A COMPARISON OF DIFFERENT PAPR REDUCTION TECHNIQUES IN OFDM USING VARIOUS MODULATIONS

Gaurav Sikri[1] and Rajni[2]

[1]Lala Lajpat Rai Institute of Engineering & Technology, Moga, Punjab, India
er.gaurav19@gmail.com
[2]Shaheed Bhagat Singh State Technical Campus, Ferozepur, Punjab, India
rajni_c123@yahoo.co.in

ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is one of the Strong candidate for Transmission of high data rate due to Multicarrier Modulation. One of the challenging Issue of OFDM is its high Peak to Average Power Ratio (PAPR or PAR). This Paper discusses different PAPR Reduction techniques in OFDM. The Classical Clipping, Selective Mapping, Tone reservation and Partial Transmit sequence Technique is used in this paper. Through the Analysis, it is shown that Clipping on 4-PAM is better than QPSK and 4-QAM with 64 subcarriers and Classical clipping is better than other techniques using QPSK modulation with 64 subcarriers.

KEYWORDS

Peak to Average Power Ratio (PAPR), Classical Clipping (CC), Selective Mapping (SLM), Tone Reservation (TR), Partial Transmit Sequence (PTS) & Orthogonal Frequency Division Multiplexing (OFDM)

1. INTRODUCTION

Orthogonal Frequency division Multiplexing (OFDM) has been considered as one of the strong standard candidates for the next generation mobile radio communication systems. OFDM technique is spectrally efficient and very robust to wireless multipath fading environment. Therefore it has been adopted as many standards of DAB/DVB (digital audio/video broadcasting) IEEE 802.11x, 3G LTE, and WiMAX systems. One of the main drawbacks of OFDM is its high Peak to Average Power Ratio (PAPR) because it is inherently made up of so many subcarriers. The subcarriers are added constructively to form large peaks. High peak power requires High Power Amplifiers (HPA), A/D and D/A converters. Peaks are distorted nonlinearly due to amplifier imperfection in HPA. If HPA operates in nonlinear region, out of band and in-band spectrum radiations are produced which appears as the adjacent channel interference. Moreover if HPA is not operated in linear region with large power backs-offs, it would not be possible to keep the out-of-band power below the certain limits. This further leads to inefficient amplification and expensive transmitters. To prevent all these problems, power amplifiers has to be operated in its linear region [1].

There are many methods on PAPR reduction such as Clipping, Coding [2], Selective Mapping (SLM), Interleaving [3,4], Nonlinear Companding Transform[5,6], Hadamard Transform [7],

DOI : 10.5121/ijmnct.2012.2406

Partial Transmit Sequence(PTS) [2] etc. The simple and widely used method is clipping the signal to limit the PAPR below a threshold level, but it is the nonlinear method which further distorts the OFDM signal. Clipping at Nyquist sampling rate will cause all the clipping noise to fall in band and suffers considerable peak regrowth after digital to analog conversion (D/A) conversion. The out-of-band radiation is produced by Filtering. Filtering causes peaks to regrow. Iterative clipping and filtering (ICF) works in recursive way to achieve less PAPR. Its modified version such as Simplified Clipping and Filtering (SCF) and one Time Iteration and Filtering is proposed in [5]. The strength of Clipping and Filtering method is based on total degradation (TD) and results show that it degrades the system performance instead of an improvement**.** This method is still considered as a good choice in 60 GHz CMOS radio transceivers because of its simple implementation and effective PAPR reduction with small degradation [6].

2. SYSTEM DESCRIPTION

An OFDM System consists of N subcarriers. The OFDM symbol $x(t)$, $0 \le t \le T$, consist of N complex baseband data $X_0, X_1, \ldots, X_{N-1}$ carried on N subcarriers, chosen to be orthogonal with constant spacing Δf as shown in Fig (1). The OFDM symbol $x(t)$ is

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k e^{jk2\pi\Delta f t} \quad ,0 \le t \le T \tag{1}$$

