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AN EFFICIENT SELECTED MAPPING BASED APPROACH FOR PAPR REDUCTION OF OFDM SIGNALS

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***Abstract*- Orthogonal Frequency Division Multiplexing has become a popular modulation method in high speed wireless communication. It has been successfully applied to a wide variety of digital communication application over the past several years. OFDM is suitable for high data rate transmission with selective mapping techniques over wireless channels. In other hand, OFDM technique has its high Peak to Average Power Ratio. In case, while using the linear power amplifier at the transmitter side, it's operating point will go to the saturation region due to the high PAPR which leads to in-band distortion and out-band radiation. This may be avoided by increasing the dynamic range of power amplifier which leads to high cost and high consumption of power at the base station. This paper presents an efficient technique for the selected mapping which reduces the PAPR. Also the analysis of bit error rate performance and the computational complexity for this technique are being discussed. This scheme has an important advantage of avoiding the extra bits along with the transmitted OFDM signal. This scheme may also be applied for the multiple transmitting antenna cases.**

Keywords— Orthogonal Frequency Division Multiplexing, Peak to Average Power Ratio, Partial Transmit Sequence, Selected Mapping, and Discrete Fourier transform

I. INTRODUCTION

This paper provides an overview on Orthogonal Frequency Division Multiplexing technique and identifies popular peak to average power Ratio reduction schemes characteristically in addition it demonstrates that selected mapping is a promising reduction techniques.

Wireless communication has many advantages, such as speed, simplicity, mobility and flexibility, but in the same time it suffers from, interference and multipath propagation. The demand of high data rate services has been increasing very rapidly and there is no slowdown in sight. We know that the data transmission includes both wired and wireless medium. Often, these services require very reliable data transmission over very harsh environment.

Most of these transmission systems experience much degradation such as large attenuation, noise, interference, time variance, nonlinearities and must meet the finite constraints like power limitation and cost factor. In multi-carrier modulation, the most commonly used technique is Orthogonal Frequency Division Multiplexing (OFDM); it has recently become very popular in wireless communication.

Unfortunately the major drawback of OFDM transmission is its large envelope fluctuation which is quantified as Peak to Average Power Ratio (PAPR). Since power amplifier is used at the transmitter, so as to operate in a perfectly linear region the operating power must lies below the available power. For reduction of this PAPR lot of algorithms have been developed. All of the techniques have some sort of advantages and disadvantages [1].

Clipping and Filtering is one of the basic technique in which some part of transmitted signal undergoes into distortion. Also the Coding scheme reduces the data rate which is undesirable. Tone Reservation (TR) technique it also allows the data rate loss. Again the techniques like Tone Injection (TI) and the Active Constellation Extension (ACE) having criteria of increasing power will be undesirable in case of power constraint environment. If we go for the Partial Transmit Sequence (PTS) and Selected Mapping (SLM) technique, the PTS technique has more complexity than that of SLM technique.

This Selected Mapping is one of the promising techniques due to its simplicity for implementation which introduces no distortion in the transmitted signal. It has been described first in [2], known as the classical SLM technique. This technique has one of the disadvantages of sending the extra Side Information (SI) index along with the transmitted OFDM signal, which may be avoided using a special technique described in [3].

On the other hand, OFDM suffers a high Peak to Average Power Ratio (PAPR). A high PAPR makes the signal peaks move into the non-linear region of the RF power amplifier which causes signal Distortion. A large PAPR increases the complexity of the analog-to-digital and digital-to-analog converters and reduces the efficiency of the RF power amplifier. Recently, researchers have discovered many techniques on PAPR reduction, for instances, clipping, coding, and selected mapping (SLM) [1].

OFDM is a combination of Modulation and Multiplexing. Multiplexing generally refers to independent signals, those produced by different sources. In OFDM the multiplexing is applied to independent signals but these independent signals are subset of the one main signal. In OFDM the signals itself is first split into independent channels, modulated by data and then re-multiplexed to create the OFDM carrier

This paper is organized as follow. Section 2 reviews the background and literature survey. Section 3 reviews the basic concepts of OFDM. In addition, it will present cyclic prefix which is a technique that is used to resolve inter symbol interference (ISI) and inters carrier interference (ICI). Section 4 discusses the PAPR and related issues. Section 5 discusses different well known reduction technique to reduce the peak-to-average power ratio (PAPR). Section 6 shows results of computer simulations on the performance of SLM technique. Finally, section 7 contains the conclusions and future work recommendation.

II. Background and Literature Survey

This section attempts to carry out a detailed literature survey specific to the objectives of this research and to identify the gaps which in turn provide the clue for the proposed research.

Mishra [1] shown that OFDM with Quadrature amplitude (QAM) technique may be used for high speed optical applications. As the order of modulation increases, the bit error rate (BER) increases, forward error correction (FEC) coding like LDPC coding is generally used to improve BER performance. LDPC provides large minimum distance and also the power efficiency of the LDPC code increase significantly with the code length.

Young [2] developed Channel estimation in the presence of frequency offsets is developed for cooperative orthogonal frequency-division multiplexing (OFDM) systems. A two-time-slot cooperative channel estimation protocol is proposed. The source broadcasts the training sequence to the relays and the destination and the relays retransmit the training sequence. Pilot designs for amplify-and-forward (AF) and decode-and-forward (DF) relays are derived.

