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Basic Overview Of PAPR Reduction Techniques

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Abstract

Orthogonal frequency division multiplexing (OFDM) is a multicarrier transmission scheme supporting high data transmission and generally requires no equalization at the receiver, making it simple and efficient. Most importantly in OFDM intercarrier bands are not required and also the crosstalk between the sub channels is eliminated. The two fundamental advantages of OFDM are its robustness against channel dispersion and its ease of phase and channel estimation in a time-varying environment. Every system has its own pros and cons, similarly OFDM as well has a few cons. The major, Disadvantage of this system is high Peak to Average Power Ratio (PAPR) resulting in performance degradation of DAC & decreases efficiency of power amplifier. In this paper we review on OFDM system, its different types of PAPR reduction techniques and comparison of different PAPR reduction techniques.

Keyword: - OFDM, PAPR, CCDF, BER, HPA, SLM, PTS

1. INTRODUCTION

Wireless Communication have experienced a fast growth and promises the better performances of the system. Multi-carrier phenomenon is considered to be one of the major developments in the wireless communication and is a widely adopted technique for digital data transmission because of its advantages.

In advance wireless communication techniques need for high-speed data transmission has become utmost priority. In this era of multicarrier modulation (MCM), OFDM is an efficient technique in which high data rate is achieved and thus becoming important standard in wireless communication and a much better candidate for recent technology.

OFDM is highly adopted modulation technique in many advance wireless technologies as it provides high spectral efficiency, robustness against multiple fading and avoid inter symbol interference using cyclic prefix concept and converts the frequency selective fading into flat fading which reduces the equalizer complexity at the receiver side. OFDM signals can be efficiently modulated and demodulated using Inverse Fast Fourier Transform (IFFT) and Fast Fourier Transform (FFT) respectively. As a result, OFDM has been chosen for high data rate communication and widely deployed as the standard transmission techniques in many wireless communications such as IEEE802.11 DAB, DVB, wireless Lan system (WLAN), WAN, PLC, HIPERLAN/2, IEEE802.11, IEEE802.16 etc.

However, OFDM apart from its advantages has two major drawbacks that is significantly high peak-to-average ratio (PAPR) at transmitter and spectral efficiency loss due to guard interval.

Out of these two, most affecting drawback of OFDM system is their high PAPR. When the OFDM signal is transformed to time domain, the resulting signal is the sum of all the subcarriers through IFFT operation. When all the subcarrier adds up in phase the result is a peak N times higher than the average power. High PAPR degrades performance of OFDM signals by forcing the analog amplifier to work in the nonlinear region distorting this way the signals and making the amplifier to consume more power. This non-linearity distortion results in band distortion and out of band distortion which ultimately results in degradation of Bit error rate (BER) performance.

Thus, PAPR becomes most important problem in up linking the transmission system.

To reduce this PAPR several techniques have been proposed where a simple PAPR reduction method can be achieved by clipping the time domain OFDM signal which is a signal distortion method. Other techniques include partial transmit sequence (PTS) selective mapping (SLM), tone reservation (TR), tone injection (TI) etc. which are nothing but signal scrambling techniques.

Thus, there are a plenty of techniques to reduce PAPR ratio in OFDM system having their own pros and cons based upon computational complexity, increase in BER, power increase and bandwidth expansion. However, the most efficient and effective PAPR reduction technique must be counted on the terms of loss of emission power and BER performance

Therefore, it is important and necessary to research on the PAPR reduction techniques and its effect on Digital to Analog Converter (DAC), Analog to Digital Converter (ADC) and High-Power Amplifier (PA).

2 BASICS OF OFDM AND PAPR

2.1 OFDM

OFDM is multicarrier modulation technique where high bitrate data stream is transmitted in parallel over a lower data rate sub carrier. These subcarriers are orthogonal to each other. Advancement in digital signal processing and Very Large-Scale Integrated Circuit, implementation of FFT/IFFT highly simplified the implementation of OFDM system.

