

Simulation and Analysis of the OFDM Transceiver Based Commutation System

Areej Munadel

Resercher

Control and Systems Eng. Department,
University of Technology, Iraq

Areejmunadel5@gmail.com

Dr. Ekhlas Kadhum

Assist .Prof

Control and Systems Eng. Department
University of Technology, Iraq

drekhaskadhum@gmail.com

ABSTRACT

As a result of the increase in wireless applications, this led to a spectrum problem, which was often a significant restriction. However, a wide bandwidth (more than two-thirds of the available) remains wasted due to inappropriate usage. As a consequence, the quality of the service of the system was impacted. This problem was resolved by using cognitive radio that provides opportunistic sharing or utilization of the spectrum. This paper analyzes the performance of the cognitive radio spectrum sensing algorithm for the energy detector, which implemented by using a MATLAB Mfile version (2018b). The signal to noise ratio SNR vs. Pd probability of detection for OFDM and SNR vs. BER with CP cyclic prefix with energy detector is calculated and analyzed. In this paper, the proposed work produces more accurate results compared to the existing techniques at low SNR values.

Keyword : OFDM, CR, ED, Spectrum Sensing, CP.

محاكاة وتحليل نظام الاتصالات على جهاز الإرسال والاستقبال لمضاعفة قسم التردد المتعامد

اريج مناضل

باحثة

جامعة تكنولوجيا - قسم هندسة سيطرة ونظم

د. اخلاص كاظم حمزة

استاذ مساعد

جامعة تكنولوجيا - قسم هندسة سيطرة ونظم

الخلاصة

نتيجة للزيادة في التطبيقات اللاسلكية ، أدى هذا إلى مشكلة في الطيف ، والتي كانت في كثير من الأحيان تقييداً كبيراً. ومع ذلك ، يبقى عرض النطاق الترددي الواسع (أكثر من ثلثي المتاحة) ضائعاً بسبب الاستخدام غير المناسب. ونتيجة لذلك ، تأثرت جودة خدمة النظام. تم حل هذه المشكلة باستخدام الراديو المعرفي الذي يوفر المشاركة الانتهازية أو الاستفادة من الطيف. تحلل هذه الورقة أداء خوارزمية استشعار الطيف الراديوي المعرفي لكشف الطاقة ، والتي يتم تنفيذها باستخدام نسخة (2018b) MATLAB Mfile. يتم حساب وتحليل نسبة الإشارة إلى الضوضاء SNR مقابل Pd احتمال الكشف عن OFDM و SNR مقابل BER مع بادئة CP الدورية مع كاشف الطاقة. في هذه الورقة ، ينتج عن العمل المقترح نتائج أكثر دقة مقارنة بالتقنيات الموجودة عند قيم SNR منخفضة.

*Corresponding author

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الكلمات الرئيسية : OFDM ، CR ، ED ، استشعار الطيف ، CP.

1. INTRODUCTION

With the growing number of wireless technologies, the frequent congestion of the radio spectrum is rising (**Mahmoud, Yucek, and Arslan, 2009**). The policy in allocating the spectrum is to assign the channel to the user who has the license for using the wireless technologies and service. In the allocated radio channels, only few users use the channels effectively for their communication. However, most of the corporations use the channels sparsely. Thus, this results in most parts of the spectrum being unused in the licensed bandwidth. For effective resource management, the licensed band can be used by the person who needs it most without affecting the licensed user's access. The user who gets the license for accessing the spectrum is called the primary user. The user who uses the licensed spectrum without getting license and without affecting the primary user's access referred to as the secondary user. The spectrum scarcity can be managed by the technique of cognitive radio networks (**Pethunachiyar and B. Sankaragomathi, 2020**). Cognitive radio is an intelligent reconfigurable radio that uses a licensed spectrum in an opportunistic fashion (**Simon and Haykin, 2005**). Reliable and automatic detection of an unused licensed spectrum is one of the key functions of cognitive radios (**Amir and Elvino, 2008**). The cognitive radio requires many components to complete its function. These include spectrum sensing, spectrum management, spectrum sharing and spectrum mobility (**Hamza, Mahdy, and Thabit, 2019**).

