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Spectrum Monitoring for OFDM Based Cognitive Radio Network

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ABSTRACT: Cognitive radios offer the promise of being a disruptive technologies innovation that would enable the future wireless world. Cognitive radios network is programmable wireless devices that could sense their environment and dynamically adapted their transmission waveform, channel access methods, spectrum used, and networking protocol as needed for better network and application performance. We anticipated that cognitive radio technologies will soon emerge from early stage laboratory trials and vertical application to become a general-purpose programmable radio that will serve as a global platform for wireless system development, much like microprocessor had served a similar role for computation. There is however a gap between having a flexible cognitive radio network, effectively a building block, and the large-scale deployment of cognitive radio networks that dynamically optimize spectrum used. Building and deploying a networks of cognitive radio network is a complex task. There is a growing concern that conventional research in this area had reach a point of diminishing returns and that further progress in the above areas will depended on a new approach involving global research teams working with real-world experimental deployments of cognitive radio.

KEYWORDS**:** cognitive radio network, orthogonal frequency division multiplexing (OFDM), multiple input multiple outputs (MIMO), energy ratio algorithm.

I.INTRODUCTION

Current telecommunication technologies will not support large traffic growth, since wireless bands below 10 GHz are already saturated. In this context, millimeter-wave (mm-wave) band is viewed as a solution with its 7 GHz unlicensed spectrum available for radio communication (57–64 GHz). Nowadays, we use static spectrum access method for wireless communication under this policy; fixed channels are assigned to licensed user or primary users (PUs) for exclusive use while unlicensed secondary users or secondary users (SUs) are prohibit from accessing PUs channels even when they are not occupied. The idea of a cognitive radio (CR) was proposed to achieve efficient utilization of the RF spectrum [1]. In cognitive networks uses the overlay network model [2] in which SUs seeks to use the spectrum when the PUs is idle. Primary and secondary users are not allow to operate simultaneously. In this method, secondary users must sense the spectrum to sense whether it is available or not prior to communication. If the primary user (PU) is idle, the SU can then use the spectrum, but it must be able to sense very weak signals from the primary user.If the SU must periodically stopcommunicating to detect the emergence of the PU, two important effects should be studied. (1) For quite periods [3], the secondary user (SU) receiver may lose its synchronization to the secondary user transmitter which causes an overall degradation in the secondary network performance. (2) The throughput of the secondary users network during sensing intervals is reduced to zero which degrading the Quality of Service (QoS) for those real-time applications like Voice over IP [4].

The spectrums are monitored by [5] the CRN receiver during reception and without any quiet periods. The idea behind this is to compare the bit error count that is produce by a strong channel code like a low density parity check (LDPC) code, for each receiving packet to a threshold value. If the number of sensed errors is above threshold value, the monitor algorithm indicates that the primary user's network user (PU) is active. The threshold is obtained by considering hypothesis test for the receiver when the primary signal (PS) is absent and the receiver statistics for the required secondary to primary power ratio (SPR). Although these techniques are simple and adds almost no complexity to the system model, the receiver statistic is subject to change by varying the system operating conditions.The error count will depended on the presence of a primary signal as well as depended on the characteristics of those impairments. Also, the receiver statistics may be changes from one receiver to the other based on the residual errors generate from estimating for different impairments. Since these are difficult to characterize the receiver statistics for all CRN receivers, it is better to find system model that is robust to synchronization errors and channel effects of the spectrum sensing.

In this paper propose a spectrum monitoring technique suitable for OFDM-based cognitive radio network as shown in Fig.1. Here, the transmitter used frequency domain based spectrum monitoring approach by introduce scheduled null-tones by which the spectrums can be monitor during CR reception. These monitoring techniques are designed to sense the reappearance of the primary user (PU) which uses OFDM technique. This technique operates over the OFDM signal chain and it does not require waiting for the decoded bits. This shows that fast response to primary user (PU) appearance. Next to this, the most important OFDM challenges [6] for cognitive radios network such as power leakage are investigated and their effects on the proposed monitoring technique are considered.