Malode [4] have used Linear Block Code (LBC) with Extended Hamming to check the improvement of the system performance in BER (bit error rate). The results are obtained for different channels Like Additive White Gaussian Noise (AWGN).

Wang [5] discussed tone reservation (TR) based OFDM systems, the peak to average power ratio (PAPR) reduction performance mainly depends on the selection of the peak reduction tone (PRT) set and the optimal target clipping level. Finding the optimal PRT set requires an exhaustive search of all combinations of possible PRT sets, which is a nondeterministic polynomial-time (NP-hard) problem, and this search is infeasible for the number of tones used in practical systems.

Sharma [6] have used the concept of Turbo coded OFDM (Orthogonal frequency division multiplexing) which improves the system throughput. Orthogonal frequency division multiplexing is a popular modulation method in high speed wireless transmission. It removes the detrimental effect of multipath fading by partitioning the wideband fading channel into flat narrow band channels. This will help to maintain the system performance under a desired bit error rate, as there were errors occurring in burst form in OFDM which eventually degrades the efficiency of the system.

Kaur and Mathur [7] have studied Orthogonal Frequency Division Multiplexing (OFDM) as it had been successfully applied to a wide variety of digital communication applications over the past several years. OFDM is a suitable candidate for high data rate transmission with forward error correction (FEC) methods over wireless channels. OFDM is a suitable candidate for high data rate transmission with forward error correction (FEC) methods over wireless channels.

In this paper, the system throughput of a working OFDM system has been enhanced by adding turbo coding. The use of turbo coding and power allocation in OFDM is useful to the desired performance at higher data rates. Simulation is done over additive white Gaussian noise (AWGN) and impulsive noise (which is produced in broadband transmission) channels.

Molish [8] shown that with increased data rates the BER (Bit Error Rate) performance may degrade. So it is a must for the Cognitive Radio to accordingly add processing circuits to maintain the BER. Orthogonal frequency division multiplexing-based transmission is a promising candidate for a flexible spectrum pooling system in DSA environment, where the implementation achieves high data rates via collective usage of a large number of subcarrier bands. This paper discusses on forward error correction by using turbo codes. The combination of OFDM and turbo coding and recursive decoding allows these codes to achieve near Shannon's limit performance in the turbo cliff region.

III. Orthogonality And OFDM

If the FDM system above had been able to use a set of sub carriers that were orthogonal to each other, a higher level of spectral efficiency could have been achieved. The guard bands that were necessary to allow individual demodulation of sub carriers in an FDM system would no longer be necessary. The use of orthogonal sub carriers would allow the sub carriers' spectra to overlap, thus increasing the spectral efficiency.

As long as orthogonality is maintained, it is still possible to recover the individual sub carriers' signals despite their overlapping spectrums. If the dot product of two deterministic signals is equal to zero, these signals are said to be orthogonal to each other.

Orthogonality may also be viewed from the standpoint of stochastic processes. If two random processes are uncorrelated, then they are orthogonal. Given the random nature of signals in a communications system, this probabilistic view of orthogonality provides an intuitive understanding of the implications of orthogonality in OFDM [9].

OFDM is implemented in practice using the Discrete Fourier Transform (DFT). Recall from signals and systems theory that the sinusoids of the DFT form an orthogonal basis set, and a signal in the vector space of the DFT may be represented as a linear combination of the orthogonal sinusoids.

One view of the DFT is that the transform essentially correlates its input signal with each of the sinusoidal basis functions. If the input signal has some energy at a certain frequency, there will be a peak in the correlation of the input signal and the basis sinusoid that is at that corresponding frequency. This transform is used at the OFDM transmitter to map an input signal onto a set of orthogonal sub carriers, i.e., the orthogonal basis functions of the DFT.

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Similarly, the transform is used again at the OFDM receiver to process the received sub carriers. The signals from the sub carriers are then combined to form an estimate of the source signal from the transmitter. The orthogonal and uncorrelated nature of the sub carriers is used in OFDM with powerful results. Since the basic functions of the DFT are uncorrelated, the correlation performed in the DFT for a given sub carrier only sees energy for that corresponding sub carrier.

The energy from other sub carriers does not contribute because it is uncorrelated. This separation of signal energy is the reason that the OFDM sub carriers spectrums may overlap without causing interference [10].

It is important to understand that the carriers generated by the IFFT chip are mutually orthogonal. This will allow understanding the signal is transmitted and receiver received the signal. Mathematically, each carrier may be described as a complex wave [10]:

$$S_c(t) = A_c(t)\, e^{[j((_c(t)+\ _c(t))]} \qquad \text{.....1}$$

The real signal is the real part of sc (t). Ac (t) and $\phi_c(t)$, the amplitude and phase of the carrier, may vary on a symbol by symbol basis. The values of the parameters are constant over the symbol duration period t. OFDM consists of many carriers. Thus the complex signal Ss (t) is represented by:

$$S_s(t) = \frac{1}{N}\sum_{n=0}^{N-1} A_N(t)e^{j\omega n(t)}e^{\phi n(t)} \qquad \text{.....2}$$

Where-

$\omega_n = \omega_0 + n$

This is of course a continuous signal. If we consider the waveforms of each component of the signal over one symbol period, then the variables Ac (t) and φc (t) take on fixed values, which depend on the frequency of that particular carrier, and so may be rewritten:

