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Comparison of Different PAPR Reduction Techniques in OFDM System

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Abstract: ***OFDM is an orthogonal frequency division multiplexing. OFDM has become popular in wireless communication. It is a digital modulation technique based on parallel transmission of information. It is a multicarrier transmission where single data is transmitted over no. of lower rate subcarriers. One of the main challenging issues for orthogonal frequency division multiplexing system is its high PAPR. In this paper, we review different PAPR reduction technique which can used to reduce PAPR and compare these techniques.***

Keywords: OFDM (Orthogonal Frequency Division Multiplexing), PAPR (Peak to average power ratio), BER (Bit Error Rate), PTS (Partial transmit sequence), SLM (Selective Mapping), CCDF (Complementary cumulative distributed function)

I. INTRODUCTION

As a promising technique, OFDM is adopted in various communication applications such as Digital Video Broadcasting (DVB), Digital Audio Broadcasting (DAB) and Wireless Local Area Network (WLAN).[5]Orthogonal frequency division multiplexing OFDM is a "Multi-carrier Modulation Scheme" .It is much easier to use single carrier transmission scheme because of its simplicity , power saving and accuracy . But the main drawback of single carrier transmission is ISI (Inter Symbol Interference). OFDM is used to overcome the shortages of single – carrier transmission scheme in the case of having high data rate. OFDM is a good solution for high speed digital communication.[10] The basic principle of OFDM is the high speed serial data stream is converted to multiple parallel low speed data stream. OFDM scheme has low chance of ISI .OFDM is getting so popular since it is less exposed to multipath effects, that makes it core technique for future standard systems, beside high efficiency of spectrum.[7] The major drawback of OFDM is its high peak to average power ratio (PAPR), which makes it sensitive to non-linear effect of power amplifier. The theoretical value of PAPR is given by the number of subcarrier in use. The PAPR of multi carrier signals is high as compared to the single a carrier. The high PAPR reduces the efficiency of power amplifier.[1]

OFDM have several attractive features which make it more advantageous for high speed data transmission over other data transmission techniques. These features include high spectral efficiency, immunity to impulse interferences, flexibility and easy equalization. But in spite of these benefits there are some obstacles in using OFDM such as high peak to average power ratio (PAPR), very sensitive to frequency errors and inter carrier interference between the subcarrier. There are various techniques to overcome PAPR. These techniques can be categorized into signal scrambling and signal distortion techniques.[7]

II. OVERVIEW OF PAPR

The OFDM suffers from the serious problem of high PAPR. When the OFDM Signal is transformed to time domain the resulting signal is the sum of the all subcarrier, and all subcarrier add in phase and result in PAPR. It degrades the performance the system by forcing amplifier to work in non linear region. The PAPR is defined as the ratio between maximum instantaneous power and its average power.[1]

$$\text{PAPR}= \frac{\max |x(t)|^2}{E[x(t)^2]}$$

Where x(t) represents the amplitude of the complex pass band signal. For the OFDM system of N sub channels the signal is provided to all the same phase summation , the signal peak power will the N times the mean power and thus baseband signal can be written as[5]

$$\text{PAPR}= 10 \ \log_{10} N$$

To calculate the probability of PAPR having greater than the threshold value, CCDF is used. If we use linear amplifier that that have larger input than the nominal value, we could have non linear distortion at the output suppose we have high power amplifier having input and output characteristics. Input power id denoted by P_{in} and output power is denoted by P_{out}. To keep linearity, the maximum output power is denoted by P_{out}^{max} while maximum input power is represented by P_{in}^{max} .Both the input and output are backed off to insure a linear operation. In case of having non linear HPA characteristics, which is caused by having larger input than its nominal value, we could have out of band radiation that makes an overlap between the adjacent signals. [1]

III. Related Work

S. Bhavi et al. [1] had proposed that OFDM was multi carrier modulation scheme. OFDM used orthogonal subcarrier and also used available bandwidth efficiency. To achieve high speed transmission OFDM was generally used. As the no of subcarrier in OFDM increase the Peak to average power ratio increased. To minimize the effect of PAPR no of promising techniques had been proposed.Clipping and filtering technique gives improvement in PAPR reduction with slight increase in BER.

S. Verma et al. [2] had proposed that OFDM is attractive transmission technique for high bit rate transmission .One main disadvantage of OFDM was high peak to average power ratio of transmitter's of side information and can reduce the peak to average power ratio in turbo coded frequency division multiplexing system was proposed.

D.Narendra et al.[3] had proposed that for high data transmission OFDM was generally used. OFDM provided high band width efficiency because the carrier was orthogonal to each other and multiple carriers share the existing data. The main drawback of OFDM system was high peak to average power ratio of the transmitted signal. In order to reduce complexity and to achieve better PAPR reduction by PTS scheme was proposed.PTS was more efficient, practical, and attractive and there was low data loss.

M. Hasan et al. [4] had proposed that OFDM was an attractive signaling scheme for communication systems and adopted in many wireless standards. The main drawback of OFDM was its high Peak-to- Average Power Ratio (PAPR) which limits its applications in communication systems. In fact PAPR could cause power degradation and spectral spreading. The performances of different PAPR reduction techniques in OFDM systems, depends on Complementary Cumulative Distribution Function (CCDF), computational complexity, bandwidth expansion, in-band signal distortion and out-of-band radiation. Extensive computer simulations show that up to 8.4 dB reduction in PAPR can be achieved by different techniques.

X.Zhong et al.[5] had proposed that using clipping and filtering algorithm reduces PAPR of the system and BER performance was improved . It was analyzed that clipping and filtering method was more efficient than direct clipping because clipping and filtering algorithm reduces more PAPR than direct clipping algorithm. Clipping and filtering method use filter to remove in band distortion and it reduces peak re growth.