An important task of a CR is to detect the spectrum holes. Secondary users (SU) use spectrum sensing technologies to identify and allow opportunistic use of unused spectrum of primary users (PUs), thus, increasing the efficiency of spectrum use (**Chin, Kao, and Le, 2014**). The number of sensing algorithms analyzed in the literature. Energy detection is the most employed technique because of its simplicity in implementation (**Daniela, Martínez and Gabriel, 2012**). OFDM is a common technology for transmission in cognitive radio networks. It easily avoids inter-symbol interference in the signal using the Cyclic Prefix (CP) (**Chin, Kao, and Le, 2014**). The CP in OFDM signals the efficiency of SU spectrum sensing, which can be improved. The Additive White Gaussian Noise (AWGN) is applied to the given signal to detect the high quality signal of the spectrum. A brief overview of a few recent OFDM technology studies was mentioned in **Table 1**.



Table 1. Overview of a few recent OFDM technology studies.

Authors	Year	Research Concepts
G. A. Pethunachiyar, B. Sankaragomathi. [2]	2020	The OFDM base band signal is generated as a first process in this paper, with the Quadrature Phase Shift Keying Modulated Input. Subsequently, the energy spectrum sensing is integrated to detect the user in an effective manner.
Chin, W.-L., Kao, C.-W., & Le, T. N. [6]	2014	In this paper the optimal spectrum sensing detector Neyman-Pearson (NP) using CP. The registry probability ratio (LR) test is developed using the correlation properties for CP repeat to detect the OFDM signal for primary users (PUs). With its practical applications, GLRT and CI-GLRT, the proposed optimal NP detector was presented over multi-channel channels and compared to CP-based detectors.
Kumar, A. and N. Pandi. [14]	2016	In this paper, the emphasis is on incorporating Cognitive Radio (using energy detection) with various OFDM frameworks to more effectively evaluate spectrum usage. Use a MATLAB, the present work is extensively analysed and applied. Probability of detection (Pd) vs. Probability of false alarm (Pfa), Pd vs. Signal to Noise Ratio (SNR) and Bit Error Rate (BER) vs. SNR for every OFDM framework with strength detector is calculated and analyzed.

In this paper, the proposed system is implemented with OFDM based CR using energy detection of spectrum sensing. The performance of the system is evaluation by analyzing the Probability of Detection and SNR for various probability of False Alarm. The remaining sections of the paper will be structure as follows: Section II proposes an Energy Detection and OFDM system model; and Section III, the OFDM-based spectrum sensing. Results and discussions are present in Section IV. Finally, the conclusion is stated in Section VI.



2. SYSTEM MODEL

The system model defines the energy detection and OFDM system model, the system design and its method presented in the OFDM-based Spectrum Sensing algorithm

2.1 Energy Detection:

Due to their low mathematical and execution complexities, the most common form of spectrum sensing is the energy detector. In reality, the cognitive user's receivers need no knowledge of the primary user's signal. The signal detected by comparing the energy detector output with the noise-dependent threshold. The energy detection dependent sensing method is modeled as the hypothesis test (**Garima and Rajesh , 2013**) where the presence of the primary user is denoted by H1 and the absence of the primary user's signal is denoted H0 (**Arjoun, Mrabet, Ghazi, & Tamtaoui, 2018**). This calculated using the following hypothesis model as defined in equations 1 and 2.

$$H_0: X(t) = n(t) \quad (\text{Primary User not exist}) \quad (1)$$

$$H_1: X(t) = s(t) + n(t) \quad (\text{Primary User exists}) \quad (2)$$

Where X(t) denotes the received signal, s(t) the signal transmitted by the primary user and n(t) is the Additive White Gaussian noise that affects the transmitted signal (**Arjoun, Mrabet, Ghazi, & Tamtaoui, 2018**).