$\emptyset_n(t) = \emptyset_n$

$A_n(t) = A_n$

If the signal is sampled using a sampling frequency of 1/T, then the resulting signal is represented by:

$$s_s\ (KT) = \frac{1}{N}\sum_{n=0}^{N-1} A_n\ e^{[j(\omega_0+n\Delta\omega)KT+\varphi_n\,]} \qquad \text{.....3}$$

At this point, we have restricted the time over which we analyze the signal to N samples. It is convenient to sample over the period of one data symbol. Thus we have a relationship: t=NT If now simplifies equation 3.3, without a loss of generality by letting ω_0= 0, then the signal becomes:

$$s_s\ (KT) = \frac{1}{N}\sum_{n=0}^{N-1} A_n\ e^{j\varphi_n}\ e^{j(n\Delta\omega)KT} \qquad \text{.....4}$$

Equation 3.4 may be compared with the general form of the inverse Fourier transform:

$$g(KT) = \frac{1}{N}\sum_{n=0}^{N-1} G\left(\frac{n}{NT}\right) e\text{^}(2\pi kn/N) \qquad \text{.....5}$$

In Equation 5, the function $A_n e^{J\emptyset_n}$ is no more than a definition of the signal in the sampled Frequency domain, and s (kT) is the time domain representation. Equation 4 and 5 are equivalent if:

$$\Delta f = \frac{\Delta\omega}{2\pi} = \frac{1}{NT} = \frac{1}{\tau} \qquad \text{.....6}$$

The given condition is required for orthogonality Thus, one consequence of maintaining orthogonality is that the OFDM signal may be defined by using Fourier transform procedures.

IV. OFDM GENERATION AND RECEPTION

OFDM signals are generated digitally due to the difficulty in creating large banks of phase locks oscillators and receivers in the analog domain. The block diagram of a OFDM transceiver is shown in Figure 1. The transmitter section converts digital data to be transmitted, into a mapping of subcarrier amplitude and phase. It then transforms this spectral representation of the data into the time domain using an Inverse Discrete Fourier Transform (IDFT).

The Inverse Fast Fourier Transform (IFFT) performs the same operations as an IDFT, except that it is much more computationally efficiency, and so is used in all practical systems. In order to transmit the OFDM signal the calculated time domain signal is then mixed up to the required frequency [11].

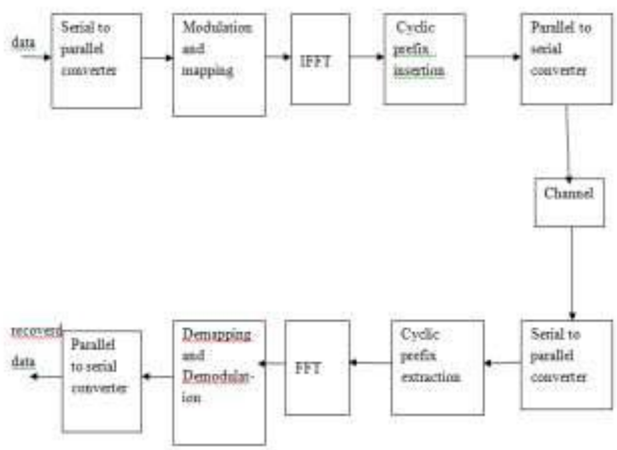

Figure 1: Block diagram of a basic OFDM transceiver

The receiver performs the reverse operation of the transmitter, mixing the RF signal to base band for processing, then using a Fast Fourier Transform (FFT) to analyze the signal in the frequency domain [12]. The amplitude and phase of the sub carriers is then picked out and converted back to digital data. The IFFT and the FFT are complementary function and the most appropriate term depends on whether the signal is being received or generated. In cases where the signal is independent of this distinction then the term FFT and IFFT is used interchangeably.

A. Serial to parallel conversion

Data to be transmitted is typically in the form of a serial data stream. In OFDM, each symbol typically transmits 40 - 4000 bits, and so a serial to parallel conversion stage is needed to convert the input serial bit stream to the data to be transmitted in each OFDM symbol. The data allocated to each symbol depends on the modulation Scheme used and the number of sub carriers. For example, for a sub carrier modulation of 16 QAM each sub carrier carries 4 bits of data, and so for a transmission using 100 sub carriers the number of bits per symbol would be 400 [12].

At the receiver the reverse process takes place, with the data from the sub carriers being converted back to the original serial data stream. When an OFDM transmission occurs in a multipath radio environment, frequency selective fading may result in groups of sub carriers being heavily attenuated, which in turn may result in bit errors. These nulls in the frequency response of the channel may cause the information sent in neighboring carriers to be destroyed, resulting in a clustering of the bit errors in each symbol.

Most Forward Error Correction (FEC) schemes tend to work more effectively if the errors are spread evenly, rather than in large clusters, and so to improve the performance most systems employ data scrambling as part of the serial to parallel conversion stage. This is implemented by randomizing the sub carrier allocation of each sequential data bit.

At the receiver the reverse scrambling is used to decode the signal. This restores the original sequencing of the data bits, but spreads clusters of bit errors so that they are approximately uniformly distributed in time [11].
This randomization of the location of the bit errors improves the performance of the FEC and the system as a whole.

