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PAPR Reduction of an MC-CDMA System through PTS Technique using Suboptimal Combination Algorithm

Gagandeep Kaur[1], Rajbir Kaur[2]
Student[1], University College of Engineering, Punjabi University, Patiala, India
Assistant Professor[2], University College of Engineering, Punjabi University, Patiala, India

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 PTS technique is investigated by using suboptimal combination algorithm, which uses binary phase factors, for BPSK and QPSK modulation techniques at different number of active users. The results show that BPSK is a more effective modulation scheme for PAPR reduction in MC-CDMA system.

Keywords: MC-CDMA, PAPR, Partial Transmit Sequence, Complementary Cumulative Distribution Function.

1. INTRODUCTION

The multicarrier transmission has been considered as an attractive technique that offers the desired high data rates for the 4G mobile environment. It also has advantages for spectral efficiency and low cost implementation. Multicarrier code division multiple access technique (MC-CDMA) is a combination of CDMA scheme and OFDM signaling is the most promising candidate for the next generation of wireless communication for achieving high data rates. In addition it provides an efficient method for frequency diversity, overcoming the inter-symbol interference (ISI) in frequency selective Rayleigh fading environment by using guard interval. [1]- [3]

However, MC-CDMA has some major drawbacks to implement it in practical telecommunication systems. One of them is that MC-CDMA signal suffers a high Peak to Average Power Ratio (PAPR). A high PAPR easily makes signal peaks to 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 RF power amplifier.

Therefore it is desirable that transmitted signal possess reduced peaks and in order to achieve this there are several PAPR reduction techniques. 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 increases 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 we have investigated PAPR reduction on partial transmit sequence (PTS) method using suboptimal combination algorithm which uses binary phase factors.

2. SYSTEM DESCRIPTION

2.1 MC-CDMA system

The transmitter model of downlink MC-CDMA system is shown in fig.1. The block of M complex valued symbol, $d^{(k)} = [d_1^{(k)}, d_2^{(k)}, ..., d_M^{(k)}]$ of the k^{th} user is firstly serial –paralleled into a M-length vector as $d^{(k)} = [d_1^{(k)}, d_2^{(k)}, ..., d_M^{(k)}]^T$, k=1,2,…,K. After this serial to parallel conversion, each symbol is frequency domain spread by a user spreading code $c^{(k)} = [c_1^{(k)}, c_2^{(k)}, ..., c_L^{(k)}]$, where L denotes length of the spreading code. As 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. The input of K users is summed up and is interleaved in frequency domain as $X = \sum_{k=1}^{K} X^{(k)} = [X_0, X_1, ..., X_{N-1}]^T$ to obtain the diversity effects by placing the chip symbol elements that corresponds to same symbol on subcarrier that are distance M apart. After frequency interleaving the symbol elements are fed into IFFT block of size $N = M \times L$ for OFDM operation. The resultant baseband signal for one MC-CDMA symbol is represented as

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

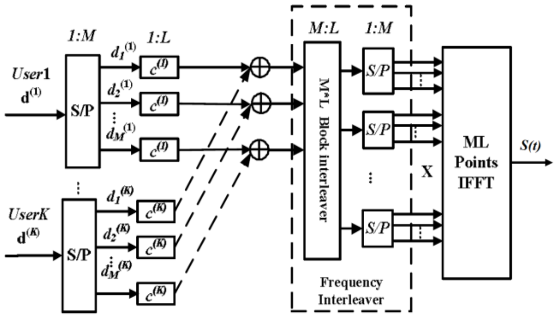

Figure 1: MC-CDMA transmitter

2.2 PAPR and Cumulative Distribution Function

Although MC-CDMA is a powerful multiple access technique but it is not problem free. MC-CDMA signal has large peak to average ratio (PAPR) .MC-CDMA consist of large number of independently modulated sub carriers where N modulated subcarriers are added with same phase, then peak power is N times the power of MC-CDMA signal.High PAPR values cause a serious problem to linear power amplifier (PA) used at transmitter.

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

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

(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 [5].

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

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

The CCDF of the PAPR of the data block is desired is our case to compare various reduction techniques. This is given by [4]:

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

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 [9]. 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 sample will give a better estimated PAPR.

3. PARTIAL TRANSMIT SEQUENCE (PTS) METHOD

This method is based on phase shifting of sub-blocks of data and multiplication of data structure by random vectors. The main purpose behind this method is that the input data frame is divided into non-overlapping sub-blocks and each sub-blocks is phase shifted by constant factor to reduce PAPR [9]. In the PTS technique, an input data block of N symbols is partitioned into disjoint sub-bocks. The subcarriers in each sub-block are weighted by phase factor for that sub-block. The phase factors are selected such that the PAPR of the combined signal is minimized. There are three different kinds of sub-block partitioning schemes on which the performance of PTS technique depends: adjacent, interleaved, and pseudorandom. [10-12]

