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PAPR Reduction of an MC-CDMA system using SLM technique

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***Abstract*- Multicarrier Code Division Multiple Access is the most promising technique for high speed data transmission. However, the MC-CDMA signals are characterized by large peak to average power ratios (PAPR), which can reduce the system efficiency. In this paper PAPR reduction of an MC-CDMA system using SLM technique is investigated for different modulation schemes. The binary phase sequences considered in this paper are generated from hadamard matrix.**

***Index terms*- MC-CDMA, PAPR and Complementary Cumulative Distribution Function.**

I. Introduction

Multicarrier code division multiple access (MC-CDMA) is a promising candidate for 4G wireless communication system. It is a technique that combines advantages for both OFDM and CDMA schemes that provide many advantages such as high data rate transmission, high bandwidth efficiency, frequency diversity and interference reduction. MC-CDMA has attracted much attention as fourth generation mobile communication system because it can realize high data rate and high capacity transmission by multiplexing information symbols of many users with orthogonal codes [1-4].

However, inspite of all such advantages, it is not yet problem free. MC-CDMA suffers from high PAPR when using large number of sub-carriers. Large peak-to-average power ratio (PAPR) distorts the signal if the transmitter contains non-linear components such as power amplifier. The non-linear effects on the transmitted MC-CDMA symbol are spectral spreading, inter-modulation and changing the signal constellation. Therefore PAs require a back off which is approximately equal to the PAPR for distortionless transmission. This decreases the efficiency for amplifier. Hence it is desirable that transmitted signal possess reduced peaks and in order to achieve this there are several PAPR reduction techniques.

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These techniques are divided into three groups: signal distortion techniques, signal scrambling techniques and coding techniques. Signal distortion schemes reduce the amplitude by linearly distorting the MC-CDMA signal at or around the peaks. This includes techniques like clipping, peak windowing, and peak cancellation [1], [5]. It is the simplest technique but it causes in-band and out-band distortion. Scrambling scheme is based on scrambling each MC-CDMA signal with large PAPR. It includes techniques such as Selected Mapping (SLM), and Partial Transmit Sequence (PTS). In case of PTS technique [7-8], MC-CDMA sequences are partitioned into sub-blocks and each sub-block is multiplied by phase weighting factor to produce alternative sequences with low PAPR. However large number of phase weighting factors increase the hardware complexity and makes the whole system vulnerable to the effect of phase noise. The SLM technique [9-16] pseudorandomly modifies the phases of the original information symbols in each MC-CDMA block several times and selects the phase modulated MC-CDMA with best PAPR performance for transmission.

In this paper PAPR reduction of an MC-CDMA system using SLM technique is investigated for different modulation schemes. The binary phase sequences considered in this paper are generated from hadamard matrix.

II. System Description

A. MC-CDMA system

The transmitter structure of an MC-CDMA system is shown in fig.1. It is assumed that there are *K* active users and each user transmits M parallel modulated symbols. $d^{(k)} = [d_1^{(k)}, d_2^{(k)}, ..., d_M^{(k)}]^T$ Denotes the M modulated data symbols of *kth* user, k=1, 2, K. Modulated data symbols of kth user $d_m^{(k)}$ are converted from serial to M parallel data streams. After this serial to parallel conversion each complex symbol is spread by the user specific code $c^{(k)} = [c_1^{(k)}, c_2^{(k)}, ..., c_L^{(k)}]$ where L denotes the spreading factor (SF). As the spreading sequences orthogonal sets of sequences are preferred for reducing low multiuser interference. Walsh-Hadamard (WH) sequences are used as spreading sequences in this procedure. Then the input of K users is summed up, and is interleaved in frequency domain as to achieve frequency diversity as

$X=\sum_{k=1}^{K}X^{(k)}=[X_0,X_1,...,X_{N-1}]^T$ to achieve frequency diversity. After interleaving the symbol element are then input to the IFFT block of size $N=M\times L$.
The resultant baseband signal for one MC-CDMA $0\le t\le T_s$ symbol is represented as

$$s(t)=\frac{1}{\sqrt{N}}\sum_{k=1}^{K}\sum_{m=1}^{M}\sum_{l=1}^{L}d_m^{(k)}c_l^{(k)}e^{j2\pi(M(l-1)+(m-1))t/NT} \quad (1)$$