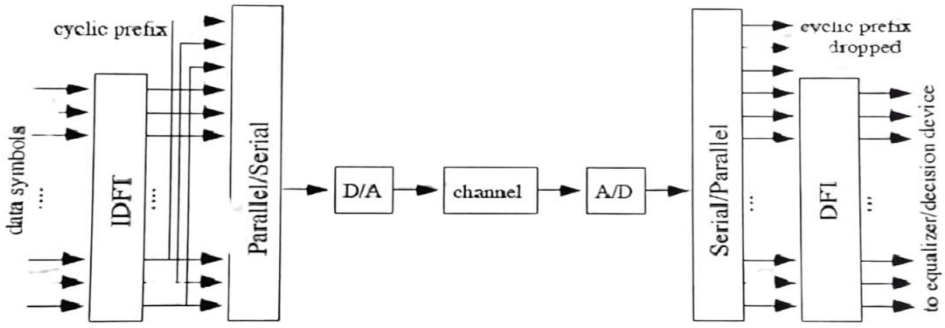

Figure 1 an OFDM system

2.2 PAPR

Presence of large number of independently modulated sub-carriers in an OFDM system the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio. Coherent addition of N signals of same phase produces a peak which is N times the average signal. [8]

The PAPR of OFDM is defined as the ratio between the maximum instantaneous power and the average power defined by,

$$PAPR = \frac{P_{Peak}}{P_{Average}} \quad (1)$$

The PAPR of the transmitted signal is defined as

$$PAPR = \frac{\max 0 \le t < NT |x(t)|^2}{1/NT \int_0^{NT} |x(t)|^2 dt} \quad (2)$$

Reducing the $max/x(t)$ is the principal goal of PAPR reduction techniques.

As PAPR distribution is stochastic in nature usually is expressed in terms of CCDF

Complimentary Cumulative DistributionFunction (CCDF) is a statistical technique that provides the amount of time, a signal spends above given power level. In modern communication CCDF measurement is considered as one ofthe precious tools offers comprehensive analysis of signal power peaks. For sufficient large number of sub carriers, the amplitude of multicarrier signal, CCDF expression for OFDM signal can be written as

$$\begin{aligned} P(PAPR > z) &= 1 - P(PAPR \le z) \\ &= 1 - F(z)^N \\ &= 1 - (1 - exp(-z))^N \end{aligned} \quad (3)$$

Where N signal samples are statistically independent

3 MOTIVATION OF PAPR REDUCTION

Nonlinear Characteristics of HPA and ADC

Transmitted signals in an OFDM can have high peak values in the time domain since many carriers added up via IFFT operation. These OFDM systems known to have high PAPR compared to single carrier system. The High PAPR makes the power amplifier to work with large dynamic range & decreases SQNR (Signal to quantization noise ratio) of ADC/DAC. Therefore, it motivates to reduce PAPR ratio before applying it to DAC and Power amplifier

Power Saving

From the Literature [1] it can be shown that by reducing the PAPR would result in increase in efficiency. For linear model of HPA efficiency is given by

$$\eta=0.5/PAPR \quad (4)$$

where η is HPA efficiency and is given by P_{out}/P_{DC}
P_{DC} is constant amount of power regard less of input power.P_{out} is average output power.

Distortions

If the OFDM signal is clipped, it will lead to introduction of in-band distortion and out of band radiation into the wireless communication system. Thus, the best solution has been to reduce PAPR before OFDM signals enters the territory of nonlinear HPA and DAC.

4 PAPR REDUCTION TECHNIQUES

The PAPR reduction includes many techniques, and it's dependent on various factors such as Spectral efficiency, Reduction Capacity, increase in Transmit signal power, loss in data rate, Computational Complexity, increase in BER, Peak Reduction Carrier. These PAPR reduction techniques are broadly classified as signal scrambling, signal distorted and other techniques. In signal scrambling, signals are scrambled to minimize the PAPR of time domain OFDM signals. Whereas signal is distorted in signal distortion method. Plenty of PAPR reduction techniques have been proposed in order to reduce the PAPR [1] as much as possible. Some of them are:

4.1 SINGAL SCRAMBLING TECHNIQUES:

1. Selective mapping (SLM)

In this method selection of optimal combination of phase factors with lower PAPR is carried out. In selective mapping side information is passed only with selected signal. That means in SLM only chosen signal is mapped. [7]

2. Partial Transmit Sequence (PTS)

In PTS the whole sequence is divided into nonoverlapping sub blocks. This sub blocks are assigned by independent rotation factor. This factor generates time domain data with lowest amplitude. This selection of lowest amplitude gives results in reduction of PAPR. PTS gives better performance than SLM.