Energy detection calculates the n sample energy obtained from the average samples over N samples as that of the square amplitude of the Fast Fourier Transformation (FFT) (**N. Giweli, S. Shahrestani, and H. Cheung, 2016**), by using the corresponding equation:

$$\text{Energy (ED)} = \sum_{n=1}^N (Y[n])^2 \quad (3)$$

The energy level compared to the threshold values in order to achieve the decision on sensing the following:

ED < λ: PU signal absent

ED > λ: PU signal present

Through probability of detection P_D and probability of false alarm P_{FA} , the probability of detection evaluated by two possibilities, namely the probability of detection and the possibility of false alarm. Probability of false alarm (pf) indicates the number of times the PU is wrong. The probability of detection indicates the number of valid discoveries (PU exists) over the total number of sensing trials, while the probability of detection (P_D) and probability of false alarm (P_{FA}) can be calculated by using the following equations 4 and 5:

$$P_D = Pr(ED > \lambda; H_1) \quad (4)$$

$$P_{FA} = Pr(ED > \lambda; H_0) \quad (5)$$

There is a threshold (λ) when the ED corresponds to the energy of N samples given by equation 3.



2.2 Orthogonal Frequency Division Multiplexing (OFDM):

Multiplexing of the (OFDM) as a multi-carrier modulation technique has inherent advantages for implementation of cognitive radio (CR) (Mahmoud, Yucek, and Arslan, 2009). The data bearing symbol stream is split into many lower-rate sources, which are transmitted on various carriers. A cyclic prefix (CP) is added to extend the OFDM symbol that is used to prevent the remaining inter-symbol conflict (ISI) (Mahmoud, Yucek, and Arslan, 2009). The OFDM device uses any of the 16-Quadrature Amplitude Modulation techniques, 64-Quadrature Amplitude Modulation, Phase Shift Keying and Quadrature Phase Shift Keys to modulate the integer inputs. In this work, the QPSK used for modulating the randomly generated integer input. The QPSK modulated data with the OFDM modulation.

2.3 OFDM-Based Spectrum Sensing

The manner of OFDM and Energy detection spectrum sensing algorithm is described in Fig. 1.

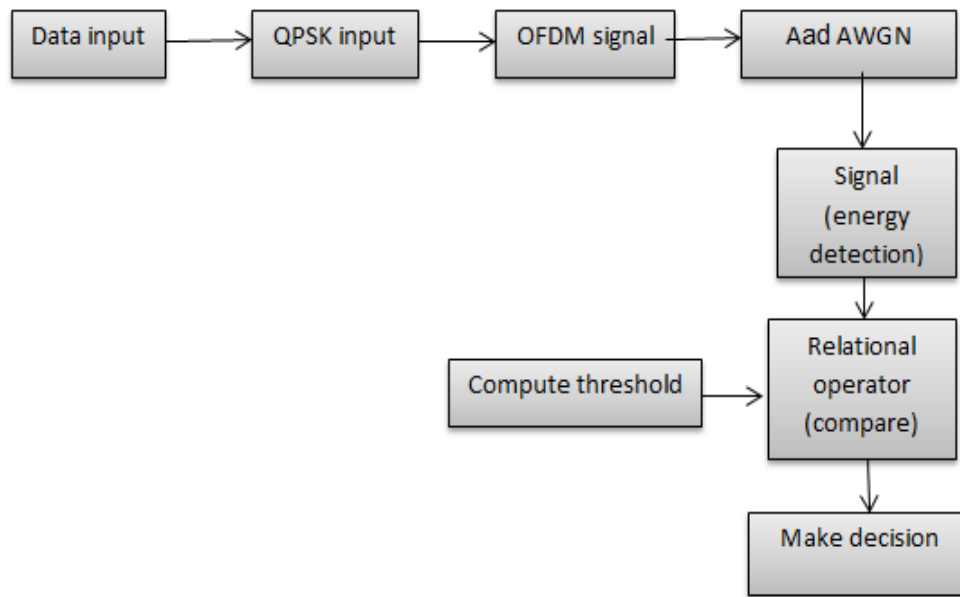


Figure 1. Proposed system configuration.