B. Analysis of Covariance

If we consider two random variables X and Y then the covariance between these two random variables is defined as-

$$C_{xy} = E[(X - \mu x)(Y - \mu y)] = E[XY] - E[X]E[Y] \quad \text{.....7}$$

Where-

$E[X] = \mu x$ (mean of X)

$E[Y] = \mu y$ (mean of Y)

As we are using the random phase vectors to generate the alternative OFDM signals in case of this SLM technique so it is important to analyze the covariance between the two alternatives phase vectors. It is because we know that the PAPR reduction performance improves if the alternative OFDM signals are mutually independent.

When the number of subcarriers N for the OFDM signal is large then according to the central limit theorem the time domain samples have a Gaussian distribution. If the OFDM signal sequences are complex Gaussian distributed then the zero covariance of two alternative OFDM signals guarantee the mutual independency between them.

But if OFDM signal sequences are not complex Gaussian distributed then the zero covariance of two alternative OFDM signals does not guarantee the mutual independency between them. So according to the central limit theorem if the N value is not very large then we may not consider the time domain samples of the OFDM signal as Gaussian distribution.

In this case instead of covariance, we consider the property of joint cumulates of alternative OFDM signals. If the joint cumulates of all orders are equal to zero then the two alternative OFDM signal sequences are mutually independent. Let us consider the lth and mth alternative OFDM signals$x_n^{(1)}$ and$x_n^{(m)}$ According to the fourth order joint cumulate between these two alternative sequences may be given as

The covariance between the average symbol power of the l^{th} and m^{th} alternative symbol sequences will be

$$\mathrm{cov}(\bar{P}^{(1)}, \bar{P}^{(m)}) = E[(\bar{P}^{(1)} - E[(\bar{P}^{(1)}])(\bar{P}^{(m)} - E[\bar{P}^{(m)}])] \quad \text{.....8}$$

With verifying the equations it is concluded that the fourth order joint cumulate is equivalent to the covariance of average symbol powers of alternative symbol sequences. By simplifying the equation, the covariance between the average symbol power of the l^{th} and m^{th} alternative symbol sequences may be found as:

$$\mathrm{cov}(\bar{P}^{(1)}, \bar{P}^{(m)}) = \frac{1}{N}(E[|A_k|^4 |\gamma_k^{(m)}|^2 |\gamma_k^{(m)}|^2] - 1) \quad \text{.....9}$$

If that equation becomes zero then $X^{(u)}$ and $X^{(m)}$ are mutually independent, that is, two alternative symbol sequences are generated independently. However in case of the conventional SLM

$$|\gamma_k^{(u)}| = 1 \text{ but } E[|A_k|^4] \neq 1 \quad \text{.....10}$$

It makes the value of covariance in equation as non zero even if the phase sequences satisfy the optimality conditions. It concludes that the mutually independent alternative OFDM signal sequences may not generated by using the conventional SLM scheme. Therefore, we have to design the scheme such that the amplitude gain$\gamma_k^{(u)}$ may be changed.

It may be possible with using two SLM schemes that are BSLM and PBISLM. As we have discussed in case of the PBISLM technique the pre selected bits of the symbol are going to be changed. For the simulation work in proposed approach, PBISLM type-I as some preselected bits of the M−QAM symbols has considered and in case of PBISLM type-II all the bits are to be considered.

The covariance plot with respect to the number of subcarriers for the conventional SLM, BSLM and the PBISLM, with considering 16-QAM and 64-QAM modulation scheme is shown in Figure 2. Considering 128 number of subcarriers and 16-QAM modulation scheme.

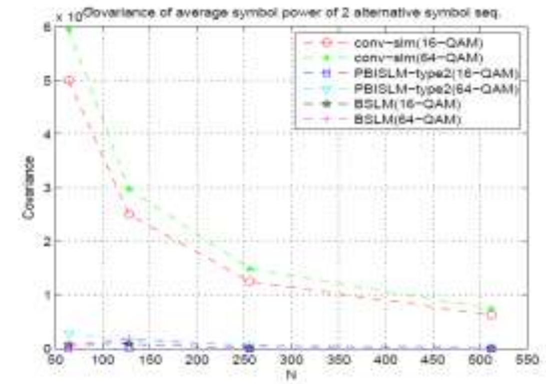

Figure 2: Covariance plot for different SLM techniques

The comparison of the theoretical PAPR reduction plot with that of the BSLM technique and the conventional SLM technique is shown in Figure 3.

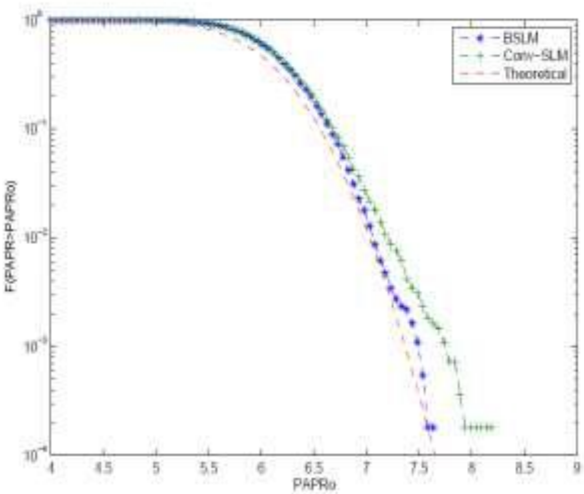

Figure 3: PAPR comparison with the theoretical plot

As we know that the covariance of average symbol powers of alternative symbol sequences for the conventional SLM is non zero, hence the PAPR reduction plot moves away from the theoretical plot. But for BSLM it follows the theoretical plot.

