Peak-to-Average Power Ratio Reduction in NC-OFDM based Cognitive Radio

Mohammad Zavid Parvez *zavidparvez@hotmail.com*
Signal Processing
Blekinge Institute of Technology
Karlskrona, 37179, Sweden

Md. Abdullah Al Baki *bakiswd@hotmail.com*
Telecommunication Systems
Blekinge Institute of Technology
Karlskrona, 37179, Sweden

Mohammad Hossain *reganmh8@gmail.com*
Telecommunication Systems
Blekinge Institute of Technology
Karlskrona, 37179, Sweden

Abstract

This paper presents a novel technique for reducing the peak-to-average power ratio (PAPR) in non-contiguous bands spectrum of Orthogonal Frequency Division Multiplexing (OFDM) based Cognitive Radio (CR). The proposed system exposed is to carry the earlier period channel information as well as the spectrum sensing to utilize the radio spectrum to achieve an appropriate PAPR reduction. It is maintaining end-to-end throughput performance by using a set of approaches in the current CR environment. The simulation results for PAPR reduction has shown that higher constellation modulation schemes are better compared to lower constellation modulation schemes.

Keywords: OFDM, NC-OFDM, PAPR, Cognitive Radio, Spectrum Sensing.

1. INTRODUCTION

High data rate wireless communications are demanded by many applications. On average, more bandwidth is required for high data rate transmission in most of the systems. With potential technology and increasing wireless devices, the spectrum is becoming scarcer in each time. In this case, efficient transmission of spectrum by Orthogonal Frequency Division Multiplexing (OFDM) and Cognitive Radio (CR) is an alternative solution.

OFDM is followed by spectrum efficient multicarrier modulation where the spectrum is divided into subcarriers with each subcarrier containing a low rate data stream. OFDM has added a remarkable interest in recent years because of its high spectral efficiency, robustness in the presence of severe multipath channel conditions with simple equalization, Inter-symbol Interference (ISI), multipath fading, etc. However, OFDM has is a major drawback of high Peak-to-Average Power Ratio (PAPR). OFDM contains lot of independent modulated subcarriers that carry to create high peak because the independent phases of the subcarriers often combined constructively.

Nowadays, CR is defined as an intelligent wireless system that continually aware about its surrounding environment during sensing and able to dynamically adjust its radio spectrum parameters. Physical layer (PHY) of CR needs to be adaptable and flexible.

The OFDM along with CR is an attractive candidate for flexibility and adaptability of spectral. This paper proposes a novel non-contiguous OFDM (NC-OFDM) technique, where the system achieves high data rates of non-contiguous subcarriers while concurrently avoids interference.

There are different techniques have been proposed to reduce PAPR [4], [5], [6], [7], [8], [9], [10], [11], [12]. An attractive solution to the PAPR problem has proposed by J. Armstrong, where clipping and filtering techniques were used for PAPR reduction in the transmitter [1]. Another paper describes the End-to-End QoS Maintenance in Non-Contiguous OFDM (NC-OFDM) based CRs [2]. In this paper combined a clipping and filtering technique and the end-to-end QoS maintenance in Non-Contiguous OFDM (NC-OFDM) based CRs to reduce PAPR and calculated performance in non-contiguous bands spectrum of OFDM based CR system.

2. SYSTEM MODEL

The system model is defined as signal model, channel model and PAPR reduction technique. The system model can be described as below:

2.1 Signal Model

In a basic OFDM system the input data symbols are supplied into a channel encoder where data are mapped onto BPSK/QPSK/QAM constellation.

The data symbols are converted into serial to parallel before using Inverse Fast Fourier Transform (IFFT) block to get the time domain representation of OFDM symbols. Time domain symbols can be represented as:

$$x_n = \text{IFFT}\{X_k\}$$

$$= \frac{1}{N}\sum_{k=0}^{N-1} X_k e^{\frac{j2\pi kn}{N}} \quad 0 \le n \le N-1 \tag{1}$$

where,
X_k is the transmitted symbol of the k^{th} subcarriers
N is the number of subcarriers.