3. Adaptive Interleaving

In adaptive interleaving early threshold termination is established So searching process is terminated when the value of PAPR reaches below the predefined threshold value. We can adapt the threshold value depending upon the application, so adaptation is done.

4. Tone Reservation

In tone reservation, reserved tones can be used to minimize the PAPR. When there are number of tones are small then there will be small PAPR reduction and vice-versa. In this method no need of decoding at the receiver end.

4.2 SIGNAL DISTORTION TECHNIQUES

1. Clipping and filtering

This is effective method for PAPR reduction in which initially clipping is done and then filtering is carried out. Since clipping is non-linear process which increase the band noise distortion, Bit Error Rate (BER) and decrease spectral efficiency. Filtering after clipping reduces out of band distortion. For PSK modulation this method is more effective.

2. Peak Windowing

In Peak Windowing technique different windows having large signal peaks like Cosine window, Kaiser window, hamming window, Gaussian window etc. are multiply with original OFDM signal. The resultant spectrum is nothing but convolution of applied window and original OFDM signal. Depending upon the application we can use the standard window.

4.3 OTHER TECHNIQUES

1. The coding technique

This technique is used to select code words that minimize or reduce PAPR. In this code words are transmitted along with original OFDM symbol, but for better result selection of proper code word are essential. It causes no distortion and no out of band radiation but it suffers from bandwidth efficiency and also suffers from complexity to find the best code. Golay complimentary codes, Reed Muller code and Hadamard code are used proposed in the literature [5-6].

2. Nonlinear companding technique.

This is the most attractive, low implementation complexity offers better BER performance than clipping technique, this based on μlaw companding with various types of distribution without the sacrifice of bandwidth [2-4].

There are many hybrid PAPR reduction techniques are proposed in the literature such as SLM and clipping DCT precoded SLM/PTS. These techniques applicable to MIMO OFDM, LTE and WIMAX environment.

5 CRITERIA FOR SELECTION OF PAPR REDUCTION TECHNIQUES

Selection of PAPR reduction techniques based on following parameters

1) PAPR reduction technique should be computationally Less complex, no in band and out of band radiation

2) It should use less average power, it results amplifier to work in less dynamic linear range it leads to minimize the cost of power amplifier

3) Since bandwidth is limited, in probabilistic and coding technique it requires more bandwidth which should be minimized

4) Selection of PAPR reduction should not lead to BER Degradation

5) It should not require additional power Based on the above factors.

Comparison of different PAPR reduction techniques is given below in the Table 1 which is self-explanatory.

Table 1: Comparison of Basic PAPR Reduction Methods

Sr. No.	Parameters / Reduction Method	Distortion less	Power Increase	Data Rate Loss	Bandwidth Expansion	BER Degradation	Implementation Complexity
1	SLM	Yes	No	Yes	Yes	No	High
2	PTS	Yes	No	Yes	Yes	No	High
3	Interleaving	Yes	No	Yes	Yes	No	Low
4	TR	Yes	Yes	No	Yes	No	High
5	Clipping	No	No	No	No	Yes	Low
6	Peak Windowing	No	Yes	No	No	No	Low
7	Coding	Yes	No	Yes	Yes	No	Low
8	NCT	No	No	Yes	No	No	Low

6 CONCLUSION AND FUTURE SCOPE

OFDM is a very promising technique for wireless communication due to its channel robustness and spectrum efficiency. One of the major drawbacks of OFDM is high PAPR. In this paper we reviewed the importance of OFDM system, High PAPR as a major drawback in OFDM system, PAPR reduction techniques, comparison of those techniques. Although many techniques available in the literature to reduce PAPR ratio in OFDM system with their own advantages and disadvantages considering various parameters.

In this paper, we have analyzed and compared eight PAPR reduction techniques. Among above analyzed techniques, it was found out that from present techniques no technique is fully effective in reduction of PAPR and is the best for the OFDM system. An effective PAPR reduction technique must be given best tradeoff between implementation complexity, data rate loss, transmission power and BER performance.

After reviewing mentioned PAPR reduction techniques, we conclude that, there is still scope to propose new simplified, low complexity, hybrid techniques to improve the performance of OFDM system. So, it is suggested to propose peak to average power ratio (PAPR) reduction scheme and design a network/model supporting it for OFDM systems after comparing existing conventional methods.

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