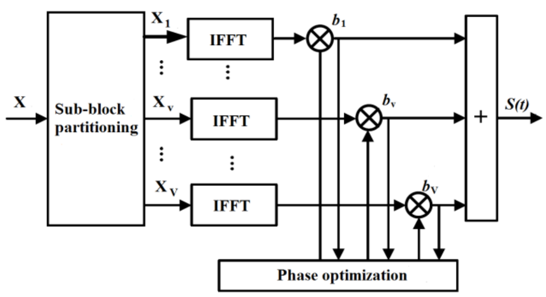

Figure 2: Block diagram of conventional PTS scheme

In the conventional PTS scheme in MC-CDMA, before applied to IFFT operation, X, i.e., the sum of all active user sequences after spreading and frequency interleaving is input to PTS model as shown in figure 2. [12]

The data block, X_n , $n=0,1,...,N-1$ is defined as vector, $X=[X_0, X_1,...., X_{N-1}]^T$. Then partition X into V disjoint sets, represented by vectors $X^{(v)}$, $v=1,2,...,V$ such that

$$X = \sum_{v=1}^{V} X^{(v)} \tag{5}$$

The objective of PTS approach is to form weighted combination of V clusters, each of equal size.

$$S = \sum_{v=1}^{V} b^{(v)} X^{(V)} \tag{6}$$

where $b^{(v)}$, $v=1,2,...,V$ are weighting factors or phase factors and are assumed to be pure rotations.

After transferring in time domain equation (6) becomes

$$s(t) = \sum_{v=1}^{V} b^{(v)} x^{(V)} \tag{7}$$

The vector $x^{(v)}$ called partial transmit sequence is the IFFT of $X^{(V)}$. The weighting factors are chosen to minimize the PAPR by searching for the appropriate combination of each cluster and by corresponding weighting clusters.

$$\left\{\tilde{b}^{(1)},\tilde{b}^{(2)},...,\tilde{b}^{(V)}\right\} = \underset{\{\tilde{b}(1),\tilde{b}(2),...,\tilde{b}(V)\}}{\arg\min}\left(\max_{0\le m\le N-1}\left|\sum_{v=1}^{V} b^{(v)} x_n^{(v)}\right|\right) \tag{8}$$

The combination with weighting factors is called rotation factor or combining sequence. Optimized transmit sequence is

$$\tilde{s}(t) = \sum_{v=1}^{V} \tilde{b}^{(v)} x_m^{(v)} \tag{9}$$

In suboptimal combination algorithm, we consider binary (i.e., ± 1) weighting factors. After dividing the input data block into V clusters, form the VN-point PTS's. As first step, assume that $b_v = 1$ for all v and compute the PAPR for the combined signal (7). Next, invert the first has factor $(b_1 = -1)$ and recomputed the resulting PAPR. If the new PAPR is lower than the previous step, retain b_1 as a part of final phase sequence; otherwise, b_1 reverts to its previous value. The algorithm continues in this fashion until all V possibilities for "flipping" the signs have been explored.

This algorithm can be summarized as :

1. Partion the input data block into V subsets as in equation (5).
2. Set all the phase factors b^v for v=1:V, find PAPR of equation (7), and set it as PAPR_min.
3. Set the v=2.
4. Find PAPR of equation (7) with b^v = -1.
5. If PAPR>PAPR_min, switch b^v back to 1. Otherwise, update PAPR_min=PAPR.
6. If v<V, increment v by 1 and go back to step 4. Otherwise, exit this process with the set of optimal phase factors, $\tilde{b}$.

4. SIMULATIONS

In this section the performance MC-CDMA system is evaluated using SLM. Table I above 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 [13]. 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
Processing Gain (L)	16
Number of data symbols per an MC-CDMA symbol (M)	8
Number of sub-carriers (N)	128
Number of active users (K)	8,16
Number of phase sequences (U)	4,8 and 16
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 (V=2, 4, 8) when considered number of active users to be equal to 8and 16. The phase sequences used are binary phase sequences {1,-1}, which are constructed by suboptimal combination algorithm. The system consists of 128 subcarriers with modulation schemes used to be BPSK and QPSK. The results are compared with the original MC-CDMA signal.

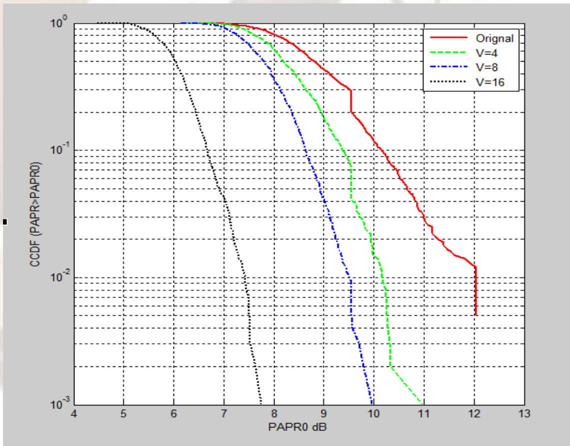

Figure 3: CCDF of PAPR of BPSK modulated MC-CDMA using PTS scheme for various values of V with K =8

Fig. 3 shows the CCDF curves of an BPSK modulated MC-CDMA system with PTS technique for 8 users (K=8). In figure 3, at CCDF=10^{-3}, the PAPR is reduced by 1dB, 2dB, 4.2dB for values of

V=4,8 and 16 respectively when compared with the original MC-CDMA signal.

