An Extensive Review on Performance Analysis for OFDM Signals with Peak Cancellation

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Abstract - The demand of high data rate services has been increasing very rapidly and there is no slowdown in sight. The explosive growth of wireless systems coupled with the proliferation of laptop and palmtop computers suggests a bright future for wireless networks, both as stand-alone systems and as part of the larger networking infrastructure. However, many technical challenges remain in designing robust wireless networks that deliver the performance necessary to support emerging applications. The gap between current and emerging systems and the vision for future wireless applications indicates that much work remains to be done to make this vision a reality. Orthogonal Frequency Division Multiplexing (OFDM), a multi-carrier transmission technique that is widely adopted in different communication applications. OFDM systems support high data rate transmission. However, OFDM systems have the undesirable feature of a large peak to average power ratio (PAPR) of the transmitted signals. The transmitted signal has a non-constant envelope and exhibits peaks whose power strongly exceeds the mean power. For reduction of this PAPR lot of algorithms have been developed. All of the techniques has some sort of advantages and disadvantages. This work presents an extensive survey on Performance Analysis for OFDM Signals with Peak Cancellation.

Keywords- Wireless communication, PAPR Reduction, OFDM, BER.

I. INTRODUCTION

The demand for high data rate services has been increasing day by day and there is no slowdown in sight. Almost every existing physical medium capable of supporting broadband data transmission to our homes, offices and schools has been or will be used in the future. This includes both wired (Digital Subscriber Lines, Cable Modems, Power Lines) and wireless media. Generally, these services require very reliable data transmission over very harsh environments. Most of the transmission systems experience many factors which leads to degradation of the system, such as noise, attenuation, multipath, fading, time variation, interference, non-linearity's. The reliable data transmission system must meet constraints, such as finite transmit power and most importantly finite cost. One physical-layer technique that has recently gained much popularity due to its robustness in dealing with these impairments is multi-carrier modulation [1]. Information transmission with high spectral efficiency and variable bit rate are major requirements for the modern communication system to deal with the high quality services to be delivered to the customers. Because in the wireless environment signals are usually impaired by fading and multipath delay spread phenomenon, hence, conventional single carrier mobile communication systems do not perform well.

We know that the data transmission includes both wired and wireless medium. Often, these services require very reliable data transmission over very harsh environment. Most of these transmission systems experience much degradation such as large attenuation, noise, multipath, interference, time variance, nonlinearities and must meet the finite constraints like power limitation and cost factor. One physical layer technique that has gained a lot of popularities due to its robustness in dealing with these impairments is multi-carrier modulation technique. In multi-carrier modulation, the most commonly used technique is Orthogonal Frequency Division Multiplexing (OFDM); it has recently become very popular in wireless communication.

Unfortunately the major drawback of OFDM transmission is its large envelope fluctuation which is quantified as Peak to Average Power Ratio (PAPR). Since power amplifier is used at the transmitter, so as to operate in a perfectly linear region the operating power must lies below the available power.

Consequently, to prevent distortion of the OFDM signal, the transmit amplifier must operate in its linear regions. Therefore, power amplifiers with a large dynamic range are required for OFDM systems. Reducing the PAPR is pivotal to reducing the cost of OFDM systems.

Wireless systems always give several errors to the transmitted bits due to several transmission and system impediments. The techniques of power control also increase the bit error rate in end to end transmission. To address this need, communication engineers have combined technologies suitable for high rate transmission with error correction codes. Forward error correction (FEC) is one of the popular techniques. FEC or similar coding techniques allow the system to operate with lower power, allow the system to give more range even under other uncontrolled impediments of the system and the transmission.

