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Review on PAR Reduction Techniques for MIMO-OFDM

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Abstract- Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier communication scheme Plays a prominent role in wireless communication technology as multicarrier transmission scheme. The combination of multiple-input multiple-output (MIMO) technology with orthogonal frequency division multiplexing is an attractive solution for next generation of wireless network. However, practical implementation of OFDM introduced a major drawback known as high Peak-to-Average Power ratio (PAR). This paper inclusion detail of peak-to-Average Power ratio and its reduction techniques.

Index Terms—*Orthogonal Frequency Division Multiplexing (OFDM), Peak-to-Average Power Ratio (PAR), Multiple-Input Multiple-Output (MIMO).*

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I. INTRODUCTION

High speed wireless communication is the growing demand of the new generation of the wireless communication. In earlier single carrier system is used for communication but it is not capable of high data rate [8]. Orthogonal Frequency Division Multiplexing (OFDM) is techniques which used multi carrier for transmitting the data at high speed in communication channel [3]. OFDM mainly used to select the frequency-selectivity of the transmission channels, achieving high data rate without inter symbol interference. The basic principle of OFDM multicarrier modulation scheme, which divides the entire frequency band into many narrowband sub channels in which high bit rate data stream, is transmitted in parallel over a number of lower data rate subcarrier.

Furthermore, to increase the capacity and performance of the system multiple antenna system is used known as the Multiple-Input Multiple-Output (MIMO) System Performance of the Multiple-Input Multiple-Output (MIMO) system with acceptable Bit-error-Rate (BER) proportionally with the number of antennas [4]. Combination of the OFDM and MIMO increase diversity gain and enhance the system capacity of the wireless channel.

However OFDM has the many drawbacks like high peak-to-average power ratio, more sensitive to Doppler spread, frequency and timing synchronization but the major drawback of OFDM is high peak-to-average power ratio (PAR) [6]. High peak-to-average power ration is due to the presence of large number of modulated sub-carrier in an OFDM system. This ratio of the peak to average power values is called as the Peak-to-Average power ratio. High PAR increased complexity in the analog to digital and digital to analog converter in both transmitter and receiver of the system. Also reduced efficiency of the Radio frequency (RF) amplifier which degrade the performance of the system. So that to improve the performance, power efficiency and bit error rate of the system high value peak-to-average must be decreased to the normal value. This paper included the various techniques for the reduction of the high peak-to-average power ratio.

II. SYSTEM MODEL

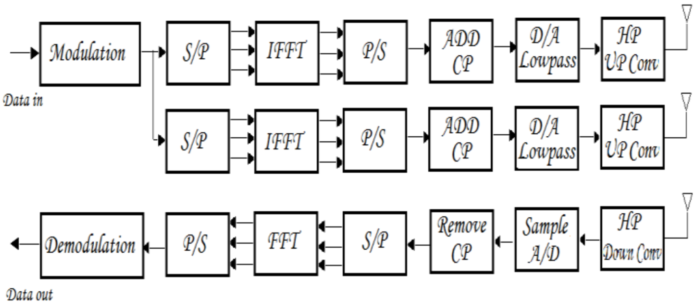

Figure 1. Basic Block Diagram of MIMO-OFDM

High data rate wireless communication access is demand by many applications in new generation. High data rate transmission required more bandwidth in traditional system. However due to limited spectral band width, it is often impractical or sometime very expensive to increase bandwidth. To increased the bandwidth and channel capacity multiple transmit and receive antennas are used which terms alternative solution of the high data rate of the system.

Combination of the MIMO with OFDM is effective solution of the new generation wireless communication. OFDM modulation with K sub-carrier turns a broadband wireless channel into a set of frequency flat MIMO channel.

A MIMO-OFDM consist of N transmit and N receiver antennas can be formulated for each sub-carrier as follows.

$$Y_k = H_k . W_k . S_k + n_k \quad (1)$$

Where Y_k is the receiver signal at k-th sub-carrier, H_k matrix represent the channel response, S_k vector contain the transmitted symbol with power constraint. W_k is the precoder matrix. n_k vector is the additive white gussian noise with zero-mean gussian. In this system modulator takes a single stream of binary input data and transform into N_t Parallel stream of data. Inverse Fast Fourier Transform (IFFT) is the part of the modulation process and Fast Fourier Transform (FFT) is the part of the demodulation process. After the IFFT cyclic prefix is added in the next stage and in demodulation process cyclic prefix is remove for recover original data stream by the demodulation.