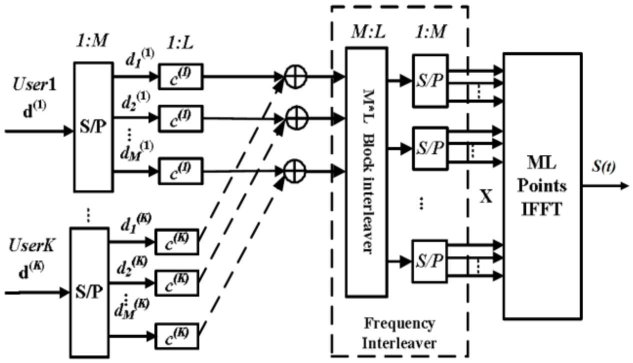

Fig. 1. MC-CDMA transmitter

B. PAPR

The PAPR of the MC-CDMA symbol is defined as ratio of the peak power and the average power:

$$PAPR=\frac{p_{peak}}{p_{average}}=10\log_{10}\frac{\max\left[|s(t)|^2\right]}{E\left[|s(t)|^2\right]} \quad (2)$$

Where p_{peak} represents output peak power, $p_{average}$ means output average power. $[\cdot]$ denotes the expected value.

The cumulative distribution function (CDF) is one of the most regularly used parameters, which 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 [4].

The CDF of the amplitude of a sample signal is given by

$$F(z)=1-\exp(z) \quad (3)$$

The CCDF of the PAPR of the data block is desired is our case to compare various reduction techniques. This is given by [3]:

$$\begin{aligned}P(PAPR>z)&=1-P(PAPR\le z)\\&=1-F(z)^N\\&=1-(1-\exp(-z))^N\end{aligned} \quad (4)$$

When calculating the PAPR, we have to consider the actual time domain signal that is in analog form. The IFFT outputs, which are symbol spaced sampling values, will miss some of the signal peaks. Therefore, if we calculate PAPR by using these sample values, then the calculated PAPR is less than the actual PAPR [6]. This is an optimistic result and will not illustrate the real situation. However, they are enough for signal reconstruction. To account for this issue, oversampling is performed by low pass filtering the IFFT signal and then sampled at higher rate. Now, the increased samples are close to the real analog signal and calculation of PAPR based on these samples will give a better estimated PAPR.

III. SELECTED MAPPING (SLM) METHOD

A block diagram of SLM is shown in fig.2. In SLM, *U*-1 statistically independent phase sequences are generated. Symbol sequences are multiplied by the *U*-1 different phase sequences $\{b_u, u = 1, 2, \ldots, U\text{-}1\}$, whose length is equal to number of carriers before IFFT process. The PAPR is calculated for *U*-1 phase rotated symbol sequences and one original phase sequence. Then the symbol sequence with the lowest PAPR is selected and transmitted as side information. The receiver performs the reverse operation to recover the data symbol. Since SLM is a linear operation, it does not cause non-linear operation. However, SLM needs the IFFT process for each phase sequence, that is, *U* IFFT processes. Thus, a large amount of calculation is needed in SLM.

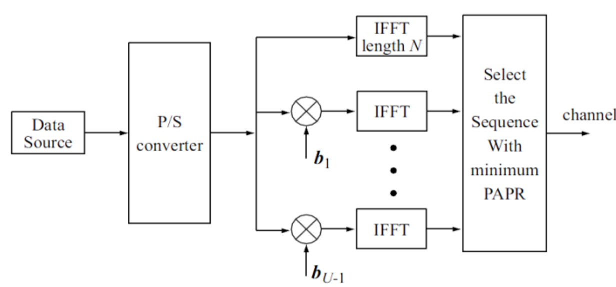

Fig. 2. A block diagram of selected mapping

The block diagram of MC-CDMA system with SLM technique is shown in fig.3. The input data sequences of each user $d^{(k)}=[d_1^{(k)},d_2^{(k)},...,d_M^{(k)}]$ with length M are first converted into M parallel data sequences $c^{(k)}=[c_1^{(k)},c_2^{(k)},...,c_L^{(k)}]$ and then each S/P converted output is multiplied with the spreading code with length L. Multiplexed symbol sequences $X=\sum_{k=1}^{K}X^{(k)}=[X_0,X_1,...,X_{N-1}]^T$ are multiplied by U-1 different phase sequences $b^u=[b_0^u,b_1^u,...,b_{N-1}^u]$ whose length is equal to the number of carriers before IFFT process resulting in U-1 modified data blocks

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$S=\sum_{u=0}^{U-1} X_n b_n^u = [X_0 b_0^{(u)}, X_1 b_1^{(u)}, \ldots, X_{N-1} b_{N-1}^{(u)}]^T$. After the IFFT process, the PAPR is calculated for U-1 phase rotated symbols sequences $s(t)=\sum_{u=0}^{U-1} x_n b_n^u = [x_0 b_0^{(u)}, x_1 b_1^{(u)}, \ldots, x_{N-1} b_{N-1}^{(u)}]^T$ and one original sequence and then the symbol sequence with lowest PAPR is selected for transmission and the corresponding selected phase sequence $\{\tilde{b}^{(0)}, \tilde{b}^{(2)}, \ldots, \tilde{b}^{(U-1)}\} = \underset{\{\tilde{b}(1),\tilde{b}(2),\ldots,\tilde{b}(U-1)\}}{\arg\min}\left(\max_{0\le n\le N-1}\left|\sum_{u=0}^{U-1} b^{(u)} x_n^{(v)}\right|\right)$ is also transmitted to the receiver side for transmission [10-16].

