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A Review: PAPR Reduction Techniques in MIMO OFDM System

Anuruddh Singh Parihar, Avinash Rai
Department of Electronics and Communication, University Institute of Technology, Bhopal

Abstract*— Orthogonal Frequency Division Multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. It is one of the modulation techniques which are multi-carrier, gives a high spectral efficiency, immunity to the frequency selective fading channels, power efficiency and multipath delay spread tolerance. It is more advantageous over other technologies. Although its advantages it has some obstacle also. The high peak-to-average ratio is the main obstacle which causes non-linearity at the receiving end. One of the major disadvantages in OFDM communication is the high peak-to-average power ratio (PAPR). In this paper we discuss about the PAPR in the OFDM system, its effect and some techniques name which can be used to reduce the PAPR according to our need. This approach has the potential of reducing the PAPR of the OFDM without affecting the bandwidth efficiency of the system and the Bit Error Rate (BER) performance..

Keywords: **OFDM, MIMO, PAPR, Precoding.**

I. INTRODUCTION

OFDM is a Multicarrier Transmission technique which divides the available spectrum into many carriers each one being modulated by a low data rate stream. OFDM is similar to Frequency Division Multiple Access (FDMA) in that the multiple user access is achieved by sub-dividing the available bandwidth into multiple channels, which are then allocated to users. However OFDM uses the spectrum much more efficiently by spacing the channels more closely simultaneously. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely. Multiple Input Multiple Output (MIMO) has been known as a technique to enhance the transmission quality and capacity. OFDM can be obtained with Multiple-Input Multiple-Output (MIMO) configuration to increase the diversity gain and to improve the system capacity. The subcarrier waveform shaping in OFDM is a form of precoding method where each OFDM block is linearly transformed by shaping matrix before modulation and transmission.

Orthogonal frequency-division multiplexing (OFDM) is a very popular technique for digital transmission over frequency selective channels. Due to the transmitter side signal processing a rather high peak-to-average-power-ratio (PAR) occurs, which leads to non-linear distortion of the power amplifier and in turn to out-of-band radiation.

In order to avoid these issues a transmitter side algorithm is necessary to decrease the PAR. OFDM uses the spectrum much more capably by spacing the channels closer together. This is achieved by making all the carriers orthogonal to one another, preventing interference between closely spaced carriers.

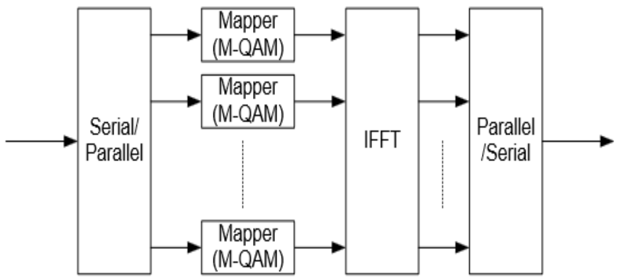

Fig.1. Principle schematic of OFDM modulator

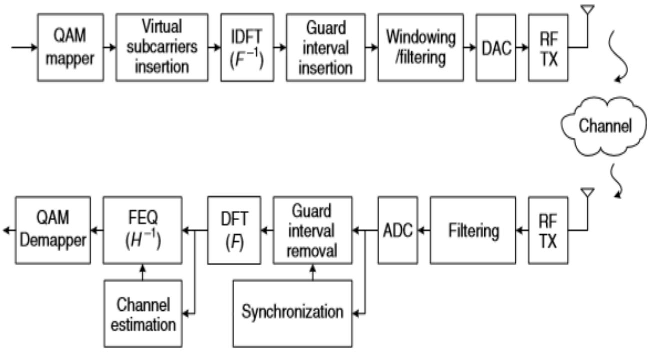

Fig.2. OFDM transceiver architecture

FDMA wastes the spectrum due to the necessity of inserting guard bands between channels for channel separation and filtering. In a typical system, up to 50% of the total spectrum is wasted in this manner [1]. This problem becomes worse as the channel bandwidth becomes narrower and the frequency band increases. In FDMA each user is typically allocated a single channel which is used to transmit all the user information. The bandwidth of each channel is typically 10-30 kHz for voice communication. However, the minimum required bandwidth for speech is only 3 kHz. The allocated bandwidth is made wider than the minimum amount required to prevent channels from interfering with one another. This extra bandwidth is to allocate for signals of neighboring channels to be filtered out and also allow for any drift in the center frequency of the transmitter or receiver. Due to the ability of achieving outstanding spectral utilization efficiency and coping with multi path frequency selective fading channel, Multiple Input Multiple Output. Orthogonal Frequency Division Multiplexing (MIMO- OFDM) is considered as a key technology of next generation wireless communication.

