International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 5 Issue 6, June-2016

Peak to Average Power Reduction (PAPR) Techniques comparison in OFDM

Jyoti[1], Umesh Gupta[2]

[1]M.Tech. Student (ECE), MERI College of Engineering, Asanda, Bahadurgarh, Haryana
[2]Asst. Professor (ECE), MERI College of Engineering, Asanda, Bahadurgarh, Haryana

ABSTRACT

OFDM is being considered as the modulation scheme. The objective of this survey is to provide the readers and practitioners in the industry with a broader understanding of the problem in orthogonal frequency division multiplexing (OFDM) systems and generate taxonomy of the available solutions to mitigate the problem. Two major limitations of OFDM systems are Peak-to-Average Power Ratio (PAPR) and Inter Carrier Interference (ICI). PAPR is a measurement of waveform calculated from the peak amplitude of the waveform divided by the RMS value of the waveform and this large peak occurs due to the constructive superimposition with a number of subcarriers or the summation of a large number of subcarriers. This high PAPR demands high power amplifiers (HPA) at the transmitter. The non-linearity effects of HPA on the transmitted OFDM symbols are spectral spreading, inter modulation and changing the signal constellation. Over the last decade a lot of research has been carried out in reducing the two major limitations of OFDM for improving the performance of the system. The large variation in envelope of OFDM signal, which causes high peak-to-average power ratio (PAPR) and the sensitivity of OFDM signal against carrier frequency offset which causes inter-carrier interference (ICI) are the focussed area of this research. Previously reported schemes like clipping and filtering, selected mapping, partial transmit sequence, tone reservation, and tone insertion provide PAPR reduction. Peak regrowth in clipping and filtering causes the transmitted signal to exceed the clipping level at some points. In case of selected mapping and partial transmit sequence technique; the transmitter needs some side information. Overall it is noticed that these techniques have large computational overhead. So in this paper we used unmodified OFDM, SLM and Hybrid approach comparison for following parameters: Symbol Error Rate (SER) at various output Back-Off (OBO) levels and performance analysis in terms of Complementary Cumulative Distribution Function (CCDF) at various threshold values.

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has grown to a popular communication technique for high speed communication in the last decade. Being an important member of the multicarrier modulation (MC) techniques, Orthogonal Frequency Division Multiplexing (OFDM), is also called Discrete Multitone Modulation (DMT) [2]. It is based upon the principle of frequency division multiplexing (FDM) where each frequency channel is modulated with simpler modulation scheme. It splits a high rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of orthogonal subcarriers [3]. Orthogonality is achieved by ensuring that the carriers are placed exactly at the nulls in the modulation spectra of each other. The increase of symbol duration for the lower rate parallel subcarriers reduces the relative amount of dispersion in time caused by multipath delay spread. Therefore OFDM is an advanced modulation technique which is suitable for high-speed data transmission due to its advantages in dealing with the multipath propagation problem, high data rate and bandwidth efficiency [4]. Although OFDM principles have been developed over several decades, its implementation for high data rate communications has only recently become popular by the reduced cost and availability of suitable signal processing components which make it a competitive technology for commercial applications also.

2. LITERATURE SURVEY

One major limitations of OFDM is the high peak-to-average power ratio of the transmit signal which occurs due to the summation of many subcarrier modulated signals. A high PAPR requires a wide dynamic range for the power amplifier at the transmitter, or more commonly the power amplifier needs to be backed off to accommodate high peaks. This results in significant reduction of the transmission power which leads to very low power efficiency. It is therefore preferable to reduce the PAPR of the signal. Several methods have been proposed by researchers to reduce PAPR, such as Clipping, Clipping and Filtering, Selected Mapping, and Partial Transmit Sequence [20].Clipping is the simplest technique for reducing the PAPR, however it causes both in-band and out-of band distortion [21]. Filtering can be employed to alleviate out-of-band distortion but results peak re-growth. Repeated clipping and filtering can lead to degradation in BER. Windowing is another approach that offers reduced out-of-band radiation but window has to be as narrow as possible in the frequency domain and the impulse response in the time domain should not last too long, otherwise more signal samples are affected. Tone reservation is also an effective technique for reducing the PAPR of OFDM signals but causes a reduction in data through-put as data carriers are used to generate an effective cancellation signal in the time domain to reduce high peaks. SLM and PTS schemes can handle any number of subcarriers. But the drawback associated with the schemes is the overhead of side information that needs to be transmitted to the receiver's end [22] [23] [24] [25].

