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A Survey on Peak-to-Average Power Ratio (PAPR) Reduction Techniques of OFDM Signals

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Abstract

Orthogonal frequency division multiplexing (OFDM) has been adopted as a standard for various high data rate wireless communication systems due to the high spectral bandwidth efficiency, robustness to frequency selective fading channels, well suited for mimo technology, Facilitate frequency-domain scheduling supports flexible bandwidth deployment etc. However, implementation of the OFDM system entails several difficulties. One of the major drawbacks is the high peak-to-average power ratio(PAPR) . High PAPR causes saturation in power amplifiers, leading to inter modulation products among the sub carriers and disturbing out of band energy. Therefore, it is desirable to reduce the PAPR. In this paper, several techniques have been studied such as clipping, windowing, coding, tone reservation, tone injection etc.

Keywords: *OFDM, PAPR, PTS, SLM, TR.*

1. Introduction

With the increase of communications technology, the demand for higher data rate services such as multimedia, voice, and data over both wired and wireless links is also increased. New modulation schemes are required to transfer the large amount of data which existing techniques cannot support. These techniques must be able to provide high data rate, allowable Bit Error Rate (BER), and maximum delay. Orthogonal Frequency Division Multiplexing (OFDM) is one of them. OFDM has been used for Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB) in Europe, and for Asymmetric Digital Subscriber Line (ADSL) high data rate wired links. OFDM has also been standardized as the physical layer for the wireless networking standard HIPERLAN2 in Europe and as the IEEE 802.11a, g standard in the US, promising raw data rates of between 6 and 54Mbps. Orthogonal Frequency Division Multiplexing (OFDM) is a digital transmission Method developed to meet the increasing demand for higher data rates in communications which can be used in both wired and wireless environments.[1]

Orthogonal frequency division multiplexing (OFDM) is a widely used modulation and multiplexing technology, which has become the basis of many telecommunications standards including wireless local area networks (LANs), digital terrestrial television (DTT) and digital radio broadcasting in much of the world. . In the past, as well as in the present, the OFDM is referred in the literature as Multi-carrier, Multi-tone and Fourier Transform. The OFDM concept is based on spreading the data to be transmitted over a large number of carriers, each being modulated at a low rate. The carriers are made orthogonal to each other by appropriately choosing the frequency spacing between them. A multicarrier system, such as FDM (aka: Frequency Division Multiplexing), divides the total available bandwidth in the spectrum into sub-bands for multiple carriers to transmit in parallel. It combines a large number of low data rate carriers to construct a composite high data rate communication system. Orthogonality gives the carriers a valid reason to be closely spaced with overlapping without ICI. [1]In OFDM systems, the number of subcarriers is typically in the order of hundreds, or even over thousands. These subcarriers are spaced close together in the frequency domain, and are supposed to be orthogonal to each other. As such, the synchronization requirement (which includes timing and carrier frequency synchronization) for OFDM systems is more stringent than that for single carrier systems [8]. In OFDM systems, carrier frequency synchronization is usually done in two steps. The first step is coarse synchronization, which usually reduces the CFO to within one-half of the subcarrier spacing [6]; this is followed by fine carrier synchronization, which further estimates and reduces the residual CFO. The performance of the system depends generally on modulation schemes, channel estimation techniques used to estimate channel.

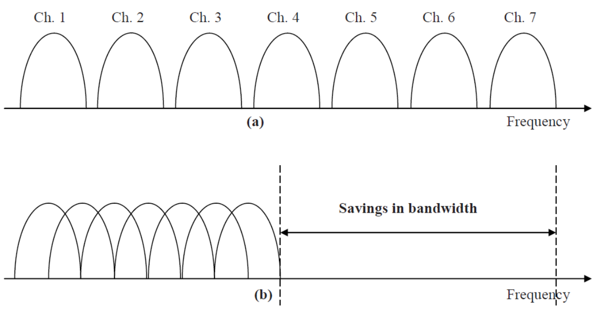

Figure 1: Concept of the OFDM Signal: (A) Conventional Multicarrier Technique and (B) Orthogonal Multicarrier Modulation Technique. [3]

2. Types of OFDM

OFDM can be further categorized into following categories or the various types of OFDM include:

2.1 Vector OFDM

Broadband silicon vendor Broadcom and Cisco Systems developed VOFDM. This system works with spatial diversity, which uses multipath signal reflections to increase bandwidth and range via special antennas and signal processing. It uses antennas to capture the signals and high-powered processing to normalize the delays into a higher throughput data stream. VOFDM is most often used in fixed-wireless metropolitan area networks (MANs).

