ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

PAPR Reduction Techniques for OFDM Systems

[1]P.Kalaivani, [2]S.R.Balasubramanian,

PG Scholar, Department of ECE, Sri Venkateswara College of Engineering, Sriperumbudur, Chennai, India

Assistant Professor, Department of ECE, Sri Venkateswara College of Engineering, Sriperumbudur, Chennai, India

ABSTRACT : In recent times OFDM is a very attractive communication technique for next generation. In this OFDM a major drawback is PAPR(Peak to Average Power Ratio). It is used in the European digital broadcast radio system, as well as in wired environment such as asymmetric digital subscriber lines (ADSL). Due to large number of subcarriers, the OFDM signal has large dynamic range with large Peak to Average Power Ratio (PAPR). Large peak-to-average ratio (PAPR) distorts the OFDM signal if the transmitter contains nonlinear components such as laser sources. The nonlinear effects on the transmitted OFDM symbols are spectral spreading , inter-modulation, and changing the signal constellation. Reducing PAPR in OFDM system by using hybrid approach by comparing Partial Transmit Sequence (PTS) Selective Mapping (SLM) Clipping & Filtering. This project proposes a Partial transmit Sequence (PTS) is best when compared to all above methods.

KEYWORDS : OFDM, PAPR, ADSL, PTS, SLM

I. INTRODUCTION

With the advancement of communication technology comes the demand for higher data rate services such as multimedia, voice, and data over both wired and wireless links. There has been explosive growth in wireless data traffic over the last few years, due to both increased user adoption of higher bandwidth services, such as interactive computer gaming and video on demand, and to higher available wireless transmission rates. Extrapolating this growth into the future, we can expect that this category of data will soon represent a significant proportion of total backbone traffic, and that much higher wireless transmission rates will be required to support more sophisticated, bandwidth –intensive applications. Considering the constraints on allowed emission levels and fundamental limit of thermal noise and Shannon limits on high data rate, such systems are limited to short-ranges. While broadband access technology demands for larger coverage of high data rate. These progresses eventually leads us to the realization of commercial transmission system based on OFDM in future. Wireless transmission systems based on orthogonal frequency division multiplexing (OFDM) modulation are attractive due to their high spectral efficiency and resistance to noise and multipath effects. Conceptually, OFDM is a specialized FDM, the additional constraint being that all carrier signals are orthogonal to one another. In OFDM, the sub-carrier frequencies are chosen so that the sub-carriers are orthogonal to each other, meaning that crosstalk between the sub-channels is eliminated and inter-carrier guard bands are not required. This greatly simplifies the design of both the transmitter and the receiver unlike conventional FDM, a separate filter for each sub-channel is not required. To transmit signals with such high PAPR, power amplifiers with very high power scope is required. These kinds of amplifiers are very expensive and have low efficiency cost. Hence PAPR reduction is necessary for an efficient OFDM system.

Previous works in this field results in many PAPR reduction schemes to overcome this problem [1],[4].The various PAPR reduction techniques are Peak Windowing, Scaling, Clipping and Filtering, Block Coding, Block Coding with error correction, Selective Mapping (SLM), Interleaving, Tone Reservation, Tone injection, PTS etc. Peak windowing, scaling and clipping are simple methods of PAPR reduction but at the cost of slight interference. These methods introduce distortion in the OFDM signal. To reduce the interference, the clipped signal undergoes filtering. Block coding technique reduces PAPR without any distortion of OFDM signal and Block coding with error correction technique provide error correction capability in addition to PAPR reduction, but these methods are suitable for short code words [1],[4]. The SLM scheme performs well with any number of sub carriers and the major drawback with this

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

scheme is that the overheads of the side information should be transmitted to the receiver but the interleaving is a simple method of PAPR reduction which does not induce any signal distortion, however this method does not give any assurance on the result [3],[5],[6]. Tone reservation is a less complex method but it can result in data rate reduction whereas Tone injection method achieves PAPR reduction of OFDM signals with no data rate loss [7]. Requirement of side information for decoding signal at the receiver side and causes complex extra IFFT operation are the drawbacks of this method [1],[4].