The Bandwidth of OFDM symbols is $B=\Delta f.N$ and symbol time $T=1/\Delta f.X_k$ is the complex baseband data modulating the k-th subcarrier for $x(t)$. The PAPR of OFDM symbol may be defined as [8]

$$\xi = \frac{\max_{t \in [0,T)} |x(t)|^2}{P_{av}} \tag{2}$$

Where P_{av} is the average power of the transmitted symbol and maximum sought over the symbol duration defined as $P_{av}=E\{|x(t)|^2\}$. Where $E\{.\}$ is the expectation operator. The value of ξ can be as large as N for Quadrature Phase Shift Keying (QPSK), Quadrature amplitude modulation (QAM) and Pulse amplitude modulation (PAM). However large PAPR occurs very less. The PAPR can be best marked by its statistical parameter, Complementary Cumulative Distribution Function (CCDF). For proper values of PAPR oversampling is necessary. L is the oversampling factor. L=1 determines discrete-time signal sampled at Nyquist rate, whereas L=4 gives sufficient samples to capture continuous-domain signal peaks. The oversampled signal can be obtained by (L-1)N zero-padding in the middle of the original input vector and converting frequency domain signal into time domain. The OFDM signal sampled at time instant $t=n\Delta t$ is then expressed as [10]

$$x(n) = x(n\Delta t), n = 0, \ldots, LN-1 \tag{3}$$

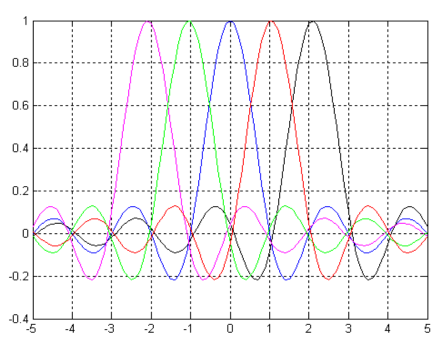


Figure 1. Orthogonal subcarriers

3. CLIPPING AND FILTERING

The Clipping based techniques clips the time domain signal to predefined level [9]. The method of Clipping and Filtering can be described with three modulation techniques, Quadrature Phase Shift Keying (QPSK) Quadrature Amplitude Modulation (QAM) and Pulse Amplitude Modulation (PAM). The OFDM signal contains high peaks so it is transferred from the clipping block shown in Fig (3b). In this when amplitude crosses the threshold or cut off level, the amplitude is clipped off shown in Fig (2), while saving the phase. The clipped sample is given by

$$x(n) = \begin{cases} |x(n)| & \text{if } |x(n)| \leq C(\text{threshold}) \\ C & \text{if } |x(n)| > C(\text{threshold}) \end{cases} \quad (4)$$

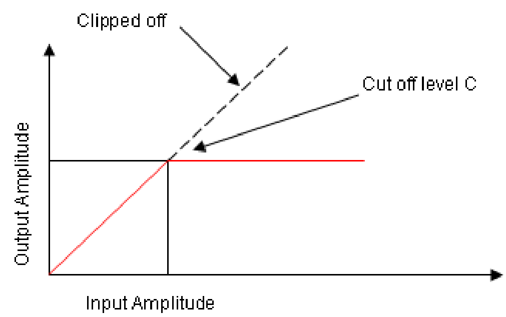


Figure 2. Clipping method

The out-of-band radiations occurred without filtering due to non linearity. To reduce the interference to neighboring channels, out-of-band components must be reduced with a band limiting filter [1]. The peak growth becomes small after filtering the oversampled signal. The repeated clipping and filtering can reduce the peak regrowth and increases the system cost. So there has been a tradeoff between PAPR and system cost.

The Modulated data can be of any type 4-QAM, QPSK or 4-PAM during classical clipping.In this paper we are trying to show the effect of clipping and filtering between the modulated data using constellation mapping of three modulations on 64 subcarriers [12]. The different PAPR reduction techniques using 64 subcarriers with QPSK modulation is used. The Smooth Clipping method is compared with classical clipping in [13].