The time domain signal is regularly extended to prevent Inter Symbol Interference (ISI) from the former OFDM symbol using cyclic prefix (CP).

The D/A Converter performed to convert the baseband digital signal into analog signal. This operation is executed in D/A block shown in Figure 1. Then, the analog signal proceeded to the Radio Frequency (RF) frontend. The RF frontend start to operations after receiving the analog signal. The signal is converted to RF frequencies using mixer and amplified by Power Amplifier (PAs) and then transmitted throughout antennas. At the receiver side, the received signal is converted to base band signal while passing throughout by the RF block.

The analog signal is re-sampled and digitized by the A/D Converter and CR is removed from the signal. The received signal in the frequency domain obtained from the Fast Fourier Transform (FFT) block is represented as:

$$Y(k) = H(k)X(k) + W(k) \tag{2}$$

where, Y (k) is the received signal of the k^{th} subcarriers, H(k) is the frequency response of the channel and W (k) is the additive noise which is generally assumed to be Gaussian random variable with zero mean and variance of σ_W^2. After this, FFT signals are de-interleaved and decoded to turn into the original signal.

In OFDM system, the realization of large number of non-contiguous subcarriers by collective procedure for high data rate transmission is referred to as a Non-Contiguous OFDM (NC-OFDM) [3]. NC-OFDM is provided the necessary of agile spectrum usage for the target licensed spectrum if spectrum is occupied by primary and secondary users. The spectrum sensing has right to deactivate the spectrum for the secondary user during spectrum occupied by primary user. Moreover, dynamic spectrum sensing can be retrieved the information while the active subcarriers are located in the vacant spectrum bands.

Fundamentally, the NC-OFDM and OFDM are quite similar in the case of transmission and reception. However, an NC-OFDM technique is offered very significant improvement for growing scarcity of the large contiguous frequency spectrum, i.e. dynamic spectrum pooling for high data rate transmissions.

2.2 Channel Model

The communication channel is the physical medium connecting the transmitter with the receiver. This paper introduced the Additive White Gaussian Noise (AWGN) channel and Rayleigh fading channel in the proposed system.

The simplest channel model in wireless communication is the well known Additive White Gaussian Noise (AWGN) model which is presented as follows:

$$Y(t) = X(t) + N(t), \tag{3}$$

where, X(t) is the transmitted signal and N(t) is the AWGN.

Multipath is the propagation phenomenon that results in radio signal reaching the receiver antennas via multiple propagation paths. Rayleigh fading model performs as reasonable channel model when there are many objects (such as building and mountain) in the propagation environment which scatter the radio signal before it arrives at the receiver.

Rayleigh distribution is given by:

$$P(t) = \begin{cases} \frac{r}{\sigma^2} \exp\left[\frac{-r^2}{2\sigma^2}\right], & 0 \le r \le \infty \\ 0, & r < 0 \end{cases} \tag{4}$$

where, σ^2 is the variance of the Rayleigh distributed variable.

Peak-to-Average Power Ratio

The PAPR of the OFDM signal can be written as:

$$\text{PAPR}\{ s(t), \tau\} = \frac{\max_{t \in \tau}[s(t)]^2}{E\{[s(t)]^2\}} \tag{5}$$

where,
s(t) is the original signal
τ is the time interval
$\max_{t \in \tau}[s(t)]^2$ is the peak signal power
$E\{[s(t)]^2\}$ is the average signal power

3. PROPOSED SYSTEM

This work described the NC-OFDM based CR architecture's block diagram. In order to reduce the high peak power ratio are introducing repeated clipping and frequency domain filtering are introduce which is demonstrated in Figure 1.

In this paper, we utilized previous channel information in Non-Contiguous OFDM (NC-OFDM) based CRs under dynamic spectrum sharing environments. In the conventional OFDM system has the resource allocation problem where the allocated transmission spectrum is fixed. In the CR system, the operating bandwidth is not always fixed and spectrum is also co-shared. The channel and power status will be tracked by this system and provided reliable response from channel state information to the transmitter. In this paper, NC-OFDM is considered and calculated the SNRs of sub-channels under total power constraints. It has been adaptively preferred high PAPR reduction approach during the operation by repeated clipping and filtering.