2.2 Wideband OFDM

The OFDM Forum says Wi-LAN's W-OFDM should be the standard version. Rather than using tightly packed orthogonal carriers, W-OFDM introduces additional frequency space between the orthogonal channels. This further reduces interference and permits higher tolerance for OFDM transmission problems such as jitter. Businesses and wireless Internet service providers are using W-OFDM in MANs, for which transceivers tend to be outdoors and require a more tolerant approach.

2.3 F-OFDM

Flarion created F-OFDM by incorporating fast-frequency-hopping spread spectrum technology, which repeatedly switches frequencies during a radio transmission. This system transmits a signal across a much wider frequency band than is required. This spreads the energy across a higher number of channels on a wider spectrum, thereby increasing signal capacity. Flarion designed F-OFDM, which is currently undergoing field testing, to deliver broadband services to cellular-phone and other mobile users.

2.4 MIMO-OFDM

Multiple-input, multiple-output OFDM was developed by Iospan Wireless. Basically, MIMO-OFDM uses OFDM to break up a signal and wirelessly transmit the pieces simultaneously via multiple antennas. The receiver subsequently reassembles the pieces. MIMO-OFDM lets providers offer fixed broadband wireless access systems that don't require a line of sight between transmitter and receiver. In OFDM data is transmitted simultaneously through multiple frequency bands, the effects of multipath delay spread can be minimized. OFDM has been proposed for many radio systems such as the next generation mobile communication, wireless LAN, digital audio/video broadcasting, and high-speed cellular data. However, one of the main disadvantages of OFDM is its high Peak-to-Average Power Ratio (PAPR). When N signals are added with the same phase, they produce a peak power that is N times the average power. A high PAPR implies that the High Power Amplifier in wireless system must have an inefficiently large linear range. Moreover, the nonlinearity leads to in-band distortion, which increases the bit-error ratio, and out-of-band radiation [1]. In order to reduce the PAPR of an OFDM signal, several techniques have been proposed, including clipping and filtering , selected mapping(SLM) , partial transmit sequences(PTS), tone reservation , tone injection and Reed-Muller codes , etc.

3. The PAPR in OFDM Systems

In OFDM systems, the baseband time domain signal consisting of N subcarriers may be written as

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n . e^{j2\pi n \Delta f t} \quad 0 \leq t \leq NT$$

Where Δf is the subcarrier spacing, NT denotes the useful data block period. The PAPR of the transmit signal can be defined as

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

Where E[.] denotes expectation.

In particular, a baseband OFDM signal with N subcarriers has

$$PAPR_{max} = 10\ log_{10} N (dB)$$

The crest factor (CF) is widely used as well, which is defined as the square root of the PAPR [4].

$$CF = \sqrt{PAPR}$$

From the central limit theorem, it follows that for large values of N (N>64), the real and imaginary values of x(t) become Gaussian distributed. Therefore the amplitude of the OFDM signal has a Rayleigh distribution, with a cumulative distribution given by$F(z) = 1 - e^{-Z}$. The probability that the PAPR is below some threshold level can be written as $P(PAPR \leq z) = 1 - (1 - e^{-Z})^N$

In fact, the complementary cumulative distribution function (CCDF) of PAPR is usually used, and can be expressed as $P(PAPR > z) = 1 - (1 - e^{-Z})^N$.

4. PAPR Reduction Techniques

Many methods have been suggested to reduce PAPR over the years PAPR reduction techniques vary according to the requirement of the system and are dependent on various factors such as PAPR Spectral efficiency, reduction capacity, increase in transmit signal power, loss in data rate, complexity of computation and increase in the bit-error rate(BER) at the receiver end are various factors which are taken into account before adopting a PAPR reduction technique of the system. Many techniques have been suggested for PAPR reduction, with different levels of success and complexity. Lots of techniques presents for the reduction of this PAPR. These techniques are divided into two groups [7] - signal scrambling techniques and signal distortion techniques [5].

4.1 Signal Scrambling Techniques

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

(ii) Signal Distortion Techniques

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

4.1 Signal Scrambling Techniques:

(i). Block coding Technique:

This is simple and appropriate for short codes. This Technique is used for the reduction of the peak to mean envelope power ratio (PAPR) of multicarrier transmission systems by selecting the various sets of code words. Three areas are identified to make code practical. Section of suitable code words is for any number of carriers, any coding rate, and any M-ary phase modulation scheme. Selection of code words to enable efficient implementation of the encoding /decoding. Selection of code words to offer error deduction and correction. The most trivial brute force approach is sequential searching for all possible code words for a given length of a given number of carriers [10].

