ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 6, Issue 7, July 2018

A Comparative Survey on PAPR Reduction in MIMO-OFDM Signal for 5G Communication System

Amod Kumar, Md. Sanowar Imam

M. Tech Scholar, Department of Electronics and Communication, TIT, (Excellence), Bhopal, India

ABSTRACT: In communication field one of the recent emerging technology is the wireless technology. The wireless communication provides high data transmission for a growing idea of 4G and 5G communications. The high data rate transmission cannot be obtained by single carrier, so multicarrier modulation where we make use of subcarriers orthogonal to each other i.e., OFDM signal. The main drawback of this signal is high peak to average powers which causes distortion like in-band and out-band radiation. This survey paper presents different PAPR reduction techniques.

KEYWORDS: PTS, STBC, MIMO, OFDM, PAPR

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a higher order modulation technique in 5G which have advantage of high efficiency and less delay. This is the reason; OFDM has been decided for information rate correspondence and has been generally utilized as a part of numerous remote correspondence benchmarks, for example Digital Video broadcasting (DVB). However, there is challenging issue in the creation of the OFDM system. One of the significant issues is its elevated PAPR. Therefore, the OFDM receiver's recognition capability is exceptionally perceptive to the nonlinear gadgets used in its circuitry, such as Digital-to-Analog convertor (DAC) and High Power Amplifier (HPA). Most remote framework utilize HPA at the sender to acquire adequate transmit power and HPA is normally worked at or close to the saturation region to attain greatest output [1].

In the current scenario, the demand for a growth of wireless communication field increased due to the increase in the high speed transmission of data. The development of wireless communication devices increasing due to the innovation step by step for efficient broadcast. The fundamental principle of OFDM is that it supports multi carrier modulation [2] i.e., a data having an high rate stream are splitter into a stream of lower data rate which are transmitted consecutively over a many subcarriers which are perpendicular to each other. OFDM scheme has a benefit of providing high spectral efficiency [3], reduced multipath and inter symbol interference and increase in the bandwidth. Due to these advantages it is used in digital television and audio broadcasting, Wireless networks and in mobile communication. One of the main disadvantages of OFDM scheme is that high peak to average power ratio, which causes nonlinear distortion in the transmission section due to in-band and out band distortion. The numbers of methods are used to deal with the PAPR reduction in OFDM signal. In this paper several methods such as, PTS-Partial Transmit Sequence [4], SLM Selective mapping technique, Companding Technique [5], clipping and filtering [6] and Tone reservation techniques are discussed [7].

In OFDM signal model, first the input transmit signal is modulated by using PSK, QPSK or QAM modulation techniques and then the signal undergoes IFFT (Inverse Fast Fourier Transform) process at the transmitter section[11]. Due to this process orthogonal subcarriers are produced at the transmitter section. This transmitted signal has a very high peaks which is referred to has peak to average power ratio(PAPR).This PAPR degrades the performance of power amplifier and causes decrease in Signal to noise ratio of the signal. So there are several techniques are introduced to reduced high PAPR. The PAPR reduction efficiency is calculated through Cumulative Distribution Function (CDF).

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II. PAPR REDUCTION TECHNIQUE

Several PAPR reduction techniques are available in the literature. These methods are basically divided in four categories:

- Signal Distortion.
- Coding Methods,
- Probabilistic (Scrambling) Techniques
- Pre-distortion Methods.

