Spectrum Sensing for WLAN and WIMAX using Energy Detection Technique

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***Abstract* - Recent trends in wireless communication suffers due to spectrum scarcity. Cognitive radio technology has emerged as potential solution to spectrum scarcity which tries to reuse free underutilized spectrum. Spectrum sensing is the key function for determining underutilized spectrum. This paper discusses receiver operating characteristics (ROC) for energy detection(ED) based spectrum sensing technique in case of BPSK and OFDM modulated signals in WLAN and WIMAX system. And paper provides the performance of energy detection for WLAN and WIMAX application.**

***Keywords*—Cognitive radio, Spectrum Sensing, Energy detection, OFDM, BPSK, WLAN, WIMAX.**

I INTRODUCTION

The electromagnetic spectrum is almost fully allocated for use in different sectors of wireless communication. However the allocated spectrum is not utilized by many the primary (licensed) users for most of time and most of free place [1]. These include application in television, radio, mobile and cellular communication. Above users are called primary users who has paid license fees to government agencies like Federal Communications Commission (FCC) in USA or Telecom Regulatory Authority of India (TRAI) in India for using spectrum. The licensed users are those users to whom frequency bands are licensed by the government licensing agencies. Cognitive radio technology is becoming enabling solution to solve the problem of inefficient spectrum utilization of FCC on allocating it to unlicensed user in uninterrupted way. FCC defines it as: "A radio or system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to modify system operation, such as maximize throughput, mitigate interference, facilitate interoperability and access secondary markets" [2].

Spectrum sensing is one of the important functions of cognitive radio to detect spectrum hole or free spectrum in primary user in band. Spectrum hole is that frequency bands which have been allotted to primary users but at the particular time and place, the band is free and can be utilized by secondary (unlicensed) users [3]. The objective of spectrum sensing is to detect free primary user in allocated band and so if it is free, make provision for secondary user such that it does not affect the efficiency of primary user. Thus, utilization of vacant band by the secondary user can alleviate the spectrum scarcity problem [3].

Cognitive radio deals with multiple technologies which include spectrum sensing to detect spectrum hole, cognitive engine for allocation of spectrum white space to unlicensed user, configurable radio that can access different carrier frequencies and switch between them very quickly. This paper investigates spectrum sensing for WLAN and [3] WIMAX applications. Spectrum sensing is though old problem in case radar and radio communication concerned. But it has taken rebirth with factors affective Cognitive radio environment [2]. Spectrum sensing generally achieved through signal processing technique which include energy detection [4], matched filter [5], cyclostationary detection [6], covariance based detection [7]etc.

Energy detection method is a simple method for spectrum detection. Presence of energy in certain band indicates availability of primary user otherwise the frequency band is assumed to be available for secondary users. It does not require any prior information about, availability of primary users. But in case low signal to noise ratio (SNR) its performance is weak and which is overcome by modified signal processing algorithms. As it is simple and easily implemented in hardware. So it is most preferred in emerging standard like IEEE 802.22. In this paper it has been assumed that primary user uses BPSK and OFDM modulated signal. Presently IEEE community is coming up with new standard on Cognitive radio like IEEE 802.22 Wireless Region Area Network (WRAN) and white-WIFI in case WLAN using TV white space of data communication. So this paper uses the WLAN and WIMAX system to test spectrum sensing using ED method. As WRAN is using same physical layer as of WIMAX and white -Fi using same as WLAN.

The paper is organized as follows: section II describes the OFDM model. Section III presents a discussion of spectrum sensing in general and ED of spectrum sensing in particular. Section IV presents simulation results and discussion while section v provides the concluding remarks.

II OFDM System Model

OFDM is a multicarrier communication technique where signal is transmitted using large number of subcarriers orthogonal to each other. OFDM divides the total bandwidth into a number of smaller bandwidths by spreading the transmitted signal over a number of subcarriers [8]. In OFDM transmitter the information in the form of symbols is passed through serial to parallel converter. These parallel bits of data are mapped to the subcarriers using an Inverse Fast Fourier Transform (IFFT) block, where the subcarriers are orthogonal to each other [8]. The OFDM symbols are then appended with a cyclic prefix to nullify the effect of inter-carrier interference and are passed through a parallel to serial converter. For further transmission Fig.1 shows the block diagram of OFDM model.

