Performance analysis of PAPR reduction techninques for MC-CDMA system

Jaswinder Kaur, Komal Arora

Abstract- MC-CDMA and OFDM systems are widely used in the existing 3rd and 4th generation wireless networks. They are also good candidates for the future generation networks for broadband and personal communications. But, high peak to average power ratios (PAPR) is serious problem in MC-CDMA which can increase complexity in the analog to digital and digital to analog converter, reduce the system efficiency and increase the overall system cost. The major scope of this paper is to reduce PAPR in MC-CDMA using PTS, SLM and Hybrid techniques. According to the simulation results presented in this paper, using PTS technique, PAPR is reduced up to 2.9 dB than original PAPR of the signal for different number of users and iterations. By analyzing the plots of Complementary Cumulative Distribution Function (CCDF) versus probability ($PAPR_0$), it has been shown that SLM technique lowers PAPR up to 2.2 dB and Hybrid technique is reduced PAPR upto1.5 dB than original PAPR of the signal.
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Index Terms— MC-CDMA, OFDM, PAPR, CCDF, SLM, PTS.

1 INTRODUCTION

Multi-Carrier Code Division Multiple Access (MC-CDMA) is fusion of OFDM (Orthogonal Frequency Division Multiplex) modulation and the CDMA multiple access technique. This multiple access technique invented in 1993 [1] and further reviewed for development in 1997 [2].

- Code-division multiple access (CDMA) schemes have been considered as attractive multiple access schemes in both second-generation (2G) and third-generation (3G) wireless systems.
- The evolution from 2G to 3G corresponds to adapting a new air interface i.e. changes of focus from voice to multimedia.
- MC-CDMA scheme has become a most likely technique for 4G air interface.
- MC-CDMA is a direct sequence CDMA, but in this applied Fourier Transform (FFT) after spreading of the signal.
- MC-CDMA is also called “CDMA-OFDM” because it is a form of orthogonal frequency division multiplexing (OFDM) but we first apply an orthogonal matrix operation to the user bits.
- MC-CDMA is also a form of frequency diversity because each bit is transmitted simultaneously on many different subcarriers.

MC-CDMA and OFDM system are widely used in the exiting 3rd and 4th generation of wireless networks. It is the most promising technique for high bit rate and high speed data transmission in mobile communications.

One of the major negative aspects with MC-CDMA is high Peak-to-Average Power Ratio (PAPR). Due to high PAPR results in nonlinear distortion at a high power amplifier (HPA) and degradation of the bit error rate (BER).

To handle these occasional large peaks, a high-power amplifier with linear characteristics is required. But this increased the complexity of the ADC and DAC converters and cost of the system. MC-CDMA spreads the signal in frequency domain. MC-CDMA performs better in downlink level, but it performs poor in uplink level. MC-CDMA has gained much regard because the signal can be easily transmitted and received using FFT device without increase the transmitter and receiver complexity and it is potential robust to channel frequency selectivity with a good frequency use efficiency. MC- CDMA system is widely used for Long Term Evaluation (LTE), WIMAX, and Digital TV transmission, Digital data Transmission over the Telephone system, Digital audio broadcasting, Digital Television, and Wireless Local Area Networks [3].

To reduce the PAPR, several techniques have been invented [3-6], which basically can be divided in three categories. First of all, signal distortion techniques which reduce the peak amplitudes simply by nonlinearly distorting the MC-CDMA signal at or around the peaks e.g. clipping [7]. Second, there are coding techniques that use DWT, DCT and DHT to lower PAPR [8]. The third technique scrambles each MC-CDMA symbol with different scrambling sequences and selecting the sequence that gives the smallest PAPR [9].

In this paper, we use SLM, PTS techniques for PAPR reduction in MC-CDMA system. We investigate the Hybrid technique which is combination of PTS and SLM technique and then MC-CDMA siganl is obtained and PAPR parameter will be calaulated.

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2 System Discription

2.1 MC-CDMA System

MC-CDMA is a multiple access scheme which allowing the system to support multiple users at the same time. The block diagram of MC-CDMA transmitter is shown in Figure 1. The working of each block describes as:

- **K user data**: The source of information can be symbol of K user. It transmits data symbol of K user simultaneously on several narrow band sub channels.
- **Spreader:** The most important purpose of the spreading codes is to help preserve orthogonality among different physical channels of the uplink user. Walsh-Hadamard codes, also known as OVSF (Orthogonal Variable Spreading Factor) codes, are used for the frequency spread coding to achieve the orthogonality among users [4].