The data input generated randomly and the symbols of each block are mapped on to the sub-carriers. For the given input, QPSK modulated signal is produced. The OFDM applied to the modulated data for getting the OFDM signal. The Energy detection method applied for the signal and the AWGN applied to the signal transmitted and forwarded to the receiver. The Receiver determines the probability of detection using the equations 4 and 5.



3. RESULTS AND DISCUSSIONS

Many parameters affect the performance of energy detection CR. The parameters that are related to energy detection in spectrum sensing are sometimes called Receiver Operating Characteristics (ROC). The following is a brief definition of the main parameters that affect the energy detection performance in CR:

- a. **Probability of Detection (Pd):** The probability of deciding the PU signal is present when H1 is real (12) i.e., $P_d = P(ED > \lambda | H_1)$. H1 is used to avoid primary user interference by the secondary user. Thus, it should be high in cognitive radio Pd for spectrum sensing.
- b. **Probability of False Alarm (Pf):** For spectrum sensing, the detector senses the primary signal H1 rather than alternating signal H0. When a detector makes a wrong choice, it should be kept small. Secondary users cannot use the free channel in this situation because the detector skipped the opportunity to check the free channel. Therefore, Pf should be kept low enough to prevent incorrect decision taken by the detector (Ranjan, Anurag, and B. Singh., 2016).
- c. **Bit Error Rate (BER):** This can be described as the error proportion in the signal obtained to the total signal transmitted (Kumar, Arun, Pandi, and Nandhakumar, 2016). It may be seen, mathematically, as:

$$BER = \frac{\text{Error in received signal}}{\text{Total transmitted signal}} \tag{6}$$

As shown in Table 2. Shows the variables.

Table 2. The variables are used in the analysis are specified in

Variables	Data
Channel	AWGN Channel
Cyclic Prefix Length	32
OFDM Frame Size	234
Number of OFDM Sub-carriers	128
Number of Data Sub-Carriers	None
OFDM Output Signals	234
Energy	Energy of the Signal
Threshold	13.5 db

The BER vs. SNR comparison for OFDM is shown in Fig. 2 with the cyclic prefix. The BER decreases with increase in SNR.

