complementary of Missed detection is Pdt.

The output of the decision device is h_1 when h_1 is true.

Pdt =P ($h1$: $h1$)= P (Y > λ : h_1) (6)

The performance of energy detection is evaluated by Pdt in a low SNR.

Let the probability density function be

$$f_y(y) = \begin{cases} \dfrac{1}{\sigma^{2v} 2^v \Gamma v} y^{v-1} e^{\frac{-y}{2\sigma^2}} & , H_0 \\ \dfrac{1}{2\sigma^2} \left(\dfrac{y}{\xi}\right)^{\frac{v-1}{2}} e^{\frac{-1\,(y+\xi)}{2\sigma^2}} & , H_1 \end{cases} \qquad (7)$$

To derive probability of false alarm under AWGN channel, we integrate (7) under $h0$.

We define

$$\phi=\frac{h^2\xi}{\sigma^2} \quad u=\frac{y}{\sigma^2}$$

$$P_{fa}=\int_{\frac{\lambda}{\sigma^2}}^{\infty}\frac{1}{2^v\Gamma v}t^{v-1}e^{\frac{-u}{2}}du \qquad ,\frac{\lambda}{\sigma^2}\geq 0$$

$$=Q_{\chi_D^2}\left(\frac{\lambda}{\sigma^2}\right) \tag{8}$$

To derive probability of detection same approach is used

$$P_{dt}=Q_{\bar{\chi}^2_{D(\gamma)}}\left(\frac{\lambda}{\sigma^2}\right) \tag{9}$$

By letting $u= y/\sigma^2$ and v= N/2, we get

$$\boldsymbol{Pdt=\int_{\lambda/2}^{\infty}\frac{1}{2}\frac{u^{\frac{v-1}{2}}}{2}e^{\left[\frac{1}{2(u+\phi)}\right]}K_{v-1}(\sqrt{\phi u})\,du} \tag{10}$$

Rayleigh fading

ED under Rayleigh channel is considered by averaging the conditional probability of detection over SNR. The distribution function is given by

$$f(\gamma)=\frac{1}{\bar{\gamma}}\exp\left(-\frac{\gamma}{\bar{\gamma}}\right) \tag{11}$$

we define $\bar{\gamma}$ as the avg. SNR ratio. Then probability of distribution of γ is given by

$$Pd.ray=\int_0^{\infty} Q_{N/2}\,(\sqrt{\gamma},\sqrt{\lambda'})f(\gamma)d\gamma \tag{12}$$

Then, substituting (11) into (12) we get

$$P_{dray}=e^{(-\lambda'/2)}\left\{(1+\beta^2)^{v-1}e^{\left(\frac{\lambda'}{2(1+\beta^2)}\right)} - \sum_{q=0}^{v-2}\frac{1}{q!}\left(\frac{\lambda'}{2(1+\beta^2)}\right)^q+\sum_{q=0}^{v-2}\frac{1}{q!}\left(\frac{\lambda'}{2}\right)^q\right] \tag{13}$$

Where v= N/2;