II. OFEM SYSTEM MODEL

A. Multicarrier Communication

OFDM is a technique for transmitting data in parallel by using a large number of low rate modulated sub-carriers. OFDM divides a given spectral allotment into many narrow subcarriers each with inherently small carrier spacing. These SCs are orthogonal to each other. The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. The spectrum of each carrier has a null at the centre frequency of each of the other carriers in the system. This result into elimination of crosstalk between SCs and inter-carrier guard bands are not required. The separation between carriers is theoretically minimal so there would be a very compact spectral utilization. OFDM systems are very attractive for the way they handle ISI, which is usually introduced by frequency selective multipath fading in a wireless environment. Each subcarrier is modulated at a very low symbol rate, making the symbols much longer than the channel impulse response. In this way, ISI is diminished. Moreover, if a guard interval is inserted between consecutive OFDM symbols, the effects of ISI can completely be vanished. This guard interval must be longer than the multipath delay. Although each SC operates at a low data rate, a total high data rate can be achieved by using a large number of SCs. ISI has very small or no effect on the OFDM systems hence an equalizer is not needed at the receiver side.

In the OFDM system, Inverse Fast Fourier Transform/Fast Fourier Transform (IFFT /FFT) algorithms are used in the modulation and demodulation of the signal respectively.

The length of the IFFT/FFT vector determines the tolerance of the system to errors caused by the multipath channel. The time duration of this vector is chosen so that it is much larger than the maximum delay time of echoes in the received multipath signal.

OFDM is generated by firstly choosing the spectrum required, based on the input data, and modulation scheme used. Each carrier to be produced is assigned some data to transmit. The required amplitude and phase of the carrier is then varied based on the modulation scheme (typically differential BPSK, QPSK, or QAM). Then, the IFFT converts this spectrum into a time domain signal.

The FFT transforms a cyclic time domain signal into its equivalent frequency spectrum. Finding the equivalent waveform, generated by a sum of orthogonal sinusoidal components, does this. The amplitude and phase of the sinusoidal components represent the frequency spectrum of the time domain signal. A more complete description of an OFDM signal can be seen in fig. 2.1 which shows, an OFDM signal is divided in both time and frequency domain and so increases the capacity of the system in addition to the less interference of the adjacent symbols.