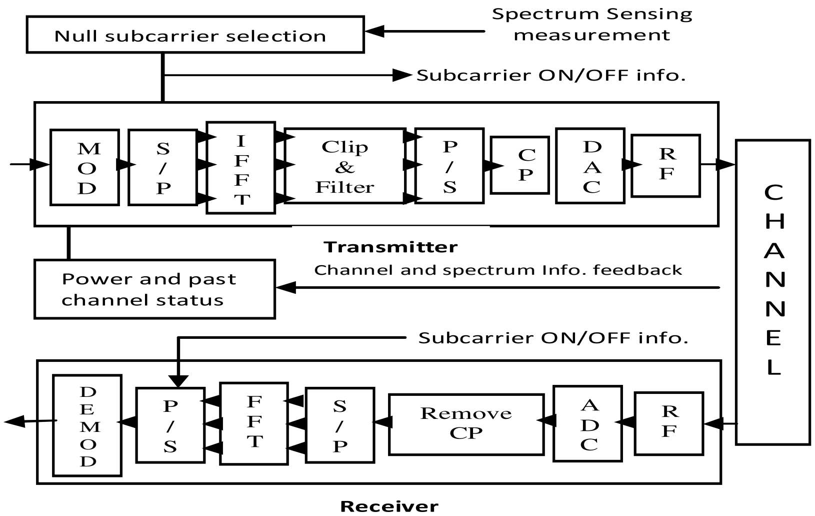

FIGURE 1: NC-OFDM based Cognitive Radio.

4. THE SIMULATION RESULTS

It is considered an NC-OFDM transceiver employing 10 MHz bandwidth, 256 FFT block size, and clipping ratio is 4. There are three modulation techniques (e.g. BPSK, QPSK, and QAM16 for clipping and filtering) as well as two channel models (e.g. AWGN and Rayleigh fading channel) used in the simulations. Finally, the two modes of output of the proposed system are shown: (1) PAPR reduction, and (2) BER calculation.

The complementary cumulative distribution functions (CCDF) of the PAPR for the transmitted signal are plotted in Figure 2, 3, and 4, where the PAPR techniques are being employed by the clipping and filtering. It is evident from these results that the PAPR can be improved by using repeated clipping and filtering.

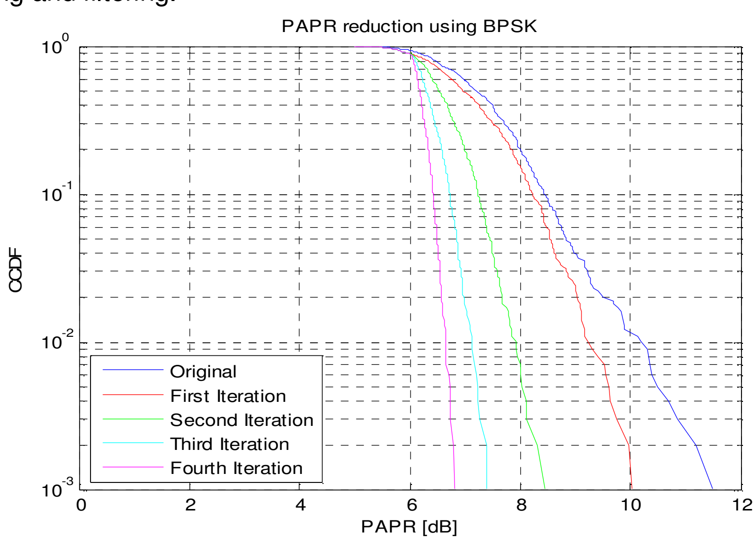

FIGURE 2: PAPR reduction using BPSK with clipping and filtering.