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II. SYSTEM MODEL

In this paper we consider a MIMO system model; to generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the orthogonality of the carriers. OFDM have several attractive features which make it more advantageous for high speed data transmission over other data transmission techniques. These features includes [5, 6]

(i) High Spectral Efficiency
(ii) strength to channel fading
(iii) Immunity to impulse interferences
(iv) Flexibility
(v) Easy equalization

But inspite of these benefits there are some obstacles in using OFDM:

(i) OFDM signal contains very high Peak to Average Power Ratio (PAPR)
(ii) Very susceptible to frequency errors (Tx. & Rx. offset)
(iii) Intercarrier Interference (ICI) between the Subcarriers

In this paper we will discuss the problem of high PAPR associated in OFDM. We will discuss what is PAPR, how it causes problem in existing OFDM & its outcome and give a review of several techniques for reduction in this problem. For reduction of this problem firstly, OFDM is generated through choosing the spectrum requisite based on the input data, and modulation scheme used. Each carrier to be produced is assigned same data to transmit. The required amplitude and phase of them are calculated based on the modulation scheme. The requisite spectrum is achieved and then converted back to its time domain signal using an Inverse Fourier Transform (IFT). In most applications, an Inverse Fast Fourier Transform (IFFT) is used. The IFFT performs the transformation very efficiently and provides a simple way of ensuring the carrier signals produced are orthogonal. The Fast Fourier Transform (FFT) transforms a cyclic time domain signal into its equivalent frequency spectrum. This is done by finding the equivalent waveform, generated by a sum of orthogonal sinusoidal components. The amplitude and phase of the sinusoidal components represent the frequency spectrum of the time domain signal. The IFFT performs the reverse process, transforming a spectrum amplitude and phase.

The PAPR are shows the relation between the maximum powers of an illustration in a given OFDM transmit symbol divided by the standard power of that OFDM symbol. PAPR happens when in a multi- carrier system the different sub-carriers are out of phase with everyone. At each moment they are different with respect to each other at different phase values. When all the points attain the maximum value at the same time; this will cause the output envelope to suddenly wound which causes a 'peak' in the output packet. Due to presence of large number of separately modulated sub- carriers in an OFDM system, the peak value of the system can be very high as compared to the average of the complete system. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio. An OFDM signal consists of a number of separately modulated sub-carriers which can give a large PAPR when added up logically. When N signals are added with the same phase they produce a peak power that is N times the average power of the signal. So OFDM signal has a very huge PAPR, which is very susceptible to non- linearity of the high power amplifier. In OFDM, a block of N symbols{X , k = 0,1,....,N -1} k , is formed with each symbol modulating one of a set of subcarriers, {f , k = 0,1,.....,N -1} k . The N subcarriers are chosen to be orthogonal, that is, f k f k = D, where D_f =1 NT and T is the original time period. The resulting signal is given as:

$$x(t) = \sum_{n=0}^{N-1} X_k e^{j2\pi f_k t}$$

$$0 \le t \le NT$$

The ratio of maximum peak power to the average power in one data block period is referred to as PAPR, and defined as

$$\text{PAPR} = \frac{\max_{0\le t<NT} |x(t)|^2}{1/NT \cdot \int_0^T |x(t)|^2 dx}$$

where N is the number of sub-carriers, T is the duration of a data symbol, and x(t) is the complex baseband representation of an OFDM signal. The nonlinearity of a solid state power amplifier (SSPA) [9] is modeled as

$$V_{out} = \frac{V_{in}}{\left(1 + \left(|V_{in}|/V_{sat}\right)^{2P}\right)^{1/2P}}$$

where Vout and Vin are the output and input voltage values, respectively, Vsat is the output saturation level. The parameter P is the knee factor that controls the smoothness of the transition from the linear region to the saturation region [3].

For practical purpose, it is possible to differentiate between the PAPR of pass band and band pass signal. As derived in [4], the PAPR of real pass band signal is twice the PAPR of consequent complex envelope. For practical PAPR CCDF results, the oversampling (usually by zero-padding in the frequency domain) of multicarrier modulation signal is necessary [4].