III. PEAK-TO-AVERAGE POWER RATIO

Peak-to-Average Power Ratio (PAPR) is defined as the relation between the maximum power divided by the average power of the OFDM system [5]. PAPR occurs when in the multi carrier system the different sub-carrier is out of the phase with each other. At each instant value of phase is different with respect to each other. When all the point achieves the maximum value simultaneously, this will cause the output envelope to suddenly increase which cause output to the out of band. Due to large number of independently modulated sub-carrier present in an OFDM system, the peak value of the system can be very high as compare to the average of the whole system. The ratio of peak power to average power value is known as peak-to-average power ratio.

An OFDM is the multi carrier modulation scheme when all the sub-carrier or an OFDM signal are added for transmission its give high PAPR. When the same phase N signals are added output shown that peak power that is N time the average power of the signal. So OFDM signal has the very high PAPR.

An OFDM signal of N sub-carrier can be represent as,

$$X(t) = \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} X[k] e^{j2\pi f_k t}, 0 \le t \le T_s \qquad (2)$$

Where T_s is the duration of OFDM signal and $f_k = {}^{k}/_{T_s}$

The high PAPR of the OFDM signal arises from the summation in the above IFFT expression.

PAPR of the OFDM signal is define as [5],

$$PAPR = \frac{P_{peak}}{P_{avg}} = \max[x_n^{\ 2}]/E[x_n^{\ 2}] \qquad (3)$$

Where E[.] denotes the expectation operation.

IV. PEAK TO AVERAGE POWER REDUCTION TECHNIQUE

Peak to Average Power ratio (PAPR) is the major problem in the Orthogonal Frequency Division Multiplexing (OFDM) [6]. For reduction or minimization of PAPR various techniques are used [7]. Some of the techniques used for the PAPR reduction like Clipping and Filtering, Coding, Partial Transmit sequence (PTS), Selected Mapping (SLM), Tone Reservation (TR), Tone Injection (TI), Active constellation Extension (ACE). These techniques are the foundation of PAPR reduction. This techniques must change hardware of transmitter and receiver according to the techniques which is used for PAPR reduction. Also used some techniques they does not change hardware this techniques are based on the software programming or also called the channel coding.

A. Basic Techniques of PAPR Reduction:

1. CLIPPING AND FILTERING

This is a very simplest technique used for PAPR reduction of OFDM signal. Clipping means the amplitude of the signal is clipped at the predefined values which limit the peak value of the input signal to a predetermined or threshold value [10]. Let X[n] denote the input signal and X_c [n] denote the clipped signal of X[n], which can to represent as,

$$X[n] = \begin{Bmatrix} -A & X[n] \le -A \\ X[n] & |X[n]| < A \\ A & X[n] \ge A \end{Bmatrix} \qquad (4)$$

Where A is the threshold or predetermines value of clipping level.

Clipping is the simple but it has some drawback. Clipping cause signal distortion which increase bit-error-rate performance. After the filtering operation performed on the clipped signal clipping level may exceed to the specified for the clipping operation.

2. Coding

Coding is the technique of reduction of PAPR by selecting such a codeword that reduced the PAPR. Coding does not cause any distortion and out of band radiation. But it suffers from bandwidth efficiency as the code rate is reduced. It is also suffer from the complexity of the algorithm to find the optimal code and store large tables for encoding and decoding for a multi-carrier system.

3. SELECTED MAPPIMG (SLM)

Selected Mapping (SLM) technique has been proposed by Bauml in 1965. This method reduced PAPR of the system by selected mapping so it is call Selected Mapping technique [11]. A set of generated signal has the same information in selected mapping, and the most favorable signal is selected for transmitted. In the SLM the input data stream is multiply by random weighted factor and the lowest PAPR is chosen for transmission. To recover the original data at the receiver side multiplying sequence can be sent as side information. SLM method for reduction the PAPR does not eliminate the peak. The drawback of this technique is the side information that requires to be transmitted to the receiver of the system in order to recover the original data stream.

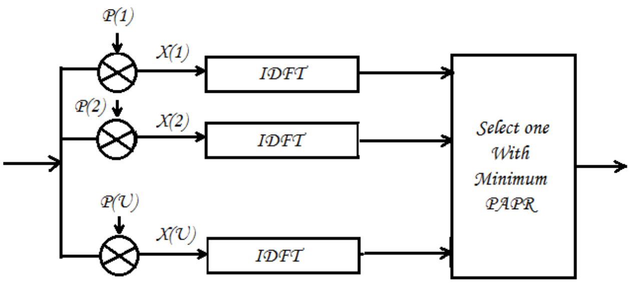

Figure 2. Block Diagram of SLM Technique

Fig shows the block diagram of selective mapping technique. Let input data block,

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$$X = [X_0, X_1, X_2, \dots\dots, X_{N-1}]^T \quad (5)$$

When multiply with independent phase sequence results,

$$P^u = [P_0{}^u, P_1{}^u, P_2{}^u, \dots\dots, P_{N-1}{}^u]^T, u = [1,2, \dots\dots u-1] \ (6)$$

u = number of Phase Sequence.