Z. Ibraheem et al.[6] had proposed that OFDM was most promising technique for transmitting of high stream data. The main disadvantage of OFDM was PAPR.PTS was the effective technique for PAPR reduction It involves partitioning of data into frames into disjoint sub blocks .It was observed that when size of partitions was increased, the performance was improved.

IV. PAPR REDUCTION TECHNIQUES

Various techniques to overcome PAPR are categorized in following two types-

A. SIGNAL SCRAMBLING TECHNIQUES

Block Coding Techniques, Selected Mapping (SLM), Partial Transmit Sequence (PTS), Tone Reservation and Tone Injection are signal scrambling techniques.

1. PARTIAL TRANSMIT SEQUENCE

Partial transmit sequence is one of the most efficient method to diminish PAPR. In PTS approach, the frequency domain sequence which are represented by vector X_m , m=0, 1, 2….M is partitioned into M disjoint sub- block of equal size in X input data block, which is represented by

$$X= \sum_{m-1}^{M} X_m$$

Then , the sub – block X_m are transformed into time – domain partial transmit sequence by used inverse discrete Fourier transform operation (IDFT), which is expressed as;

$$x_m = \sum_{m=1}^{M} \text{IDFT}\{X_m\}$$

Each sub- block is multiplied by phase factor and combined together to create a set of candidate. The candidate with the lowest PAPR is chosen for transmission. After combination, the time domain signal is given by-

$$x = \sum_{m=0}^{m} b_m \; x_m$$

There are three well known partitioning methods for PTS scheme: interleaved, adjacent and pseudorandom. Among all these schemes pseudorandom partitioning PTS scheme cab be obtained the better PAPR performance but the computational complexity is higher than other partitioning. The adjacent partitioning is also attractive due to its performance very close to pseudorandom in PAPR reduction The PTS works with an arbitrary number of subcarriers and any modulation scheme.[6][3]

2. BLOCK CODING TECHNIQUES

Block coding is the simple technique to reduce PAPR. The basic idea behind it is select words with the low peak power after coding gram all symbols. With N sub –carriers QPSK modulation provides 2N bits and thus 2^{2N} messages.

If k bit is encoded by (n, k) block code with generation of matrix G at transmitter and a phase rotator vector b is used to produce encoded output. By dividing large information sequence into different blocks and encode theses sub-blocks with system on programmable chips (SOPC) large PAPR is reduced.[9]

3. SELECTIVE MAPPING

Selective mapping is a most promising technique because it introduces no distortion and yet reduces PAPR. In this scheme input signal is divided into different sub blocks. Signal with low PAPR is selected from different phase sequences that have same information at transmitter. The selected index is called side information index .The transmitter use side information so that receiver can make use if that side information and tell which candidate is selected.SLM leads to reduction of data rate.[9][3]

4. TONE RESERVATION

The simplest way to reduce PAPR is tone reservation. This method shows that reserving a small fraction of tones leads to large reduction of PAPR with simple operation at transmitter. The unused tones may be reserved tones that do not carry data or tones that cannot carry data reliably due to their low SNR There is no need of side information and other additional operation and there is no complexity at the receiver end. It is based o summing of data block and time domain signal. The time domain

signal can be calculated at transmitter end and it stripped off at receiver. It has less complexity and little BER performance is improved. This method is distortion less and leads to very simple decoding of data symbol, which is detected from the used tones of received symbols, and the receiver can reject symbols of the unused tones.[8][3]

5. TONE INJECTION

It is based on additive method for PAPR reduction. This additive method can reduce PAPR of multicarrier signal without any data loss. The basic idea is that it modifies is equivalent to injecting a tone of appropriate constant C to their OFDM symbols. The constants are carefully selected so that PAPR can be reduced and it doesn't increase BER. It uses set of constellation points for an original constellation points to reduce PAPR.[8]

B. SIGNAL DISTORTION TECHNIQUES

Clipping and Filtering, Peak windowing etc are signal distortion techniques.

1. CLIPPING and FILTERING

It is one of the simple methods of PAPR reduction .In this method signal with high amplitude peaks are clipped off before passing it through the power amplifier. This is done with the help of clipper that limit the signal up to predetermined level known as clipping level (CL).Clipping is non linear process, which cause in band and out band distortion. In- band distortion cannot be removed by filtering. While the out band distortion cause spectral spreading that can be eliminated by filtering and will improve the BER performance but it results in peak re growth. Clipping & filtering algorithm is more efficient than direct clipping because it reduces more PAPR. [5] [1]

2. PEAK WINDOWING

It is possible to remove large peaks at the rate of a little amount of interference when large peak arise through this method. It reduces PAPR at cost of increase of BER .In this method large signal peaks are multiplied with a specific window such as Gaussian shaped window, Kaiser, Cosine and hamming window. This will result in spectrum of convolution of original OFDM spectrum with spectrum of window. The size of the window should be narrow otherwise it will effect number of signal samples and it will increase BER. [9]

V. OVERALL ANALYSIS OF VAROIUS TECHNIQUES

TECHNIQUE	DISTORTION	POWER	DATA LOSS	BER IMPROVED
PTS	YES	NO	YES	YES
BLOCK COADING	YES	NO	YES	YES
SLM	YES	NO	YES	YES
TI&TR	YES	YES	NO	YES
CLIPPING	NO	NO	NO	NO
PW	NO	YES	NO	NO

VI. CONCLUSION

Multicarrier systems are better than single carrier systems for transmission. OFDM is a digital modulation technique where orthogonal subcarriers are used to carry data. High PAPR is the main drawback of OFDM systems. In this paper different reduction techniques for different parameters are analyzed and also compared to reduce PAPR at the cost of loss in data rate, transmit signal power increase, BER performance degradation and so on.

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