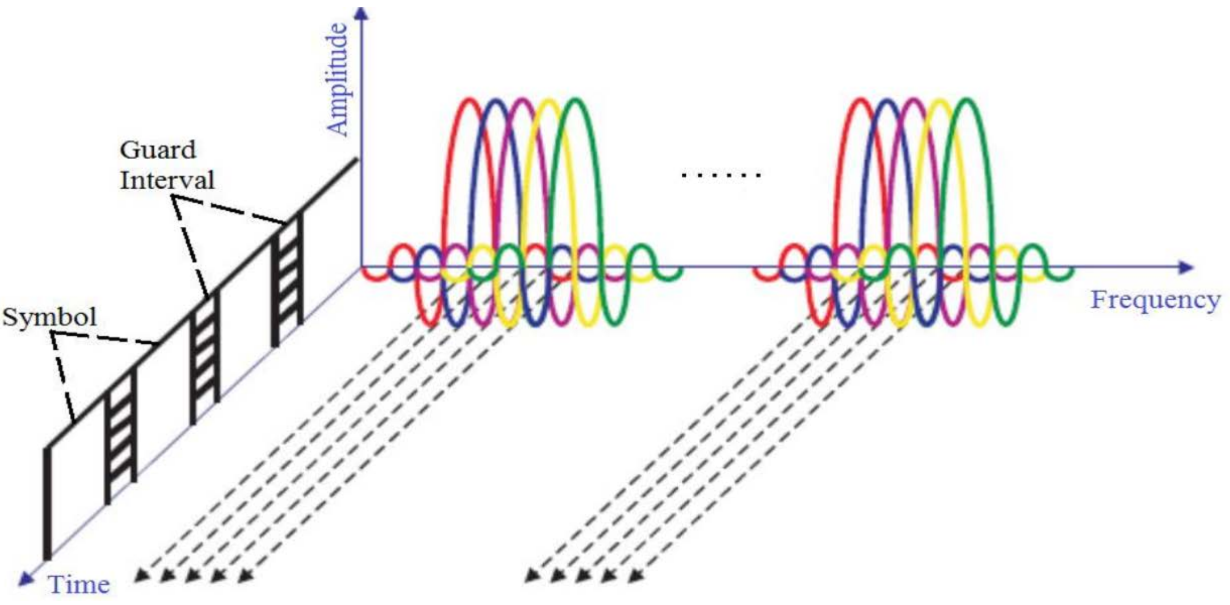

Figure 2.1 OFDM time/frequency representation.

Multicarrier transmission system uses two or more modulated signals, each carry a single data stream over a communication channel. The received signals are independently demodulated in the receiver resulting in the received bit stream. OFDM is a type of Frequency Division Multiplexing (FDM) scheme that allows users to transmit information at high data rates offers a more reliable alternative to traditional single- frequency transmission system in the noisy communication channels that suffers from fading. OFDM offers more efficient use of available RF spectrum than single-carrier frequency communication system because of simultaneous use of multiple frequencies for data communication. Guard intervals are inserted during the OFDM transmission process to preserve carrier frequency orthogonality, which reduce the potential maximal spectral efficiency of this scheme [2].

OFDM is a special form of multicarrier transmission technique, where a single data stream is transmitted over a number of lower rate modulated subcarriers. OFDM divides a given spectral allotment into many narrow subcarriers each with inherently small carrier spacing. It is a revolutionary communication technology as it forms the basis for all wireless 4G (fourth generation) communication systems [2]. One of the main reasons to use OFDM is to increase the robustness against frequency selective fading and narrowband interference. In a single carrier system, a single fade or interferer can cause failure to the entire communication system, but in a multicarrier system, only a small percentage of subcarriers will be affected. Error correction coding can then be used effectively to correct the few erroneous subcarriers.

B. PAPR Reduction Techniques

It is defined as the ratio between the maximum power and the average power for the envelope of a baseband complex signal s(t) i.e.

$$PAPR\ \{\check{s}\ (t)\} = \frac{\max|\check{s}(t)|^2}{E|\check{s}(t)|^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq.1$$

for complex passband signal s(t) Equation 1 can Also be written as

$$PAPR\ \{s(t)\} = \frac{\max|s(t)|^2}{E|s(t)|^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq.2$$

A lot of techniques presents for the reduction of this PAPR [1]. About some of the reduction techniques like Clipping and Filtering, Coding, Partial Transmit Sequence, Selected Mapping, Tone Reservation, Tone Injection, Active Constellation Extension are briefly described here.

a. Clipping and Filtering

This is a simplest technique used for PAPR reduction. Clipping means the amplitude clipping which limits the peak envelope of the input signal to a predetermined value.

Clipping causes in-band signal distortion, resulting in Bit Error Rate performance degradation.

It also causes out-of-band radiation, which imposes out-of-band interference signals to adjacent channels. This out-of-band radiation can be reduced by filtering.

This filtering of the clipped signal leads to the peak regrowth. That means the signal after filtering operation may exceed the clipping level specified for the clipping operation.

b. Coding

The coding technique is used to select such codewords that minimize or reduce the PAPR. It causes no distortion and creates no out-of-band radiation, but it suffers from bandwidth efficiency as the code rate is reduced. It also suffers from complexity to find the best codes and to store large lookup tables for encoding and decoding, especially for a large number of sub carriers.

c. Partial Transmit Sequence

In the Partial Transmit Sequence(PTS) technique, an input data block of N symbols is partitioned into disjoint sub blocks. The sub-carriers in each sub-block are weighted by a phase factor for that sub-block. The phase factors are selected such that the PAPR of the combined signal is minimized. But by using this technique there will be data rate loss.