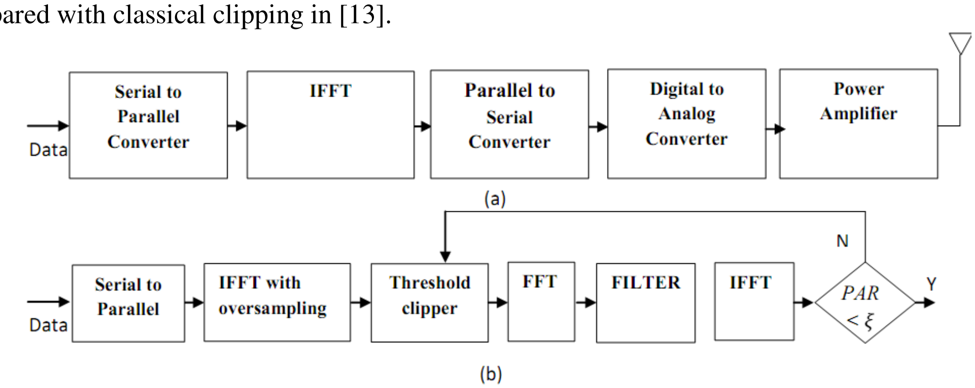


Figure 3. Block Diagram of (a) Original OFDM system (b) Clipped using threshold

4. SELECTIVE MAPPING

The input data sequences are multiplied by each of the phase sequences to generate alternative input symbols sequences. Each of these alternative input data sequence is made the IFFT operation, and then the one with the lowest PAPR is selected for transmission. In Fig (4) each data block is multiplied by V different phase factors, each of length *N*, $B_v = \left[b_{v,0}, b_{v,1}, \ldots, b_{u,N-1}\right]^T (v = 0,1,\ldots,V-1)$, resulting in V different data blocks. Thus, the vth phase sequence after multiplied is $X^v = \left[X_0, b_{v,0}, X_1 b_{v,1}, \ldots, X_{N-1} b_{v,N-1}\right]^T$ $(v = 0,1,\ldots,V-1)$. Therefore, OFDM signals can be taken as

$$x^V(T) = \frac{1}{\sqrt{N}} \sum_{N=0}^{N-1} X_N B_{V,N} E^{J2\Pi F_N T} \tag{5}$$

Where $0 \leq t \leq NT, v = 1,2,\ldots,V-1$.

Among the data blocks $X^v(v - 0,1,\ldots,V-1)$, only one with the minimum PAPR is selected for transmission and the matching selected phase factors $b_{v,n}$ also should be transmitted to receiver as side information. SLM requires V IFFT operation and the number of required bits as side information is $\lfloor \log_2 V \rfloor$ for each data block.

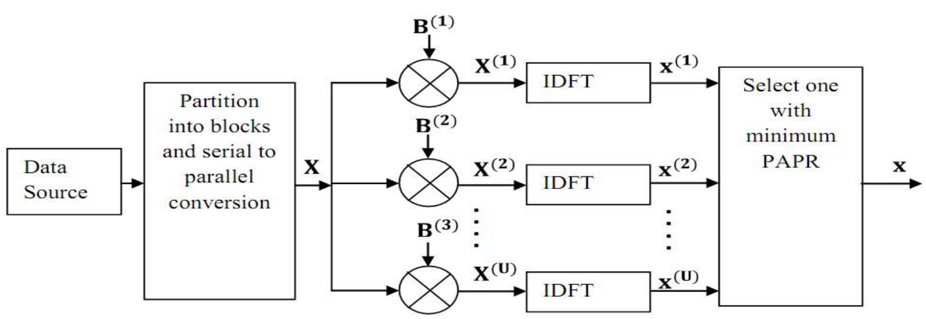


Figure 4. Selective Mapping Technique

5. TONE RESERVATION

A signal c[n] is added to the original data signal x[n] for PAPR reduction. In TR, the objective is to find the time domain signal to be added to the original time domain in order to reduce the PAPR. The PAPR reduction gain is defined by subtracting PAPR with PAPR reduction from PAPR without PAPR reduction. The G_{PAPR} means the amount of peak reduction in dB. (N is fast fourier transform (FFT) size.) [11]

$$G_{PAPR} = 10 \log \left(\frac{\max_{0 \leq n \leq N-1} |x[n]|^2}{\max_{0 \leq n \leq N-1} |x[n] + c[n]|^2} \right) \tag{6}$$

To reduce PAPR, the TR method assigns the signal to the reserved subcarriers which are not used for the data transmission as shown in Fig (5). The data vector changes and results in a new modulated OFDM.

$$X_k + C_k = \begin{cases} X_k, & k \in S \\ C_k & k \in S^c \end{cases} \tag{7}$$

The data symbols X_K and the symbols C_K to reduce PAPR are placed exclusively (S is a set of subcarrier indices for the data transmission). Thus there are no signal distortion and no additional processing to get the data signal at the receiver. Assuming a linear channel, and since symbol demodulation at the receiver is done in the frequency domain on a tone-by-tone basis, the subchannels with reserved tones can be discarded at the receiver.