Eqn. 13 defines Pdt under Rayleigh fading channel

RESULTS AND DISCUSSION

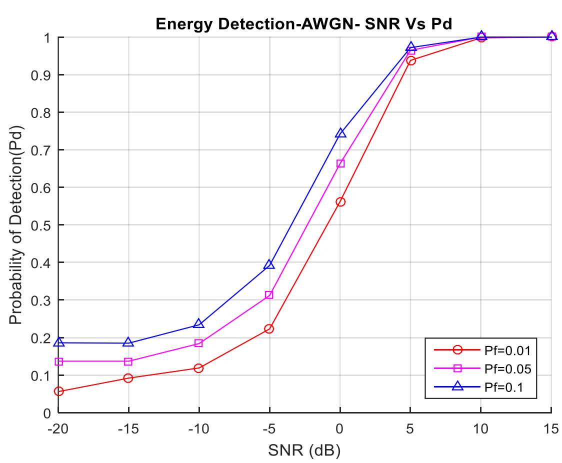

Fig.1 Pd Vs SNR for Pf = 0.01, 0.05 and 0.1 under AWGN channel

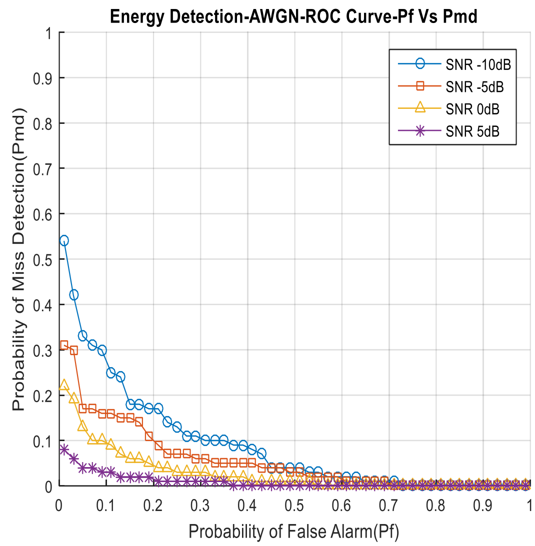

Fig.2 ROC curve Pf Vs Pmd for different values of SNR under AWGN

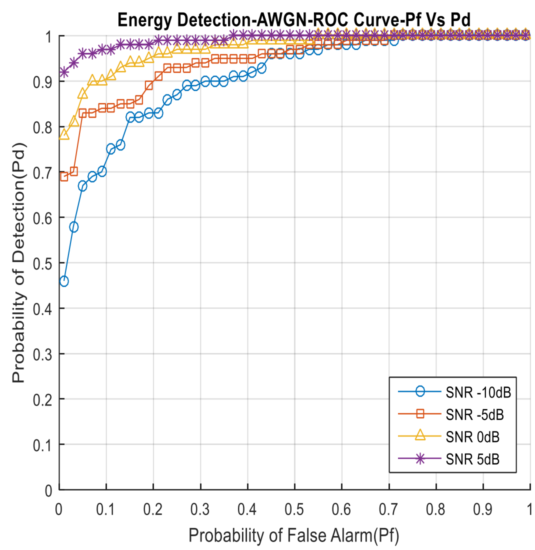

Fig.3 ROC curve Pf Vs Pd for different values of SNR under AWGN

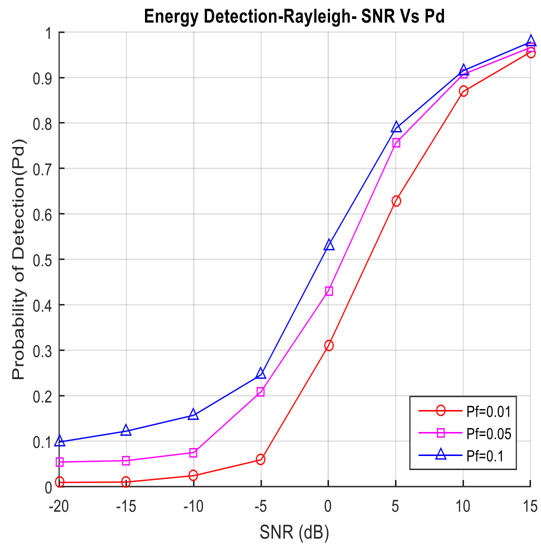

Fig.4 Pd Vs SNR for Pf = 0.01, 0.05 and 0.1 under Rayleigh channel

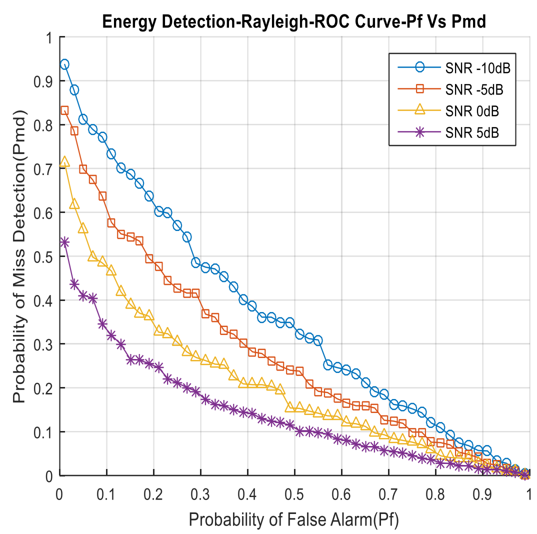

Fig.5 ROC curve Pf Vs Pmd for different values of SNR under Rayleigh channel

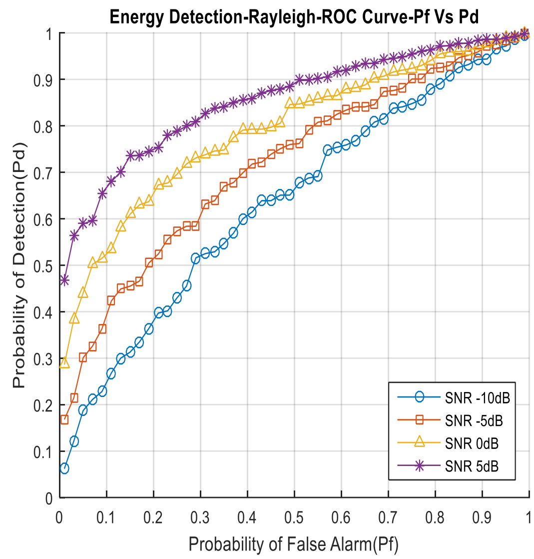

Fig.6 ROC curve Pf Vs Pd for different values of SNR under Rayleigh channel

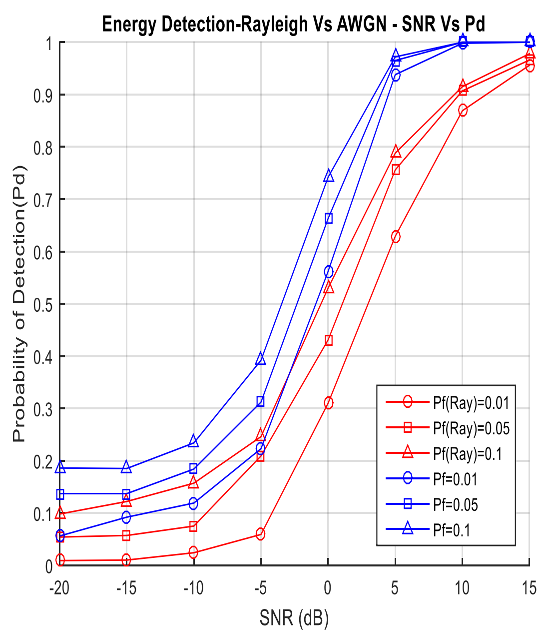

Fig.7 Comparing AWGN Vs Rayleigh ROC curve of Pdt vs SNR for Pf =0.01, 0.05 and 0.1

The performance of ED spectrum sensing under AWGN and Rayleigh channel is evaluated for different conditions for both probability of detection versus SNR curves and complementary receiver operating characteristics (ROC) curves. ROC is vastly used in signal detection theory due to the fact that it is preferable technique to quantify the trade-off between Pdt and Pfa.
Fig. 1 and Fig. 4 shows Pdt versus SNR for