Then get the time domain signal by applying IFFT getting data block with different PAPR values and phase sequence.

$$X^u = [X_0{}^u + X_1{}^u + X_2{}^u + \cdots + X_{N-1}{}^u]^T \quad (7)$$

After IFFT operation select one with low PAPR for transmits. For measurement the PAPR commutative distributed function (CDF) and Complementary commutative distributed function (CCFD) is used. CCDF is measure the probability that the PAPR of a data block exceed the given threshold value.

4. *PARTIAL TRANSMIT SEQUENCE (PTS)*

Partial transmit sequence technique has been proposed by Muller and Hubber in 1997. In this technique first step is the phase shifting of the sub-block and then multiplication of data structure by random vector [12]. The main idea behind this technique is that input data block is divided into non-overlapping sub-block and each sub-block is phase shifted by a constant factor to reduced PAPR. PTS technique is modified version of the SLM technique. PTS method has a capability that more minimized the PAPR then SLM and main advantage of the PTS technique is no need to send side information. This advantage reduced the complexity of the PTS technique

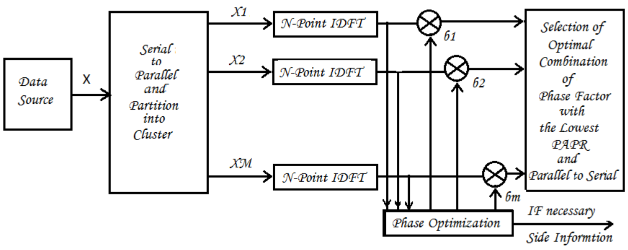

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Figure 3. Block Diagram of PTS Technique

5. *TONE RESERVATION (TR)*

Tone reservation technique is proposed for PAPR reduction. In this technique small set of tone is used for PAPR reduction. This can be originated as convex problem and this problem can be solved accurately. The amount of PAPR reduction is depend on the number of reserved tones, location of the reserved tones, amount of complexity and allowed power on reserved tone [13].

Tone reservation show that reserving a small fraction of tones give larger minimization in PAPR even using simple algorithm.

The advantages of tone reservation method is that it is less complex, no side information is sent, and also no additional operation can be performed at the receiver side.

6. *TONE INJECTION (TI)*

Tone injection technique has been proposed by Muller, S. H, and Huber. This technique is based on the increased size of the constellation. Each point of the original constellation is mapped into several equivalent points in the extended constellation [13]. So that all the information can be mapped into several equitant constellation point.

In Tone injection replacing the new point extended constellation in place of basic constellation which injecting a tone with a proper phase and frequency in multi carrier system.

The drawback of the tone reservation is need to decoding side information at the receiver side and so that needed extra IFFT operation which increased the complexity of the system.

7. *ACTIVE CONSTELLATION EXTENSION (ACE)*

This technique is similar to the tone injection technique for reduction of PAPR of the system. In the technique some of the outer signal constellation points in the data blocks are extended towards the outside of the original constellation such that PAPR of system reduced or minimized [17].

TABLE 1 COMPARISON OF PAPR REDUCTION TECHNIQUES

NAME OF SCHEMES	**NAME OF PARAMETERS**		
	Distortion less	Power increase	Data rate loss
Clipping and Filtering	No	No	No
Coding	Yes	No	Yes
Selective Mapping (SLM)	Yes	No	Yes
Partial Transmit Sequence (PTS)	Yes	No	Yes
Tone Reservation (TR)	Yes	Yes	Yes
Tone Injection (TI)	Yes	Yes	No
Active Constellation Extended (ACE)	Yes	Yes	No

B. *Precoding Based Techniques:*

In MU-MIMO system, the base station transmits the message signal in same frequency and time slot to different user in the cell. so that the transmitted signal may overlap. It is necessary to implement the system which is capable of suppressing interference due to same frequency and time slot used for the different user. Suppression of interference can be reduced by using linear precoding and decoding at transmitter and receiver [17].