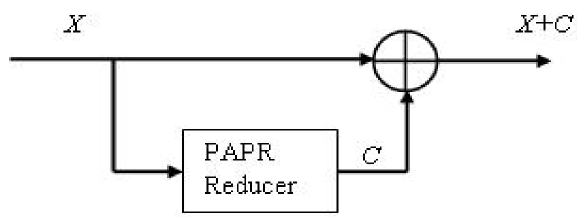


Figure 5. Tone Reservation technique

6. PARTIAL TRANSMIT SEQUENCE

In PTS technique, the input data block in X is partitioned into M disjoint subblocks, which are represented by vectors $\{X^m, m = 0,1,\dots,M-1\}$ as shown in Fig (6). Therefore, we can get

$$X = \sum_{M=0}^{M-1} X^M \tag{8}$$

Where $X^m = [X_0^m, X_1^m \dots X_{N-1}^m]$ with $X_k^m = X_k$or $0\ (0 \le m \le M-1)$. Normally for PTS technique, the known subblock partitioning methods can be classified into three types [2]: adjacent partition, interleaved partition and pseudorandom partition. Then, the subblocks X^m are transformed into M time-domain partial transmit sequences

$$x^m = [x_0^m x_1^m \dots x_{LN-1}^m] = IFFT_{LN \times N}[X^m] \tag{9}$$

These partial sequences are rotated independently by phase factors $b = \{b_m = e^{j\theta_m}, m = 0,1,\dots M-1\}$. The approach is to optimally combine the M subblocks to obtain the time domain OFDM signals with the minimum PAPR

$$\tilde{x} = \sum_{m=0}^{M-1} b_m x^m \tag{10}$$

So, there are two important issues should be taken into consideration in PTS: high computational complexity for finding the optimal phase factors and the overhead of the optimal phase factors as side information required to transmitted to receiver for the correct decoding of the transmitted bit sequence. Normally, PTS needs M IFFT operations for each block, and number of required side information bits is $[M\log_2^W]$, where $[x]$ denotes the smallest integer that does not exceed x.

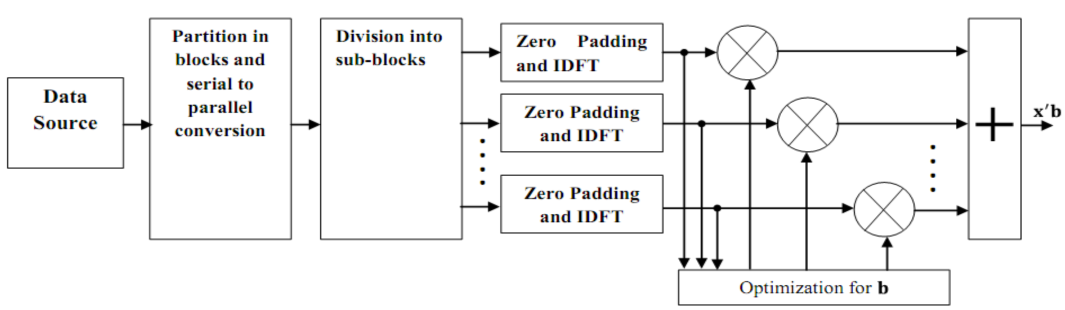


Figure 6. Partial Transmit Sequence

7. RESULTS AND SIMULATIONS

We use the computer simulations to evaluate the performance of the proposed PAPR reduction technique over different types of modulated data. As a performance measure for proposed technique, we use the CCDF of the PAPR. Performances of the proposed system are first compared without clipping and filtering to OFDM for a multicarrier system with QAM and PAM symbols modulated on N=64,128,256 subcarriers and then with QAM and QPSK symbols modulated on N=64,128,256 subcarriers. 10000 random OFDM blocks were generated to obtain the CCDF. Fig (7) shows the CCDF of PAPR of QAM signals is better than PAM and is given in Table (1). Fig (8) shows the CCDF of QPSK signals is better than QAM without clipping and filtering. The increase in the number of subcarriers results into more PAPR as given in Table (2). Fig (9) shows the effect of clipping and filtering over the CCDF of PAPR of QAM, PAM and QPSK signals with N=64. The decrease in PAPR is 7.89 dB over QAM, 9.73 dB over PAM and 7.68 dB over QPSK due to the effect of classical clipping. A comparison of QPSK, QAM and PAM with N=64 shows the difference of 1.12 dB as given in Table (3). The different PAPR reduction techniques with QPSK modulation and 64 subcarriers are shown in Fig (10).