V. NEW SCHEME FOR REDUCED COMPLEXITY

According to the idea in SLM the original data block will be converted into several independent signals and the signal having lowest PAPR is going to be transmitted. To get back the original data block it must be required to send side information as a set of bits along with the selected signal.

The erroneous detection of this side information will give arise to loss of the whole data block? So this is one of the disadvantages of SLM technique. Another disadvantage of this technique is its high complexity due to presence of a lot of IFFT blocks before selecting a particular OFDM signal. Here a method is being proposed to generate a random matrix from the existing phase matrix of the classical SLM technique which fulfils the criteria that the new matrix has less number of rows than that of the existing matrix.

According to the discussion in the previous section that, the reduction of number of rows leads to the reduction in computational complexity. Also by using this new technique the original data block may be detected without sending any side information along with the selected signal. But for detecting the information about the row of the random matrix that has been multiplied at the transmitter side here we have applied the sub-optimal algorithm.

The PAPR of this technique is also being reduced than that of the classical SLM technique. The alternative phase vectors that are used in the classical SLM technique may be considered as a U × N matrix, where U denotes the total number of alternative signals and N denotes the number of subcarriers as shown in Figure 4.

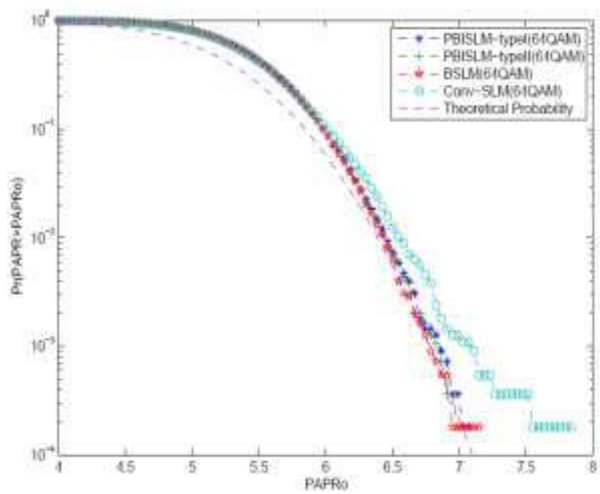

Figure 4: PAPR comparison with the theoretical plot

According to the classical SLM technique we should generate the random matrix on the basis of the criteria described. So we got the matrix B, where B (u, n) is the nth value of the U^{th} row. Then generate a new matrix B_1 having $\frac{U}{2}$ number of rows according to the following steps.

- Find each row of the new matrix by doing the following additions

$$B_1(1) = B(1) + B(2)$$
$$B_1(2) = B(3) + B(4)$$
$$B_1\,(U_2) = B(U-1) + B(U)$$

- Then we may get some elements of the matrix as zero. So we should apply the following condition. If $B_1(u, n) = 0$ then put $B_1(u) = 1$ otherwise put $B_1(u) = -1$.

Each row of the matrix B is a set of random variables. Let us consider two random Variables X and Y with variances σ_x^2 and σ_y^2 respectively. The sum of two random variables will be another random variable i.e. Z = X + Y having variance σ_z^2 defined as-

$$\sigma_x^2 = E\,[(Z - \mu z)^2] \qquad .....11$$
$$E = \{[(X - \mu x) + (Y - \mu y)]^2\}$$

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Where, μx, μy and μz are the mean of X, Y and Z respectively

E{X} = μx

E{Y} = μy

E{Z} = μz

$$Z = X + Y$$

$$\mu z = \mu x + \mu y$$

After simplifying the above equation we will get that-

$$\sigma_x^2 = \sigma_x^2 + 2p_{xy}\,\sigma_x\sigma_y + \sigma_y^2 \qquad \text{.....12}$$

where-

Pxy = the correlation coefficient

= the ratio between the covariance of two random variables X and Y to the product of their standard deviations.

$$p_{xy} = \frac{C_{xy}}{\sigma_x\sigma_y} \qquad \text{.....13}$$

As the rows of this random matrix are mutually independent to each other so the covariance will be zero hence,

$$\sigma_z^2 = \sigma_x^2 + \sigma_x^2 \qquad \text{.....14}$$

From the analysis it is to be known that by adding to random variables the variance of the resulting random variable increases. So the variance of each row of the matrix B_1 will be more than that of the matrix B which leads to the further reduction of PAPR compared to the classical SLM technique. The number of complex additions and multiplications for N point DFT using FFT algorithm will be Nlog2 N and $\frac{N}{2}\log_2 N$ respectively.

For the classical SLM technique:

- Number of complex additions = $UN\log_2 N$
- Number of complex multiplications = $\frac{UN}{2}\log_2 N$

For the proposed technique:

- Number of complex additions = $\frac{U}{2} N \log_2 NU$
- Number of complex multiplications = $\frac{U}{2}\frac{N}{2}\log_2 NU$

So by using this technique 50 percent complexity for computations has been reduced. The simulation plot for PAPR reduction performance with considering 128 number of subcarriers and with over sampling factor of 4 is shown in the Figure 5. According to this figure the proposed scheme i.e. the new SLM technique has better PAPR reduction than the conventional one.