Prominent part of the precoding techniques is the channel matrix. In precoding the all streams of data is given for base band modulation. In conventional OFDM techniques modulated data directly giving into IFFT block to generate OFDM signal. In precoding OFDM techniques the modulated data is first multiply with a channel matrix. This channel

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matrix is also called as the precoding matrix. After the multiplying the data stream this data stream apply to IFFT operation. To reduce the PAPR precoding matrix should be design very carefully. This precoding matrix is denote by P and is define as

$$P = \begin{bmatrix} P_{00} \cdots \cdots\cdot & P_{0,L-1} \\ \vdots & \vdots \\ P_{L-1,0} \cdots \cdots & P_{L-1,N-1} \end{bmatrix} \quad (8)$$

Where $P_{ij,s}$ are the entries (complex number) of this precoding matrix.

To reduced PAPR more effectively and without destroying design procedure of precoding schemes must be very important of the system.

1. *Lest square precoding (Zero forcing Precoding)*

In MIMO system precoding can be design in different ways. The optimal method used for maximize SINR for each user but its precoding matrix expression is complex so that it cannot be obtained closed from the values. Zero-Forcing (ZF) is the simpler approach for optimization. In ZF place constraint that the interference a user faces is zero. Block diagonalization (BD) implements ZF beam forming and is a generalization of channel inversion for the multiple antenna. This technique may be used to maximize throughput by applying this constraint or minimize quality of services guarantee in terms of rate.

2. *MATCHED FILTER PRECODING:*

Match filter (MF) tries to maximize the power associated with the desired signal. However, MF does not suppress totally the interference at the received signal. Hence the performance of the MF is not good.
For the purpose to maximize the desired signal $H_w\ B_w d_w$, MF is designed as:

$$B_w^{MF} = \frac{H_w^H}{\| H_w \|} \quad (9)$$

Where B_w transmitted filter, d_w data stream, H_w is channel matrix.

3. *PMP (Joint precoding, Modulation and PAR Reduction)*

Jointly perform MU precoding, OFDM modulation and PAR reduction referred to as PMP [9]. Each time domain signal after the OFDM modulation would reduce the PAPR but unfortunately no longer allow the equalization of ISI using conventional OFDM demodulation. This type of techniques need sophisticated equalization schemes in each terminal. To enable the use of conventional OFDM demodulation in the receiver formulate convex optimization problem which jointly perform MU precoding, OFDM Modulation and PAR reduction.

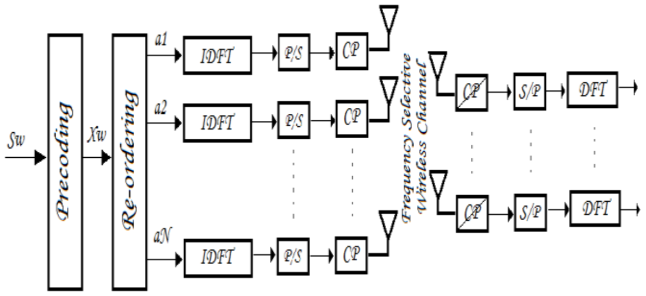

Figure 4. Basic Structure of PMP

In order to remove MUI PMP constraint must hold

$$S_w = H_w X_w \quad (10)$$

PAR reduction is achieved similarly to (P-INF), with main difference that minimize the $l_{\infty norm}$ of the time-domain sample. In order to simplify notation the linear mapping between the time-domain and frequency-domain transit vactor.

V. Performance Parameter Of PAPR

The Cumulative Distribution Function (CDF) is the most important parameters of the OFDM for measure the PAPR. CDF is used to measure the efficiency of any PAPR techniques. CDF is regularly used parameter but to measure the probability that the PAPR of the data block exceeds the predefined value or not complementary of the CDF is used. Complementary of the CDF is known as the Complementary Cumulative Distribution Function (CCDF) [16]-[9].
PAPR of the OFDM is expressed as

$$PAPR = \frac{P_{peak}}{P_{avg}} = \max[x_n{}^2]/E[x_n{}^2]$$

The Cumulative function of the X_{max} is given by,

$$FXmax(x) = P(Xmax < x)$$

$$CDF = (1 - e^{\frac{-x^2}{2\sigma^2}})$$

The probability that the PAPR is below threshold value can be written as,

$$P(PAR \le X) = (1 - e^{\frac{-x^2}{2\sigma^2}})^N$$

Now consider as the complementary cumulative distribution function

$$CCDF = 1 - (1 - e^{\frac{-x^2}{2\sigma^2}})^N$$

By using this CCDF values different techniques compared and shows the graphical representation which shows the performance of techniques is best.

VI. Conclusion

MIMO-OFDM is prominent techniques for the high speed wireless communication. Peak to Average Power Ration is major drawback of OFDM which has been discussed in this paper. In this different PAPR reduction has also been discussed. All techniques have its some merit and demerit.