The concentration of this paper is the Partial transmit Sequence (PTS) scheme, which is one of the most efficient methods for PAPR reduction and is much better than SLM and other techniques [7]. However the computational complexity of this method is very high and also phase sequence applied to the PTS scheme reduces its complexity but the PAPR reduction degrades slightly [2],[3]. This paper introduces a combination of PTS scheme with new phase sequence and the clipping technique. As the clipping technique is a simple method of PAPR reduction, the introduction of this technique to the system of PTS with new phase sequence does not increase the complexity. But the application of peak clipping technique introduces some distortion in the signal. However the slight clipping of peak of the signal at a particular value gives better PAPR reduction at the cost of small distortion of signal.

The tool used for the simulation is MATLAB R2012a. PAPR is described by its complementary cumulative distribution function (CCDF). Also the PAPR of the OFDM system before and after the application of the PAPR reduction techniques are analyzed. This paper is organized as follows. Section II includes the OFDM system and signals generation, Section III presents the PAPR, its causes and effects. Section IV presents the PTS, PTS with new phase sequence and low complexity PTS with clipping schemes. Section V and VI discuss the simulation results and conclusions respectively.

II. OFDM

OFDM is an efficient method of high data rate transmission in communication systems. OFDM system consists of large number of independent sub carriers. These closely spaced orthogonal sub carriers are used to carry data. At the transmitter section the data is divided into several parallel streams of channels, one for each sub carriers. These sub carriers are modulated by phase-shift keying (PSK) or quadrature amplitude modulation (QAM) mapping techniques. Transfer of signal over a channel is only possible in its time domain. For which IFFT is performed on this modulated signal, to convert the OFDM signal in frequency domain to time domain. Then cyclic prefix is inserted. The cyclic prefix is a periodic extension of the last part of an OFDM symbol that is added to the front of the symbol in the transmitter, and is removed at the receiver before demodulation. The different sub carriers are added up to form the OFDM signal. The signal is amplified using a power amplifier to overcome the fading effects and passed through the AWGN channel where the signal undergoes distortion from white Gaussian noise and multipath effects. At the receiver section the vice-versa of the operations at transmitter side is performed.