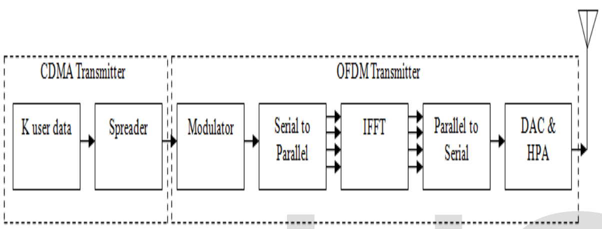

Figure 1: MC-CDMA Transmitter

Walsh Hadamard spreading code: In MC CDMA scheme, Walsh-Hadamard codes are used for the frequency spread coding to achieve the orthogonality among users. This code is simply obtained by selecting as codewords, the rows of Hadamard matrix. +1 and –1 denote the elements of the Hadamard matrix. The Hadamard matrix H_n is an n´n matrix such that n is an even integer with the property that any row differs from any other rows in exactly $n/2$ positions. Usually, the first row of the matrix contains all +1s. The other rows contain +1s of $n/2$ and -1s of $n/2$. The rows of the Hadamard matrix are then mutually orthogonal. To generate the code, the fundamental unit of Hadamard matrix is given as

$$H_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \qquad (1)$$

The following recursive matrix operation is employed to produce the Walsh-Hadamard codes of length $2n$.

$$H_{2n} = \begin{bmatrix} H_n & H_n \\ H_n & -H_n \end{bmatrix} \qquad (2)$$

where the matrix, $\mathbf{H}_{2n}$, of the size $2n*2n$ is formed by using the matrix, $\mathbf{H}n$, of size $n*n$ with $\mathbf{H}_2$ given above. These codes fulfill completely the orthogonality between each other when synchronization is regularly held. [4]

- **Modulator:** Modulation is the technique by which the signal wave is transformed in over the communication channel in order to minimize the effect of noise. QPSK modulation is used.
- **Serial to parallel converter**
  Data to be transmitted is in the form of a serial data stream. 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.
- **IFFT:** By working with MC-CDMA in frequency domain the modulated QPSK data symbols are fed onto the orthogonal sub-carriers. But transfer of signal over a channel is only possible in its time-domain. For which we implement IFFT which converts the MC-CDMA signal in from frequency domain to time domain. [10]
- **Parallel to serial converter:** The parallel to serial converter is used to converted data back into serial data form.
- **Digital to Analog Converter and high power amplifier:** After the parallel to serial conversion of the data stream send to the digital to analog converter followed by high power amplifier and up convertor for transmission.
- **Channel:** This is the channel through which the data is transferred. Presence of noise in this medium affects the signal and causes distortion in its data content.

2.2 PAPR of signal

The ratio of the peak to average power value is termed asPeak-to-Average Power Ratio [1-6].

$$PAPR = \frac{\max\,[|p(t)^2|]}{E\,[|p(t)^2|]} \qquad (3)$$

where E[.] denotes expected value.

2.2.1 Disadvantages of high PAPR

- Increased complexity in the analog to digital and digital to analog converter.
- Reduction is efficiency of RF amplifiers.
- Increased cost of the system

2.3 Cumulative Distribution Function

The cumulative distribution function (CDF) parameter is used to measure the efficiency on any PAPR technique. Normally, the Complementary CDF (CCDF) is used instead of CDF, which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold [1-17]. The CDF of the amplitude of a signal sample is given by

$$F(Z) = 1 - \exp \qquad (4)$$

The CCDF of the PAPR of the data block is desired is our case to compare outputs of various reduction techniques. This is given by

$$P(PAPR > Z) = 1 - P(PAPR \le Z) \qquad (5)$$

$$= 1 - F(Z)^N \qquad (6)$$

$$P(PAPR > Z) = 1 - exp(Z))^N \qquad (7)$$

3 PAPR Reduction Techniques

PAPR reduction techniques [1-17] vary according needs of the system and dependent on various factors such as PAPR reduction capacity, increase in power in transmit signal, loss in data rate, complexity of computation and increase in the bit-error rate at the receiver end etc.