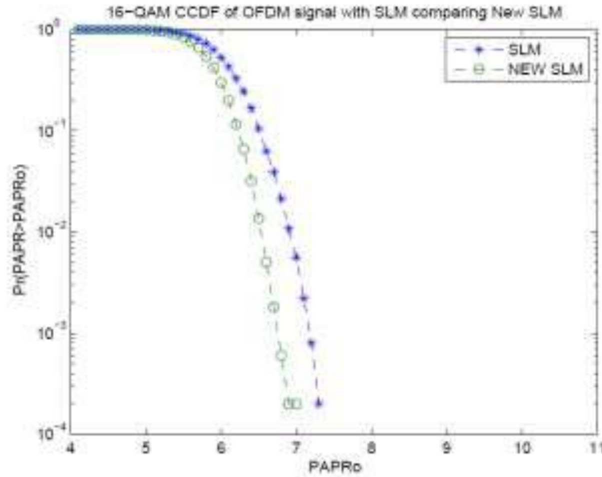

Figure 5: PAPR comparison with the Conventional SLM technique

Also with using this technique the extra side information is not required to send along with the selected OFDM signal. This side information may be detected with using the sub optimal algorithm. The bit error rate plot performance is shown in Figure 6.

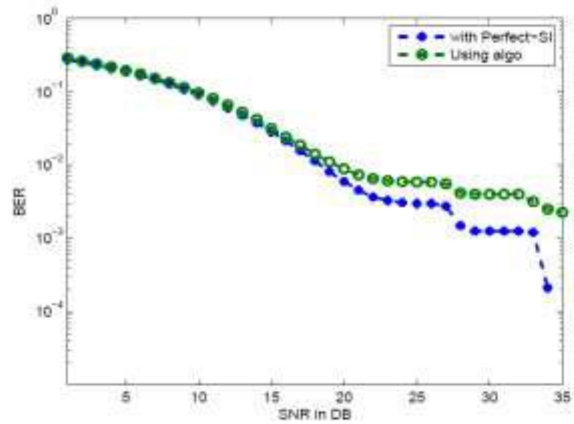

Figure 6: Bit Error Rate Performance

It shows the bit error rate between the two cases, one with considering the detection of perfect SI (Side Information) index at the receiver side another one with applying sub-optimal algorithm at the receiver side.

VI. Reduction Techniques

A. PAPR Reduction Techniques

A lot of techniques presents for the reduction of this PAPR. About some of the reduction techniques like Clipping and Filtering, Coding, Partial Transmit Sequence, Selected Mapping, Tone Reservation, Tone Injection, Active Constellation Extension are briefly described here.

B. Clipping and Filtering

It is a simplest technique used for PAPR reduction. Clipping means the amplitude clipping which limits the peak envelope of the input signal to a predetermined value.

Let x[n] denote the pass band signal and xc[n] denote the clipped version of x[n].

A is the pre-specified clipping level. However this technique has the following drawbacks:

- Clipping causes in-band signal distortion, resulting in Bit Error Rate performance degradation.
- It also causes out-of-band radiation, which imposes out-of-band interference signals to adjacent channels. This out-of-band radiation may be reduced by filtering.
- This filtering of the clipped signal leads to the peak re-growth. That means the signal after filtering operation may exceed the clipping level specified for the clipping operation. So we came to know that this clipping and filtering technique has some sort of distortion during the transmission of data.

This technique may not increase power and low implementation complexity, No bandwidth expansion. In this PAPR reduction technique BER degradation

C. Coding

The coding technique is used to select such codeword that minimize or reduce the PAPR. It causes no distortion and creates no out-of-band radiation, but it suffers from bandwidth efficiency as the code rate is reduced. It also suffers from complexity to find the best codes and to store large lookup tables for encoding and decoding, especially for a large number of sub carriers. No power increase no, BER degradation increase. It increases in band width expansion and low implementation complexity.

D. Partial Transmit Sequence

In the Partial Transmit Sequence (PTS) technique, an input data block of N symbols is partitioned into disjoint sub blocks. The sub-carriers in each sub-block are weighted by a phase factor for that sub-block. The phase factors are selected such that the PAPR of the combined signal is minimized. But by using this technique there will be data rate loss. It has high implementation complexity, Increase in band width expansion, and No degradation. In other hand, In this technique there is no power increases.

E. Tone Reservation

According to this technique the transmitter does not send data on a small subset of subcarriers that are optimized for PAPR reduction. Here the objective is to find the time domain signal to be added to the original time domain signal such that the PAPR is reduced. Here the data rate loss will be take place also probability of power increase is more. It increases in power implementation complexity and band width expansion.

F. Tone Injection Technique

The basic idea used in this technique is to increase the constellation size so that each symbol in the data block may be mapped into one of the several equivalent constellation points, these extra degrees of freedom may be exploited for PAPR reduction. Here the transmitted power increases. It increases in power implementation complexity and band width expansion. But, it increases the power.

G. Selected Mapping (SLM) Technique

The basic idea of this technique is first generate a number of alternative OFDM signals from the original data block and then transmit the OFDM signal having minimum PAPR. But data rate loss and complexity at the transmitter side are two basic disadvantages for this technique. This technique has been described exhaustively in this section .

This is an effective and distortion less technique used for the PAPR reduction in OFDM. The name of this technique indicates that one sequence has to be selected out of a number of sequences. According to the concept of discrete time OFDM transmission we should make a data block considering N number of symbols from the constellation plot.

