Indian Journal of Science and Technology, *Vol 9(16), DOI: 10.17485/ijst/2016/v9i16/90230, April 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Analysis of OFDM System with Energy Detection Spectrum Sensing

P. Nandhakumar* and Arunkumar

Department of ECE, JECRC University, Jaipur - 303905, Rajasthan, India
nandhakumar.1402062004@jecrcu.edu.in, arun.kumar@jecrcu.edu.in

Abstract

In cellular communication, spectrum is always a major constraint, but still a large bandwidth (more than two third of the available) is wasted due to the improper utilization, affecting the QoS (Quality of Services) of the system. The spectrum can be used in a better manner, if ideal bandwidth is available without any interference. This work is focused on integration of Cognitive Radio (using energy detection) with different OFDM frameworks to analyze the utilization of spectrum more efficiently. The present work is thoroughly analyzed and implemented by using a MATLAB. 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 each OFDM framework with energy detector is calculated and analyzed. Different OFDM framework with energy detection can be one of the most promising technologies for next generation cellular communication with better spectrum utilization, enhanced data rate, reduced interference and better QoS.

Keywords: Cognitive Radio, CP, Energy Detection, OFDM, Spectrum Sensing

1. Introduction

The Consistent growth of wireless appliances (Wi-Fi) gives the clustered ISM (Industry, Scientific and Medical) bands. People are not able to utilize the spectrum properly due to the growth in ISM bands which leads to a demand for an additional spectrum for good QoS. Multiple-carrier transmission is one of the most advanced techniques used in many recent applications; the concept behind this technique is to divide one carrier into number of multiple-subcarriers. The available bandwidth is subdivided into small limited bandwidth, each subcarrier having a smaller bandwidth compared to the Single carrier system. Each Symbol is modulated with each carrier and transmitted through antenna to the channel and received signal is demodulated by the demodulators. Implementing bank of Modulators and Demodulators is challenging and practically it is not possible. IFFT (Infinite Fast Fourier Transform) and FFT (Fast Fourier Transform) can be used to reduce the complexity and to simplify the system as compared to traditional N-Modulator and N-Demodulator approach. This is the fast operation, implemented on a DSP chip, in a modern communication system[1-3]. In single carrier system, the spectrum bandwidth allocation is much as compared to the multicarrier system. By using multicarrier system like OFDM (Orthogonal Frequency Division Multiplexing) and FBMC (Filter Bank Multicarrier), the same bandwidth is distributed among more subcarriers compared to conventional multiple-carrier system, which leads to an effective data rate and the less consumption of band width. In conventional cellular communication environment, there is no particular scanning scheme for identifying ideal users, so there is no special initiation for getting information of available bandwidth. Cognitive radio technology will provide a solution to the above problem and it will automatically scan the ideal users and make their unused bandwidth available for other users.

** Author for correspondence*

If primary user is idle then bandwidth of primary user is allocated to secondary user without any interference. CR is considered as prominent techniques as it uses the radio-spectrum effectively by sharing the radio resources with licensed networks[4,5]. TV broadband frequency is not used properly. In November 2008, FCC (Federal Communications Commission) issued ruling, to allow a secondary user (Unlicensed user) to work in TV broadcast frequency band (White space) without creating interference to primary user (Licensed user) which leads to the arrival of Cognitive Radio[6]. Cognitive Radio (CR) is one of the most advanced technologies to equalize the spectrum issue of wireless environment. It attains higher spectrum ability using dynamic spectrum access. It permits unlicensed user (Secondary user) to use the available bandwidth from licensed user (Primary user) while pertaining no involvement to initial user transmissions. Cognitive radio gives efficient result to the spectral congestion by giving opportunistic application of the frequency bands that are not highly used by licensed users[7,8]. It uses dynamic spectrum access for channel sensing by unlicensed users to identify the primary users in a channel for accessing the white space spectrum without any interference[9]. In Spectrum sharing; it gives the good spectrum scheduling technique by the coexisting users[10]. The uniqueness of Cognitive Radio (CR) lies in it's capability and re-configurability. CR networks are wireless in nature, so it faces security attacks compared with traditional wireless and wired network. The general security objectives for all wireless systems are privacy, Integrity, Availability and access control[11]. The main goal of this technology is to increase the throughput and minimize the obstruction to primary user. CR is capable to measure sense, discover and beware of radio channel individuality, accessibility of spectrum and radio's operational setting. There are three important sensing schemes in CR, and they are.