III. LITERATURE REVIEW

In 2012 Arunjeeva, L. Arunmozhi, S. presented their work "A novel complexity PAPR reduction scheme for MIMO-OFDM systems" IEEE Conference in which they have used a number of peak-to-average power ratio (PAPR) reduction techniques have been proposed for (MIMO-OFDM) systems; however, most of them involve very high computational complexity and are not applicable to MIMO-OFDM systems with space frequency block coding (SFBC). A novel complexity PAPR reduction scheme for SFBCMIMO-OFDM systems is proposed.

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In 2011 Wei Xuefeng presented their work "A new algorithm for reduction of peak-to-average power ratio in MIMO-OFDM system" IEEE Conference in which they have used the copy theory based mixed on the traditional SLM scheme, this paper proposes a new kind of mimo-ofdm system reduces the SLM PAPR algorithm and presents the corresponding policy results. According to the simulation results, we can see this improved technique not only keeps the former probability scheme's advantages, but also further reduces the probability of high PAPR value.

In 2011 Wang, L., Liu, J. presented their work "Cooperative PTS for PAPR reduction in MIMO-OFDM" IET JOURNALS & MAGAZINES Partial transmit sequence (PTS) provides attractive peak-to-average power ratio (PAPR) reduction performance in OFDM or MIMO-OFDM. However, it leads to prohibitively large computational complexity. A cooperative PTS (co-PTS) is proposed. In co-PTS, alternate optimization and spatial sub-block circular permutation are employed. Simulation results show that co-PTS can reduce computational complexity dramatically and achieve better PAPR reduction performance compared to ordinary PTS.

In 2010 Umeda, S. Suyama, S. Suzuki, H. Fukawa, K. presented their work "PAPR Reduction Method for Block Diagonalization in Multiuser MIMO-OFDM Systems" IEEE Conference This paper proposes BD transmission selected mapping (BD-SLM) that can reduce PAPR while maintaining the BD effect. BD-SLM performs the phase shift to modulation signals of all users before the linear precoding. From several phase sequences, it selects a phase sequence that minimizes the peak of the time-domain signals at all transmit antennas. Computer simulations demonstrate that BD-SLM can drastically reduce PAPR in 16 × 4 MIMO-OFDM with four users, and that it can alleviate the performance degradation even when the power amplifier causes nonlinear distortion.

In 2009 Biao Yan ; Hui Zhang ; Yinxia Yang ; Qian Hu ; Mengdong Qiu presented their work "An improved algorithm for peak-to-average power ratio reduction in MIMO-OFDM systems" IEEE Conference in which they have used Sub-block Successive Transform (SST) algorithm is an effective method to reduce the PAPR of the MIMO-OFDM signals, and can fully utilize the degrees of freedom in space domain to overcome the shortage of Successive Suboptimal Cross-Antenna Rotation and Inversion (SS-CARI) algorithm. However, the degrees of freedom in frequency domain are not considered in SST algorithm. For this problem, an improved SST (ISST) algorithm is proposed, in which, not only Sub-blocks are permuted in the same way as SST algorithm in space domain, but also sub-blocks on the same antenna are successively rotated in frequency domain. So it can fully use the degrees of freedom in both space domain and frequency domain. Simulation results indicate that the effect of PAPR reduction of presented method is obviously better than that of SST algorithm.

Year	Author	Title	Approach	Result
2009	Biao Yan ; Hui Zhang ; Yinxia Yang ; Qian Hu ; Mengdong Qiu	An improved algorithm for peak-to-average power ratio reduction in MIMO-OFDM systems	Sub-block Successive Transform (SST) algorithm	Reduce the PAPR of the MIMO-OFDM signals
2010	Umeda, S. Suyama, S. Suzuki, H. Fukawa, K.	PAPR Reduction Method for Block Diagonalization in Multiuser MIMO-OFDM Systems	BD transmission selected mapping (BD-SLM)	Reduce PAPR in 16 × 4 MIMO-OFDM with four users
2011	Wang, L., Liu, J.	Cooperative PTS for PAPR reduction in MIMO-OFDM	Cooperative PTS (co-PTS) Method	Achieve better PAPR reduction performance
2011	Wei Xuefeng	A new algorithm for reduction of peak-to-average power ratio in MIMO-OFDM system	Copy theory based mixed on the traditional SLM scheme	Reduces the probability of high PAPR value
2012	Arunjeeva, L. Arunmozhi, S.	A novel complexity PAPR reduction scheme for MIMO-OFDM systems	SFBCMIMO-OFDM systems Used	Reduce PAPR in MIMO-OFDM