Let us consider X is the data block with X (k) as the mapped sub symbol(i.e. the symbol from the constellation). Where $k = \{0, 1, 2, \ldots\ldots\ldots N-1\}$. Let the $u^{(th)}$uth phase vector is denoted as $B^{(u)}$ where $u = \{1, 2, \ldots\ldots\ldots U\}$. The u^{th} candidate vector that is generated by the multiplication of data block with the phase vector is denoted as $X^{(u)}$. So we may write the equation to get the k^{th} element of u^{th} candidate vector as-

$$x^{(u)}(k) = X(k)\, B^{(u)}(k) \qquad \ldots..15$$

Then by doing IFFT operation to each candidate vector we will obtain U number of alternative OFDM signals, so the n^{th} symbol of u^{th}. So out of the U number of alternative OFDM signals the signal having minimum PAPR is to be selected for transmission. Let that selected OFDM signal is denoted as $x^{\widetilde{(u)}}(k)$. This selected mapping technique is known as the classical SLM.

In this technique for generation of alternative OFDM symbols the independent phase vectors has to generate., the $k^{(th)}$ kth value of uthphase vector is denoted as B^{u} (k) and may be found by-

$$B^{u}(k) = e^{j\emptyset^{(u)}(k)} \qquad \ldots..16$$

Where-

$\emptyset(k)$ = the random phase value

So from the equation 16 we get that $X^{(u)}(k)$ be a phase rotated version of X (k). Two-phase vectors $B^{(m)}$ and $B^{(1)}$ is dependent if any joint cumulant between them is nonzero [13]. So the condition of mutual independence between $B^{(m)}$ (n) and $B^{(1)}$ (n) is given as-

$$E[e^{j\emptyset}] = 0 \qquad \ldots..17$$

To make satisfy the above condition $\emptyset$ should be uniformly distributed in $[0, 2\pi)$. According to this selection criteria of $\emptyset$ the variation of the PAPR reduction performance will be shown in the next subsection.

This selected OFDM signal at transmitter side has to be detected at the receiver. So the receiver must have the information about the perfect phase vector that has been multiplied to generate that selected OFDM signal. Hence, to fulfill the requirement of the receiver some side information (SI) has to be transmitted along with the selected OFDM signal.

This SI index is generally transmitted as a set of $[\log_2 U]$ bits. For the efficient transmission of these extra bits channel coding technique should be required. If any SI index may not be detected perfectly then that total recovered transmitted block will be in error. So we should follow a new SLM technique [3] which avoids the sending of SI index. This technique is discussed briefly in the following sections. Selected Mapping (SLM) Technique has high implementation complexity and increase in band width expansion. But, there is No power increase.

H. THRESHOLD SELECTED MAPPING (TSLM)

The threshold selected mapping (TSLM) is extended version of selected mapping (SLM). In TSLM the comparison of phase sequence till threshold level. After this threshold level phase mapping is not useful for reducing PAPR. The idea of thresholding the PAPR of a SLM system was first mentioned in [40]. From eq. (41), Let us assume that the average power of x_n is equal to 1, and Z_N is the independently and identically distributed (i.i.d) Rayleigh random variables. The probability density function of Z_N.

The maximum value of Z_N is equivalent to PAPR. If $Z_{Max} = Max_{n=0.1\ldots\ldots N-1}\, Z_N$ then the cumulative distribution function (CDF) of Z_{Max} and the probability of peak to average power ratio (PAPR) below threshold.

The complementary cumulative distribution function (CCDF) is used when PAPR value exceeds the threshold. To find the probability that PAPR of an OFDM signal exceeds the threshold (Z_0), assume the following complementary cumulative distribution function (CCDF) [9],

In TSLM technique each data block will create U times phase sequences, if each mapping considered statistically independent, then CCDF of the Peak to Average Power Ratio (PAPR) in Threshold Selected Mapping (SLM).

The TSLM has high implementation complexity and increase in band width expansion. But, it has is low power increase.

VII. RESULT ANALYSIS

This section discusses the performance of selected mapping (SLM) with different values of subcarriers N and phase sequences U. it may be seen from the simulations results that it is possible for SLM scheme to reduce peak to average power ratio (PAPR).

A. The Performance Analysis

This high PAPR is very important situation because it is reducing the efficiency of RF power amplifier, and resulting in inter carrier interference as shown in Figure 9.

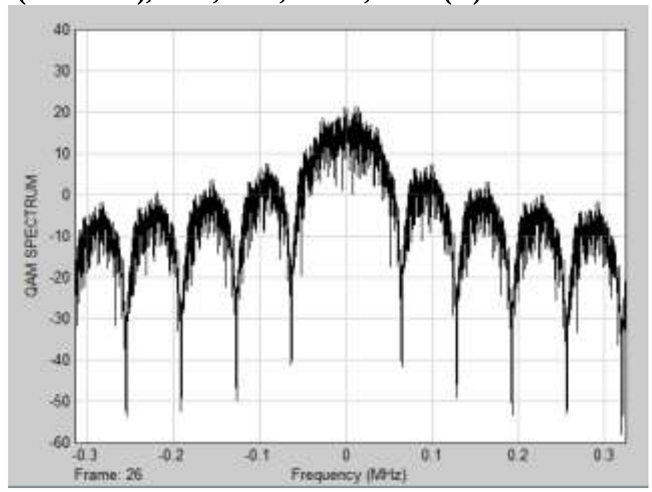

Figure 9: Frequency Spectrum of Transmitted Signal

Thus, SLM scheme is the promising technique in reducing the effect of PAPR. The frequency spectrum of QAM signal and frequency spectrum of OFDM signal is shown in Figure 10.