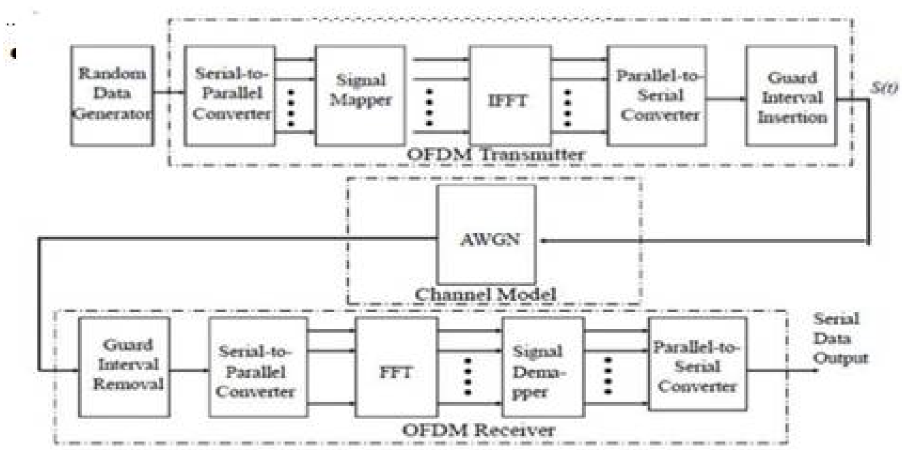

Fig: 1 OFDM Block Diagram.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

An OFDM symbol is made of sub-carriers modulated by constellations mapping. For an OFDM system with N subcarriers, the high-speed binary serial input stream is denoted as{ai}. After serial to parallel (S/P) conversion and constellation mapping, a new parallel signal sequence {d0,d1,d2,….di,…dN-1} is obtained, di is a discrete complex valued signal. When QPSK mapping is used, di {±1, ±i} and when BPSK is used di {±1}. Each element of parallel signal sequence is supplied to N orthogonal sub-carriers for modulation, respectively. Finally, modulated signals are added together to form an OFDM symbol. Use of discrete Fourier transform simplifies the OFDM system structure. The complex envelope of the transmitted OFDM signals can be written as using equation (1):

$$x(t) = 1/\sqrt{N} \sum_{k=0}^{N-1} X(k) e^{j2\Pi k \Delta ft} \qquad 0 \le t \le T \qquad \text{eq.(1)}$$

where $X(k)$ is the data symbol of k-th sub carrier, N is the number of sub carriers, Δf is the frequency difference between sub carriers and T is the OFDM symbol duration [8].

III. PEAK TO AVERAGE POWER RATIO

The PAPR of OFDM signals x(t) is defined as the ratio between the maximum instantaneous power and its average power [4]. The PAPR (in dB) of the transmitted OFDM signal can be defined in equation (2) as:

$$\text{PAPR} = \frac{\max_{0 \le t \le T} [|x(t)|^2]}{E[|x(t)|^2]} \qquad \text{eq.(2)}$$

Where $E[.]$ is the expected value operator. In an OFDM system the different sub carriers are added together to form the OFDM symbol. That is the system output is the superposition of multiple sub-carriers. In this case some instantaneous power output might increase greatly and become far higher than the mean power of system. This causes high PAPR in an OFDM system. High PAPR signals would require a large range of dynamic linearity from the analog circuits which usually results in expensive devices and high power consumption with lower efficiency. If no measure is taken to reduce the high PAPR, OFDM system could face serious restriction for practical applications.

PAPR is a random variable because it is a function of the input data, and the input data are random variable. Therefore PAPR can be calculated by using level crossing rate theorem that calculates the average number of times that the envelope of a signal crosses a given level. Knowing the amplitude distribution of the OFDM output signals, it is easy to compute the probability that the instantaneous amplitude will be above a given threshold and the same goes for power. This is performed by calculating the complementary cumulative distribution function (CCDF) using equation (3) for different PAPR values as follows;

$$\text{CCDF} = \Pr(\text{PAPR} > \text{PAPR0}) \qquad \text{eq.(3)}$$

The Cumulative Distribution Function (CDF) is one of the most regularly used parameters, which is used to measure the efficiency of any PAPR technique. The CCDF helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold.

IV. PAPR REDUCTION TECHNIQUES

PAPR reduction methods can be mainly divided into two domain methods:

1. Frequency domain method and
2. Time domain method.

The basic notion of frequency domain method is to increase the cross correlation of the input signal before IDFT and decrease the output of IDFT peak value or average value. Selective Mapping (SLM), Partial Transmit Sequence(PTS) etc., are examples of frequency domain method. In time domain method PAPR is reduced by distorting the signal

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

before amplification and added of extra signals which increase the average power. Clipping and filtering, Peak widowing etc., are examples of time domain method.
Broadly PAPR reduction techniques are classified into four sections as follows,

1. Signal scrambling technique

The fundamental principle of these techniques is to scramble each OFDM signal with different scrambling sequences and select one which has the smallest PAPR value for transmission. Apparently, this technique does not guarantee reduction of PAPR value below to a certain threshold, but it can reduce the appearance probability of high PAPR to a great extent. This type of approach include: Selective Mapping (SLM) and Partial Transmit Sequences (PTS). SLM method applies scrambling rotation to all sub-carriers independently while PTS method only takes scrambling to part of the sub-carriers.