3.1 Selective Mapping

Selective Mapping Technique is called signal scrambling technique with explicit side information. The MC-CDMA with SLM is shown in Figure 2. In this technique the input data frame is divided into non-overlapping sub-blocks and each sub-block is phase shifted by constant factor. After it the block with minimum PAPR is select for transmission. The PAPR value is also depend upon the phase shift factor. [18-19]

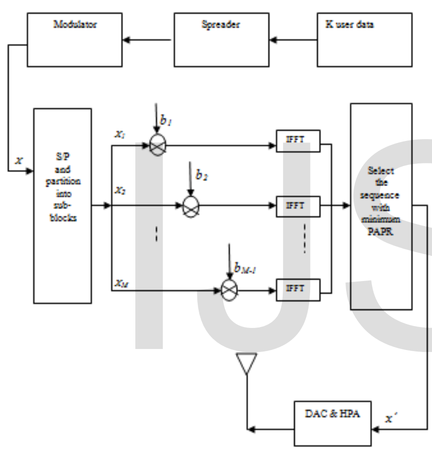

Figure 2: MC-CDMA with SLM

3.2 Partial Transmit Sequence

Partial Transmit Sequence is called signal scrambling with explicit side information or distortion less technique. The MC-CDMA with PTS is shown in Figure 3. The basic idea of symbol scrambling is that, for each MC-CDMA symbol, the input sequence is divided by a certain number of sub-blocks. The output signal with the smallest PAPR is transmitted. In this technique, data of varying sub-carrier is only transmitted which covers all the information to be sent in the signal as a whole is called Partial Transmit Sequence Technique. [19-20]

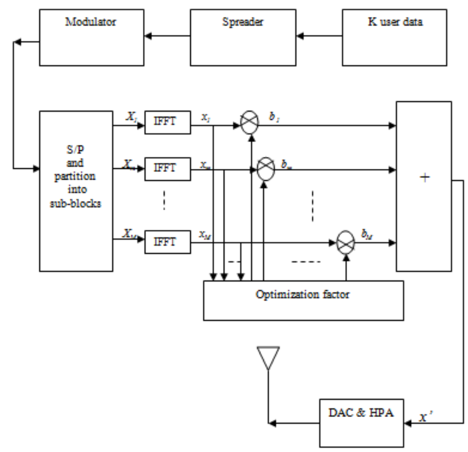

Figure 3: MC-CDMA with PTS

3.3 Hybrid Technique

Hybrid technique is combination of Partial Transmit Sequence and Selective Mapping Technique. The MC-CDMA with Hybrid technique is shown in Figure 4. This technique is signal scrambling technique. In this technique, first input signal is applied to SLM and after it; output of SLM is applied to PTS. The lowest PAPR is selected by each optimization block of PTS. [21]

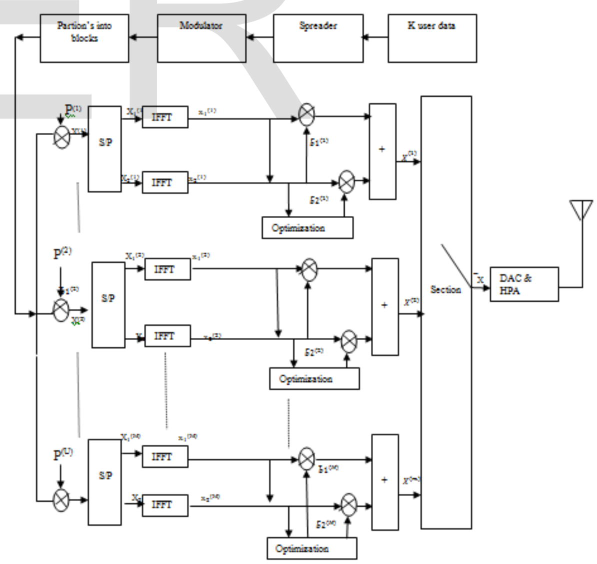

Figure 4: MC-CDMA with Hybrid technique

4 Simulation Results

This section is devoted to the graphical and simulation results of SLM, PTS and Hybrid techniques. The system parameters for different techniques, used in thesis are listed in Table 1.

TABLE 1
Simulation Parameter

Simulation Parameter	Specification
No. of iterations	100
No. of users	8,16,32
Spreading code	Walsh Hadamard
Modulation process	QPSK
PAPR reducing Techniques	SLM, PTS, Hybrid

4.1 The PAPR Reduction Performance for SLM:

The PAPR reduction performance for SLM shows in Figure 5, 6 and 7 for 8, 16 and 32 input users with 100 iterations respectively. The graph is plotted between CCDF [PAPR>PAPR0] versus PAPR0 [dB]. The improvement in PAPR reduction at CCDF= 0.1 is listed in Table 2.