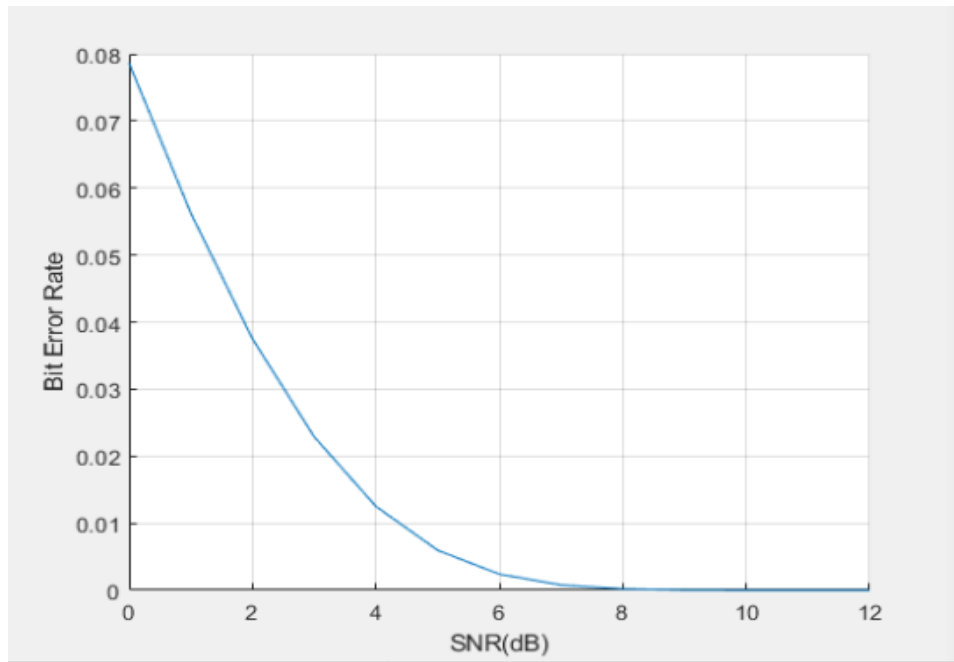


Figure 2. SNR vs. BER for OFDM with CP.

The detection probability is of major impact because it offers the likelihood of correct sensing of the presence of primary users within the frequency band. The goal of the sensing schemes is to maximize the detection probability for a low probability of false alarm. Receiver Operating Characteristics Curve (ROC) are used in this paper to plotted for the extraordinary fake alarm value chances to determine the model tool performance. The ROC curves represent the export-off between detection probabilities and signal-to-noise ratio at set false alarm levels. In **Fig. 3** the performance of the system model is analyzed while it passes via the AWGN channel. This Figure displays the simulation outcomes of the energy detection system. This is indicated by P_d vs. SNR, sample number=117, and the P_f can be set to a constant value ($P_f = 0.05, 0.1$ and 0.2 in order to select the threshold value and then get the desired P_d . According to the curve in **Fig. 3**, the increase in SNR values leads to the increase in probability of detection. **Table 3.** Show the results of **Fig. 3** for different pf.