Every method has some drawbacks and merits. There is always a trade-off between PAPR reduction and some other factors like bandwidth, computational complexity, average power etc. An ideal PAPR reduction technique should have following characteristics:

- High capability of PAPR reduction with few harmful side effects such as in-band distortion and out-of-band radiation.
- Low implementation complexity: Due to high implementation and computational complexity the delay in transmission increases which reduces data rate.
- Low average power: any increase in average power requires a larger linear operation region in HPA and thus resulting in the degradation of BER performance.
- No bandwidth expansion: The bandwidth is a costlier resource for any wireless communication systems. Therefore, it is required to reduce PAPR without increasing bandwidth of transmitted signal. The bandwidth expansion directly results in the data code rate loss due to side information. Therefore, the loss in bandwidth due to side information should be avoided or at least be kept minimal.
- No BER performance degradation: The PAPR should be reduce but not at the cost of BER reduction. The BER performance should be same as that of the original OFDM system.
- Without additional power needed: Any increases in power requirement reduce the efficiency of system, and power is an important resource for any wireless communication system. Therefore, it is necessary for any PAPR reduction scheme to reduce PAPR without increasing power requirement.
- No spectral spillage: The PAPR reduction techniques should not destroy the inherit feature (orthogonally) of OFDM signal.

Many PAPR reduction techniques are proposed in the literature. In this section, we investigate some such techniques and discuss their advantages and disadvantages in terms of PAPR reduction capability, BER degradation and computational complexity [20]. The PAPR reduction schemes are majorly divided into two categories
a) Distortion Based Techniques
b) Non-distortion Techniques

2.2.1 Distortion Based Techniques

The schemes that introduce spectral re-growth belong to this category. Distortion based techniques are the most straightforward PAPR reduction methods. Furthermore, these techniques distort the spectrum, this spectrum distortion or "spectral re-growth" can be corrected to a certain extent by using filtering operation. Further they can be sub divided.

Clipping and Filtering

Clipping is one of the simplest techniques to reduce the PAPR of OFDM signal. It reduces the peak of the OFDM signal by clipping the signal to the desired level. This operation can be implemented on discrete time samples prior to the DAC or by designing the power amplifiers with saturation level lesser than the OFDM signal dynamic range. The amplitude clipper limits the peak of the envelope of the input OFDM signal to a predetermined threshold value or otherwise passes the input signal unperturbed.

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Iterative Clipping and Filtering

Jean Armstrong proposed the repeated clipping and filtering scheme [8], in which clipping and frequency domain filtering operations are repeated several times to reduce both the out of-band radiation and PAPR to the desired level. The PAPR performance and amount of out of-band radiation mainly depends on the number of iterations to be performed, more the number of iterations lesser is the value of out-of-band radiations and PAPR. But, the computational complexity of iterative clipping and filtering scheme increases with the number of iterations. We have studied the effect of iterative clipping and filtering of OFDM signal through computer simulation. In this simulation, we have considered an amplitude clipper with a threshold γ o = 0.01 and four iterations.

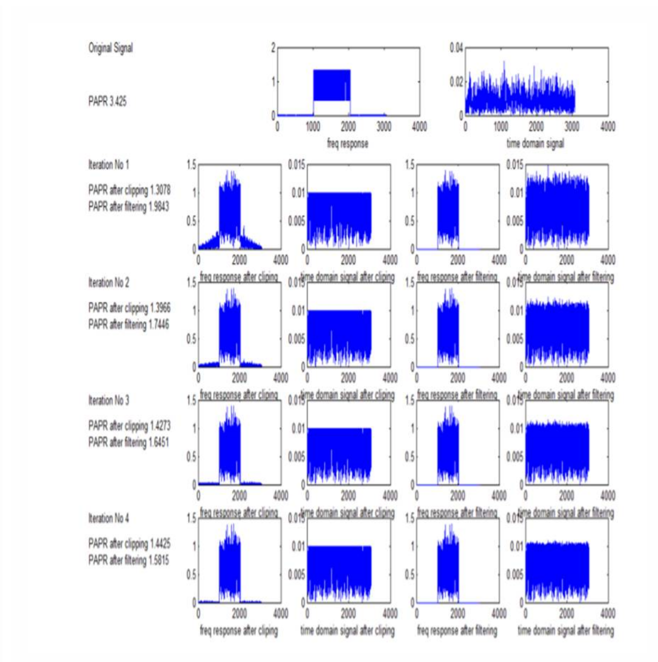

Figure 1: Time and frequency domain OFDM signal after Clipping and frequency domain filtering