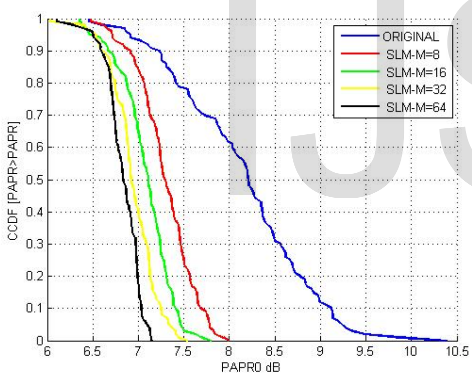

Figure 5: PAPR reduction performance of Selective Mapping for 8 input users

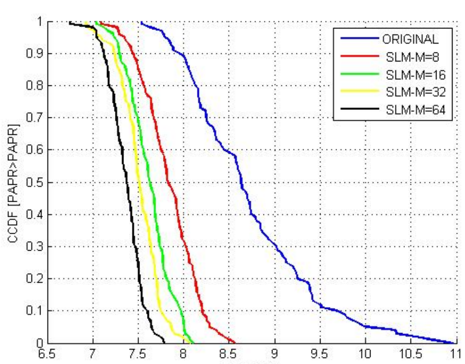

Figure 6: PAPR reduction performance of Selective Mapping for 16 input users

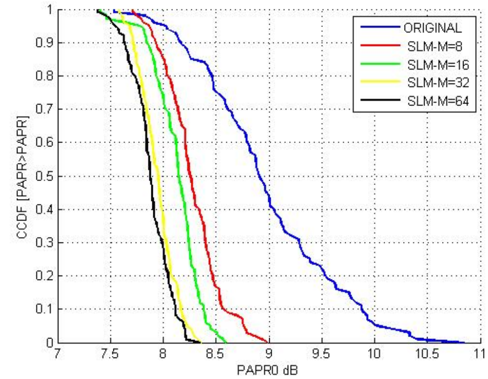

Figure 7: PAPR reduction performance of Selective Mapping for 32 input users

TABLE 2
Improvement in PAPR reduction using SLM for different number of input users

Number of input users	Original PAPR (dB)	PAPR with applied technique (dB)	Improvement (dB)
8	9.3	7.1	2.2
16	9.6	7.6	2.0
32	9.8	8.2	1.6

Table 2 shows that using Selective Mapping, PAPR maximum reduced up to 2.2 dB for 8 input users with 100 itreations.

4.2 The PAPR Reduction Performance for PTS:

The Figure 8, 9 and 10 illustrate the PAPR reduction performance for PTS for 8, 16, 32 input users with 100 iterations respectively. The improvement in PAPR reduction at CCDF= 0.1 is listed in Table 3.

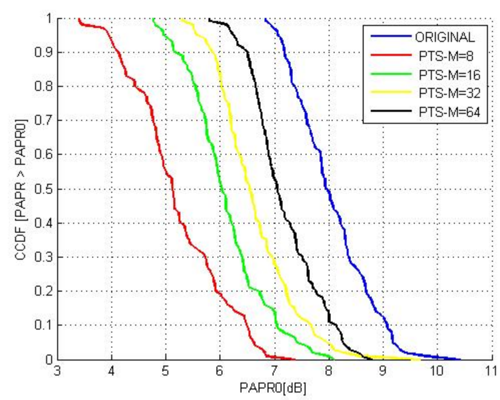

Figure 8: PAPR reduction performance of Partial Transmit Sequence for 8 input users

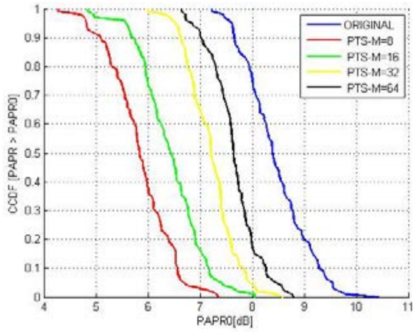

Figure 9: PAPR reduction performance of Partial Transmit Sequence for 16 input users

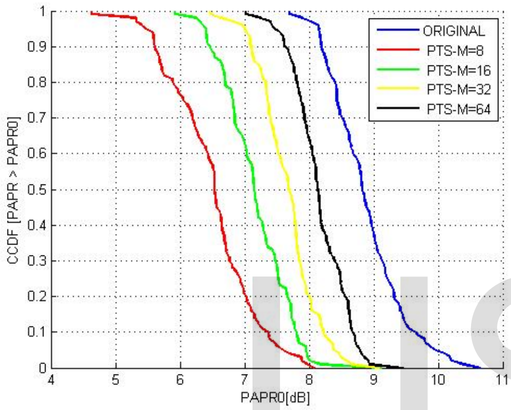

Figure 10: PAPR reduction performance of Hybrid technique for 32 input users

TABLE 3
Improvement in PAPR reduction using PTS for different number of input users