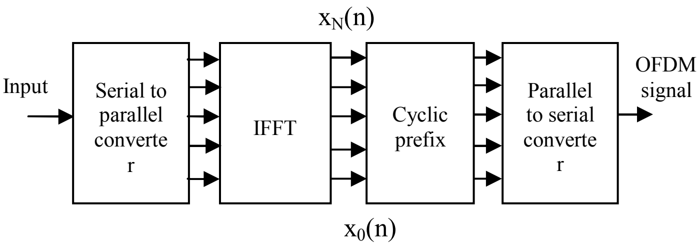

Fig.1 Block Diagram of OFDM model

A block of data consists of information bits that can be represented as

$$\boldsymbol{s(n)} = [s(n-1), s(n-2), \ldots, s(0)\ ] \qquad (1)$$

The IFFT operator is applied to ***s(n)*** which converts frequency domain signal into time domain signal [8] and the corresponding time domain signal is given by

$$\boldsymbol{x(n)} = \left[x_0(n), x_1(n), x_2(n), \ldots, x_{(n-1)}(n)\right] \qquad (2)$$

Where, N is the block length of IFFT.

The output of the IFFT block is an OFDM symbol. A cyclic prefix is inserted before the OFDM symbol. Ncp numbers of cyclic prefix bits are added and the transmitted signal becomes:

$$[x_{-\mathrm{Ncp}}(n), \ldots, x_{-2}(n), x_{-1}(n), \ldots, x_0(n), x_1(n), \ldots, x_{(N-1)}(n)] \qquad (3)$$

Where the extra cyclic block is represented as

$$\boldsymbol{xcp(n)} = [x_{\ -Ncp}(n), \ldots, x_{-2}(n), x_{-1}(n)] \qquad (4)$$

This signal is transmitted through the AWGN channel. This signal is detected at receiver to detect availability of primary user.

III SPECTRUM SENSING USING ENERGY DETECTION

Spectrum sensing is one the main functional blocks in the cognitive radio which identifies the presence or absence of licensed user. It is based on the following binary hypothesis [9] [10]

$$y(n) = \begin{cases} w(n) & H_0 \\ w(n)\ +\ x(n) & H_1 \end{cases} \qquad (5)$$

n=0, 1,…, N-1

Where *y(n)* is the received signal with Additive white Gaussian Noise(AWGN), *x(n)* is the AWGN noise signal, *x(n)* is the input signal and N is the number of samples.
H_0 represents primary user is absent and H_1 represents that in received signal primary user is present [9].

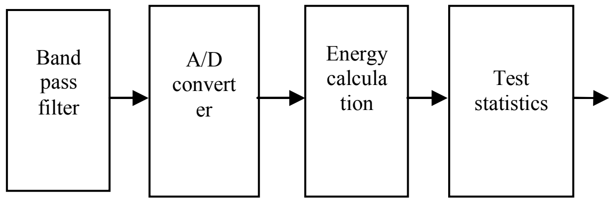

Fig.2 Simplified Energy detection Diagram

It is the responsibility of the receiver to detect presence of primary user. Presently Cognitive radio presents many spectrum sensing techniques. Among them ED is simplest and inexpensive technique. As it makes decision based on average energy of signal.
The simplified energy detector technique block diagram is shown in Fig.2 [10]. In this method received signal is passed through band pass filter which is used to get the bandwidth of signal [1]. The energy of received signal is calculated by

$$\boldsymbol{E} = \sum_{\boldsymbol{n=1}}^{\boldsymbol{N}} |\boldsymbol{y(n)}|^{\ 2} \qquad (6)$$

Calculated energy is compared with the predefined threshold value. If the signal energy is more than the threshold value [11], then PU is present and if the energy of the signal is less than the threshold value then PU is absent. Zero mean Gaussian noise is used to model the AWGN noise signal. The primary signal energy varies with respect to the noise [9]. In the ED method, Test statistics E follows a noncentral chi-square distribution with variance σ^2=1 and central chi-square distribution with 2N degree of freedom [9].

$$\mathrm{E} \sim \begin{cases} X_{2N}^2 & ,\ H_0 \\ X_{2N}^2(2\gamma) & ,\ H_1 \end{cases} \qquad (7)$$

Where $\gamma = \sigma_x^2 / \sigma_w^2$ is the signal to noise ratio (SNR*)*, σ_x^2 is the signal variance and σ_w^2 is the noise variance. Then performance of ED method is measured by analyzing ROC in term of probability of detection (P_d) vs. probability of false alarm ($P_{fa)}$ for given threshold and probability of detection vs. SNR for given probability of false alarm. The signal is detected when the primary user is present and false alarm is occurring when the user is absent. The probability of detection and probability of false alarm are evaluated by:

$$\boldsymbol{P_d} = \boldsymbol{Pr}\ (\boldsymbol{E} > \lambda|\boldsymbol{H1}) = \boldsymbol{QN}(\ \sqrt{\boldsymbol{2\gamma}}, \sqrt{\lambda}) \qquad (8)$$

$$\boldsymbol{P_{fa}} = \mathbf{Pr}\ (\mathbf{E} > \lambda|\mathbf{H0}) = \frac{\Gamma(\boldsymbol{N}, \frac{\lambda}{2})}{\Gamma(\boldsymbol{N})} \qquad (9)$$

Where Γ(.) , Γ(.,.) are complete and incomplete gamma function [9] and Q_N(.,.) is the generalized Marcumm Q function [9] and λ is threshold value.