(ii) Selective mapping:

Selective mapping is considered as a promising technique for PAPR reduction because it does not produce distortion yet maintain the system performance to a great extent. In this scheme, data blocks are firstly converted into several independent blocks and the block with lower PAPR is sent, in which converting process involves multiplying data sequences to random phase sequences generated. The selected index is called side-information index which must also be transmitted to allow re covery of the data block at the receiver side. SLM leads to the reduction in data rate. In this method, main complexity occurs in recovering the side information.

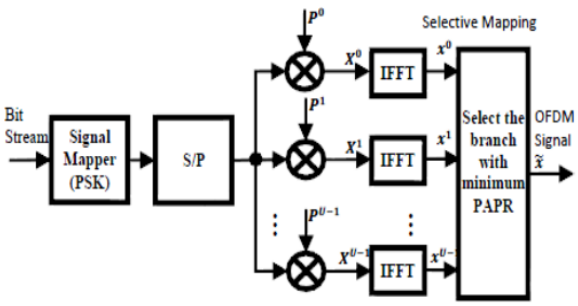

Figure 2: Shows block diagram of SLM technique

In selected mapping method , firstly M statistically independent sequences which represent the same information are generated and next the resulting M statistically independent data blocks Sm=[Sm,0,Sm,1,…,Sm,N-1]T, S=1,2,…,; are then forwarded into IFFT operation simultaneously. Finally, at the receiving end, OFDM symbols xm =[1,S2…,xN]T in discrete time-domain are acquired, and then the PAPR of these M vectors are calculated separately. Eventually, the sequences with the smallest PAPR will be elected for final serial transmission [8]. The key point of selected mapping (SLM) method lies in how to generate multiple OFDM signals when the information is same. Figure 2 shows the detailed block diagram

(iii) Partial transmit sequence:

A block diagram of PTS technique is shown in figure 3 below. The idea of partial transmit sequences (PTS) algorithm is to divide the original OFDM sequence into several sub-sequences and for each sub-sequence, multiplied by different weights until an optimum value is chosen. In the PTS approach, the input data block is partitioned into V non overlapping sub blocks X(v) which are combined to minimize the PAPR.

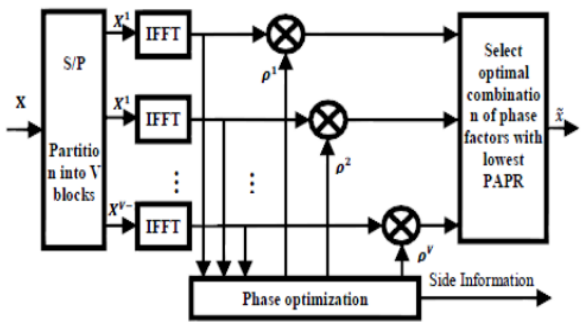

Figure 3: Shows the block diagram of PTS technique

Each carrier in the sub blocks X(v) is multiplied with the same rotation f actor $b(v) = e^{-j\varphi(v)}$. The time domain vector can be composed by the IFFT [8].

$$y = IFFT(Y) = \sum_{v=1}^{v} b(v)x(v)$$

of SLM technique.

(iv) Interleaving:

This method is also termed as Adaptive Symbol Selection Method. Multiple OFDM symbols are created by bit interleaving of input sequences. The basic Idea is to use W interleaving ways and selecting one with the lowest PAPR. The basic idea in adaptive interleaving is to set up an initial terminating threshold. PAPR value goes below the threshold rather than seeking each interleaved sequences. The minimal threshold will compel the adaptive interleaving (AL) to look for all the interleaved sequences, whereas for the large threshold value, AIL will search only a fraction of the interleaved sequences. The main important of the scheme is that it is less complex than the PTS technique but obtains comparable result. This method does not give the assurance result for PAPR reduction [10].

(v) Tone Injection

The tone injection method for PAPR reduction [9] is presented. The reduction signal also uses the data carrying tones, i.e. both the reduction as well as data carrying signal uses the same frequencies. But at the same time the constellation size is increased so that each point in the original basic constellation can be mapped into several equivalent points in the expanded constellation. On the receiver side the point is brought back to the original position by a modulo operation after the FFT. This method is called tone injection because substituting the points in the basic constellation for the new points in the extended constellation is equivalent to inject a new tone of suitable frequency and phase in the multicarrier symbol. This method has a few drawbacks e.g. side information for decoding the signal is require d on the receiver side and due to an extra IFFT operation it is mo re complex.