The other major limitation of OFDM is its sensitivity against carrier frequency offset which causes attenuation and rotation of subcarriers, and inter-carrier interference (ICI) [28]. Because of the orthogonality of the sub-carriers, we are able to extract the symbols at the receiver as they do not interfere with each other. Orthogonality is preserved as long as sub-carriers are harmonics to each other. If at the receiver's end there is a change in frequency of the sub-carriers due to any reason, then the orthogonality among them are lost and ICI occurs. As a result the signal degrades heavily. This change in frequency is called frequency offset. There are two main reasons for frequencies offset which are frequency mismatch between transmitter & receiver and Doppler Effect. The undesired ICI degrades the performance which is discussed in [28]. Several methods have been presented to reduce ICI, including self-cancellation schemes [29], frequency domain equalization, and time domain windowing at the receiver. Among them frequency domain equalization and time domain windowing methods are not so efficient because they do not address to the major cause of ICI which is due to the frequency mismatch between the transmitter and receiver, and Doppler shift.

3. PROPOSED SCHEME

A high PAPR requires a wide dynamic range for the power amplifier at the transmitter, or more commonly the power amplifier needs to be backed off to accommodate high peaks. This results in significant reduction of the transmission power which leads to very low power efficiency. To evaluate the performance of the proposed PAPR reduction technique and to approximate the effect of nonlinear power amplifier in the transmitter, we adopt Rapp's model for amplitude conversion [15]. I.e. approximation of non-linearity effect is calculated. the difference in PAPR improvement between the proposed technique and the ordinary SLM technique is closely related to the value of n, k or the code rate r = k/n.

The simulation model OFDM system is presented in fig 1. This model consists of a transmitter, a channel and a receiver. A brief description of the model is provided below.

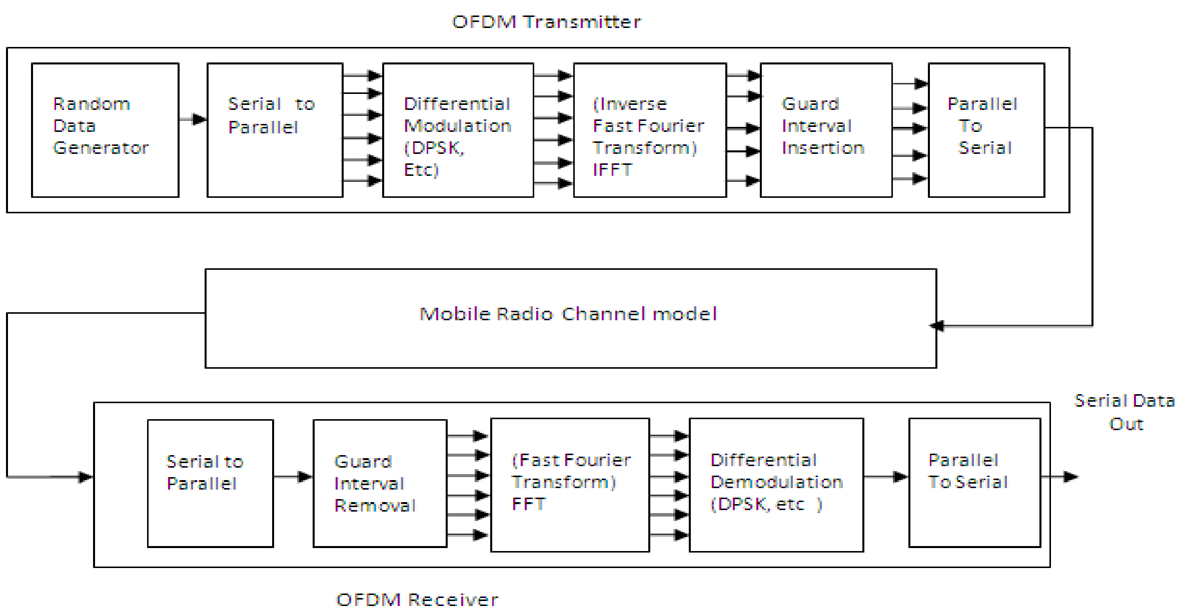

Fig 1: OFDM model used for simulation

Random Data Generator

Random data generator is used to generate a serial random binary data. This binary data stream models the raw information that going to be transmitted. The serial binary data is then fed into OFDM transmitter