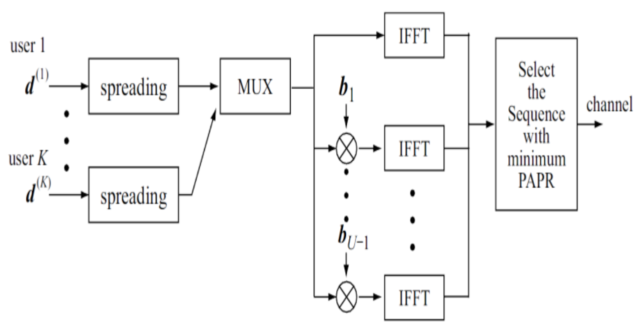

Fig. 3. MC-CDMA system using SLM

IV. SIMULATIONS

In this section the performance MC-CDMA system is evaluated using SLM. Table I below shows the simulation parameters. If we oversample a transmitted signal by a factor of four, the discrete PAPR is almost the same as continuous PAPR [16]. Thus we oversample the transmitted signal by a factor of four in IFFT process.

TABLE I
SIMULATION PARAMETERS

Spreading codes	Walsh Hadamard
Modulation process	BPSK, QPSK, MSK
Processing Gain (*L*)	8
Number of data symbols per an MC-CDMA symbol (*M*)	16
Number of sub-carriers (*N*)	128
Number of active users (*K*)	8
Number of phase sequences (*U*)	4,8 and16
Oversampling factor	4

The performance metric utilized in evaluating PAPR reduction scheme is CCDF of the PAPR of transmitted continuous time signal. The resulting CCDF curves are presented for 1,000 input symbol sequences for different number of phase sequences (U=4, 8 and 16) when considered number of active users to be equal to 8. The phase sequences used are binary phase sequences {1,-1}. The rows of hadamard matrix are used in phase factor generation, in this case, with processing gain equal to 8. The system consists of 128 subcarriers with modulation schemes used to be BPSK, QPSK, and MSK. The results are compared with the original MC-CDMA signal.

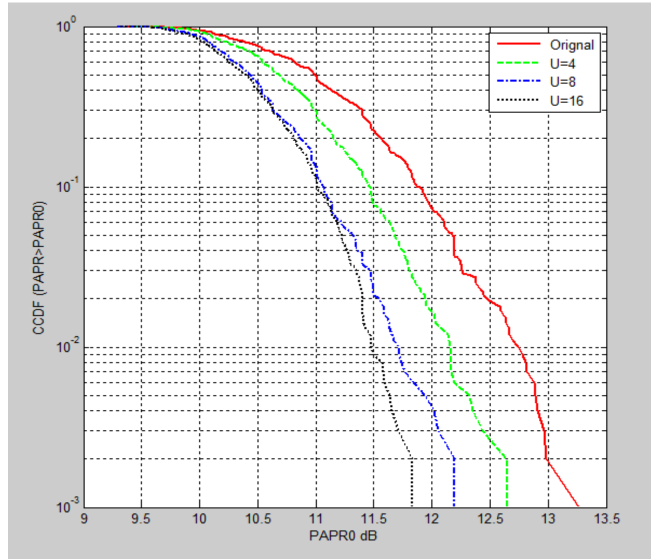

Fig. 4. CCDF of PAPR of MC-CDMA using SLM for various U where QPSK is used as a modulation technique.

In fig. 4, at CCDF=10^{-3}, MC-CDMA with SLM method applying QPSK as modulation technique, the PAPR is reduced by 0.7dB, 1.1dB, 1.5dB for values of U=4, 8 and 16 respectively when compared with the original MC-CDMA signal.

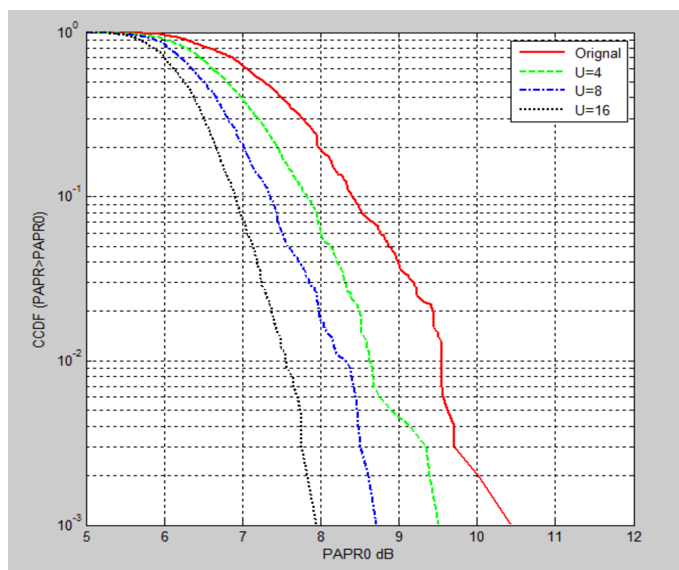

Fig. 5. CCDF of PAPR of MC-CDMA using SLM for various U where BPSK is used as a modulation technique.