Pf=0.01, 0.05 and 0.1 under AWGN and Rayleigh channel respectively. It can be observed that as Pf increases, Pd increases. With the increase of average SNR ,Pd increases almost linearly.

Fig. 2 and Fig. 5 shows ROC curves Pf versus Pmd for SNR = -10dB, -5dB, 0dB and 5dB under AWGN and Rayleigh channel respectively. Pmd is complementary of Pd.

Fig. 3 and Fig. 6 shows ROC curves Pd versus Pf for SNR = -10dB, -5dB, 0dB and 5dB under AWGN and Rayleigh channel respectively. It can be observed that Pd increases with the increase in SNR. Also, Pd increases logarithmically with the increase of Pf.
Fig. 7 shows ROC curve of Pd versus SNR for
Pf = 0.01, 0.05 and 0.1. It gives comparison between AWGN versus Raleigh fading channel.

Conclusion

In this paper, we evaluate the performance of ED spectrum sensing over AWGN and Rayleigh channels. Our analysis includes theoretical description of ED and simulation results which are carried out on MATLAB. We can conclude that increasing sensing time would improve the Pdt; moreover, noise uncertainties in the channel makes it difficult for the signal detection below a certain level even if the sensing time is improved. The current results will provide the framework for the future, where we would like to consider few other fading channels and compare the results. We might likewise want to define an optimal design for energy detection.

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