Serial to Parallel Conversion

The input serial data stream is formatted into the word size required for transmission, and shifted into a parallel format. The data then transmitted in parallel by assigning each data word to one carrier in the transmission.

Modulation of Data

The data to be transmitted on each carrier is then differential encoded with previous symbols, then mapped into a Phase shift Keying (PSK) format. Since differential encoding requires an initial phase reference an extra symbol is added at the start for this purpose. The data on each symbol is then mapped to a phase angle based on the modulation method.

Inverse Fast Fourier Transform

After the required spectrum is worked out, an Inverse Fourier Transform is used to find the corresponding time waveform. The guard period is then added to the start of each symbol.

Guard Period

The type of guard period used in this simulation is a cyclic extension of the symbol. The length of guard period is then added to the start of each symbol.

Parallel to Serial Conversion

After guard period has been added, the symbol is then converted back to a serial time waveform. This signal is the baseband signal for the OFDM.

Channel

A channel model is then applied to the transmitted signal. Hence both AWGN and Rayleigh fading model are included for investigation. The AWGN is applied to the OFDM signal by adding noise factor $10^{(-SNR/10)}$ to the transmitted signal. In Rayleigh fading model the power of a signal will very randomly according to a Rayleigh distribution. Multipath delay spread then added by simulating the delay spread using an FIR filter. The length of FIR filter represents the maximum delay spread while the coefficient amplitude represents the reflected signal magnitude. The power clipping is applied to the OFDM signal by cutting the signal that higher than a certain determined power value.

Receiver

The receiver basically does the reverse operation to the transmitter. The guard period is removed. The FFT of each symbol is then taken to find the original transmitted spectrum. The phase angle of each transmission carrier is then evaluated and converted back to the data word by demodulating the received phase. The data words are then combined back to the same word size as the original data.

4. RESULT & SIMULATION

Approximation of effect of Non-linearity

We use MATLAB simulations to evaluate the performance of the proposed PAPR reduction technique. To approximate the effect of nonlinear power amplifier in the transmitter, we adopt Rapp's model for amplitude conversion [15]. The relation between amplitude of the normalized input signal g(A) and amplitude of the normalized output signal of the nonlinear power amplifier is given by

$$g(A) = A/(1+A^{2p})^{1/(2p)} \qquad (15)$$

Where p is a parameter that represent the nonlinear characteristic of the power amplifier. The power amplifier approaches linear amplifier as p gets larger. We choose p=3 which is a good approximation of a general power amplifier [15]. The phase conversion of the power amplifier is neglected in this paper. Fig. 2 shows the input-output relation curve of the Rapp's power amplifier model when p=3. The input signal is normalized by a normalization factor to appropriately fit the input signal into the desired range in the input-output relation curve. The normalized output signal is processed back into original scale before normalization. The amount of nonlinear distortion depends on the output back-off (OBO) which is defined as

$$OBO = P_{max}/P_{avg} \quad (16)$$

Where, P_{max} is the output power at the saturation point and P_{avg} the power of the output signal.