- Energy Detection
- Cyclo-Stationary Detection
- Matched Filter Detection

In the present work, Energy Detection (radiometric detection) is considered with OFDM system. One of the major problems associated with Energy Detection is that it provides a good performance only under higher SNR conditions. If the SNR is low, then the performance will be poor[12]. Another Challenging task in Cognitive Radio (CR) is channel quality prediction. Other users are allowed to access the primary channel without any interference. However, the channel quality may differ significantly and the good quality channels drastically decrease the efficiency of spectrum and so the major drawback arises, like how to predict the channel quality to enhance the dynamic spectrum efficiency[13]. OFDM system utilizes the Cyclic Prefix (CP) between the symbols to reduce the Inter Symbol Interference (ISI) which is considered as one of the biggest problem in wireless communication system but use of CP also results in wastage of bandwidth. All over the world, researchers are trying to compensate the wastage of spectrum occurring in OFDM system. Energy detection is one of the spectrum sensing techniques of cognitive radio which is considered as one of the future technologies to overcome the loss of spectral efficiency in OFDM system and also utilizes the unused spectrum allotted to the subscribers. Hence, the research on integration of cognitive radio with OFDM system is highly in demand. In this work an OFDM system-with CP and without CP, with filter at transmitter and with filter at transmitter and receiver both sides, is integrated with Energy detection and analyzed by determining the efficiency and throughput of the system. Double Threshold Feature Detector technique is proposed in[14] to detect the primary user at low SNR and to develop Cognitive Radio Network (CRN) on an AWGN channel. The performance of the system is increased because of using the double threshold for detection. A low temperature handshake between the unlicensed user and sensing devices in the cognitive radio is proposed in[15]. Author designed a prototype that changes the very high priced sensing device in secondary user and places the sensing device in primary user, so that the sensing device in primary side detect and assign control for unlicensed users without an individual channel control. It is a cost effective technology making it economically viable for practical uses. An OFDM based cognitive radio is proposed in[16], using a low complexity scheme to decline out-of-band power and Peak to Average Power Ratio so that the transmission performance is improved. A model and network architecture of cognitive emergency communication system is proposed in[17] to increase the social service efficiency of emergency communication in space and ground, which improves the network performance and spectrum utilization. An iterative synchronization Assisted detection of OFDM signal in CRN is proposed in[18] to detect a OFDM signal and synchronized based on cyclic prefix using a iterative synchronization scheme for reducing the Synchronization error, which gives a better detection performance. FRESH or Frequency shift filters is proposed in[19] to detect a Cyclo-stationary based hypothesis test on the filter output to enable spectrum sensing in CR. This gives better detection probability in low SNR condition.

2. Proposed Methodology

The present work is implemented by using a MATLAB 2013b. The parameters considered in present work are briefly described below:

2.1 OFDM Model

The information symbols are expressed as

a(n) = a(0) a(1) a(2) … … … a(N-1) $\quad 0 \le n \le N-1$

The serial form of symbols are converted into parallel and IFFT is applied to each symbols is given as

A(n) = A(0) A(1) A(2) … … … A(N-1) $\quad 0 \le n \le N-1$

Therefore the composite OFDM modulated signal is given by following mathematical expression.

$$Z(t) = \sum_{K=0}^{N-1} A(t) k e^{j2\pi k \triangle ft} \qquad 0 \le t \le T_q \tag{1}$$

Where Z(t) = Composite OFDM modulated signal.

A(t = IFFT of information signal.

Δf = Spacing between carriers.

T_q = Symbol time.

The signal is orthogonal if it satisfies the condition T_q Δf = 1. Cyclic Prefix is added between the symbols to avoid the Inter Symbol Interference. Therefore OFDM modulated signal with CP can be written as

$$Z_{cp}(t) = \sum_{K=0}^{N-1} A(t) k e^{j2\pi k \triangle ft} + cp \tag{2}$$

Where $Z_{cp}(t)$ = Transmitted OFDM signal.

The received signal is written as

$$Y(t) = H(t)\, Z_{cp}(t) + N(t) \tag{3}$$

Where Z(t) = Received signal across t^{th} subcarrier.

H(t) = Channel co-efficient of t^{th} subcarrier.

N(t) = Noise across t^{th} subcarrier.

The impulse response of the channel is given as

$$h(t) = \sum_{i=0}^{L-1} C_i \delta(t - \tau_i) \tag{4}$$

Where C_i = Attenuation factor

τ_i = Delay

L = No. of Path.

2.2 Energy Detection

Energy detection is a popular method in CR for spectrum sensing and it identifies the presence of spectrum hole and optimizes the detection probability. It compares the received signal energy with threshold value (λ) following the SNR to get two hypotheses - whether the signal is absent or present.