Number of input users	Original PAPR (dB)	PAPR with applied technique (dB)	Improvement (dB)
8	9.1	6.5	2.6
16	9.3	6.7	2.6
32	9.6	7.4	2.2

Table 3 shows that PAPR is reduced maximum up to 2.6 dB for 8 and 16 input users respectively**.**

4.3 The PAPR Reduction Performance for Hybrid Technique:

The Figure 11, 12 and 13 shows the PAPR reduction performance for and Hybrid technique for 8, 16 and 32 input users with 100 iterations respectively. The improvement in PAPR reduction at CCDF= 0.1 is listed in Table 4.

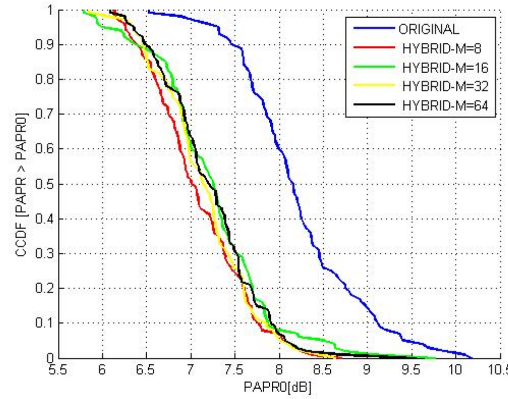

Figure 11: PAPR reduction performance of Hybrid technique for 8 input users

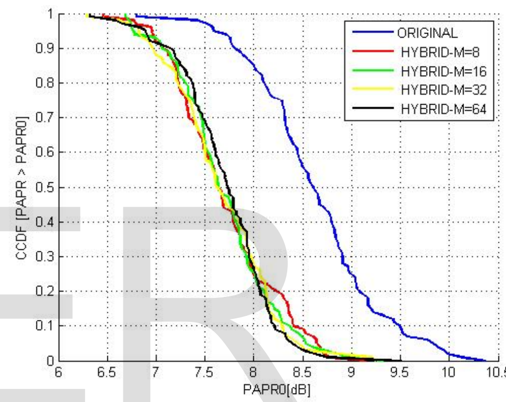

Figure12: PAPR reduction performance of Hybrid technique for 16 input users

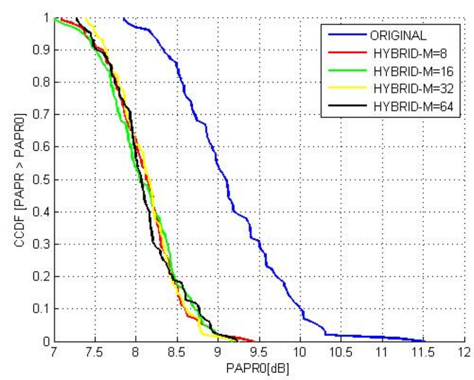

Figure 13: PAPR reduction performance of Hybrid technique for 32 input users

TABLE 4
Improvement in PAPR reduction using Hybrid technique for different number of input users with 100 iterations

Number of input users	Original PAPR (dB)	PAPR with applied technique (dB)	Improvement (dB)
8	9.2	7.7	1.5
16	9.5	8.4	1.1
32	10	8.6	1.4

Table 4 shows that PAPR reduction using Hybrid techniques remained approximately constant for different number of input users with 100 iterations

5 Conclusion

MC-CDMA gained a lot of attention for future generation of wireless communication systems. Different methods SLM, PTS have been investigated to lower the PAPR in MC-CDMA systems. With the reduction of PAPR, MC-CDMA has applications in the area of wireless communications such as Broadband Multi-User Communications, WLANs and Broadcasting. In this paper, three PAPR reduction techniques have been discussed. The Performance of PAPR reduction techniques has been evaluated using CCDF [PAPR>PAPR0] versus PAPR0 [dB] plots.
The PTS technique reduces the PAPR up to 2.6 dB than original PAPR of the signal for different number of users with 100 iterations. With 100 iterations, SLM technique reduced PAPR up to 2.2 dB than original PAPR of the signal. It has been observed that PAPR of the hybrid technique lies always between 1.1-1.5 dB for different number of users. In the case of hybrid technique, the PAPR is reduced maximum up to 1.5 dB than original PAPR.

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