

PAPR Reduction Technique in OFDM System For 4G Wireless Applications Using Partial Transmit Sequence Method

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ABSTRACT: At present for high data rate transmission, orthogonal frequency division multiplexing (OFDM) is the best and efficient modulation and multiplexing scheme adapted for 4G wireless communication applications. OFDM is an efficient method of data transmission for high speed communication system. OFDM is a multicarrier modulation technique that provides high band width efficiency because the carriers are orthogonal to each other and multiple carriers share the existing data. The main drawback of OFDM system is the high peak to average power ratio (PAPR) of the transmitted signal. OFDM consist of large number of independent sub carriers as a result of which amplitude of such a signal can have high peak valves .The Different PAPR reduction techniques available, such as Clipping, Companding, Selective Mapping (SLM), Interleaving, Tone reservation (TR) Tone Injection (TI) and Partial Transmit Sequence (PTS) and made comparison between them. In this paper, we analyzed and simulated PTS technique for 4G wireless communication applications. In this the data block to be transmitted is partitioned in to disjoint sub blocks. It is the combination of phase factors to minimize PAPR. It is observed that the PTS techniques are more efficient, practical and attractive.

Keywords: OFDM System, 4G Wireless Communications, LTE, PAPR, PTS

I. INTRODUCTION

At present OFDM is effectively used for many high speed data communications systems after long term evaluation of wireless systems, due to its robustness to multipath fading, high spectral efficiency, immunity to impulse interferences, flexibility and easy equalization over single carrier communication systems. The OFDM is a multicarrier modulation technique, in which the bit stream is divided over several orthogonal subcarriers, each modulated at a low rate. The block diagram of OFDM system is described in figure1. The orthogonality condition is assured by choosing appropriate frequency spacing between them. The number of sub-carrier is chosen to insure that each sub-channel has a bandwidth less than the channel coherence bandwidth thereby experiencing flat fading.

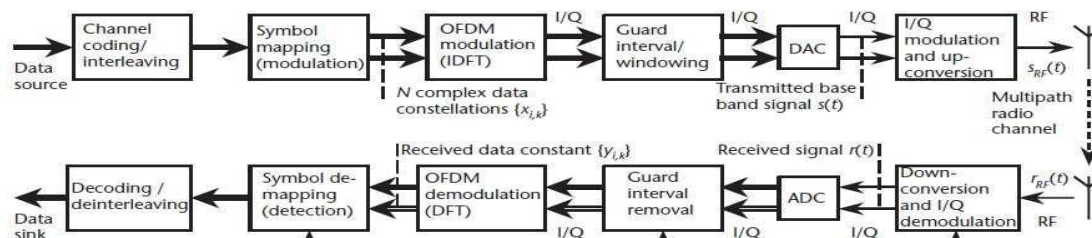


Fig. 1 The block diagram of OFDM system

The main disadvantage of OFDM is its high Peak-to-Average Power Ratio (PAPR) which causes distortion in the signal when it passes through High Power Amplifier (HPA) and Digital-to-Analog converter (DAC). It results in lower mean power level. The PAPR of the transmitted signal is defined as ratio of peak power to the average power of the signal. The PAPR cannot be increased just by increasing the signal power. The PAPR can be increased by using many techniques have been proposed by various researchers which include Clipping, Companding, Coding, Interleaving, Selective Mapping, Partial Transmit Sequence, and Active Constellation Extension. Tone Reservation and Tone Injection. The Many PAPR reduction techniques result in

performance degradation in terms of BER as compared to original OFDM signal. The PAPR problem in OFDM is represented as an expression of one OFDM a symbol starting at $t = t_s$ is represent as

$$S(t) = Re \left\{ \sum_{i=-\frac{N_s}{2}}^{\frac{N_s}{2}-1} d_i + N_s/2 \exp(j2\pi (f_c - \frac{i+0.5}{T}) t - ts) \right\} ts \leq t \leq ts + T \quad (1)$$

$$S(t) = 0, t < s(t) = 0, t < ts + t \quad (2)$$

Where d_i are complex modulation symbols N_s is the number sub-carrier, T the symbol duration and f_c the carrier frequency.