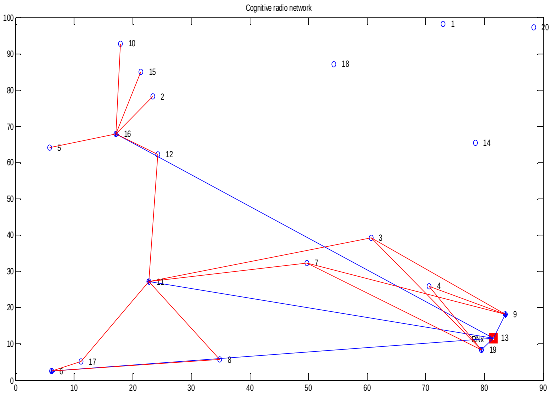

Fig. 1 Cognitive radio monitoring network

II. LITERATURE SURVEY

[1] A. Ghosh and W. Hamouda, “Cross-layer antenna selection and channel allocation for MIMO cognitive radios”, *IEEE Trans. Wireless Commun.*, vol. 10, no. 11, pp. 3666–3674, Nov. 2012.

In this paper A. Ghosh and Hamouda had proposed algorithm to address the spectrum efficiency and fairness issues of multi band multiuser Multiple- Input and Multiple-Output (MIMO) cognitive ad-hoc networks. To improve the transmission efficiency of the MIMO system, a cross layer antenna selection algorithm is proposed. Using the transmission efficiency results, user data rate of the cognitive ad-hoc network is determined. Objective function for the average data rate of the multi band multiuser cognitive MIMO ad-hoc network is also defined. For the average data rate objective function, primary users’ interference is considered as performance constraint**.**Disadvantage: In this paper they are not commenting on OFDM impairments. With this they have just explained Cognitive MIMO ad-hoc network.

[2] W. S. Jeon, D. G. Jeong, J. A. Han, G. Ko, and M. S. Song, “An efficient quiet period management scheme for cognitive radio systems”, *IEEETrans. Wireless Commun.*, vol. 7, no. 2, pp. 505–509, Feb. 2014.

In this paper author try to explain cognitive radio (CR) systems, the channel sensing scheme for detecting the presence of primary user directly affects the quality-of-service of CR users and primary user. They had proposed a sensing scheme that consists of a series of consecutive energy detections followed by feature detection, where the energy detection time is much shorter than the feature detection time. With the proposed scheme, multiple energy detections decrease the feature detection due to false alarm and the overall channel sensing time. The performance evaluation using Markov analysis shows that the proposed scheme can heighten the maximum channel utilization of CR users, while maintaining the detection delay of primary user under a predefined value**.**Disadvantage: Author explained new method for detection of primary user, with this scheme they are used markov analysis which makes cognitive network analysis more complex.

[3] D. Cabric, S. M. Mishra, and R. W. Brodersen, "Implementation issues in spectrum sensing for cognitive radios", in *Proc. Conf. Rec. 38th AsilomarConf. Signals, Syst. Comput.*, vol. 1, pp. 772–776, Nov. 2013.

There are new system implementation challenges involved in the design of cognitive radios, which have both the ability to sense the spectral environment and the flexibility to adapt transmission parameters to maximize system capacity while co-existing with legacy wireless networks. The critical design problem is the need to process multi-gigahertz wide bandwidth and reliably detect presence of primary users. This places severe requirements on sensitivity, linearity, and dynamic range of the circuitry in the RF front-end. To improve radio sensitivity of the sensing function through processing gain they investigated three digital signal processing techniques: matched filtering, energy detection, and cyclo-stationary feature detection. Our analysis shows that cyclo-stationary feature detection has advantages due to its ability to differentiate modulated signals, interference and noise in low signal to noise ratios. In addition, to further improve the sensing reliability, the advantage of a MAC protocol that exploits cooperation among many cognitive users is investigated.Disadvantage: This paper shows author had worked only to improve radio sensitivity by using traditional spectrum sensing method. This method is slow, require more time to detect primary user power leakage with this method is large.

[4] R. Saifan, A. Kamal, and Y. Guan, "Efficient spectrum searching and monitoring in cognitive radio network", in *Proc. IEEE 8th Int. Conf.MASS*, pp. 520–529, 2014.