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According to requirement or the implement cost techniques are used for PAPR reduction.

REFERENCES

[1] E. G. Larsson, S. O. Edfors, Fredrik Tufvesson and Sweden Thomas L. Marzetta, "Massive MIMO for Next Generation Wireless Systems", IEEE Communication Magazine, February 2014.

[2] H. Q. Ngo, Mattaiou and Laesson, "Performance analysis of Large scale MU-MIMO with optimal linear receivers", IEEE Communication technologies workshop, pp. 59-64, Oct. 2012.

[3] N. lasorte, W. J. Barnes and H. H. Refai, "The History of Orthogonal Frequency Division Multiplexing", IEEE Communication Magazine, pp. 26-35, Nov. 2009.

[4] A. K. Sahu and S. S. Singh,"BER Performance Improvement Using MIMO Technique Over Rayleigh Wireless Channel With Different Equalizers", International Journal Of Engineering And Technology (Ijet), Vol 4 No 5 Oct-Nov 2012.

[5] Wulich D., "Definition of efficient PAPR in OFDM", IEEE Communication Letters, pp. 832-834, Sept. 2005.

[6] A. Gangwar and M. Bhardwaj, "An Overview: Peak to Average Power Ratio in OFDM system & its Effect", International Journal of Communication and Computer Technologies Volume 01 – No.2, Issue: 02 September 2012.

[7] P. Choudhury and A. Deshmukh, "Comparison and analysis of PAPR reduction techniques in OFDM", in IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) ISSN: 2278-2834, ISBN: 2278-8735. Volume 4, Issue 5 Jan. - Feb. 2013.

[8] J. Zhang, Y. Pei and N. Ge, "Comparison of Achievable Rates of OFDM and Single Carrier Communication Systems", Tsinghua Science And Technology Volume 17, Number 1, February 2012.

[9] C. Studer and E. G. Larsson,"PAR-Aware Large-Scale Multi-User MIMO-OFDM Downlink", in IEEE Journal On Selected Areas In Communications, Vol. 31, No. 2, pp 303-313, February 2013.

[10] D. Guel And Jacques, "Palicotanalysis And Comparison Of Clipping Techniques For OFDM Peak-To-Average Power Ratio Reduction", IEEE Digital Signal Processing 2009.

[11] W. Meng, Z. Feng, Li Yu1 and Qi Song, "Research on SLM Algorithm for PAPR reduction in MB-OFDM UWB Systems," Procedia Environment Sciences, pp 227-231, 2011.

[12] A. Goel, P. Gupta and M. Agrwal, "SER analysis of PTS based Techniques for PAPR reduction in OFDM system", Digital Signal Processing, pp. 302-313, September 2012.

[13] T. Wattanasuwakull and W. Benjapolakul, "PAPR Reduction for OFDM Transmission by using a method of Tone Reservation and Tone Injection", IEEE ICSC, pp 273-277 2005.

[14] B. Kang, H-G. Ryu, and saangburm Ryu, "A PAPR Reduction Method Using New ACE (Active Constellation Extension) With Higher Level Constellation", IEEE International Conference on Signal Processing and Communications, November 2007, pp 24-27..

[15] Namitha.A.S and Sudheesh.P, "Improved Precoding Method for PAPR Reduction in OFDM with Bounded Distortion", International Journal of Computer Applications Volume 2 – No.7, June 2010, pp 0975 – 8887.

[16] S. Ramavath and R. S. Kshetrimayum, "Analytical calculations of CCDF for some common PAPR reduction techniques in OFDM systems", International Conference on Communications, Devices and Intelligent Systems, pp 393-396 2012.

[17] N. A. Abdual Latiff, N.I.A Ishak and M. H Yusoff "Performance Analysis on Peak-to-Average Power Ratio (PAPR) Reduction Techniques in Orthogonal Frequency Division Multiplexing (OFDM) system", International Journal of Inventive Engineering and Science, vol. 1, Issue-9, August 2013.

[18] B. M. Lee, Rui J.P. de Figueiredo, " MIMO-OFDM PAPR reduction by selected mapping using side information power allocation", Digital Signal Processing, pp 462–471, July 2009.

[19] W. O. Popoola, Z. Ghassemlooy, and B. G. Stewart, "Pilot-Assisted PAPR Reduction Technique for Optical OFDM Communication Systems", Journal Of Lightwave Technology, Vol. 32, No. 7, April 2014.

[20] S. K. Mohammed and E. G. Larsson, "Per-Antenna Constant Envelop Precoding for Large Multi-User MIMO System", IEEE Transactions on Communication, vol. 61, No. 3, pp 1059-1071, March 2013.