In fig. 5, at CCDF=10^{-3}, MC-CDMA with SLM method applying BPSK as modulation technique, the PAPR is reduced by 0.9dB, 1.7dB, 2.45dB for values of U=4, 8 and 16 respectively when compared with the original MC-CDMA signal.

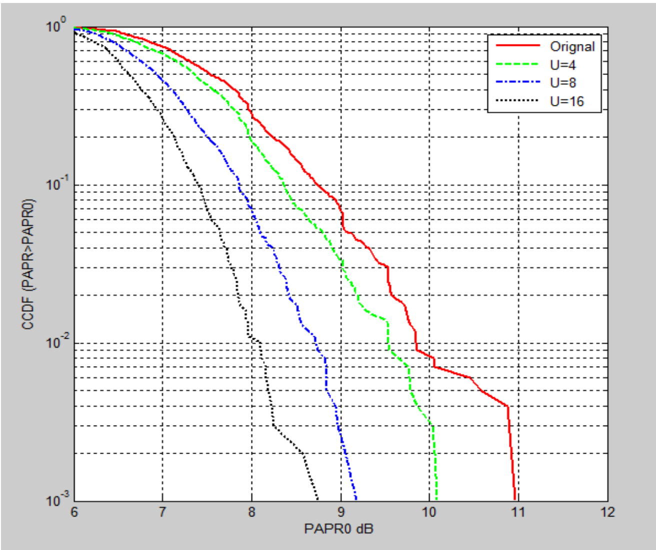

Fig. 6. CCDF of PAPR of MC-CDMA using SLM for various U where MSK is used as a modulation technique.

In fig. 6, at CCDF=10^{-3}, MC-CDMA with SLM method applying MSK as modulation technique, the PAPR is reduced by 0.95dB, 1.9dB, 2.2dB for values of U=4, 8 and 16 respectively when compared with the original MC-CDMA signal.

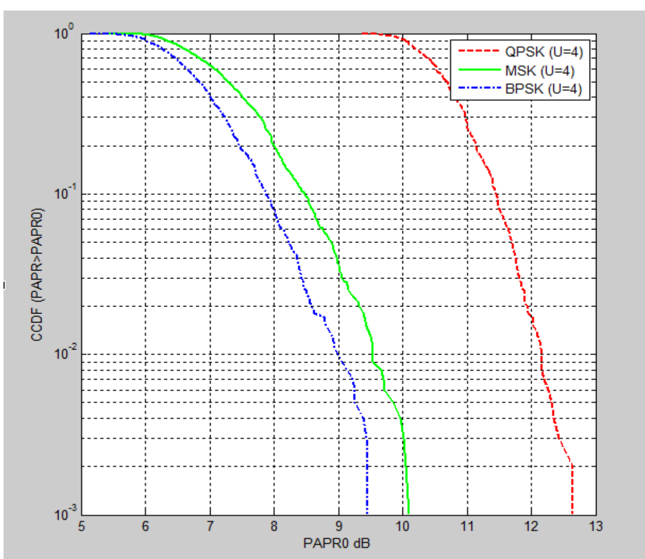

Fig. 7. Comparison of PAPR reduction performance for SLM at U=4 by different modulation techniques

In comparison of performance on PAPR reduction of MC-CDMA system using SLM at U=4 for described modulation schemes (BPSK, QPSK, MSK) as shown in fig. 7 BPSK has better performance of PAPR reduction than QPSK and MSK. For the same CCDF probability 10^{-3}, the PAPR value equals to 9.4dB when BPSK is employed, while the PAPR raise upto10.05dB for MSK and the value further rises to 12.75dB when QPSK is employed under the same circumstances.

V. CONCLUSION

In this paper we examined the effect of SLM to reduce PAPR of MC-CDMA for different modulation schemes. The binary phase sequences considered in this paper are generated from hadamard matrix. From the MATLAB simulation, the results shows that PAPR reduction performance depends upon various number of phase sequence factors (U) and it significantly improves with increase in number of U. PAPR performance is also compared for different modulation schemes (QPSK, BPSK and MSK) and the result showed that SLM is more effective when BPSK is used as modulation scheme.

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