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SURVEY OF RECENT PAPR REDUCTION APPROACHED IN OFDM SYSTEMS

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1.1 Abstract

As the OFDM (Orthogonal Frequency-Division Multiplexing) is a promising way of high bit-rate transmission methods. It's utilized in lots of applications due to the robustness to frequency selective fading or narrowband disturbance, higher bandwidth efficacy and efficient execution. 1 big drawback of OFDM may be that the massive peak-to-average power ratio (PAPR) of the delivered signal. Recently a promising method of improving the numbers of this PAPR of OFDM signals was suggested: that the partial transmit arrangement (PTS) technique. Nevertheless, the search sophistication of this standard PTS technique grows significantly with the selection of all sub-blocks. Additionally optimization methods also have demonstrated an ability to supply sub-optimal and intimate enough methods for the problem at lesser time The PAPR performance of Cuckoo algorithm has also been improved about compared to existing techniques. Many PAPR reduction methods have been proposed. Some methods are designed based on employing redundancy, selective mapping, or tone reservation. An apparent effect of using redundancy for PAPR reduction is the reduced transmission rate. In this work, we survey the various PAPR reduction techniques for OFDM.

Keywords: *OFDM, PTS, PAPR Reduction.*

1.2 Introduction

In high-speed wireless and mobile communications era, OFDM technology [1] is a special Multi-Carriers Modulation transmission scheme which can be seen as either a modulation technology or a multiplexing technology enabling transmission of multiple signals simultaneously, over a single transmission path. In OFDM a high rate data stream is divided into many low data streams and these steams are then multiplied by corresponding carrier frequency signals that are orthogonal to each other. A composite signal so formed by multiplexing these modulated signals is called the OFDM signal. A simple OFDM system is shown in figure. It is advancement over traditional Frequency Division Multiplexing (FDM) technique which is used to carry only one signal over one path. OFDM uses the principles of Frequency Division Multiplexing (FDM) [2] but in much more controlled manner, allowing an improved spectral efficiency [3]. The basic principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. These subcarriers are overlapped with each other. Because the symbol duration increases for lower rate parallel subcarriers, the relative amount of dispersion in time caused by multipath delay spread is decreased. Inter symbol interference (ISI) is eliminated almost completely by introducing a guard time in every OFDM symbol. OFDM faces several challenges. The key challenges are ISI due to multipath-use guard interval, large peak to average ratio due to non linearity of amplifier; phase noise problems of oscillator, need frequency offset correction in the receiver. Large peak-to-average power (PAP) ratio which distorts the signal if the transmitter contains nonlinear components such as power amplifiers (PAs). The nonlinear effects on the transmitted OFDM symbols are spectral spreading, inter modulation and changing the signal constellation. In other words, the nonlinear distortion causes both in-band and out-of-band interference to signals. Therefore the PAs requires a back off which is approximately equal to the PAPR for distortion-less transmission. This decreases the efficiency for amplifiers. Therefore, reducing the PAPR is of practical interest.

Many PAPR reduction methods have been proposed. Some methods are designed based on employing redundancy, such as coding [4], [5], selective mapping with explicit or implicit side information [6], [7], [8], or tone reservation [9], [10]. An apparent effect of using redundancy for PAPR reduction is the reduced transmission rate. PAPR reduction may also be achieved by using extended signal constellation, such as tone injection [11], or multi-amplitude CPM. The associated drawback is the increased power and implementation complexity. However optimization based works in PAPR reduction are showing better results. In this work, we survey the various optimization based PAPR reduction techniques for OFDM. A simple PAPR reduction method can be achieved by clipping the time-domain OFDM signal. In this work, we survey the PAPR reduction techniques for OFDM.

1.3 PAPR in an MIMO-OFDM System

Consider an OFDM system with K subcarriers that uses M transmitting and N receiving antennas. We can assume that $X_i(k)$ is the data pattern of the i-th transmitting antenna with $1 \leq i \leq M$ and $0 \leq k < K$. Let $x_i(n)$ be the IFFT of this data pattern as follows:

$$x_i(n) = IFFT\left[X_i(k)\right]$$

where, n is the time domain index of an OFDM symbol $(0 \leq n \leq K\text{-}1)$. Thus, $x_i(n)$ can be represented in vector form by the vector $\mathbf{x}_i$ as follows:

$$\mathbf{x}_i = \left[x_i(0), x_i(1), \ldots . x_i(n), \ldots .. x_i(K-1)\right]^T$$

Since each subcarrier in OFDM is modulated, independently, the combined OFDM signals are likely to have large peak powers at certain instances. The peak power increases as the number of subcarriers increases. The peak power is generally evaluated in terms of the PAPR, which is given by:

$$PAPR = \frac{\max\left|x_i(n)\right|^2}{E\left[\left|x_i(n)\right|^2\right]}$$

where, the numerator represents the maximum envelope power and the denominator represents the average power.