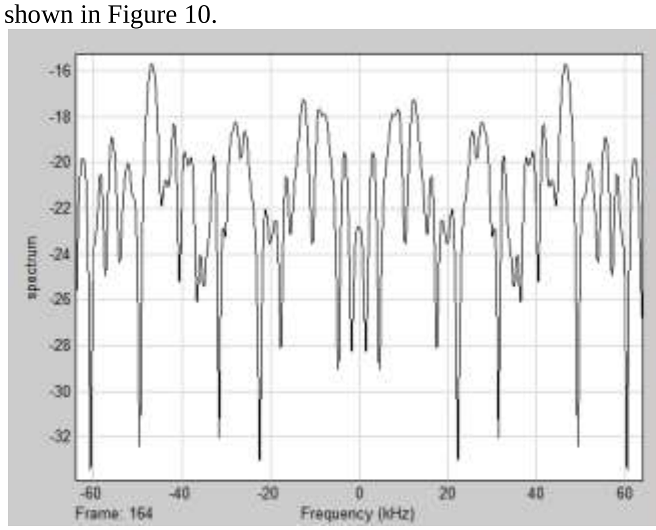

Figure 10: Frequency Spectrum of OFDM Signal

OFDM signal consists on high peak to average power due to adding up subcarriers coherently with the same phase as shown in Figure 10. The time domain of modulated OFDM signal with 256 subcarriers and M-ary is set to 16 is shown in Figure 11.

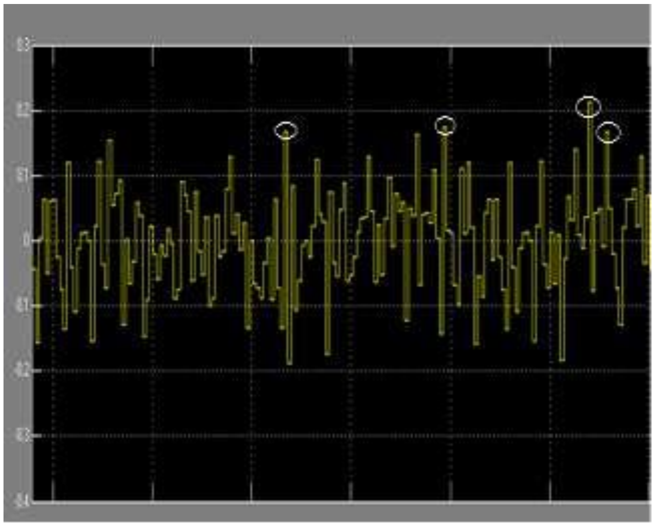

Figure 11: OFDM Signal in Time Domain

B. Threshold selected mapping

This section discusses PAPR reduction and it indicates that large PAPR reduction is possible with selected mapping scheme. Through increasing the number of phase sequences U better PAPR reduction may be obtained. For instance, a plot of PAPR reduction curves for OFDM symbol where N=62 is shown in Figure 12.

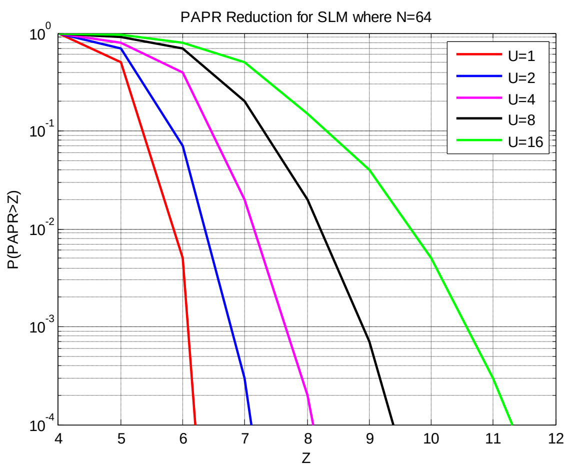

Figure 12: PAPR Reduction for SLM where N = 64 and U = 1, 2, 4, 8, 16

From the Figure 12 it may be seen that when there is no SLM which is at U=1 threshold needed to get good PAPR reduction performance is 10.5, while for U = 16, only 6.2 is needed to get good PAPR reduction performance.

VIII. Conclusion and Future Work

Selected mapping technique has been verified for the PAPR reduction performance. Some techniques are also being there which avoids the sending of side information index along with the selected OFDM signal. The proposed scheme has better PAPR reduction performance than that of the classical SLM. Moreover it also fulfills the criteria of low computational complexity. But this amount in reduction of complexity is not better than that of the technique depending upon the PBISLM.

Peak to average power ratio issues are explored effectively to know the effect of the transmitted signal. There are different reduction techniques are surveyed to solve high peak to average power ratio such as, Signal distortion techniques, Coding Schemes, and Symbol-scrambling techniques. Selected mapping (SLM) technique is the main focus of the paper. This paper also showed the simulation results of OFDM symbol with and without SLM. The simulation results indicated that large PAPR reduction is possible with selected mapping scheme.

The application of this Selected Mapping technique also may be verified in the OFDMA system. Analysis for avoiding the sending of SI index in case of the Riemann matrix should be done. Two suggested future work are, first improving power efficiency by using selective mapping. Second, monomial phase sequences for selected mapping detection.

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