According to DVB-T standard as the emitted signal represented as

$$S(t) = Re \left\{ e^{j2\pi f_c t} \sum_{m=0}^{\infty} \sum_{i=0}^{67} \sum_{k=kmin}^{kmax} C_{m,i,k} \psi_{m,i,k}(t) \right\} \quad (3)$$

$$\psi_{m,i,k}(t) = \begin{cases} e^{j2\pi k(t - \Delta - l.T_s - 68.m.T_s)} & \text{else} \\ 0 \leq (l + 68.m + 1).T_s \leq t \leq (l + 68.m).T_s \end{cases} \quad (4)$$

PAPR is usually defined as

$$PAPR = \frac{P_{peak}}{P_{average}} = 10 \log_{10} \frac{\max [|x_n|^2]}{E [|x_n|^2]} \quad (5)$$

Where P_{peak} represents peak output power $p_{average}$ means average output power denotes the expected value of x_n that represents the transmitted OFDM signals which are obtained by taking IFFT operation on modulation input symbol x_k mathematical, x_n is expressed as:

$$x_n = \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} X_K W_N^{nk} \quad (6)$$

For an OFDM system with N sub-carrier, the peak power of received signal is N times the average power when the phase are same.

II. PAPR REDUCTION TECHNIQUES AND ITS COMPARIISON

The Clipping is simplest technique for PAPR Reduction in which a predetermined threshold signal level is used for clipping. It introduces both in-band and out-of-band distortion which can destroy Orthogonality of the subcarriers. The windowing of the clipped signal can be done which should be ideally to made the signal as narrow as possible. Clipping also introduces peak re-growth in OFDM signal which can be reduced by Repeated Clipping And Filtering (CAF) method, Deep Clipping, combined CAF and Interleaving described in previous papers already. The Clipping operation is always performed on oversampled signal to reduce in-band distortion.

The companding in OFDM signal are two types- linear and non-linear. Linear companding focuses on expanding small signals only while non-linear companding enlarges small signals as well as compresses the large ones thereby obtaining uniform distribution of signals. Therefore, the average power is increased and thus the PAPR of the Orthogonal Frequency Division Multiplexing systems can be reduced, which in turn helps in increasing the efficiency of the power amplifiers. In terms of BER Linear companding performs well.

Coding techniques such as FEC codes are used to mitigate the effect of the distortion techniques. The code OFDM is termed as COFDM so that the signal degradation can be made less. The basic concept is that when N signals are added in phase they add up to the signal power, such arrangements can be made with different coding schemes like Simple Odd Parity Code (SOBC), Cyclic Coding (CC), Simple Block Code (SBC) Complement Block Coding (CBC) and Modified Complement Block Coding (MCBC), Reed-Solomon, Simplex codes, Reed-Muller codes and Go lay complementary codes described in previous papers already can significantly reduce PAPR.

The Interleaving is also termed as Adaptive Symbol Selection Method. Multiple OFDM symbols are created by bit interleaving of input sequences .The basic Idea is to use W interleaving ways and selecting one with the lowest PAPR. PAPR Reduction capability depends on the number of interleave used in OFDM. To recover the signals the receiver need to know the information about which interleave is used.

The Selective Mapping (SLM) is most promising because it introduces no distortion yet can achieve significant PAPR reduction. Data blocks are converted into several independent blocks and the one with lower PAPR is sent in which converting process involves multiplying data sequences to random phase sequences generated. The selected index is called side-information index (SI Index), must also be transmitted to allow recovery of the data block at the receiver side. SLM leads to the reduction in data rate. Probability of erroneous SI detection has a significant influence on error performance of the system.

In Partial Transmit Sequence (PTS) technique, an input data block of N symbols is partitioned into disjoint sub-blocks and then the signal is transmitted. Another factor that may affect the PAPR reduction performance in PTS is the sub-block partitioning, which is the method of division of the subcarriers into multiple disjoint sub-blocks .There are three kinds of sub-block partitioning schemes that is adjacent, Interleaved and pseudo-random partitioning. The PTS technique works with an arbitrary number of subcarriers

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and any modulation scheme. Advantage is that works with an arbitrary number of subcarriers any modulation scheme. But, this scheme includes complexity and side information like SLM.

Active Constellation Extension (ACE) technique deals with extending the constellation points outside the signal constellation which is then used to cancel the time domain peaks. In this, the points where these constellation points can be extended is a technique that has several advantages like no loss of data, no degradation in system performance, lower BER as compared to other techniques and bears no side information like SLM. Some variations of this method like clipping-based ACE and Adaptive ACE in which repeated CAF and in later an adaptive control has been used to optimize the performance.

In Tone Reservation (TR) and Tone Injection (TI), some set of tones are reserved called as peak reduction carriers. These tones are added to the data signal to isolate energy to cancel large peaks. This tones does not bear any information and are orthogonal to each other. The Tone Injection technique reduces the PAPR without reducing the data rate similar to ACE some constellation points are extended outside the signal constellation but in a different way than in ACE.