Companding

Companding is another popular PAPR reduction scheme. Companding is a composite word formed by combining compressing and expanding. In this scheme, at the transmitter a signal with high dynamic range is applied to a compander and at the receiver a decompanding function (the inverse of companding function) is used to recover the original signal. Initially, it was used in digital communication systems to increase the dynamic range of digital to analog converters (DACs). The μ-law and A-law are the two most popular compressing functions used worldwide. In [9], Wang et al. proposed a scheme a μ-law companding scheme to reduce the PAPR of OFDM signal.

2.2.2 NON-DISTORTION TECHNIQUES

These types of PAPR reduction schemes do not distort the shape of the OFDM signal and therefore no spectral re-growth take place.

Selected Mapping

Selected mapping is one of the most popular distortions-less PAPR reduction scheme. In this scheme a block of N modulated data symbols $\{X_k\}$ k is partitioned into S disjoint sub blocks, where S < N. After partitioning, S data sub-blocks are represented by $[X_k$, s = 0, 1, 2, S −1, k = 0, 1,..., N −1], here the length of each data sub-block is N and all of them are disjoint in a sense that the value of X_k is non-zero only for one particular value of s, s ∈ 0,1, 2,……..S −1.

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In this simulation, we have considered a QPSK modulated OFDM signal with N=64 subcarriers. It can be seen from Figure 3.2 that the PAPR reduction capability of SLM-OFDM system increases by increasing the value of the number of phase sequences (U) in phase sequence set. But, this gain in PAPR reduction capability is obtained at the cost of increased computational complexity because for a phase sequence set with U phase sequences requires U IFFT operations to find the OFDM signal with lowest possible PAPR. Moreover, higher the value of U more is the number of bits required to encode the side information and therefore data rate loss is also more.

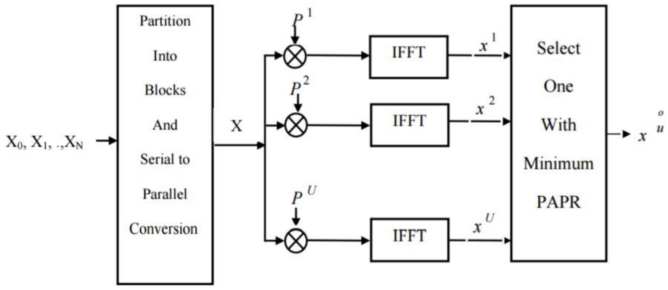

Figure 2: Block diagram of conventional SLM-OFDM transmitter

Tone Reservation (TR) and Tone Injection (TI)

Tone reservation was first described by Tellado and Cioffi in 1997. The basic idea is to reserve certain numbers (R) of subcarriers or tones for reducing the PAPR of the OFDM signal. The subcarriers or tones reserved for PAPR reduction are known as PAPR reduction tones (PRT). Here, the main objective is to choose the value of data signals to be transmitted on reserved tones to minimize the PAPR of time domain OFDM signal. The PAPR reduction capability of this scheme mainly depends on the number of PRTs and their location in the frequency band. The PRT locations are known in advance to both transmitter and receiver. The PRTs are not used for data transmission and therefore it results in data rate loss.