Table 1. Comparison of 4-QAM and 4-PAM using 64,128 and 256 subcarriers without clipping

Modulations	64 subcarriers	128 subcarriers	256 subcarriers
QAM	11.35 dB	11.97 dB	12.27 dB
PAM	11.73 dB	13.59 dB	12.76 dB

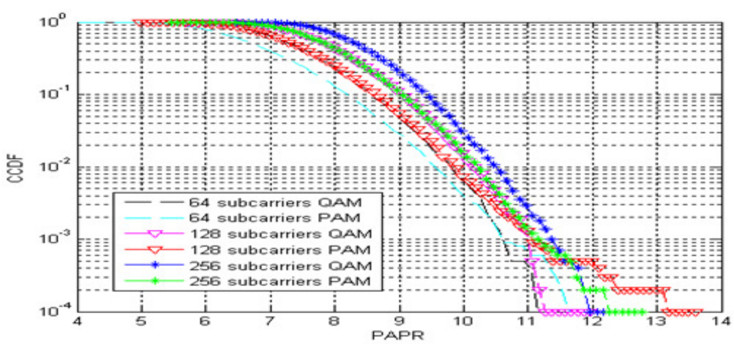


Figure 7. PAPR of 4-QAM and 4-PAM using 64,128 and 256 subcarriers without clipping

Table 2. Comparison of 4-QAM and QPSK using 64,128,256 subcarriers without clipping

Modulations	64 subcarriers	128 subcarriers	256 subcarriers
QAM	11.63 dB	12.02 dB	12.40 dB
QPSK	11.58 dB	11.41 dB	12.04 dB

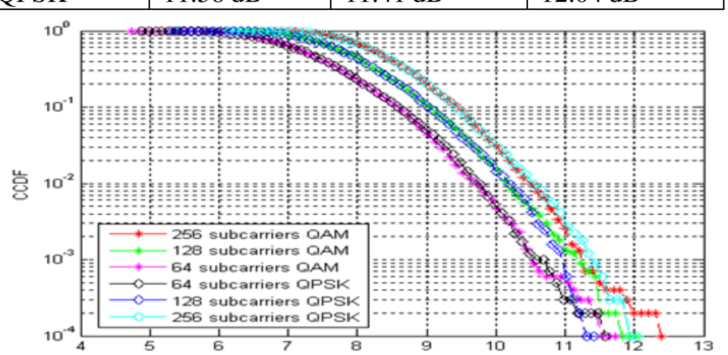


Figure 8. PAPR of 4-QAM and QPSK using 64,128 and 256 subcarriers without clipping

Table 3. Comparison of 4- QAM, 4-PAM and QPSK using 64 subcarriers with and without clipping

Modulations	Without Clipping	With Clipping
4-QAM	11.10 dB	3.21 dB
4-PAM	11.82 dB	2.09 dB
QPSK	10.89 dB	3.21 dB

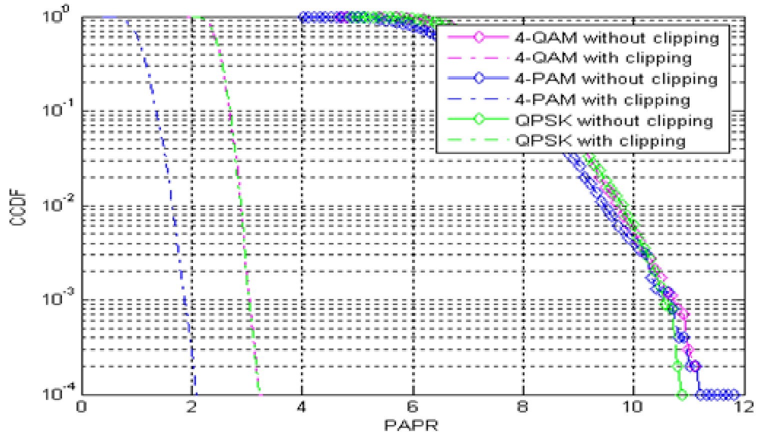


Figure 9. PAPR of 4-QAM, 4-PAM and QPSK using 64 subcarriers with and without clipping

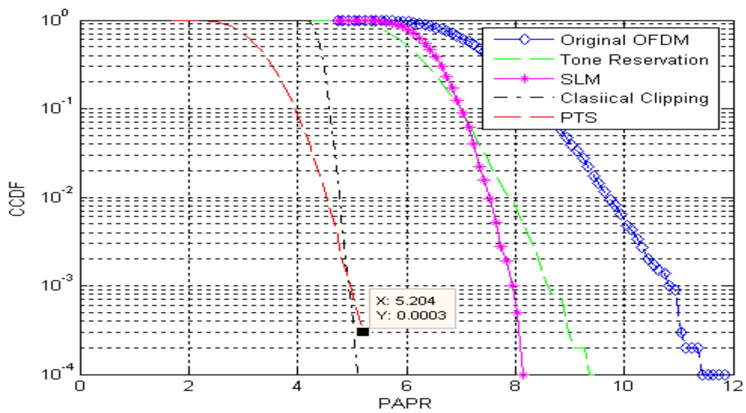


Figure 10. PAPR of different techniques using QPSK modulation with 64 subcarriers