d. Tone Reservation

According to this technique the transmitter does not send data on a small subset of subcarriers that are optimized for PAPR reduction. Here the objective is to find the time domain signal to be added to the original time domain signal such that the PAPR is reduced. Here the data rate loss will be take place also probability of power increase is more.

e. Tone Injection Technique

The basic idea used in this technique is to increase the constellation size so that each symbol in the data block can be mapped into one of the several equivalent constellation points, these extra degrees of freedom can be exploited for PAPR reduction. Here the transmitted power increases.

f. Active Constellation Extension (ACE) Technique

This technique for PAPR reduction is similar to Tone Injection technique. According to this technique some of the outer signal constellation points in the data block are dynamically extended towards the outside of the original constellation such that PAPR of the data block is reduced. In this case also there will be increase of transmitted power take place.

g. Selected Mapping (SLM) Technique

The basic idea of this technique is first generate a number of alternative OFDM signals from the original data block and then transmit the OFDM signal having minimum PAPR.

III. RELATED WORK

SR. NO.	TITLE	AUTHORS	YEAR	APPROACH
1	Performance Analysis for OFDM Signals With Peak Cancellation,	J. Song and H. Ochiai	2016	A rigorous theoretical analysis of PC applied to band-limited orthogonal frequency division multiplexing (OFDM)
2	An adaptive peak cancellation method for linear-precoded MIMO-OFDM signals,	T. Kageyama, O. Muta and H. Gacanin,	2015	Adaptive peak cancellation to reduce the high peak-to-average power ratio (PAPR),
3	Improved channel estimation for OFDM system with peak cancellation,	Xianbing Zou, L. Dan, Y. Xiao, Wei Xiang and Wen Xiaojie,	2015	A new PC signaling format characterized by mitigating the inference on the positions of pilot symbols
4	Performance evaluation of OQAM based OFDM systems using an ACLR and EVM restricted peak amplitude cancellation scheme,	T. Hino, O. Muta and H. Furukawa,	2014	An adjacent channel leakage power ratio (ACLR) and error vector magnitude (EVM)restricted peak amplitude cancellation scheme for peak-to-average power ratio (PAPR) reduction
5	Single-carrier FDMA with blanking/clipping for mitigating impulsive noise over PLC channels	K. M. Rabie and E. Alsusa,	2014	Single-carrier FDMA (SC-FDMA), which inherently has low PAPR properties, combined with a nonlinear preprocessor at the receiver
6	FPGA implementation of peak cancellation for PAPR reduction of OFDM signals,	J. Song and H. Ochiai,	2014	A cost-effective implementation scheme for PC is presented.

J. Song and H. Ochiai, [1] Peak cancellation (PC) is known as one of the simplest peak-to-average power ratio (PAPR) reduction techniques that are applicable to various communications standards. The salient advantage of PC is its ease of hardware implementation, but it induces in-band distortion and out-of-band radiation. In order to restrict the amount of distortion within an acceptable level, it is critical to carefully design the cancelling pulses as well as the envelope threshold over which PC is applied. In most studies, however, they are determined empirically through computer simulations. This research work thus focuses on a rigorous theoretical analysis of PC applied to band-limited orthogonal frequency division multiplexing (OFDM) signals, and discusses its validity and limitation for practical applications. Based on the level-crossing rate approximation of the peak distribution, derive a closed-form expression for the achievable signal-to-distortion power ratio (SDR). also analyze the adjacent channel leakage ratio (ACLR) as well as error vector magnitude (EVM), with which the symbol error rate (SER) over an additive white Gaussian noise (AWGN) channel is obtained. All the theoretical results developed in this work are compared with those based on the corresponding computer simulations to justify our analytical approach. It thus serves as a useful and accurate tool for designing cancelling pulses as well as the threshold level, for given specific system requirements such as SDR (or EVM) and ACLR.