2.Signal distortion technique

This technique reduces the PAPR by distorting the OFDM signal nonlinearly. It include methods like clipping and filtering, peak windowing, and non-linear companding. These methods are applied after the generation of OFDM signal.

3. Coding technique

The coding technique employed some error correcting codes for PAPR reduction. The coding methods select such code words that minimize or reduce the PAPR. The basic idea of all coding schemes for the reduction of PAPR is to reduce the occurrence probability of same phase of many signals. It causes no distortion and creates no out of band radiation. The error correcting codes like block codes, cyclic codes, Golay complementary sequence, Reed-solomon (RS) code, Read-Muller(RM) code, Hadamard code and Low density parity check(LDPC) code can be used.

3.1 TONE RESERVATION TECHNIQUE

The main idea of this method is to keep a small set of tones for PAPR reduction. This can be originated as a convex problem and this problem can be solved accurately. Tone reservation method is based on adding a data block and time domain signal. A data block is dependent time domain signal to the original multicarrier signal to minimize the high peak. The amount of PAPR reduction depends on some factors such as number of reserved tones, location of the reserved tones, amount of complexity and allowed power on reserved tones . It shows that reserving a small fraction of tones leads to large minimization in PAPR ever using with simple algorithm at the transmitter of the system without any additional complexity at the receiver end. Here, N is the small number of tones, reserving tones for PAPR reduction may present a non–negligible fraction of the available bandwidth and resulting in a reduction in data rate. The TR technique attracted much attention for reducing PAPR for current and future OFDM standard systems because TR provides good PAPR reduction performance without BER performance degradation and signal distortion. In addition, the TR technique is simple and effective, and it causes no interference to the data signal. However, one of the disadvantages of TR is the increase in mean power of the transmitted signal because of corrective signal addition. Also, the computational complexity of the optimization algorithm is to calculate the optimized corrective tones which reduce the original signal's PAPR. The advantage of TR method is that it is less complex, no side information and also no additional operation is required at the receiver of the system.

3.1.1 ALGORITHM

Intializing the BPSK modulated subcarriers.
• There are four different reduction carriers are used to map on different combinations.
• These peak reduction carriers are transmitted on 12 subcarriers to create peak.
• Summing of all 12 subcarriers with 16 different combinations.
• Calculate the PAPR for all.
• PAPR=10*log((peak^2)/avg)

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

The Results of various PAPR value based on TR method is tabulated below:

PAPR VALUE	RANGE (IN db)
PAPR 0	28.880
PAPR 1	29.2990
PAPR 2	25.8413
PAPR 3	25.4080
PAPR 4	**21.6240**
PAPR 5	**21.7348**
PAPR 6	25.4585
PAPR 7	24.3934
PAPR 8	23.6455
PAPR 9	24.5452
PAPR 10	22.8342
PAPR 11	26.3100
PAPR 12	25.7989
PAPR 13	26.0764
PAPR 14	23.2783
PAPR 15	**22.1395**
PAPR 16	23.4401

Table 1: Various PAPR values based on Tone Reservation Technique.

The simulation is done for 16 point IFFT. Random signals are generated and coded by different coding rates for Tone Reservation technique. The uncoded signal has maximum of 21.04 dB of PAPR. The coded signal 1 can have reduced PAPR up to 1.76 dB. As we go for coding scheme with Phase shift of 15 and 16 it reduce PAPR upto 0.32 dB and 0.19 dB.

V. COMPARISONS OF PAPR REDUCTION TECHNIQUES

The various techniques are used to reduce the PAPR. The techniques implemented here are Partial Transmit Sequence (PTS), Selective Mapping (SLM), clipping and filtering . By comparing these techniques which can able to minimize the PAPR is to be considered. The proposed techniques is PTS which gives minimum peak to average power ratio. Simulation results are denote evaluate PAPR.