IV RESULTS and DISCUSSION

In this paper BPSK is taken as basic module to demonstrate the performance of ED method. Then we have considered WLAN and WIMAX systems based on OFDM to test the ED method. IEEE 802.22 emerging standard for cognitive radio. The parameters considered for testing i.e P_{fa}=0.1, P_d=0.9 and lowest SNR=-20 dB are considered as guiding principal for simulation.

In MATLAB Monte-Carlo method is used to generate BPSK, WLAN and WIMAX signals. The parameters chosen for WLAN and WIMAX are presented in Table.1 [8], which are compliable with IEEE standards 802.11a and 802.16. Fig.3 presents the probability of detection vs. SNR for fixed P_{fa} of 0.1, 0.05 and 0.01 for theoretical and actual value. From Fig.3 it is reveals that at low SNR with high P_{fa} probability of detection is poor. So from Fig.3 it shows that for large SNR value with optimal P_d, ED method is best. Same thing also reveled in Fig.4 with ROC curves which provide the information about P_d vs. P_{fa} for different SNR. Similarly for WLAN and WIMAX performance are measured in Fig 5, 6, 7 and 8. Table.2 and Table.3 shows SNR vs. probability of detection for different values of probability of false alarm for WLAN and WIMAX respectively.

Table.1

Simulation Parameters for WLAN and WIMAX

Parameters	WLAN	WIMAX
FFT LENGTH	64	256
No of data	48	192
No of pilot	4	8
No of null	16	56
Cyclic prefix	1/4	1/4
Bandwidth(GHz)	2.4	3.5