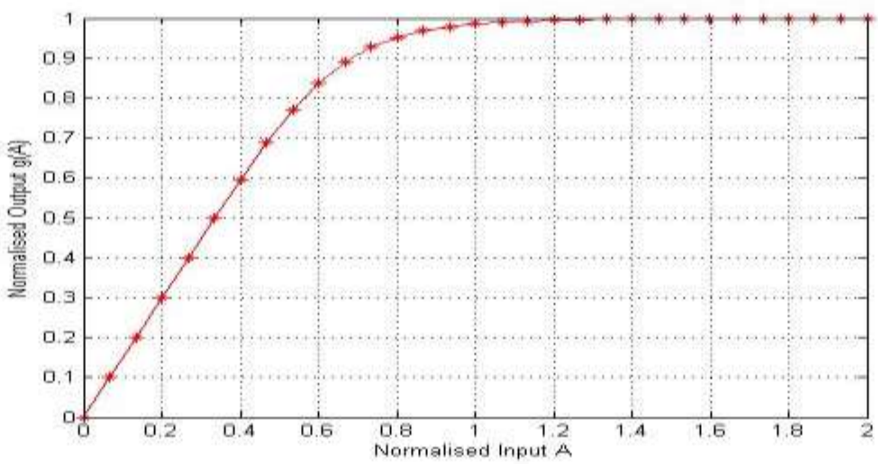

Fig. 2: Input–output relation curve showing non linearity when p=3.

Performance analysis in terms of Symbol Error Rate (SER)

Fig. 2, 3 & 4 shows SER analysis of the proposed technique, ordinary SLM technique and unmodified OFDM. Proposed scheme perform better than ordinary SLM scheme over entire range. To quantify results take Eb/No=5db, here SER for unmodified scheme is 10^{-2}, for ordinary SLM it is $9*10^{-3}$ and for proposed scheme it is $2*10^{-4}$.The performance difference between the proposed technique and the ordinary SLM technique is due to the fact that, in the proposed technique, the phase sequences have a limitation on their structure and thus the improvement of PAPR provided by the proposed technique is not so much as the that from the ordinary SLM technique. In fact, the difference in PAPR improvement between the proposed technique and the ordinary SLM technique is closely related to the value of n, k or the code rate r = k/n. If code rate is close to 0, there is little difference between the CCDF of the proposed technique and that of the ordinary SLM technique. On the contrary, the higher the code rate is, the larger the difference is. But the difference remains quite small when compared with the difference between the proposed technique and unmodified OFDM signal if the code rate is lower than about a half.

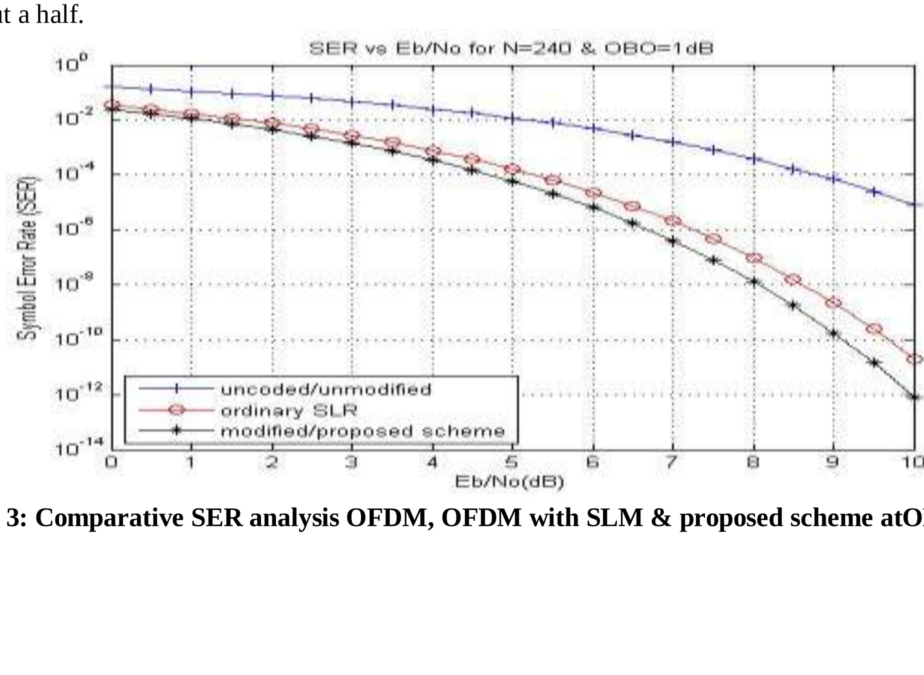

Fig. 3: Comparative SER analysis OFDM, OFDM with SLM & proposed scheme atOBO =1 dB