5.1 SELECTIVE MAPPING METHOD

The key point of selected mapping method lies in how to generate multiple OFDM signals when the information is the same. In selected mapping method, firstly *M* statistically independent sequences which represent the same information are generated and next the resulting *M* statistically independent data blocks are then forwarded into IFFT operation simultaneously. This method can significantly improve the PAPR performance of OFDM system.

The CCDF can be written as original sequence PAPR above threshold PAPR0 is written as

$$\Pr\{PAPR>PAPR0\} \quad \text{eq.(4)}$$

The probability of PAPR larger than a threshold Z can be written as

$$P(PAPR>Z) = F(Z)N = (1-EXP(-z))N \quad \text{eq.(5)}$$

The idea stems from the fact that as the PAPR is determined by the sequence of the transmit data vectors, Xm multiplying the data vectors by some random phase will change the PAPR properties after the IFFT. Mathematically, a

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

set of U markedly different, pseudo random fixed vectors are generated, Figure 3.3 assume that the original input data X [X1, X2,…,XN-1] multiplied with independent phase sequences P=[P1 (u) P2 (u),…,PN(u)](u=0,1, U-1) , where U is the number of phase sequences. Both the input data and phase sequences have the same length N (u= 0, 1…, U-1). After multiplication, inverse fast Fourier transform (IFFT) will be applied on each sequence to convert the signal from frequency domain to the time domain. The result from multiplication will generate the data block of an OFDM system that has different time domain signals, with length of U, and different PAPR values.

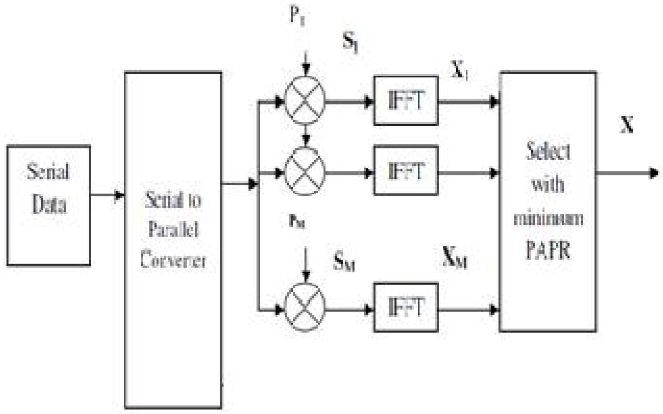

Fig:2 Selective Mapping Technique.

5.2 PARTIAL TRANSMIT SEQUENCE METHOD

Partial Transmit Sequence (PTS) algorithm is a technique for improving the statistics of a multicarrier signal. The basic idea of partial transmit sequences algorithm is to divide the original OFDM sequence into several sub-sequences and for each sub-sequences multiplied by different weights until an optimum value is chosen and figure.3 shows the block diagram of PTS method.

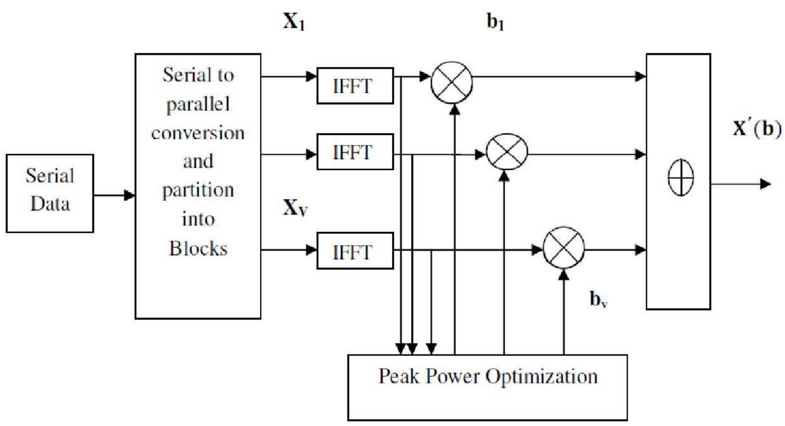

Fig:3 Partial Transmit Sequence Method.