(vi) Tone Reservation

In the tone reservation method [9] the orthogonality between the different subcarrier is exploited to generate the peak reduction signal. In the OFDM system not all subcarriers are used for data transmission. Some of them are reserved for the reduction signal. Due to the fact that all subcarrier are orthogonal the signal generated by the re served tones does not disturb the data carrying tones. In the tone reservation method both transmitter and receiver know the set of data carrying subcarriers. The construction of the reduction signal can be done in different ways with different complexities. The PA PR reduction method using tone reservation method can be transformed into a convex optimization problem. Advantages of tone reservation include among other no side information and low complexity.

4.2 Signal Distortion Techniques

(i) Peak Windowing:

The paper, by van Nee and Wild [11] proposes that as large PAP ratios occur only infrequently, it is possible to remove these peaks at the cost of a slight amount of self interference. Clipping is one example of a PAPR reduction technique creating self interference. Peak Windowing technique provides better PAPR reduction with better spectral properties than clipping. Peak windowing can achieve PAPR around 4dB for an arbitrary subcarriers, at the cost of slight increase in BER and out-of-band (OOB) interference. In windowing technique a large signal peak is multiplied with a certain window, such as Gaussian shaped window, cosine, Kaiser and Hamming window. Since the OFDM signal is multiplied with several of these windows, the resulting spectrum is a convolution of the original OFDM spectrum with the spectrum of the applied window. Ideally the window should be as narrow band as possible, on the other hand the window should not be too long in the time domain because that implies that many signal samples are affected increasing the BER. With windowing method, PAPR can be reduced down to about 4dB, independent of the number of sub carriers. The loss of SNR caused by the signal distortion is limited to about 0.3dB. A back off relative to maximum output power of about 5.5dB is required in order to keep undesired spectra distortion at least 30dB below the in-band spectral density [14].

(ii) Envelope Scaling:

The paper, by Foomooljareon and Fernando[12], proposed an algorithm to reduce PAPR by scaling the input envelope for some sub carriers before they are sent to IFFT. The main idea behind the scheme is that the envelopes of all the subcarriers input, with PSK modulation, are equal. The envelope of the input in some subcarriers can be scaled to obtain the minimum PAPR at the output of IFFT. The final input that gives the lowest PAPR will be sent to the system. The input sequences has the same phase information as the original one but the envelopes are different. So the receiver can decode the received sequence without any side information. The main idea behind the scheme is that the envelope of the input in some subcarriers is scaled to obtain the minimum PAPR at the output of the IFFT. The scheme seems only suitable to PSK schemes, where all the envelope of all subcarriers input are equal. When the OFDM system implements the QAM modulation scheme, the carrier envelope scaling will result in the serious BER degradation. To limit the BER degradation, amount of the side information would also be excessive when the number of subcarriers is large.

(iii) Peak Reduction Carrier:

The paper, by Tan and Wassell, [13] proposes the use of the data bearing peak reduction carriers (PRCs) to reduce the effective PAPR in the OFDM system. The technique involves the use of a higher order modulation scheme to represent a lower order modulation symbol. This allows the amplitude and phase of the PRCs to lie within the constellation region representing the data symbol to be transmitted. For example, to use a PRC that employs a 16 PSK constellation to carry QPSK data symbol, the 16 phases of the 16 PSK constellations are divided into four regions to represent the four different values of the QPSK symbol. This technique uses the higher order modulation schemes for representing lower order modulation scheme data. This will incur the penalty of an increased probability of error, thus worsening the overall BER performance. So there exists a tradeoff between PAPR reduction and BER performance when selecting the constellation of the PRCs [14].

(iv) Clipping And Filtering:

Clipping is by far simplest technique for PAPR Reduction in which signal above a predetermined threshold level is clipping which introduces both in-band and out-of-band distortion which can destroy orthogonality of the subcarriers .For the later windowing of the clipped signal can be done which should be ideally as narrow as possible.