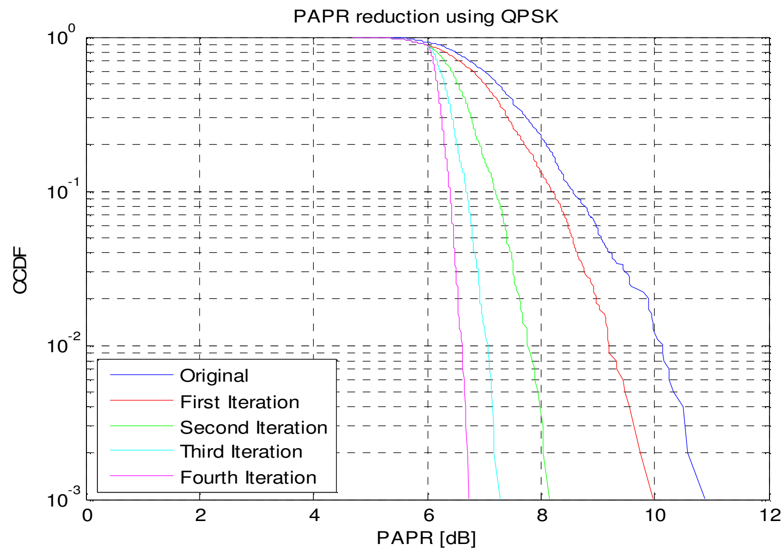

FIGURE 3: PAPR reduction using QPSK with clipping and filtering.

In Figure 2-4, by increasing PAPR for BPSK, QPSK, and QAM16, it is shown that CCDF is 10^{-3} at 11.5, 10.9, and 10.7 dB, but during next iteration, same 10^{-3} is achieved at less PAPR, i.e., 10.05, 9.95, and 9.7 dB. At fourth iteration, PAPR is 6.8, 6.7, and 6.65 dB.

Repeated clipping and filtering are significantly reduce PAPR, where modulation schemas are BPSK, QPSK, and QAM16. PAPR of QAM16 is low compared to BPSK and QPSK which gives better result shown in Figure 4. According to the fourth iteration, PAPR are given respectively 6.8, 6.7, and 6.65 dB for BPSK, QPSK, and QAM16.

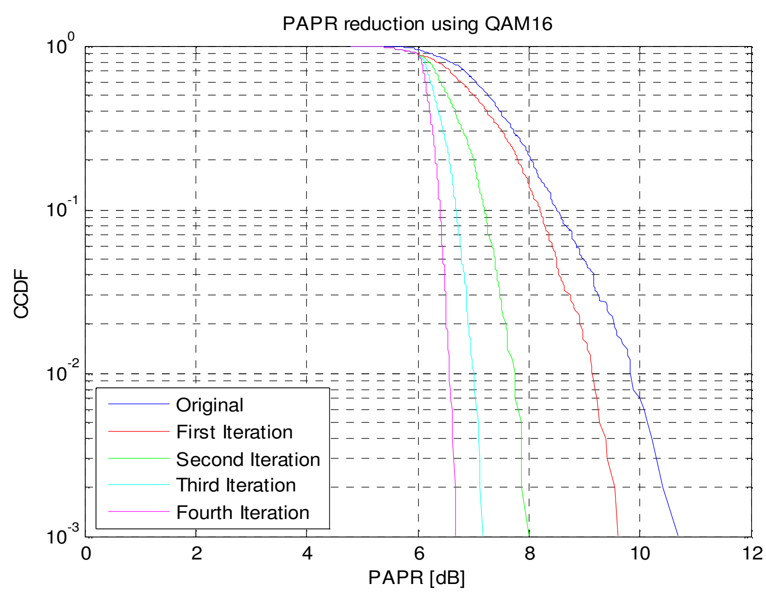

FIGURE 4: PAPR reduction using QAM16 with clipping and filtering.