R(t) = {n(t)} $\qquad H_0$

R(t) = {h * u(t) + n(t)} $\qquad H_1$

Where R(t) = Secondary User

U(t) = Primary User's transmitted signal

n(t) = Additive White Gaussian Noise

h = Amplitude gain of the channel

H_0= No Primary user

H_1= Primary user is present.

2.3 Probability of False Alarm (Pfa)

This is one phenomenon that occurs during the spectrum sensing detection where noise is misrepresent as a signal at the receiver due to which the received signal exceeds the threshold value.

Mathematically it can be seen as:

$$Pfa = P[X_n(t) \ge \theta] \tag{5}$$

Where θ is threshold and $X_n(t)$ is received signal with noise (where noise is greater than signal).

2.4 Bit Error Rate (BER)

It may be defined as the ratio of error in received signal to the total transmitted signal.

Mathematically it can be seen as:

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

3. Results and Discussion

The results are thoroughly analyzed by using a mathematical model of cognitive OFDM system and implementing a code in MATLAB:

3.1 BER vs. SNR for OFDM with and without CP

The analysis of BER vs. SNR for OFDM, with and without cyclic prefix is shown in Figure 1. In both case the BER decreases with increase of SNR. For 0 to 3 dB, BER for OFDM CP and OFDM without CP is approximately equal whereas with the increase of SNR, BER performance of OFDM with CP is much better than OFDM without CP. Analytical results prove that the former system is much efficient and reliable with less ISI and BER as compared to latter one.

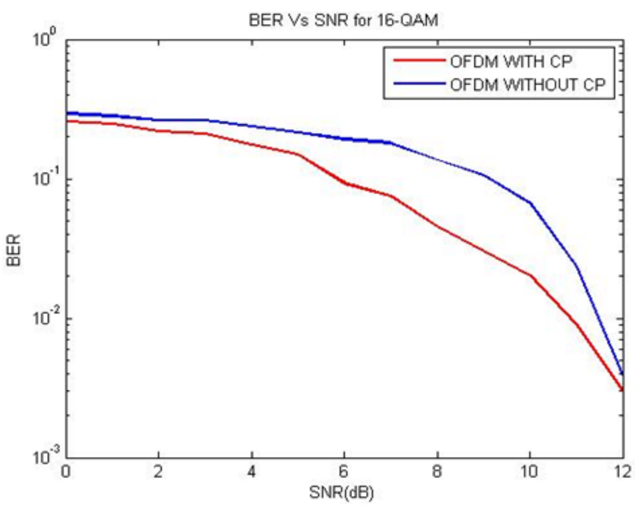

Figure 1. SNR vs. BER for OFDM with and without CP.

3.2 BER vs. SNR for OFDM with Filter at Transmitter and Receiver

The analysis of BER vs. SNR for OFDM with filter at transmitter and receiver is shown in Figure 2. In OFDM with filter at transmitter the BER decreases with increase of SNR. But OFDM with filter at both transmitter and receiver side gives a constant BER for all SNR. So it proves OFDM with filter at transmitter is better as compared to OFDM with filter at both transmitter and receiver.

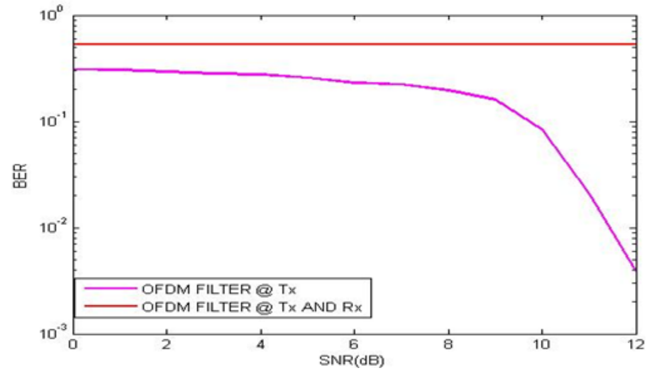

Figure 2. BER vs SNR for OFDM with filter at Transmitter and Receiver.

3.3 Pd vs. SNR for OFDM with and without CP

The analysis of Pd vs. SNR for OFDM with and without cyclic prefix is shown in Figure 3. In both case the Probability of detection (Pd) increases with the increase of SNR. As shown below the detection in OFDM with CP is possible for smaller SNR whereas detection for OFDM without CP needs a high SNR.