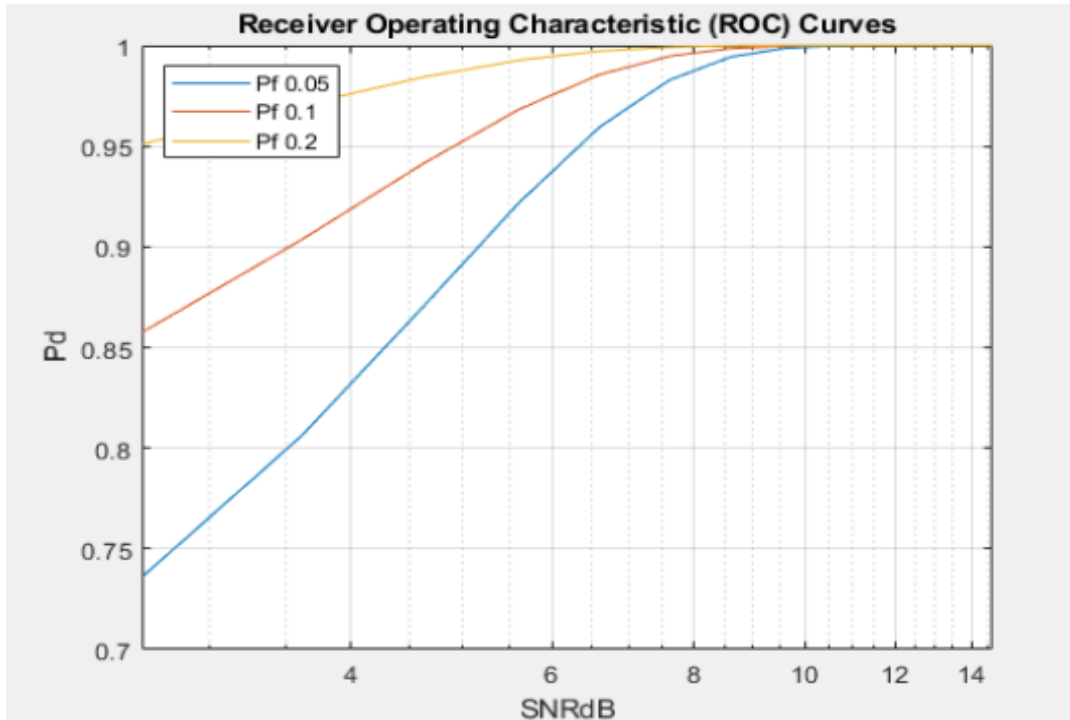


Figure 3. SNR vs. Pd For different Pf values

Table3. The results of Fig. 3

SNR	PD	PF
8.9 db	100%	0.05
8 db	100%	0.1
6.8 db	100%	0.2

In the **Fig. 4** use the same variables used in simulation but Pf=0.06, according this figure the SNR will decrease when probability detection decrease. Table.4 Show the results for **Fig. 4**.

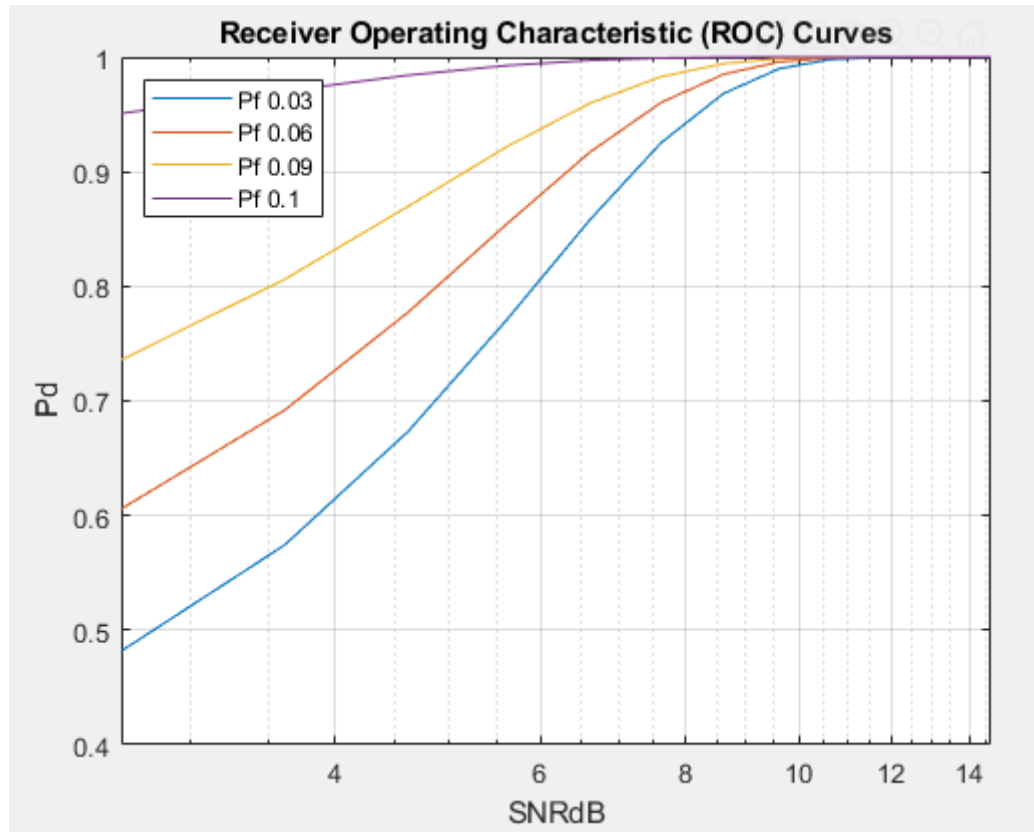


Figure 4. SNR vs. Pd for different Pf values

Table 4. The results of Fig 4.

SNR	PD	PF
10 db	100%	0.06
6.4 db	90%	0.06

4. CONCLUSION

This paper presents and successfully analyzes the performance of the energy detector based spectrum sensing mathematical model to detect the primary signal of the OFDM. The mathematical model increase the probability of detection with SNR increase. The proposed approach was implemented using M-fill MATLAB.



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