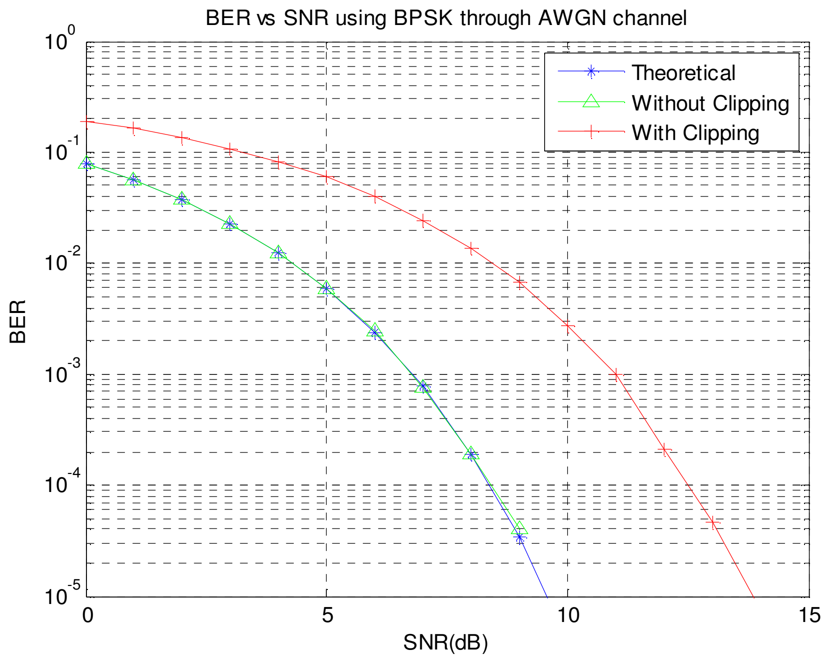

FIGURE 5: BER Vs SNR using BPSK through AWGN channel.

The performance of the system is measured by measuring BER using different channel models with different modulation schemes. The performance of NC-OFDM transceiver is shown in terms of curves representing BER against SNR values and are compared with theoretical, without clipping, and with clipping for every channel models.

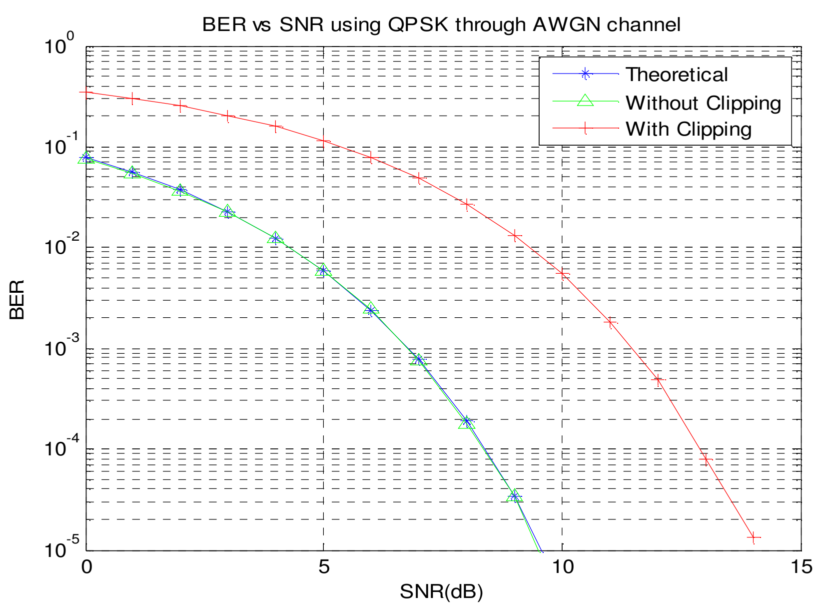

FIGURE 6: BER Vs SNR using QPSK through AWGN channel.

Figure 5 and 6 illustrated BER versus SNR for AWGN channel which is employed with BPSK and QPSK modulation schemes. In these figures, SNR for BPSK and QPSK, it can be seen that BER is 10-3 at 7 dB for theoretical and without clipping. On the other hand, SNR for BPSK and QPSK, BER is 10^{-3} at 11.2 and 11.5 dB with clipping.