T. Kageyama, O. Muta and H. Gacanin,[2] Recently, an adaptive peak cancellation was proposed to reduce the high peak-to-average power ratio (PAPR), while keeping the out-of-band (OoB) power leakage as well as an in-band distortion power (EVM) below the pre-determined (permissible) level. However, the peak cancellation in MIMO-OFDM systems was not considered. In this research work, propose a peak cancellation method for linearly pre-coded MIMO-OFDM systems using eigen-beam space division multiplexing (E-SDM). evaluate and discuss the performance of the system using the proposed peak cancellation in terms of bit error rate (BER), complementary cum-mulative distribution function (CCDF) of PAPR and the system's computational complexity. Our results show the improvements with respect to both the achievable BER and PAPR with the proposed peak cancellation in E-SDM systems under the restriction of OoB power radiation.

Xianbing Zou, L. Dan, Y. Xiao, Wei Xiang and Wen Xiaojie,[3] This research work provides a new scheme to improve the channel estimation performance of peak cancellation (PC) aided orthogonal frequency division multiplexing (OFDM) system. The proposed scheme is based on a new PC signaling format characterized by mitigating the inference on the positions of pilot symbols. It achieves better channel estimation performance and hence to improve the system performance in fading channels without the increase of computational complexity.

T. Hino, O. Muta and H. Furukawa,[4] In this research work, investigate the performance of offset quadrature amplitude modulation based orthogonal frequency division multiplexing (OQAM-OFDM) systems using an adjacent channel leakage power ratio (ACLR) and error vector magnitude (EVM) restricted peak amplitude cancellation scheme for peak-to-average power ratio (PAPR) reduction, where peak amplitude of the transmit signal that exceeds a give threshold level is iteratively suppressed by adding a peak cancellation (PC) signal which exhibits sharp peak amplitude at the midpoint of pulse waveform in time domain. In addition, using this scheme, both ACLR and EVM are automatically adjusted so as to meet a given requirement. In the proposed scheme, both PAPR reduction performance and system requirements such as out-of-band spectrum radiation and in-band distortion are simultaneously taken into consideration. Through computer simulation results, it is demonstrated that the proposed PAPR reduction scheme is effective in reducing PAPR of pulse shaped OQAM-OFDM signals, while both ACLR and EVM requirements are simultaneously fulfilled.

K. M. Rabie and E. Alsusa, [5] Communication signals over power-line channels can be affected greatly by impulsive noise (IN). The effect of this noise is commonly reduced with the application of a nonlinear preprocessor at the receiver such as blanking, clipping or hybrid (combined blanking and clipping) that blanks and/or clips the received signal when it exceeds a certain threshold. Erroneous blanking/clipping of the unaffected signals can lead to significant performance degradations. It is found that determining the optimal blanking/clipping threshold is the key for achieving best performance. In contract to these studies, show in this research work that the performance of the nonlinear preprocessing-based method is not only impacted by the blanking/clipping threshold but also by the transmitted signal's peak-to-average power ratio (PAPR). In light of this and for more efficient IN cancellation we, therefore, propose to implement single-carrier FDMA (SC-FDMA), which inherently has low PAPR properties, combined with a nonlinear preprocessor at the receiver. The results reveal that the proposed system can provide significant enhancements in terms of minimizing the probability of IN detection error as well as achieving up to 4dB gain in the output signal-to-noise ratio relative to the conventional OFDM case.

J. Song and H. Ochiai,[6] Peak-to-average power ratio (PAPR) reduction techniques play an important role for achieving highly efficient operation of power amplifiers. Peak cancellation (PC), known as a computationally efficient PAPR reduction method, has several advantages over other techniques. In this research work, a cost-effective implementation scheme for PC is presented. The design methodology and practical implementation issues based on field-programmable gate array (FPGA) are discussed, with particular emphasis on the resulting resource utilizations. The experimental results show that in certain scenarios, our approach outperforms the well-known clipping and filtering (CAF) approach in terms of achievable error vector magnitude (EVM) and adjacent channel leakage ratio (ACLR), with much lower hardware overhead.