In this paper author has classified in enhancing false alarm probability (P) and detection probability (Pd), optimizing inter-sensing time, in-band sensing (monitoring) time optimization, and out-of-band sensing (search) time optimization. The PU model used in most of these work was a simple two states model (busy/idle renewal process). In this work, they developed a model for the PU in its idle state. The model enables the CR node to benefit from its previous measurements. It assumes that there are multi-idle states, each with specific length and known probability of staying in it. This model is used to find the best sensing time, energy detection threshold, and false alarm probability of the channel being sensed in monitoring. Also, we developed an out-of- band optimization formulation. The formulation finds the best number of channels to sense, the threshold of each channel, the sensing time of each channel, and $Pf$of each channel such that the PU is protected, the sensing time is minimized, and the CR will find an available channel with very high probability.Disadvantage: With this model they are unable to comment on selective frequency fading. They had not explained OFDM impairments.

[5] H. Mahmoud, T. Yucek, and H. Arslan, "OFDM for cognitive radio: Merits and challenges", *IEEE Wireless Commun.*, vol. 16, no. 2, pp. 6–15, Apr. 2011.

CR is an exciting and promising technology that offers a solution to the spectrum crowding problem. On the other hand, the OFDM technique is used in many wireless systems and has proven to be a reliable and effective transmission method. OFDM can be used for realizing the CR concept because of its inherent capabilities that are discussed in detail in this article. By employing OFDM transmission in CR systems, adaptive, aware, and flexible systems that can interoperate with current technologies can be realized. However, the challenges identified in this article must be researched further to address the open issues. Practical CR systems can be developed using two approaches: current wireless technologies can evolve to support more cognitive features over time, or new systems that support full cognitive features can be developed. In either case, Author foresee that OFDM will be the dominant PHY technology for CR.Advantages: In this paper author had explain all merits and demerits of OFDM system for cognitive network. They explained how OFDM is reliable to cognitive network.

[6] W. Hu *et al.*, "Cognitive radios for dynamic spectrum access—Dynamic frequency hopping communities for efficient IEEE 802.22 operation", *IEEE Commun. Mag.*, vol. 45, no. 5, pp. 80–87, May 2013.

In this paper W. Hu et.al. explains wireless cognitive radio network and spectrum monitoring for WRANs network. One of the key challenges of the emerging cognitive radio-based IEEE 802.22 wireless regional area networks (WRANs) is to address two apparently conflicting requirements: ensuring QoS satisfaction for WRAN services while providing reliable spectrum sensing for guaranteeing licensed user protection. To perform reliable sensing, in the basic operation mode on a single frequency band (non-hopping mode), one must allocate quiet times, that is, periodically interrupt data transmission that could impair the QoS of WRAN. This critical issue can be addressed by an alternative operation mode proposed in 802.22 called dynamic frequency hopping (DFH), where WRAN data transmission is performed in parallel with spectrum sensing without interruptions. DFH community, as described in this article, is a mechanism that coordinates multiple WRAN cells operating in the DFH mode, such that efficient frequency usage and reliable channel sensing are achieved. The key idea of DFH community is that neighboring WRAN cells form cooperating communities that coordinate their DFH operations.

III.METHODOLOGY

For reducing the effect of Inter-Symbol Interference (ISI) in frequency domain OFDM system, the last Ng samples of the time domain OFDM symbol is copy to the beginning of the symbol to form a guard time or cyclic prefix. Therefore, the OFDM block has a period of Ts = (Ns + Ng)/Fs where Fs is the sampling frequency. At the receiver, the inverse block is applied. After time synchronization (frame detection, start of symbol timing, and SFO estimation and compensation) and frequency synchronization (CFO estimation and correction), the cyclic prefix is removed. Then, the received OFDM symbol are transformed into the frequency domain through an Ns point DFT. The channel is then estimated and the received data is equalized. The complex data output is then mapped to bits again through the De-mapper. De-interleaving, decoding, and randomization is applied later to the received block to recover the original source bits. From the network point of view, we consider a cognitive radio network of K SUs and one PU. The PU occupies a spectrum of a certain bandwidth for its transmission, while the same sensed spectrum is shared by the SUs. In fact, the spectrum is totally utilized by one SU (the master node or the fusion node) to send different data to the other K -1 SUs (the slave nodes).

In our model, the fusion node constructs OFDM frames in the downlink path such that the same pilots are transmitted to all slaves but the data sub-carriers are allocated in time and frequency for different users based on a predefined scheduling technique. For the return path, Orthogonal Frequency Division Multiple Access (OFDMA) is assumed to divide the spectrum and the time into distinct and non-overlapping channels fordifferent slaves, so that interferences between the slaves is avoided. The fusion node fully controls the timing of each slave, possibly by letting the slave know the required time advance or delay, so that the combined signal from all slaves seem to be synchronized at the fusion node receiver. In this case, the fusion node can convert the signal back to the frequency domain to extract the data and control information from different slaves.