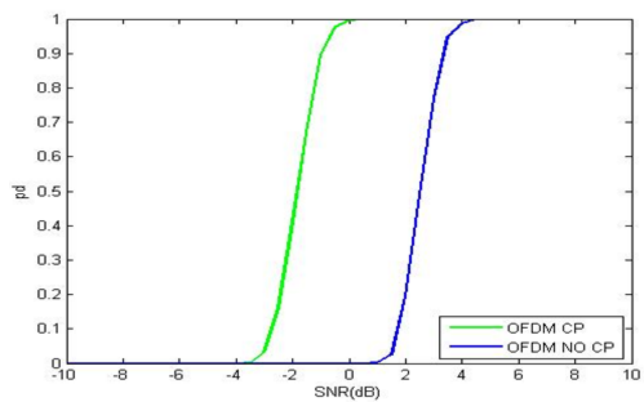

Figure 3. Pd vs SNR for OFDM with and without CP.

3.4 Pd vs. SNR for OFDM with Filter at Transmitter and Receiver

The analysis of Pd vs. SNR for OFDM with filter at transmitter and receiver is shown in Figure 4. In both cases the Probability of detection (Pd) increases with the increase of SNR. As shown below the detection in OFDM with filter at transmitter is possible for smaller SNR whereas detection for OFDM with filter at both transmitter and receiver needs a high SNR.

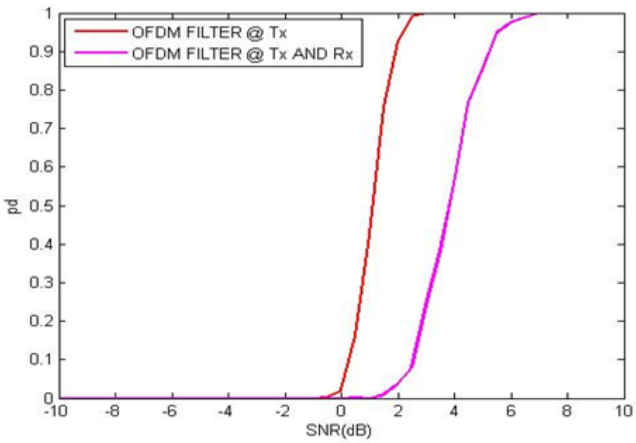

Figure 4. Pd vs SNR for OFDM with filter at Transmitter and Receiver.

3.5 Energy Detection for OFDM with and without CP

The analysis of Pd vs. Pfa for OFDM with and without cyclic prefix is shown in Figure 5. In both cases the Probability of detection (Pd) increases with the increase of Pfa. For OFDM with CP, the probability of missed detection is more even for lesser Pfa whereas for OFDM without CP, the Pfa requirement is more for missed detection which means the effect of Pfa in latter system is less as compared to former one.

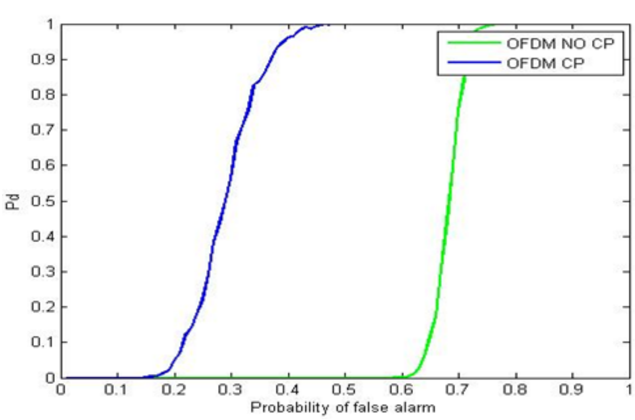

Figure 5. Pd vs Pfa for OFDM with and without CP.

3.6 Energy Detection for OFDM with Filter at Transmitter and Receiver

The analysis of Pd vs. Pfa for OFDM with filter at transmitter and receiver both is shown in Figure 6. In both cases the Probability of detection (Pd) increases with the increase of Pfa. For OFDM with filter at both transmitter and receiver, the probability of missed detection is more even for lesser Pfa whereas for OFDM with filter at transmitter, the Pfa requirement is more for missed detection which means the effect of Pfa in latter system is less as compared to former one.

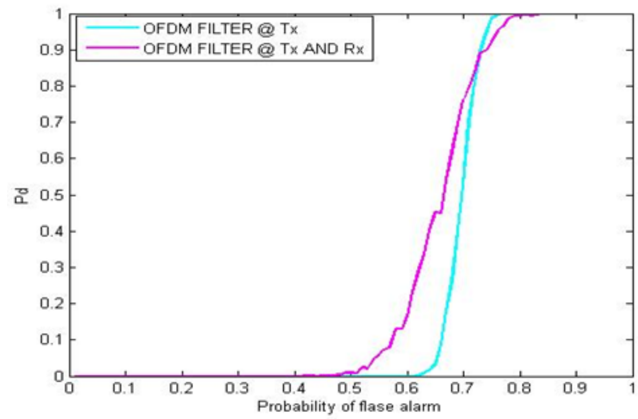

Figure 6. Pd vs Pfa for OFDM with filter at Transmitter and Receiver.