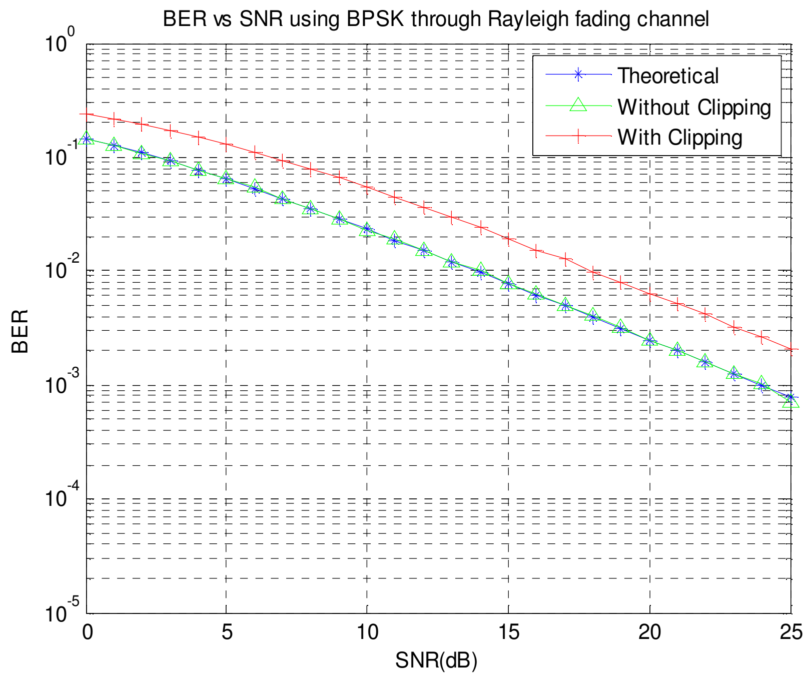

FIGURE 7: BER Vs SNR using BPSK through Rayleigh fading channel.

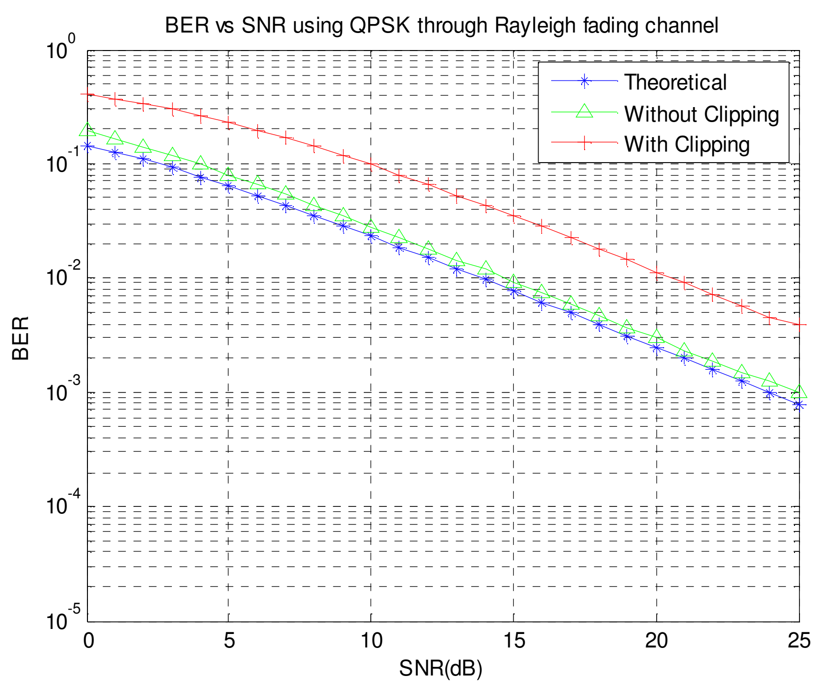

FIGURE 8: BER Vs SNR using QPSK through Rayleigh fading channel.