3.1) ENERGY RATIO ALGORITHM

The overall algorithm is illustrated by Fig. 2. It is assumed that the primary signal appears after some time during the monitoring phase. At the secondary receiver, after CP removal and frequency domainprocessing on the received signal, the reserved tones from different OFDMsymbols are combined to form one sequence of complex samples. Two consecutive equal-sized sliding windows are passed over the reserved tone sequence in the time direction. The energy of the samples that fall in one window is evaluated and the ratio of the two energies is taken as the decision making variable and hence the name *energy ratio*. The algorithm aims to check the change in variance on the reserved tones over time. In a mathematical form, let Z_i be the i^{th} sample of the reserved tone sequence. The decision making variable, X_k, can be defined as given by (1) where N is the number of samples per window, U_k is the energy of the second window, V_k is the energy of the first window, and k is an integer such that $k = 1,2,3, \ldots$

$$X_k = \frac{U_k}{v_k} = \frac{\sum_{i=N+k}^{2N+k-1} |Z_i|^2}{\sum_{i=k}^{k+N-1} |Z_i|^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .(1)$$

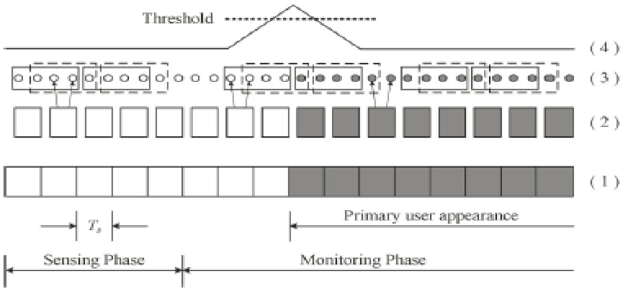

Fig 2: Energy ratio processing details (1) the time domain sequence for the OFDM blocks (2) frequency domain sample (3) reserved tones processing with two sliding windows for NRT = 2 & N= 4.(4) Decision making variable Xk.

It is mention that the reserved tones processing done by the energy ratio algorithm starts from the beginning of the sensing phase. Meaning that, the decision making variable is evaluated during both sensing and monitoring phases. However, it provides decisions only during monitoring phase. During the sensing phase, if the decision from the spectrum sensing algorithm is that the PU is inactive, then the energy ratio algorithm has been properly calibrated to be able to detect the appearance of the PU during monitoring phase. Calibrationmeans that both sliding windows are filled with pure unwanted signals. During the monitoring phase, the receiver monitors the reserved tones by evaluating the parameter, Xk. If it exceeds a certain threshold, then the secondary user assumes that there is a power change on the reserved tones which perhaps due to the primary user appearance and it is time to vacate the band. If not the secondary user can continue transmission. Indeed, if there is no primary user in band, then the energy of each window still involves only the strength of the unwanted signals including the noise, the leakage from the neighbouring sub-carriers, and the effects of ICI produced by the residual synchronization errors. Therefore, if N is large enough, the ratio will be very close to unity since the strength of the unwanted signals does not offer significant changes over time.

Once the primary user appears, the second window will have two types of signalling which are the primary user interference and the unwanted signals. Meanwhile, the first window will only maintain the unwanted signals without the primary user interference. The ratio of the two energies will result in much higher values when compared to one. The value will of course depend on the primary user power. When the two windows slide again, the primary signal plus the unwanted signals will be observed by the two windows and the decision making variable returns to the initial state in which the ratio is close to unity. Thus, we can expect that the decision variable produces a spike when the primary user is detected. Otherwise, it changes very slowly maintaining the energy ratio close to one as shown in Fig. 2 part (4). This approach can resist the different impairments involved in the received signal on the account of reducing the throughput of the secondary user by the ratio of the number of reserved tones to the number of useful tones. However, this reduction can be easily overcome since OFDM systems allow adaptive modulation where good conditioned sub-carriers are loaded with higher modulation order.