Table 1: Comparison of PAPR Reduction Techniques

Technique	Complexit	Distortio	Data	Power
Clipping	No	yes	no	No
Interleaving	No	no	yes	No
Coding	No	No	yes	No
Compandin	No	No	yes	Yes
ACE	No	No	no	No
SLM	Yes	No	yes	No
PTS	Yes	No	yes	Yes
TR and TI	No	No	no	Yes

Table 1 depicts comparison between various PAPR Reduction schemes for OFDM signal. All the PAPR reduction techniques results in some BER performance degradation when compared to original OFDM signal. Efficient PAPR reduction scheme is one which reduces the PAPR to minimum without affecting much to the performance and also with low implementation cost.

III. PARTIAL TRANSMIT SEQUENCE TECHNIQUE

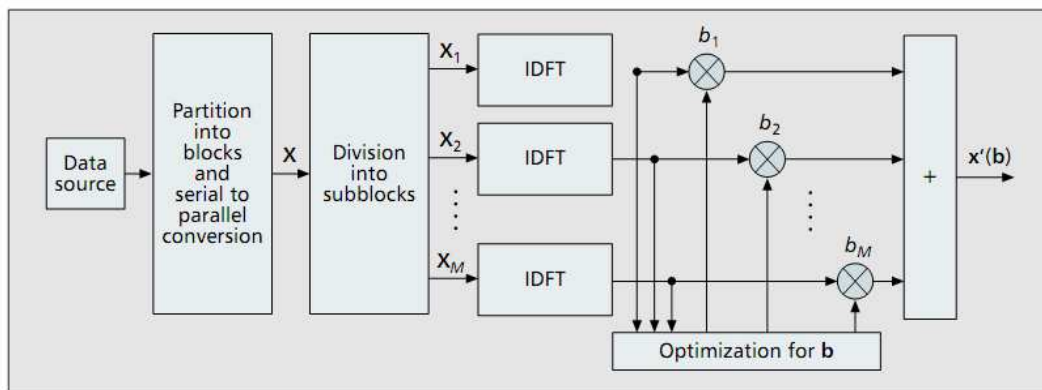


Fig. 2 Block diagram of Partial Transmit Sequence

The Block diagram of PTS is shown in Figure 2. In the PTS technique, an input data block of N symbols is partitioned into disjoint sub-blocks and then the signal is transmitted. Another factor that may affect the PAPR reduction performance in PTS is the sub-block partitioning, which is the method of division of the subcarriers into multiple disjoint sub-blocks. There are three kinds of sub-block partitioning schemes: adjacent, interleaved and pseudo-random partitioning. The PTS technique works with an arbitrary number of subcarriers and any modulation scheme. Advantage is that works with an arbitrary number of subcarriers any modulation scheme. But, this scheme includes complexity and side information like SLM. The Partial transmit sequence (PTS) algorithm is a technique for improving the statistics of a multi carrier signal.

The basic idea of partial transmit sequences algorithm is to divide the original OFDM sequence. In to several sub-sequence and for each sub-sequence multiplied by different weights until an optimum value chosen above diagram the block diagram of PTS technique. From the left side of diagram, the data information in the frequency domain X is separated into V non-overlapping sub-blocks and sub-block

vector has the same size N. so for each and every sub-block it contain N/V non zero element and set the rest part to zero. Assume that these sub-blocks have the same size and no gap between each other.

The sub-block vector is given by

$$X = \sum_{v=1}^V b_v x_v \quad (7)$$

Where the signal in time domain is obtained by applying IFFT operation on that is

$$\hat{x} = IFFT(X) = \sum_{v=1}^V b_v IFFT(X_v) = \sum_{v=1}^V b_v X_v \quad (8)$$

For the optimum result one of the suitable factor from combination $b = [b_1, b_2, \dots, b_v]$ is selected and the combination is given by

$$b = [b_1, b_2, \dots, b_v] = \underset{(b_1, b_2, \dots, b_v)}{\operatorname{argmin}} (\max_{1 \leq n \leq N} |\sum_{v=1}^V b_v X_v|) \quad (9)$$

Where $\operatorname{argmin}[(\cdot)]$ is the condition that minimize the output value of function

As a performance measure the complementary cumulative distribution function (CCDF) is one of the most frequently used for PAPR reduction techniques, which denotes the probability that the PAPR of a data block exceeds a given threshold z and is calculated by Monte carol simulation with nyquist rate sampling is derived as $P(\text{PAPR} > z) = 1 - (P(\text{PAPR} \leq z))^N = 1 - (1 - e^{-z})^N$ (10)

IV. SIMULATION OF OFDM

In this section, discussion of results of OFDM and PTS are presented.