Figure 7 and 8 shown BER versus SNR for Rayleigh fading channel is using BPSK and QPSK modulation schemes. In these figures, SNR for BPSK and QPSK, it can be seen that BER is 10^{-2} at 14 dB for theoretical and without clipping. On the other hand, SNR for BPSK and QPSK, BER is 10^{-2} at 18 and 20.05 dB with clipping.

5. CONCLUSION

This paper presents an overview of Orthogonal Frequency Division Multiplexing (OFDM) and Cognitive Radio (CR). The OFDM is a smart candidate for CR systems for its flexibility and adaptability characteristics. This paper possesses a novel non-contiguous OFDM (NC-OFDM) technique, where the system achieves high data rate of non-contiguous subcarriers while simultaneously avoiding interference to the transmissions. The main goal of this paper work is to investigate PAPR reduction techniques for non-contiguous bands of OFDM based CR system. Simulation results of PAPR reduction has shown that the performance of QAM16 is good compared to other modulation schemes such as BPSK, QPSK. According to the BER results, we need higher value of SNR to achieve the same BER as compared to lower constellation modulation schemes.

ACKNOWLEDGEMENT

We would like to give our sincere gratitude to honorable Professor Abbas Mohammed, Signal Processing, Blekinge Institute of Technology (BTH), Sweden for his assistance and good guidance time after time which made our work become more precise and attractive.

REFERENCES

[1] Armstrong, J, “New OFDM Peak-to-average power reduction scheme”, vehicular technology conference, vol-1, 6-9 May 2001, pp 756-760.

[2] W.M. Joseph, B.L. Khaled, and C. Zhigang, “ Robust end-to-end QoS maintenance in non-contiguous OFDM based Cognitive Radio”, Dept. of Electronic and Computer Engineering, Hong Kong University of Science and Technology, Hong Kong.

[3] Rakesh Rajbanshi, Alexander M. Wyglinski, Gary J. Minden, "Adaptive-Mode Peak-to-Average Power Ratio Reduction Algorithm for OFDM-based Cognitive Radio," The University of Kansas, 2006.

[4] Wilkison, T. A. and Jones A. E., "Minimization of the Peak to mean Envelope Power Ratio of Multicarrier Transmission Schemes by Block Coding," IEEE, Vehicular Conference, Vol.2, Jul. 1995.

[5] Ahn, H., Shin, Y. m and Im, S., "A Block Coding Scheme for Peak to Average Power Ratio Reduction in an Orthogonal Frequency Division Multiplexing System ," IEEE Vehicular Conference Proceedings, Vol.1, May 2000.

[6] Bauml , R. W. , Fischer, R. F. H. , and Huber, J. B., "Reducing the Peak to Average Power Ratio of Multicarrier Modulation by Selective Mapping," IEEE Electronics Letters, Vol.32, Oct. 1996.

[7] Jayalath, A. D. S. , and Tellambura C., "The use of Interleaving to Reduce the Peak to Average Power Ratio of an OFDM Signals ," IEEE Global telecommunications conference, Vol.1, Nov. 2000.

[8] J. Tellado-mourelo, "Peak to Average Power reduction of OFDM signals using Peak Reduction Carriers," James Cook University Signal Processing Research, 22-25 August, 1999.

[9] Muller , S. H. , and Huber, J. B., "OFDM Reduced Peak to Average Power Ratio by optimum combination of Partial Transmit Sequences," IEEE Electronics letters, Vol.33, Feb. 1997.

[10] Van Nee, R. , and Wild, A., "Reducing the Peak to Average Power Ratio of OFDM," in IEEE Vehicular Technology Conference, May 1998, Vol.3.

[11] Foomooljareon , P and Fernando, W. A. C., "Input Sequence Envelope Scaling in PAPR Reduction of OFDM," in IEEE 5th International Symposium on Wireless Personal Multimedia Communications, , Vol.1, Oct 2002.

[12] Tan, C. E. Wassell I. J., "Data bearing peak reduction carriers for OFDM systems," in IEEE Proceedings of the 2003 Joint Conference of the Fourth International Conference of Information, Communication Signal Processing and Fourth Pacific Rim Conference On Multimedia, , Vol.2, Dec 2003.