International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 5 Issue 6, June-2016

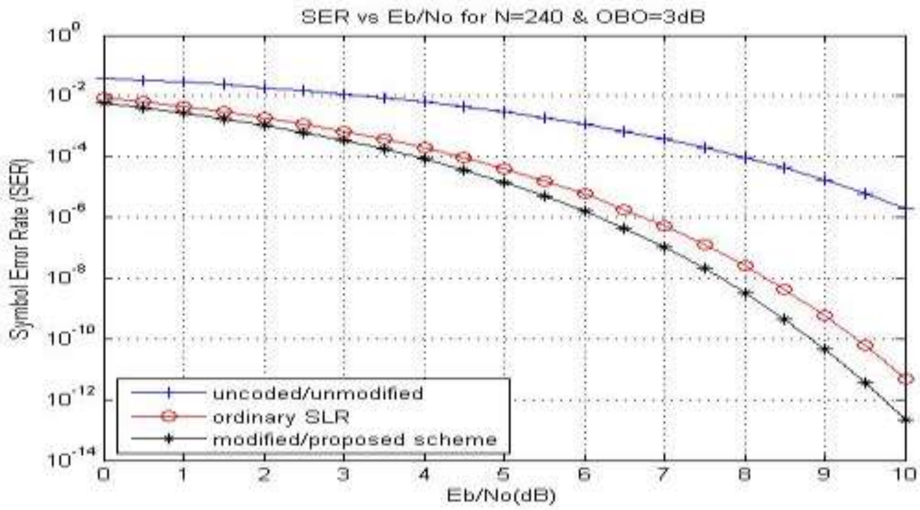

Fig. 4: Comparative SER analysis OFDM, OFDM with SLM & proposed scheme atOBO =3 dB

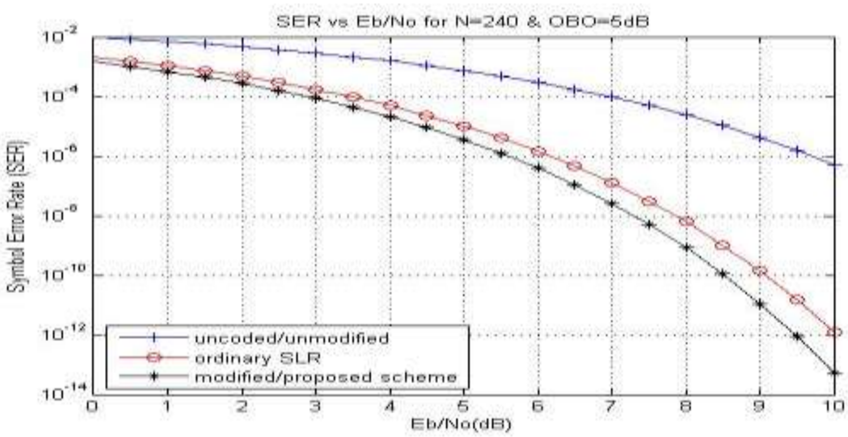

Fig. 5: Comparative SER analysis OFDM, OFDM with SLM & proposed scheme atOBO =5 dB