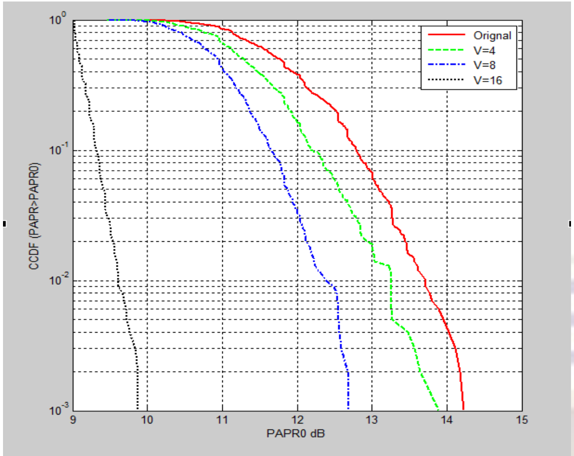

Figure 4: CCDF of PAPR of QPSK modulated MC-CDMA using PTS scheme for various values of *V* with *K*=8

Fig. 4 shows the CCDF curves of a QPSK modulated MC-CDMA system with PTS technique for 8 users (*K*=8). In figure 4, at CCDF=10^{-3}, the PAPR is reduced by 0.3dB, 1.4dB, 4.3dB for values of V=4,8 and 16 respectively when compared with the original MC-CDMA signal.

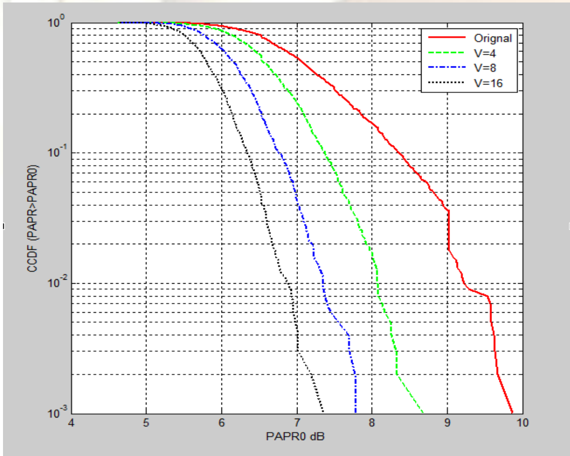

Figure 5: CCDF of PAPR of BPSK modulated MC-CDMA using PTS scheme for various values of *V* with *K* =16

Fig. 5 shows the CCDF curves of a BPSK modulated MC-CDMA system with PTS technique for 16 users (*K*=16). In figure 5, at CCDF=10^{-3}, the PAPR is reduced by 1.2dB, 2.1dB, 2.5dB for values of V=4,8 and 16 respectively when compared with the original MC-CDMA signal.

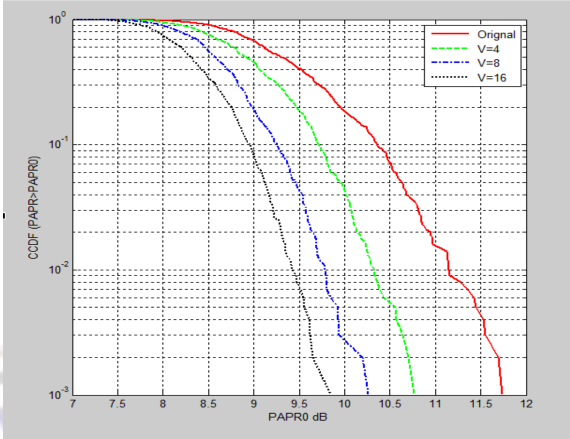

Figure 6: CCDF of PAPR of QPSK modulated MC-CDMA using PTS scheme for various values of *V* with *K* =16

Fig. 6 shows the CCDF curves of a QPSK modulated MC-CDMA system with PTS technique for 16 users (K=16). In figure 6, at CCDF=10^{-3}, the PAPR is reduced by 1dB, 1.4dB, 1.9dB for values of V=4,8 and 16 respectively when compared with the original MC-CDMA signal.

5. CONCLUSION

In this paper we examined the effect of PTS to reduce PAPR of MC-CDMA for different modulation schemes. The binary phase sequences considered in this paper are generated with the help of suboptimal combination algorithm. From the computer simulation, the results obviously shows that PAPR reduction performance depends upon various number of phase sequence factors (*V*) and it significantly improves with increase in number of *V* for any number of active users and the modulation technique. PAPR performance is also compared for different modulation schemes (QPSK and BPSK) and simultaneously for different number of users. The results show that higher PAPR reduction performance is achieved when BPSK is used as a modulation technique than QPSK for same number of active users. The results showed that PTS is more effective when BPSK is used as modulation scheme. From the graphs it can also be concluded that PAPR reduction performance increases with increase in number of active users.

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