Table 1: Summary of Literature Review

IV. PROBLEM OF PEAK-TO-AVERAGE POWER RATIO IN OFDM SYSTEMS

High Peak-to-Average Power Ratio has been predictable as one of the major practical difficulty involving OFDM modulation. High PAPR results from the nature of the modulation itself where multiple subcarriers / sinusoids are added jointly to form the signal to be transmitted. When N sinusoids add, the peak magnitude would have a value of N, where the standard might be quite low due to the negative interference between the sinusoids. High PAPR signals are usually unnecessary for it usually strains the analog circuitry. High PAPR signals would require a large range of dynamic linearity from the analog circuits which usually results in exclusive devices and high power utilization with lower

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efficiency (for e.g. power amplifier has to operate with larger back-off to maintain linearity). In OFDM system, some input sequences would result in higher PAPR than others. For example, an input sequence that requires all such carriers to transmit their maximum amplitudes would positively result in a high output PAPR. Thus by preventive the possible input sequences to a negligible sub set, it should be possible to achieve output signals with a assured low output PAPR. The PAPR of the transmit signal x(t) is the ratio of the maximum instantaneous power and the average power.

$$\text{By definition, } PAPR = \underset{0 \le t \le T}{Max} \frac{[x(t)]^2}{E\{|x(t)|^2\}}$$

Where E {.} denotes expectation operator.

If a signal is a sum of N signals each of maximum amplitude equal to 1 Volt, then it is conceivable that we could get maximum amplitude of N Volts, that is, all N signals add at a moment at these maximum points. For an OFDM signal, that has 126 carriers each with normalized power of 1W, then the maximum PAPR can be as large as 10 log10 126 or 21 db. This is at the instant when all 126 carriers combine at their maximum point unlikely but possible [2]. The RMS PAPR will be around half of the number as 10-12 db. The large amplitude variation increases in-band noise and increases the Bit Error Rate (BER) which the signal has to go through amplification nonlinearities.

V. CRITERIA FOR PAPR REDUCTION METHOD SELECTION

The criteria of the PAPR reduction are to find the approach that it can reduce PAPR mainly and at the same time it can keep the good concert in terms of the following factors as probable. The following criteria should be considered in using the techniques:

i) The high capacity of PAPR reduction is main factor to be considered in selecting the PAPR reduction technique with as few injurious side effects such as in-band deformation and out-of- band radiation.

ii) Low average power: even though it also can reduce PAPR through average power of the original signals increase, it requires a larger linear operation PAPR Reduction Techniques

Many methods have been recommended to reduce PAPR over the years [7] [8] [9] [10] [11]. PAPR reduction techniques differ according to the necessity of the system and are reliant on various factors such as PAPR Spectral efficiency, reduction capacity, increase in transmit signal power, failure in data rate, difficulty of calculation and increase in the bit-error rate (BER) at the receiver end are various factors which are taken into report before adopting a PAPR reduction technique of the system. Many techniques have been recommended for PAPR reduction, with different levels of success and complexity. Many techniques presents for the reduction of this PAPR [12]. These techniques are divided into two groups signal scrambling techniques and signal distortion techniques which are given below:

Signal Scrambling Techniques

- Block Coding Techniques
- Block Coding method with Error Correction
- Selected Mapping (SLM)
- Partial Transmit Sequence (PTS)
- Interleaving Technique
- Tone Reservation (TR)
- Tone Injection (TI)

Signal Distortion Techniques

- Peak Windowing
- Envelope Scaling
- Clipping and Filtering
- Peak Reduction Carrier

VI. CONCLUSION

Multicarrier systems are proving better in transmission than single carrier systems. OFDM is a digital multi-carrier modulation method where a great number of closely spaced orthogonal sub- carriers are used to carry data. One of the major drawbacks of in OFDM systems is that the complex transmit signal can display a very high PAPR when the input sequences are highly associated. In this paper, we described numerous important aspect related to the PAPR & its overall effect on the OFDM system & give names several techniques adopted by the system according to the necessity. These techniques can be used to reduce the PAPR at the cost of loss in data rate, transmit signal power increase, BER performance degradation, and computational difficulty increase.

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AUTHOR’S PROFILE

Anuruddh Singh Parihar is a research scholar, pursuing his M. Tech. in Digital Communication from University Institute of Technology, Rajiv Gandhi Technical University, Bhopal. His research interests are OFDM MIMO system and enhancement in modern digital communications.

Avinash Rai is an Asst. Proff. In UIT RGPV BHOPAL.