From the left side of diagram, the data information in frequency domain X is separated into V non-overlapping sub-blocks and each subblock vectors has the same size N. So for each and every sub-block it contains N/V nonzero elements and set the rest part to zero. Assume that these sub-blocks have the same size and no gap between each other. The sub-block vector is given by

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

$$X = \sum_{v=1}^{V} b_v X_v \qquad \text{eq.(5.2.1)}$$

Where $b_v = e^{j\phi_v} (\phi_v \in [0, 2\pi])\{v = 1,2,\ldots.. X_v\}$

is a weighting factor been used for phase rotation. The signal in time domain is obtained by applying IFFT operation $\tilde{x} = IFFT(X) = \sum_{v=1}^{V} b_v IFFT(X_v) = \sum_{v=1}^{V} b_v X_v$ For the optimum result one of the suitable factor from combination

b = [b1, b2,.., bv] is selected and the combination is given by

$$b = [b_1, b_2, \ldots.. b_v] = \arg\min_{(b_1, b_2, \ldots b_v)} \max_{1 \le n \le N} \left| \sum_{v=1}^{V} b_v X_v \right|^2$$

where arg min [(·)] is the condition that minimize the output value of function.

5.3 CLIPPING & FILTERING

One of the simple and effective PAPR reduction technique is clipping, which cancels the signal components that exceed some unchanging amplitude called clip level. Clipping is nonlinear process and causes in-band noise distortion, which causes degradation in the performance of bit BER and out-of-band noise, which decreases the spectral efficiency. Clipping and filtering technique is effective in removing components of the expanded spectrum. Although filtering can decrease the spectrum growth, filtering after clipping can reduce the out-of-band radiation, but may also cause some peak re-growth, which the peak signal exceeds in the clip level . The technique of iterative clipping and filtering reduces the PAPR without spectrum expansion. However, the iterative signal takes long time and it will increase the computational complexity of an OFDM transmitter. But without performing interpolation before clipping causes it out-of-band. To avoid out-of-band, signal should be clipped after interpolation. However, this causes significant peak re-growth. So, it can use iterative clipping and frequency domain filtering to avoid peak re-growth. Using MATLAB the simulation was done and the results were obtained. PAPR in the proposed scheme is considerate and tolerable than other reduction methods. The comparison results are shown in figure.4.

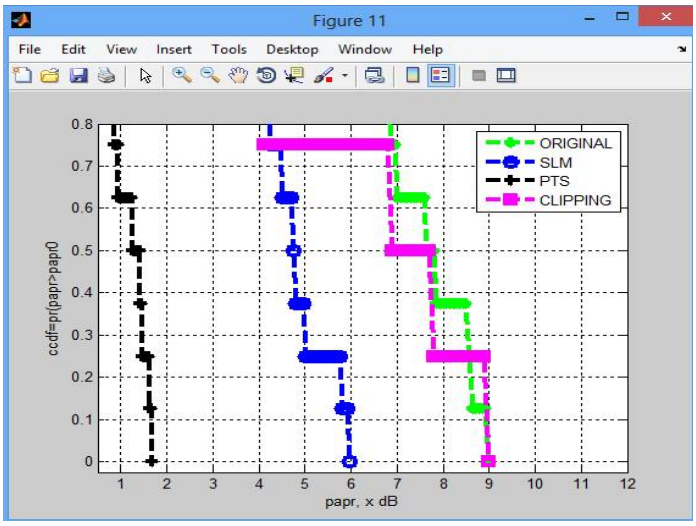

Fig:4 Comparisons of PAPR Techniques.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Special Issue 3, April 2017

VI. SIMULATION RESULTS

The simulation results are showing the performance of Partial Transmit Sequence for reducing the PAPR of OFDM system. The Simulation results of proposed technique is compared with other techniques. These simulations were done by using MATLAB. In these simulations OFDM symbols are randomly generated. In Fig. 5 the various PAPR techniques such as SLM at 6.1 db, Clipping & Filtering at 9 db, Original signal without PAPR reduction at 9 db, PTS at 1.9 db.