For the previous discussion, it is assumed that the primary user should appear at the boundaries of the OFDM blocks. Therefore, the reserved tones should have the full power, which is supposed to be for those sub-carrier indices, of the primary user when it is active. In reality, the primary user may appear any time within any OFDM block in the monitoring phase. In this case, we have to consider two effects. (1) The FFT window applied by the SU receiver will have a time-shifted version of the PU signal which involves a phase rotation to the PU sub-carriers. Since the energy is the useful parameter for our algorithm, the phase shift is acceptable to happen with no effect on the algorithm. (2) The power on the reserved tones will not have the full power transmitted by the primary user on those sub-carriers since part of the signal is truncated. However, the next OFDM symbol will have that full power. Similar to the near-far problem, if the PU power is large enough, then the reserved tones form the first OFDM symbol, in which PU signal appears, are considered to be full. Otherwise, the reserved tones from this OFDM symbol are considered as noise if N>>NRT.

3.2) ENERGY RATIO ALGORYTM FOR MIMO SYSTEM

To evaluate the energy ratio from complexity point of view, we propose architecture for the algorithm and then analyse the corresponding complexity and compare it to the traditional energy detectors. The proposed architecture is shown in Fig. 4.First, the reserved tone sequence is injected to be squared. Next, two first-In first-Out (FIFO) memories are used to store the squared outputs to manage the energy evaluation for the two windows.The idea depends on the sliding concept for the windows where the total energy enclosed by one window can be evaluated by only adding the absolute squared of the new sample and subtracting the absolute squared of the last sample in the previous window as given

$$V(k) = \sum_{i=k}^{N+k-1} |Z_i|^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$
$$V(k) = V(k-1) + |Z_{N+k-1}|^2 - |Z_{k-1}|^2$$

The ratio may not be evaluated directly, instead we can multiply the energy of the first window by the threshold and the multiplication output is then compared to the energy of the second window.

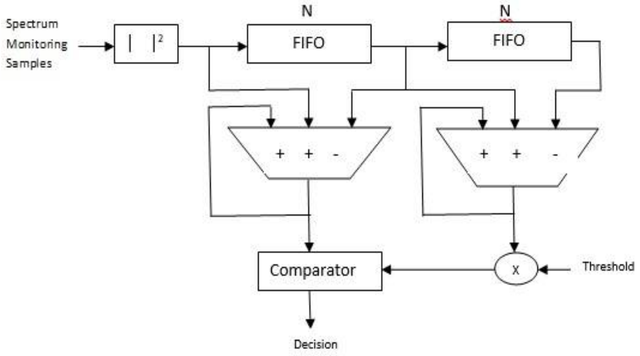

Fig. 3 Proposed architecture for the energy ratio algorithm.

IV.SIMULATION RESULTS

Our energy ratio detector does not require any additional complexity to the OFDM system with efficient detection capabilities. Once the primary user appears, the second window will have two types of signalling which are the primary user interference and the unwanted signals. Meanwhile, the first window will only maintain the unwanted signals without the primary user interference. The ratio of the two energies will result in much higher values when compared to one. The value will of course depend on the primary user power. When the two windows slide again, the primary signal plus the unwanted signals will be observed by the two windows and the decision making variable returns to the initial state in which the ratio is close to unity. Thus, we can expect that the decision variable produces a spike when the primary user is detected, below graph shows Comparison between LDPC with Energy ratio algorithm.