III. SYSTEM MODEL

MIMO in combination with OFDM is widely used nowadays due its best performance in terms of capacity of channels, high data rate and good outcome in frequency selective fading channels. In addition to this it also improves reliability of link. This is attained as the OFDM can transform frequency selective MIMO channel to frequency flat MIMO channels [8]. So it is widely used in future broadband wireless system/communications. Cyclic prefix is the copy of last part of OFDM symbol which is appended to the OFDM symbol that is to be transmitted. It is basically 0.25% of the OFDM symbol. We can say that one fourth of the OFDM symbol is taken as CP (cyclic prefix) and appended to each OFDM symbol. IFFT is used at the transmitter and FFT is used at the receiver which substitutes the modulators and demodulators. Doing so eliminates the use of banks of oscillators and coherent demodulators. Moreover the complex data cannot be transmitted as it is; therefore it is first converted to analog form which is accomplished by IFFT. It basically converts the signal from frequency domain to time domain. Prior to IFFT operation symbol mapping is performed which is nothing but the modulation block. Any of the widely used modulation techniques can be applied like BPSK, QPSK, QAM, PSK etc. Further there are higher order modulations are also available which provide more capacity at little expense of BER performance degradation. After IFFT block pilot insertion is done and then CP (cyclic prefix) is added. Figure 1 below shows the block diagram constituting MIMO and OFDM. Any antenna configuration for the MIMO can be used according to the system requirement. Higher the configuration more will be the capacity and more will be the computational complexity of the transceiver design. It is seen that in the case of estimating channel the computational complexity is increased. Mapper defines the modulation to be used. Symbol encoder takes the shape of the STBC (Space Time Block Code) if spatial diversity is to be used and it takes the shape of the de-multiplexer/multiplexer if spatial multiplexing is to be used.

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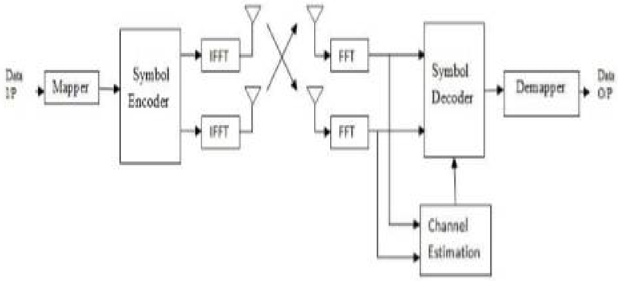

Figure 1: MIMO-OFDM system model

The received signal at j^{th} antenna can be expressed as

$$R_j[n.k] = \sum H_{ij}[n,k]\, X_i\, [n,k] + W[n,k] \quad (1)$$

Where H is the channel matrix, X is the input signal and W is noise with zero mean and variance. Also $b_i[n,k]$ represents the data block i^{th} transmit antenna, n^{th} time slot and k^{th} sub channel index of OFDM. Here i and j denoted the transmitting antennas index and receiving antenna index respectively.

The MIMO-OFDM system model [9] with NR receives antennas and NT transmits antennas can be given as:

$$\begin{bmatrix} Z_1 \\ Z_2 \\ \vdots \\ Z_N \end{bmatrix} = \begin{bmatrix} H_{1,1} & H_{1,2} & \cdots & H_{1,NT} \\ H_{2,1} & H_{2,2} & \cdots & H_{2,,NT} \\ \vdots & \vdots & \ddots & \vdots \\ H_{NR,1} & H_{NR,2} & \cdots & H_{NR,NT} \end{bmatrix} \begin{bmatrix} A_1 \\ A_2 \\ \vdots \\ A_{NT} \end{bmatrix} + \begin{bmatrix} M_1 \\ M_2 \\ \vdots \\ M_{NT} \end{bmatrix} \quad (2)$$

Where, Z represents O/P data vector, H denotes Channel matrix, A denotes I/P data vector and M represents Noise vector. The wireless channel used is AWGN channel. After receiving the signal the CP is removed then the pilots are also removed from main signal received. After this the signal that is in time domain can be again converted to frequency domain by taking FFT of the received signal.

The sequence on each of the OFDM block is then provided to channel estimation block where the received pilots altered by channel are compared with the original sent pilots. Channel estimation block consists of the algorithms that are applied to estimate the channel.

IV. CONCLUSION

OFDM is broadly conveyed in wireless 5G system because of its spectral competence and robustness of channel. But high PAPR is an issue in OFDM. In this paper we studied various PAPR diminishment methods, which have both merits and demerits (loss in data rate, degraded BER, increment in signal power, increased complexity).These techniques should be utilized according to the application.

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