8. CONCLUSION

In this paper, a Classical clipping and filtering technique is introduced to reduce the PAPR in multicarrier system applying 4-QAM, 4-PAM and QPSK with N=64 subcarriers. The PAPR of three different modulation techniques is compared with each other. Results show that PAM modulated with N=64 by clipping and filtering is better than QAM and QPSK. The different PAPR reduction techniques are shown using 64 subcarriers with QPSK technique. Results show that Classical clipping is better than Tone Reservation, Selective Mapping and Partial Transmit Sequence.

REFERENCES

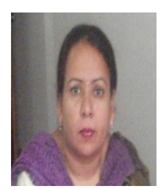
[1] H.G. Ryu,(2010) "Combination of PAPR reduction and linearization for the OFDM communication system", Wireless Communication and Mobile Computing, pp.46-52.
[2] T.Jiang & Y.Wu, (2008)"An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals", IEEE Transactions on broadcasting, pp.257-68.
[3] T.Jiang & Y.Imai,(2008) "An overview: peak-to-average power ratio reduction techniques for OFDM signals," IEEE Transaction On Wireless Communications, pp.56-57.
[4] S.H. Han & J.H.LEE,(2005) " An overview of peak-to-average power ratio reduction techniques for multicarrier transmissions", IEEE transactions on Wireless Communication, pp.56-65.
[5] L.Q.Wang & C.Tellambura,(2005) "A Simplified Clipping and Filtering Technique for PAR Reduction in OFDM systems", IEEE Signal Processing Letters,Vol.12, No.6, pp.453-456.
[6] A.K.Gurung, S. Fawaz, Al-Qahtani, A.Z. Sadik, & Z.M. Hussain,(2008) " Power Savings Analysis of Clipping and Filtering Method in OFDM Systems", IEEE ATNAC, pp.204-208.
[7] Park,M., Heeyong,J., Cho,N., Hong,D. & Kang,C.,(2000) "PAPR reduction in OFDM transmissions using Hadamard transform", IEEE International Conference of Communications, Vol.1, pp.430-33.
[8] L.Wang and C.Tellambura, (2006) "An Overview of Peak-to-Average Power Ratio Reduction Techniques for OFDM systems", IEEE International Symposium on Signal Processing Processing and Information technology, pp.840-845.
[9] X,Li and L.J. & Cimini.,(1998) "Effects of clipping and filtering on the performance of OFDM", IEEE Communication Letters vol.2, no.5,pp.131-133.
[10] Rajni & G. Sikri,(2012) "Reducing Peak to Average by Classical Clipping over BPSK and QPSK in OFDM System", proceedings of International conference on recent advances and future trends, pp 26-28.
[11] Son, C.H. Nam & H.S. Lee,(2009) "An approach for PAPR Reduction based on Tone Reservation Method", IEEE Conference on Consumer Communications and Networking, pp.1-2.
[12] G.Sikri & Rajni,(2012) , " Peak to Average power Ratio Reduction in OFDM system over PAM, QAM and QPSK modulation" ,Advances in Intelligent Systems and Computing, available on springerlink, Vol.176,pp 685-90.
[13] G.Sikri, Rajni & S.Sahai,(2012) , "A Study of PAPR reduction technique for orthogonal frequency division modulation" ,International conference on advance computing technology,gurukul,pp.1-9

Authors

Gaurav sikri

is currently Assistant Professor at LLR institute of Engineering and Technology, Moga, India. He has completed his B.tech from PTU, Jalandhar in 2009. He is pursuing part time M.Tech. from SBS State Technical Campus Ferozepur, India. His areas of interest includes Wireless communication and Wavelet based OFDM.

Ms. Rajni



is currently Assistant Professor at SBS State Technical Campus, Ferozepur, India. She has completed her M.E. from NITTTR, Chandigarh, India, B.Tech. from NIT, Kurukshetra, India. Ms. Rajni has about fourteen years of academic experience. She has aut hored a number of research papers in national, international conferences and reputed journals. Her areas of interest include Wireless communication, and Antenna design.