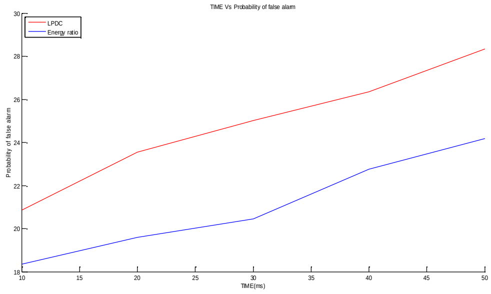

Fig. 4 Probability of false alarm

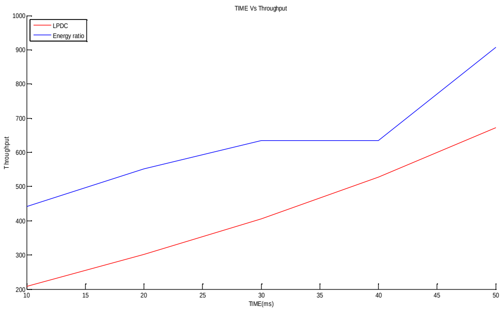

Fig. 5 Throughput

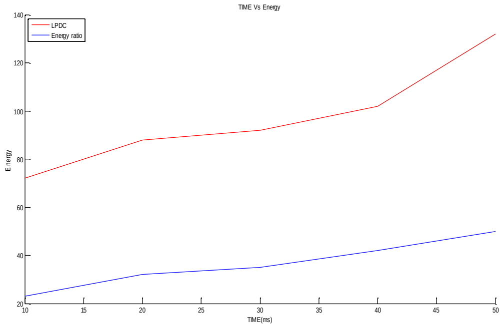

Fig. 6 Energy consumption

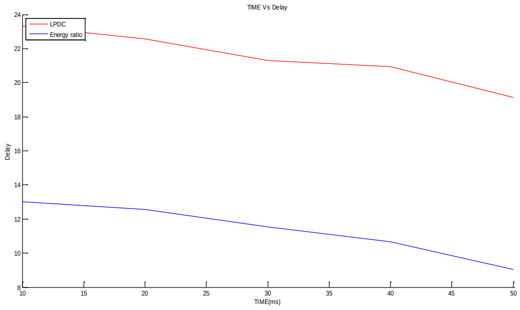

Fig. 7 End to end delay

V. CONCLUSION

We conclude that the proposed architecture typically uses double the components applied for the traditional energy detector. Moreover, traditional spectrum sensing which is applied prior to spectrum monitoring surely involves multipliers and accumulators. To further reduce the complexity, these modules can be reused and shared with the energy ratio algorithm during spectrum monitoring as sensing and monitoring are non-overlapped in time.

REFERENCES

[1] S. Haykin, “Cognitive radio: Brain-empowered wireless communications,” *IEEE J. Sel. Areas Commun.*, vol. 23, no. 2, pp. 201–220, Nov 2013.
[2] A. Ghosh and W. Hamouda, “Cross-layer antenna selection and channel allocation for MIMO cognitive radios,” IEEE Trans. Wireless Commun., vol. 10, no. 11, pp. 3666–3674, Nov. 2012.
[3] W. S. Jeon, D. G. Jeong, J. A. Han, G. Ko, and M. S. Song, “An efficient quiet period management scheme for cognitive radio systems,” IEEE Trans. Wireless Commun., vol. 7, no. 2, pp. 505–509, Feb. 2014.
[4] W. Hu et al., “Cognitive radios for dynamic spectrum access—Dynamic frequency hopping communities for efficient ieee 802.22 operation,” IEEE Commun. Mag., vol. 45, no. 5, pp. 80–87, May 2012.
[5] S. W. Boyd, J. M. Frye, M. B. Pursley, and T. C. Royster, “Spectrum monitoring during reception in dynamic spectrum access cognitive radio networks,” IEEE Trans. Commun., vol. 60, no. 2, pp. 547–558, Feb. 2012.
[6] H. Mahmoud, T. Yucek, and H. Arslan, “OFDM for cognitive radio: Merits and challenges,” IEEE Wireless Commun., vol. 16, no. 2, pp. 6–15, Apr. 2010.
[7] D. Cabric, S. M. Mishra, and R. W. Brodersen, “Implementation issues in spectrum sensing for cognitive radios”, in Proc. Conf. Rec. 38th Asilomar Conf. Signals, Syst. Comput., vol. 1, pp. 772–776, Nov. 2013.
[8] R. Saifan, A. Kamal, and Y. Guan, “Efficient spectrum searching and monitoring in cognitive radio network”, in Proc. IEEE 8th Int. Conf. MASS, pp. 520–529, 2014.
[9] H. Mahmoud, T. Yucek, and H. Arslan, “OFDM for cognitive radio: Merits and challenges”, IEEE Wireless Commun., vol. 16, no. 2, pp. 6–15, Apr. 2011.
[10] D. Galda and H. Rohling, “Narrow band interference reduction in ofdm based power line communication systems”, in Proc. IEEE ISPLC, pp. 345–351, Apr. 2011.
[11] R. Xu, M. Chen, C. Tian, X. Lu, and C. Diao, “Statistical distributions of ofdm signals on multi-path fading channel”, in Proc. Int. Conf., pp. 1–6, 2010.
[12] H. Mahmoud, T. Yucek, and H. Arslan, “OFDM for cognitive radio: Merits and challenges”, IEEE Wireless Commun., vol. 16, no. 2, pp. 6–15, Apr. 2011.