4. Conclusion

OFDM System with and without cyclic prefix, with filter at transmitter and with filter at transmitter and receiver, both sides-integrated with Energy detection, is implemented and analyzed. The BER vs. SNR and Pd vs. SNR results reveal that the performance and efficiency of OFDM with CP is better than that of OFDM without CP, OFDM with filter at transmitter and OFDM with filter at transmitter and receiver both. But results of Pd vs. Pfa reveal that performance of OFDM without CP is better as compared to other techniques implemented above. However, researchers throughout the world exploring on OFDM without CP, so to utilize the loss of spectral efficiency occurs in OFDM with CP.

5. References

1. Kumar A, Gupta M. A review on OFDM and PAPR reduction techniques. American Journal of Engineering and Applied Sciences. 2015; 8(2):202-9.
2. Kumar A, Gupta M. Design, comparative study and analysis of CDMA for different modulation techniques. Egyptian Informatic Journal. 2015; 16(5). doi:10.1016/j.eij.2015.07.004

3. Eghbali SM, Beiranvand I. PTS OFDM scheme based on ICA algorithm for PAPR reduction in satellite communication. Indian Journal of Science and Technology. 2015 Jun; 8(12).
4. Haider F, Ge X. Spectrum and energy efficiency analysis for cognitive radio networks. IEEE Transaction on Wireless Communications. 2015; 14(6):2969-80.
5. Padmavathi G, Shanmugavel S. Performance analysis of cooperative spectrum sensing technique for low SNR regime over fading channels for cognitive radio networks. Indian Journal of Science and Technology. 2015 Jul; 8(16).
6. Sun L, Zheng W, Rawat N, Sawant V, Koutsonikolas D. Performance comparison of routing protocols for cognitive radio networks. IEEE Transaction on Mobile Computing. 2015; 14(6):1272-86.
7. Muthumeenakshi K, Radha S. Optimal techniques for sensing error minimization with improved energy detection in cognitive radios. International Journal On Smart Sensing And Intelligent Systems. 2014; 7(4):2014-34.
8. Avila KT. Upgraded spectrum sensing method in cognitive radio network. Indian Journal of Science and Technology. 2015 Jul; 8(16).
9. Akin S, Gursoy C. Performance analysis of cognitive radio systems with imperfect channel sensing and estimation. IEEE Transaction on Communications. 2015; 63(5):1554-66.
10. Akyildiz IF, Lee WY, Vuran MC, Mohanty S. Next generation/dynamic spectrum access/cognitive radio wireless network: A survey. Computer Networks. 2006; 50(13):2127-59.
11. Fragkiadakis AG, Tragos EZ, Askoxylakis IG. A survey on security threats and detection techniques in cognitive radio networks. IEEE Communication Surveys and Tutorials. 2013; 15(1):428-45.
12. Benitez M, Casadevail F. Signal uncertainty in spectrum sensing for cognitive radio. IEEE Transactions on Communications. 2013; 61(4):1231-41.
13. Xing X, Jing T, Huo Y, Li H, Cheng X. Channel quality prediction based on Bayesian inference in cognitive radio networks. IEEE INFOCO; 2013. p. 1465-73.
14. Khan I, Singh P. Double threshold feature detector for cooperative spectrum sensing in cognitive radio networks. IEEE INDICON; 2014. p. 1-5.
15. Han Z, Fan R, Jiang H. Replacement of spectrum sensing in cognitive radio. IEEE Transactions on Wireless Communications. 2009; 8(6):2819-26.
16. Dang LY, Marks RJ. Reduction of out-of-band power and peak to average power ratio in OFDM based cognitive radio using alternating projection. IEEE Texas Symposium on Wireless and Microwave Circuits and Systems (WMCS); 2013. p. 1-4.
17. Wang H. Construction radio based emergency communication system and application scenario analysis. International Journal of Smart Home. 2013; 7(3).
18. Chin WL, Kao CW, Chen HH, Liao TL. Iterative synchronization assisted detection of OFDM signals in cognitive radio systems. IEEE Transactions on Vehicular Technology. 2014; 63(4):1633-44.
19. Saggar H, Mehra DK. Cyclo-stationary spectrum sensing in cognitive radios using FRESH Filters. Indian Institute of Technology. 2013.