IV. PROBLEM STATEMENT

In Parallel data transmission, an available frequency band is divided into several channels by independently modulating a number of carriers of different frequency. Since each channel occupies a relatively narrow frequency band, parallel transmission is effective in combating the effects of amplitude and delay distortion and impulsive noise. But to eliminate inter channel interference problem, it is required to avoid spectral overlap of channels, which leads to poor spectral efficiency. Due to the high PAPR the Q-point moves to the saturation region hence the clipping of signal peaks takes place which generates in-band and out-of band distortion. So to keep the Q-point in the linear region the dynamic range of the power amplifier should be increased which again reduces its efficiency and enhances the cost. Hence a trade-off exists between nonlinearity and efficiency. And also with the increasing of this dynamic range the cost of power amplifier increases.

V. CONCLUSION

In this work various types of PAPR optimization technique have been reviewed based on their literature survey. The multi-carrier modulations like OFDM have the main disadvantage of peak power of OFDM based systems can be improved with PAPR techniques. This creates additional BER to the overall performance. Different methods like adaptive equalization and channel coding can be used to increase the performance. However it is difficult use these methods at high data rate because inherent delay also increases with bit rate. Orthogonal frequency division multiplexing (OFDM) is an example of multicarrier communication and is preferred modulation scheme in modern high data rate wireless communication systems.

REFERENCES

[1] (J. Song and H. Ochiai, "Performance Analysis for OFDM Signals With Peak Cancellation," in IEEE Transactions on Communications, vol. 64, no. 1, pp. 261-270, Jan. 2016.).

[2] (T. Kageyama, O. Muta and H. Gacanin, "An adaptive peak cancellation method for linear-precoded MIMO-OFDM signals," 2015 IEEE 26th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC), Hong Kong, 2015, pp. 271-275.)

[3] (Xianbing Zou, L. Dan, Y. Xiao, Wei Xiang and Wen Xiaojie, "Improved channel estimation for OFDM system with peak cancellation," 2015 10th International Conference on Communications and Networking in China (ChinaCom), Shanghai, 2015, pp. 871-873.).

[4] (T. Hino, O. Muta and H. Furukawa, "Performance evaluation of OQAM based OFDM systems using an ACLR and EVM restricted peak amplitude cancellation scheme," 2014 IEEE International Conference on Communication Systems, Macau, 2014, pp. 419-423.).

[5] (K. M. Rabie and E. Alsusa, "Single-carrier FDMA with blanking/clipping for mitigating impulsive noise over PLC channels," 18th IEEE International Symposium on Power Line Communications and Its Applications, Glasgow, 2014, pp. 340-345.)

[6] J. Song and H. Ochiai, "FPGA implementation of peak cancellation for PAPR reduction of OFDM signals," 2014 IEEE International Conference on Communication Systems, Macau, 2014, pp. 414-418.

[7] R. van Nee and R. Prasad, OFDM for Wireless Multimedia Communications. Norwood, MA, USA: Artech House, 2000.

[8] H. Ochiai and H. Imai, “On the distribution of the peak-to-average power ratio in OFDM signals,” IEEE Trans. Commun., vol. 49, no. 2, pp. 282¬289, Feb. 2001.

[9] T. Hentschel, M. Henker, and G. Fettweis, “The digital front-end of software radio terminals,” IEEE Pers. Commun., vol. 6, no. 4, pp. 40-46, Aug. 1999.

[10] R. Bauml, R. F. H. Fischer, and J. Huber, “Reducing the peak-to-average power ratio of multicarrier modulation by selected mapping,” Electron. Lett., vol. 32, no. 22, pp. 2056-2057, Oct. 1996.

[11] H. Ochiai and H. Imai, “Performance analysis of deliberately clipped OFDM signals,” IEEE Trans. Commun., vol. 50, no. 1, pp. 89-101, Jan. 2002.