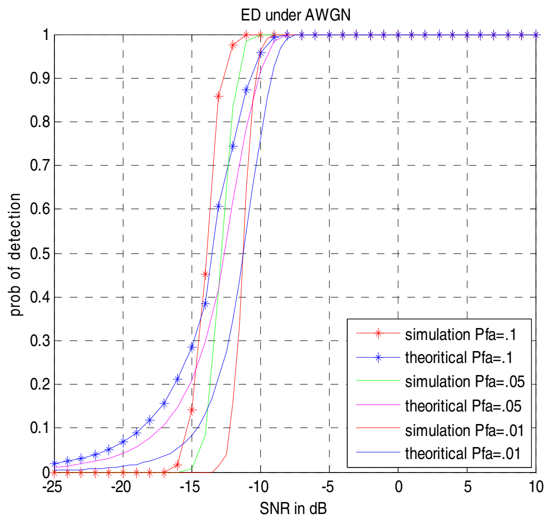

Fig.3 ROC for BPSK, P_{fa}=0.1, P_{fa}=0.01, P_{fa}=0.5

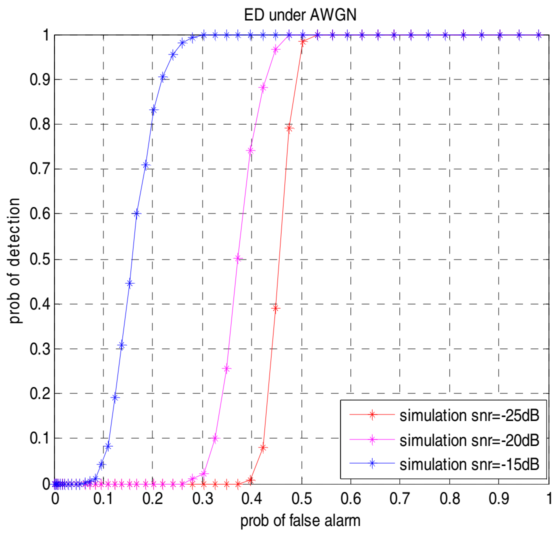

Fig.4 ROC for BPSK at different SNR

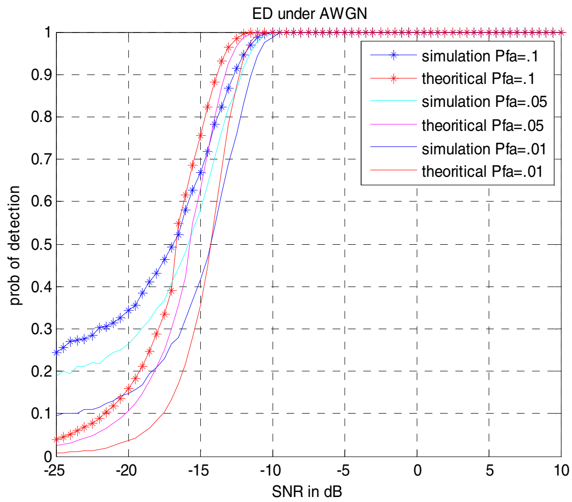

Fig.5 ROC for WLAN, P_{fa}=0.1, P_{fa}=0.05, P_{fa} =0.01

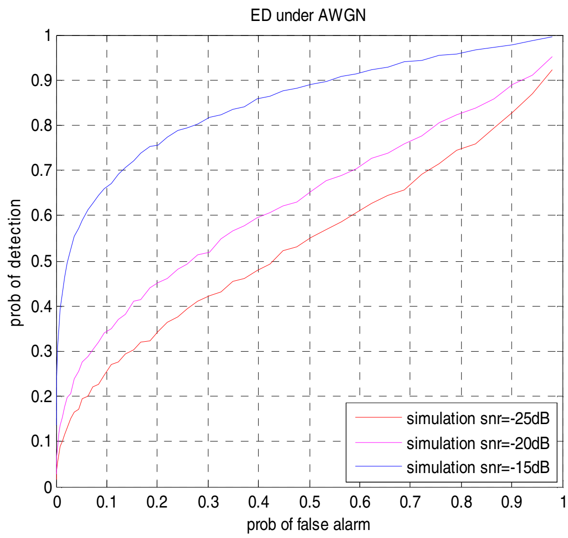

Fig.6 ROC for WLAN scenario at different SNR

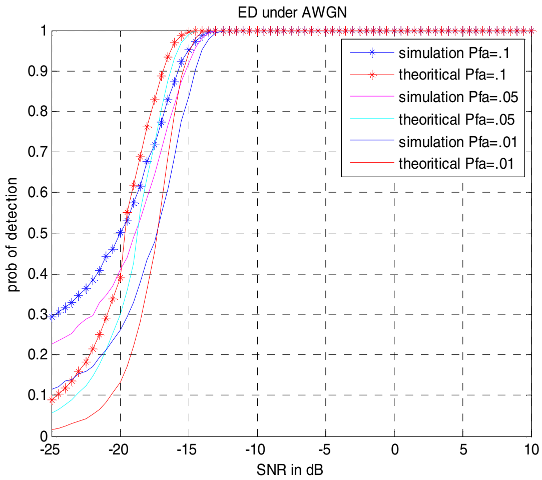

Fig.7 ROC for WIMAX, P_{fa} =0.1, P_{fa} =0.05, P_{fa}=0.01

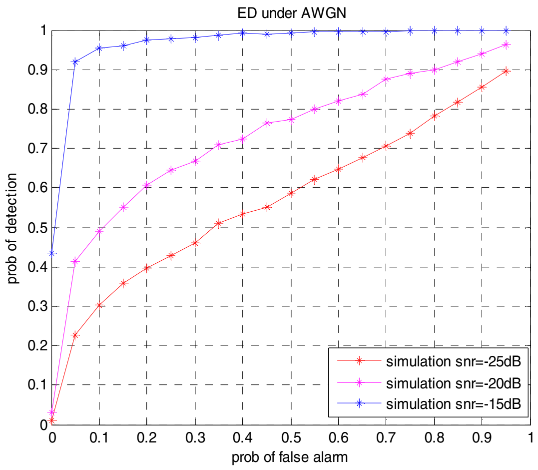

Fig.8 ROC for WIMAX scenario at different SNR

Table.2

SNR vs. probability of detection for different values of probability of false alarm for WLAN

SNR(dB)	P_{fa} =0.1, P_d	P_{fa} =0.05, P_d	P_{fa} =0.01, P_d
-25	0.260	0.187	0.096
-20	0.338	0.2583	0.149
-15	0.655	0.591	0.418
-10	0.998	0.996	0.991
-5	1	1	1
0	1	1	1
5	1	1	1
10	1	1	1

VI. CONCLUSION

In this paper simulation are performed using Monte-Carlo method for AWGN channel. The performance of BPSK as basic model is carried out. The simulation for OFDM in the field of WLAN and WIMAX are done. ED method is simulated to show the ROC curve and probability detection performance with change in SNR. The tabulation for WLAN and WIMAX for SNR vs. probability of detection for different values of probability of false alarm for WLAN and WIMAX are given. The future work is carried out using other channels and FPGA implementation of energy detection technique.

Table.3

SNR vs. probability of detection for different values of probability of false alarm for WIMAX

SNR(dB)	P_{fa} =0.1, P_d	P_{fa} =0.05, P_d	P_{fa} =0.01, P_d
-25	0.294	0.225	0.116
-20	0.501	0.410	0.260
-15	0.950	0.91910	0.837
-10	1	1	1
-5	1	1	1
0	1	1	1
5	1	1	1
10	1	1	1

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