VII .CONCLUSION

In this paper the PAPR reduction problem in the OFDM system was considered. By comparing the various techniques of PAPR reduction such as Partial transmit Sequence, Selective Mapping, Clipping & Filtering, , the PTS method is best among all techniques. The performance of OFDM system is simulated by using MATLAB. It is observed that there is a significant reduction in PAPR value. Simulations which were conducted using MATLAB, have confirmed the theoretical considerations, and showed that proposed scheme performs better than traditional methods.

REFERENCES

1. H. Li, T. Jiang, and Y. Zhou (2011), "An improved tone reservation scheme with fast convergence for PAPR reduction in OFDM systems," IEEE Transaction Broadcast., vol. 57, no. 4, pp. 902 906.
2. J.-C. Chen, (2010), "Application of quantum-inspired evolutionary algorithm to reduce PAPR of an OFDM signal using partial transmit sequences technique," IEEE Transaction. Broadcast., vol. 56, no. 1, pp. 110–113.
3. A. Martinez, A. G. i Fabregas, and G. Caire, (2011) "Error probability analysis of bit-interleaved coded modulation," IEEE Transactions. Information Theory, vol. 52, pp. 262–271.
4. Jo. L. Rebola and Adolfo V. T. Cartaxo, (2016) "Estimating the Performance of OFDM Optical Sy stems Impaired by In-Band Crosstalk Using the Moment Generating Function" , IEEE journal of light wave technology, Vol. 34, no. 10.
5. J. Li, J. Yuan, R. Malaney, M. Xiao, and W. Chen, (2012) "Full-diversity binary frame-wise network coding for multiple-source multi-relay networks over slow-fading channels" IEEE Transactions InformationTechnology., vol. 61, pp. 1346–1357.
6. M. Huemer, C. Hofbauer, and J. Huber, (2012), "Non-systematic complex number RS coded OFDM by unique word prefix," IEEE Trans. Signal Process., vol. 60, no. 1, pp. 285–299.
7. J.-C. Chen and C.-K. Wen, (2010), "PAPR reduction of OFDM signals using cross-entropy-based tone injection schemes" IEEE Signal Process., vol. 17, no. 8, pp. 727–730.
8. Ho-Lung Hung, Chung-Hsen Cheng and Yung-Fa Huang (2013), "PAPR reduction of OFDM using invasive weed optimization-base optimal peak reduction tone set selection" EURASIP Journal on Wireless Communications and Networking 244.
9. Yuta Hori, Student Member, *IEEE*, and Hideki Ochiai, Member, IEEE, (2016), "Performance Analysis and Interleaver Structure Optimization for Short-Frame BICM–OFDM Systems", IEEE transactions on wireless communications, vol. 15, no. 1.
10. Sonika Chouhan and Deepak Sharma, (2013) "Performance Improvement Of OFDM System By Using ICI Self Cancellation Technique" in Proc. Of the International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE), Vol. 2,.
11. S. Y. L. Goff, (2012) "Signal constellations for bit-interleaved coded modulation," IEEE Transactions. Information. Theory, vol. 49, pp. 307–313.
12. S. Gazor and R. AliHemmati, (2012) "Tone reservation for OFDM systems by maximizing signal-to-distortion ratio," IEEE Trans. Wireless Communication., vol. 11, no. 2, pp. 762–770.
13. Yong Soo Cho, Jeakon Kim, Won Young Yang, Chung G. Kang, (2010) "MIMO OFDM Wireless Communications With Matlab" *John Wiley Sons, Ltd.*
14. F. Gianaroli, F. Pancaldi and G. M. Vitetta, (2014), "The Impact of Statistical Noise Modelling on the Error Rate Performance of OFDM Powerline Communications", IEEE Trans. Power Del., vol. 29, no. 6, pp. 2622- 2630.