4.1. Simulation Results of OFDM Spectra

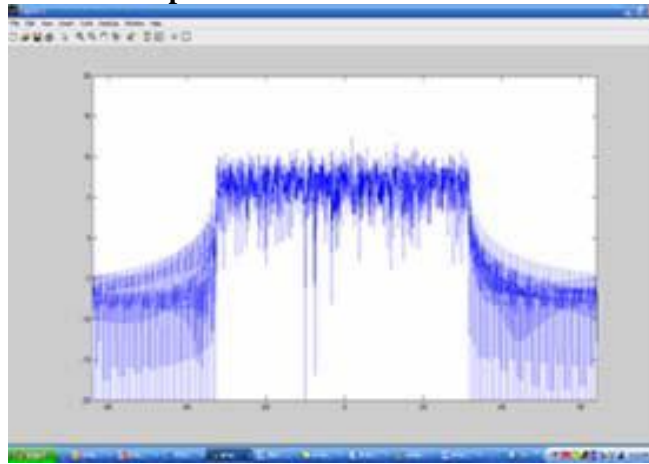


Fig. 3 OFDM Spectrum

The Figure 3 shows the simulation result of the OFDM spectrum is obtained through MATLAB simulation. For this simulation, the number of data bits transmitted is 1024 and data symbol per frame to IFFT is 64. The Guard Interval (GI) length is 2. From the simulation results it is concluded that by carefully selecting the carrier spacing, the OFDM signal spectrum is made flat and the Orthogonality among the sub-channels is guaranteed. The guard interval is added to maintain the orthogonality of the sub-carriers and to avoid inter symbol interference (ISI) and inter carrier interference (ICI). Since the spectra of the OFDM signal is not strictly band limited, linear distortion such as multipath cause each sub-channel to spread energy into the adjacent channels and consequently cause ISI. A simple solution is to increase the symbol duration or the number of carriers so that distortion becomes insignificant.

Random data is taken and transmitted. The transmitted data after being appended with cyclic prefix. This data is fed as input to the QPSK Modulator block. After the signal is QPSK modulated, it is fed as input to the IFFT block where the IFFT operation is performed and finally transmitted. The received signal is corrupted with the noise present in the channel. Fast Fourier Transform is performed on all the four sub-carriers and the signal characteristics are obtained. The QPSK demodulator output signal clearly matches the original signal that is transmitted data is clearly received by the receiver.

4.2 Simulation of PTS in OFDM

In order to evaluate and compare the performance of PAPR reduction, a MATLAB simulation was performed and results are shown in figure 4. Computer simulation was performed for the OFDM systems which have 128 subcarriers, QPSK modulation and oversampling factor of 4. Simulation, in which four sub-blocks ($M=4$) and the set of phase weighting factors $\{1, -1, j, -j\}$ ($W=4$) with adjacent sub-block partition are considered. The results show that the proposed PTS scheme achieves better PAPR reduction. It is observed that the original OFDM signal has high PAPR of 10.4 dB, the Conventional PTS (C-PTS) has PAPR of 5dB. Hence, the proposed scheme achieves 5.4 dB of more PAPR reduction is achieved. It is observed that from figure 4 the number of sub-carriers (N) are given as 64, the over sampling factor considered as 4, the modulation scheme is used is QPSK, the number of sub-blocks used in PTS method is assumed 4, the total number of combinations of IFFT selected as weighting factors 256, and the number of OFDM signal considered are 1000.

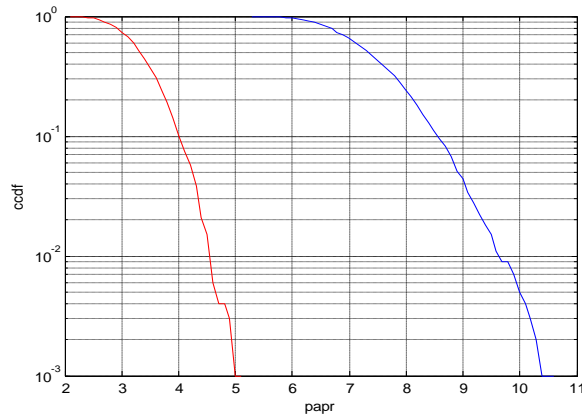


Fig.4 CCDF using PTS N=64

V. CONCLUSION

High PAPR of transmitted signal is one of the major drawbacks of OFDM systems. In the conventional PTS scheme, the computational complexity increases extensively with the number of sub-blocks. In order to reduce this complexity and to achieve better PAPR reduction by PTS scheme is proposed. Theoretical analysis and simulation results show that, the proposed scheme can obtain more PAPR reduction. Moreover, the proposed scheme does not require side information to recover the original signal. Firstly PAPR reduction concept will be expand for distortion less transmission and identifying the best alternatives in terms of performance increase. Secondly, PAPR reduction technique will be develop for low data rate loss and efficient use of channel. A study of the complexity issues of the PAPR reduction technique is required, especially looking at ways of future reducing the complexity of the sphere decoder.

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