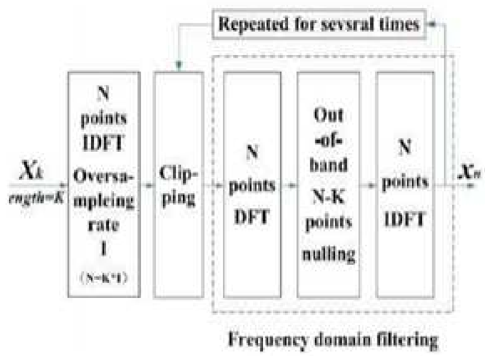

Figure 4: Repeated Clipping and Filtering

Clipping also introduces peak regrowth in OFDM signal which can be reduced by Repeated Clipping And Filtering(CAF) method , Deep Clipping , combined CAF and Interleaving described in .Block diagram of repeated CAF is shown in figure 4 where the filtering process is repeated several times to remove peak re-growth of the signal.[6]. Clipping operation is always performed on oversampled signal to reduce in-band distortion

5. Conclusion

OFDM is a very striking technique for wireless communications due to its spectrum efficiency and channel robustness One of the serious drawbacks of OFDM systems is that the composite transmit signal can exhibit a very high PAPR when the input sequences are highly correlated .Several techniques have been discussed. In this paper which gives a concrete idea about the functioning of different PAPR reduction

References

[1] Manushree Bhardwaj, Arun Gangwar , Devendra Soni, “ A Review on OFDM: Concept, Scope & its Applications”, IOSR Journal of Mechanical

and Civil Engineering (IOSRJMCE) ISSN : 2278-1684 Volume 1, Issue 1 (May-June 2012), PP 07-11.

[2] Zhou, Hao, Amaresh V. Malipatil, and Yih-Fang Huang. (2008) OFDM Carrier Synchronization Based On Time-Domain Channel Estimates. Wireless Communications, IEEE Transactions on 7, no. 8 (2008): 2988-2999.

[3] Gamidi, V. R. (2009). Semi Blind Time Domain Equalization for MIMO-OFDM Systems (Doctoral dissertation)

[4] Lin CHEN, Xuelong HU, "Research on PAPR Reduction in OFDM Systems", Journal of Computational Information Systems 6:12 (2010) 3919-3927. Available at http://www.Jofcis.com

[5] Radheshyam Patel, Chirag Prajapati, Vishal Naik, Prof. T. P. Dave "PAPR Reduction Techniques in OFDM System", International Journal of Computer Science Trends and Technology (IJCST) – Volume 2 Issue 1, Jan-Feb 2014.

[6] Leman Dewangan, Mangal Singh, Neelam Dewangan , "A Survey of PAPR Reduction Techniques in LTE-OFDM System", International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-1, Issue-5, November 2012.

[7] Arun Gangwar, Manushree Bhardwaj, " An Overview: Peak to Average Power Ratio in OFDM system & its Effect", International Journal of Communication and Computer Technologies Volume 01 – No.2, Issue: 02 September 2012 ISSN NUMBER : 2278-9723.

[8] Monika Phulia and O.P. Sahu, "Peak-to-Average Power Ratio (PAPR) Reduction of OFDM Signals Using a Modified PTS Technique", International Journal of Electronic and Electrical Engineering. ISSN 0974-2174, Volume 7, Number 1 (2014), pp. 79-84.

[9] Gondge Sagar S, Jawalkoti Chaitanya B ,Raut Pranoti N , Ms.N.K. Bhandar "PAPR Reduction in OFDM Systems", International Journal of Engineering and Computer Science ISSN: 2319 -7242 Volume 3 Issue 4 April, 2014 Page No. 5307-5313.

[10] Rajnish Saxena , Poonam Singla, Vatsala Sharma, "The Comparative Study of Peak-to-Average Power Ratio Reduction Techniques for LTE OFDM system & its Effect", International Journal of Electronic and Electrical Engineering. ISSN 0974-2174 Volume 7, Number 10 (2014), pp. 1103-1118

[11] Van Nee, R., and Wild, A., "Reducing the peak to average power ratio of OFDM", IEEE Vehicular Technology Conference, Vol.3, may 1998

[12] Foomooljareon, P. and Fernando, W.A.C., "Input sequence envelope scaling in PAPR reduction of OFDM", IEEE 5th international symposium on wireless personal multimedia communications, Vol.1, Oct 2002.

[13] Tan, C.E. Wassell, I.J., "Data bearing peak reduction carriers for OFDM systems", IEEE Proceedings of the 2003Joint Conference of the Fourth International Conference of Information, Communications and Signal Processing, 2003 and the Fourth Pacific Rim Conference on Multimedia, Vol.2, Dec 2003.

[14] V. Vijayarangan , DR. (MRS) R. Sukanesh , "An Overview Of Techniques For Reducing Peak To Average Power Ratio And Its Selection Criteria For Orthogonal Frequency Division Multiplexing Radio Systems", Journal of Theoretical and Applied Information Technology, © 2005 - 2009 JATIT. All rights reserved.