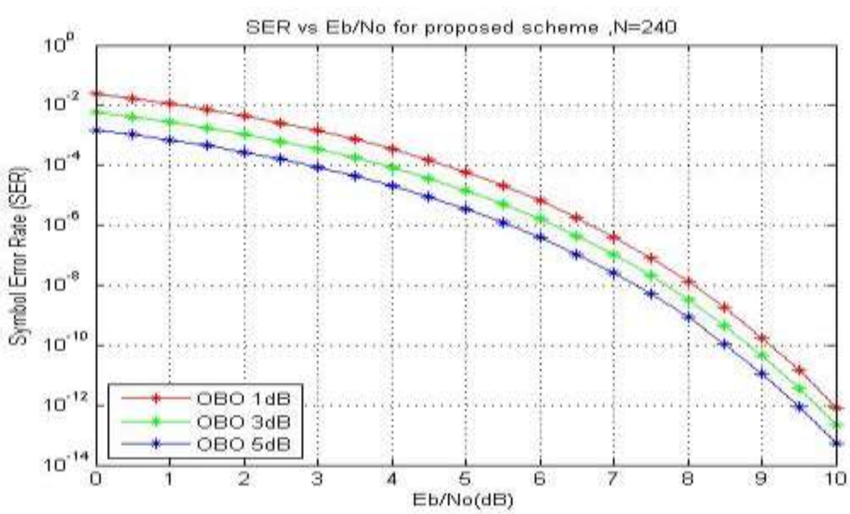

Fig. 6: Comparative SER scheme for various OBO levels.

Fig. 6 show the SER for OBO= 1dB, OBO= 3dB, OBO= 5dB respectively. Performance of system is better for larger value of OBO since the amount of nonlinear distortion is less for larger OBO.

Performance analysis in terms of (Complementary Cumulative Distribution Function) CCDF

Fig. 7, 8 plots the approximate expression for the CCDF of the unmodified OFDM, ordinary SLM technique and proposed SLM technique. Fig. 7 and 8 shows the CCDF of PAPR for N=120 (N represent block length). The CCDF of the ordinary SLM technique is plotted by using with α=2.3 and that of the modified SLM technique is plotted by using (14) with α=2.3 and β=0.8, 0.75, 0.70 for U=8, 16, 32, respectively.

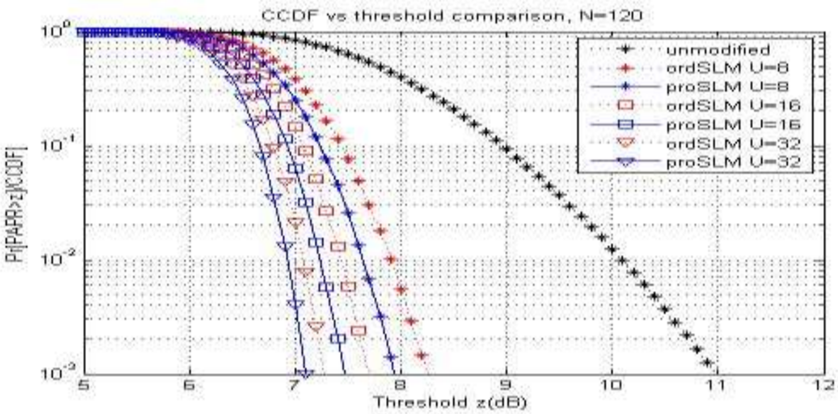

Fig. 7: Comparative analysis of OFDM, OFDM with SLM & proposed scheme in terms of CCDF, N=120

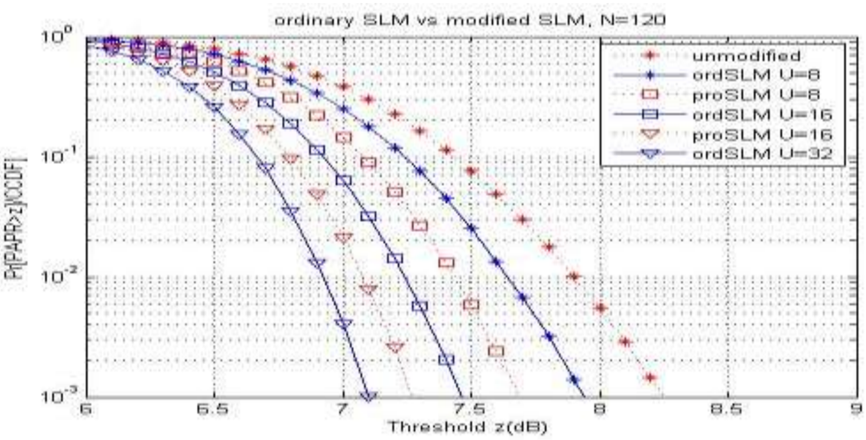

Fig. 8: Comparative analysis ordinary SLM & proposed scheme in terms of CCDF, N=120

CONCLUSION AND FUTURE SCOPE

The paper begins with an introduction to orthogonal frequency division multiplexing technology with its literature survey. Also the OFDM system simulation model and the BER performance of OFDM models have been analyzed. In this paper, an efficient PAPR reduction technique comparison with unmodified OFDM, SLM and proposed scheme has been shown. Design parameters of modified technique are incorporated in the basic OFDM system are studied and optimized. The performance difference between the proposed technique and the ordinary SLM technique is due to the fact that, in the proposed technique, the phase sequences have a limitation on their structure and thus the improvement of PAPR provided by the proposed technique is not so much as the that from the ordinary SLM technique. In fact, the difference in PAPR improvement between the proposed technique and the ordinary SLM technique is closely related to the value of n, k or the code rate r = k/n. If code rate is close to 0, there is little difference between the CCDF of the proposed technique and that of the ordinary SLM technique. On the contrary, the higher the code rate is, the larger the difference is. But the difference remains quite small when compared with the difference between the proposed technique and unmodified OFDM signal if the code rate is lower than about a half. By concluding this paper, the following are some pointers for scope of further research.

- Modified PAPR reduction technique can be applied in MIMO-OFDM, which is the key technology for further 4G applications.
- Minimum interference power criteria can be further imposed on proposed scheme to provide further improvement in performance.

REFERENCES

[1]. R.W Chang, “Synthesis of Band-Limited Orthogonal Signals for Multi-channel Data Transmission,” Bell Syst. Tech., Vol.45, pp.1775-1797, Dec. 1966.
[2]. R.W Chang, “Orthogonal Frequency Division Multiplexing,” U.S Patent 3388455, Jan 6, 1970, Filed Nov.4.1966.
[3]. B.R. Satzberg, “Performance of an Efficient Parallel Data Transmission System,” IEEE Trans. Commun. Technol.,Vol.COM-15, no.6, pp. 805-811, Dec 1967.
[4]. S .Weinstein and P. Ebert, “Data Transmission by Frequency Division Multiplexing Using the Discrete Fourier Transform,” IEEE Transaction on Communication, Vol.19, and Issue: 5, pp. 628–634, Oct.1971.
[5]. B. Hirosaki, “An Analysis of Automatic Equalizers for Orthogonally Multiplexed QAM Systems,” IEEE Transaction Communication, Vol.28, pp.73-83, Jan.1980.
[6]. B. Hirosaki, S. Hasegawa, and A. Sabato, “Advanced Group-band Data Modem Using Orthogonally Multiplexed QAM Technique,” IEEE Trans. Commun. Vol. 34, no. 6, pp. 587-592, Jun. 1986.
[7]. A. Peled and A. Ruiz, “Frequency Domain Data Transmission using Reduced Computational Complexity Algorithms,” Acoustics, Speech, and Signal Processing, IEEE International Conference on ICASSP '80, Vol. 5, pp.964 –967, Apr. 1980.
[8]. M.S Zimmerman and A.L Kirsch, “ The AN/GSC-10 (KATHRYN) Variable rate data modem for HF radio,” IEEE Trans. Commun. Technol.,Vol.15, no.2, pp. 197-205, Apr. 1967.
[9]. W.E. Keasler, Jr., “ Reliable Data Communications over the Voice band-width Telephone Using Orthogonal Frequency Division Multiplexing,” Ph.D dissertation, Univ. Illinois, Urbana, Il, 1982.
[10]. L. J. Cimini, “Analysis and Simulation of a Digital Mobile Channel using Orthogonal Frequency Division Multiplexing,” IEEE Transaction Communications, Vol.33,pp. 665-675. July 1985.
[11]. E.F. Casas and C. Leung, “OFDM for Data Communication over Mobile Radio FM Channels. I. Analysis and experimental results,” IEEE Transaction Communications, Vol.39, no.5, pp. 783-793, May. 1991.
[12]. B.S. Krongold, K. Ramchadran, and D.L Jones, “Computationally Efficient Optimal Power Allocation Algorithms for Multicarrier Communication Systems,” IEEE Transaction Communication,Vol.48, no.1, pp.23-27, Jan. 2000.
[13]. L.J. Cimini, Jr.B. Daneshrad, and N.R Sollenberger, “Clustered OFDM with Transmitter Diversity and Coding,” in proceeding of IEEE Global Tele. Communications. Conf. 1996, pp. 703-707.
[14]. P. H. Moose, “A Technique for Orthogonal Frequency Division Multiplexing Frequency Offset correction,” IEEE Transaction. Communication, Vol. 42, no.10, pp. 2908–2914, 1994.
[15]. T. S. Rappaport, Wireless Communications, principles and practice, 2nd Edition, prentice- Hall publications, 2002.
[16]. V. N. Richard and R. Prasad, OFDM for Wireless Multimedia Communication, Artech house Publisher, London, 2000.
[17]. Joseph Thaliath, Mabel Mary Joy, Elizabeth Priya John, and Debabrata Das, “Service Class Downlink Scheduling in WiMAX,” IEEE International conference on Communication System software and middleware (COMSWARE 2008), Jan 5-10, 2008, Bangalore, India.
[18]. G. V. Rangaraj, D. Jalihal, and K. Giridhar, "On usefulness of multipath diversity for multiple antenna OFDM systems,"IETE Technical Review , vol.21, no.5, pp. 317--324, Sept.-Oct. 2004.
[19]. C. Pradabpet, K.Eupree, S. Chivapreecha, k. Dejhan, “A New Reduction Technique for OFDM-WLAN in 802.11a Systems,” Ninth ACIS International Conference on Software Engineering, Artificial Intelligence, Networking, and Parallel Distributed Computing, 2008. SNPD ‘08’, pp.179-184, 6-8 Aug. 2008.
[20]. S. H. Han and J. H. Lee, "An Overview of Peak-to-Average Power Ratio Reduction Techniques for Multicarrier Transmission," IEEE Wireless Communications, Vol. 12, no. 2, pp. 56-65, 2005.
[21]. Josef Urban and Roman Marsalek, “OFDM PAPR Reduction by Combination of Interleaving with Clipping and Filtering,” IEEE Communication Letter ,pp. 249– 252, June 2007.
[22]. S.H Muller and J.B Huber, “OFDM with Reduced Peak-to-Average power Ratio by Optimum Combination of Partial Transmit Sequences,” IEEE Electronics Letters on Communication & Signal Processing, Vol. 33, Issue. 5, pp. 368-369, 27 Feb. 1997.
[23]. Bauml, R.W.; Fischer, R.F.H.; Huber, J.B, “Reducing the Peak-to-Average Power Ratio of Multicarrier Modulation by Selected Mapping,” IEEE Electronics Letters, Vol.32, pp. 2056-2057, 24 Oct. 1996.
[24]. R.F.H. Fischer, “Widely-Linear Selected Mapping for Peak-to- Average Power Ratio Reduction in OFDM,” IEEE Electronics Letters, pp. 766–767, July 2007.
[25]. L. J. Cimini Jr. and N. R. Sollenberger, "Peak-to-Average Power Ratio Reduction of an OFDM Signal using Partial Transmit Sequences,"IEEE Communications Letters, Vol. 4, no. 3, pp. 86-88, 2000.
[26]. T. T. Nguyen and L. Lampe, "On Partial Transmit Sequences to Reduce PAR in OFDM Systems," Proceedings of IEEE Global Telecommunications Conference (GLOBECOM '06), pp. 1-6, San Francisco, Calif, USA, November-December 2006.
[27]. Siegl, Christian and Fisher, F. H. Robert, “Partial Transmit Sequences for Peak-to Average Power Ratio Reduction in Multi-antenna OFDM,” EURASIP Journal on Wireless Communications and Networking,Vol.8, pp. 1-11, Jan. 2008.
[28]. J. Armstrong, “ Analysis of New and Existing Methods of Reducing Intercarrier Interference due to Carrier Frequency Offset in OFDM,” IEEE Transaction Communication, Vol. 47, no. 3, pp. 365–369, Mar. 1999.
[29]. Russell. M, Stuber. G.L, “Intercarrier interference analysis of OFDM in a mobile environment,” Vehicular Technology Conference, IEEE 45th, Vol.2, pp.820-824,July 1995.