1.4 PAPR reduction Techniques

A large PAPR would drive PAs at the transmitter into saturation, producing interference among the subcarriers that degrades the BER performance and corrupts the spectrum of the signal. To avoid driving the PA into saturation, the average power of the signal may be reduced. However, this solution reduces the signal-to-noise and consequently, the BER performance. Therefore, it is preferable to solve the problem of high PAPR by reducing the peak power of the signal. PAPR reduction techniques can be broadly classified into three main categories

1. Signal distortion techniques,
2. Multiple signaling and probabilistic techniques and
3. Coding techniques.

1.4.1 Signal Distortion Techniques

Signal distortion techniques reduce the PAPR by distorting the transmitted OFDM signal before it passes through the PA. The well-known distortion techniques are as:

1. **Clipping and Filtering:**
   This method employs a clipper that limits the signal envelope to a predetermined clipping level (CL) if the signal exceeds that level; otherwise, the clipper passes the signal without change
2. **Peak Windowing**
   In this scheme a predetermined threshold level is defined and if the high peak goes beyond this predetermined threshold, it is multiplied by a weighting function known as window function. The most commonly used window functions include Cosine, Hamming, and Gaussian Windows.
3. **Companding Transforms**
   This method basically applied for audio signals. Companding consist compression and expansion. After companding, the lower peak values are increased but higher peaks remain constant and hence, average power of OFDM signal is increased. Hence the peak to average power ratio decreases. Companding transform can be generally classified into four classes: linear symmetrical transform (LST), linear asymmetrical transform (LAST), nonlinear symmetrical transform (NLST), nonlinear asymmetrical transform (NLAST). Many companding transforms which belongs to the above four mentioned classes, are discussed in the literature.

1.4.2 Multiple Signalling and Probabilistic Techniques

This method either generate multiple permutation of the OFDM signal and transmit the one with minimum PAPR or to modify the OFDM signal by introducing phase shifts, adding peak reduction carrier or changing constellation points. Major techniques under this category are follows

1. **Selective Mapping (SLM)**
   The basic idea in SLM technique is to generate a set of sufficiently different candidate data blocks by the transmitter where all the data blocks represents the same information as the original data block and select the favorable having the least PAPR for transmission.
2. **Partial Transmit Sequence (PTS)**
   In PTS, an input data block of length N is partitioned into a number of disjoint sub-blocks. Then each of these sub-blocks are padded with zeros and weighted by a phase factor.
3. **Interleaved OFDM**
   This technique is very similar to SLM, the only difference is that interleaver is used instead of phase sequences. Interleaver is a device that operates on a block of N symbols and reorder or permutated them in a specific manner.
4. **Tone Injection (TI)**
   This technique increases the constellation size so that each of the point in the original basic constellation can be mapped into several equivalent points in the expanded constellation. Since substituting a point in the basic constellation for a new point in the larger constellation is equivalent to injecting a tone of the appropriate frequency and phase in the multicarrier signal, therefore, this technique is called tone injection.
5. **Tone Reservation (TR)**
   In this technique a subset of tones having low SNR is reserved for PAPR reduction. These tones carry no information data and added to the existing OFDM symbols so that the summation has lower PAPR values. Finding and optimized the set of peak reduction tones or peak reduction carriers (PRT's/PRC's) increases the complexity of transmitter and also increases required transmission power. Various works are available in literature mainly focusing on complexity reduction of optimization problem.
6. **Active Constellation Extension (ACE)**
   This technique is similar to Tone Injection (TI). The only difference is that in ACE, only the outer constellation points are dynamically extended away from the original constellation. Extending outer point from decision boundary increases the spacing between the constellation point and thus reducing BER and if adjusted properly PAPR could also be reduced. Various literatures are available on ACE and suggested modification

1.4.3 Coding Techniques

The basic idea behind coding technique is to select those codeword that reduce the PAPR for transmission. A forward error correction (FEC) code is defined by (n,k), where n are the data bits and k represents redundant bits, so the idea is to add redundant bit in a manner that overall PAPR value is minimized. Turbo codes which are derived from convolution codes are also discussed in literature for PAPR reduction. Multicarrier transmission such as OFDM is one of the most attractive techniques for both wired and wireless applications due to its high data rates, robustness to multipath fading and spectral efficiency. However, it has a major drawback of generating high peak to-average ratio. Lots of PAPR reduction techniques are proposed in literature and discussed in this review paper. All of proposed schemes have the potential to reduce PAPR substantially but at the cost of loss in data rate, transmit signal power increase, BER increase, computational complexity increase and so on. Thus, the PAPR reduction technique should be carefully chosen according to various system requirements.

1.5 Literature Review

MD Sakir Hossain, Member, IEEE and Tetsuya Shimamura, Member, IEEE(2016) [12]], suggested a low -- sophistication data gleaned subcarrier switching-based peak to average power ratio (PAPR) reduction strategy to its OFDM system, which offers increased bit error rate. By that conducted that the shifting between your info and null sub carriers such a manner that space between both changed null subcarrier remains steady. This method may reach upto 6 db signal to noise ratio advantage and shed the machine sophistication by a lot more than 98 percent of their traditional strategy, with a small compromise of their PAPR reduction capability.

R. Chandrasekhar, M. Kamaraju, K. Rushendra Babu and B. Ajay Kumar (2016) [13], suggested a Book code way to decrease PAPR. By the investigation different coding methods it's found that the Publication code is also a powerful way to decrease PAPR when in comparison to Hamming code along with uncoded platform.

Ling-Yin Wang, Hua Yuan and Li-Guo Liu (2016) [14], suggested a discerning weighting PTS (SW-PTS) strategy for achieving computational complexity reduction and similar PAPR reduction operation weighed against Original-PTS. In suggested SW-PTS, the discerning weighting can be used for reducing computational complexity. Subsequently a few, technical phase weighting sequences have been generated for weighting the very first subblock order to boost PAPR reduction operation. Computer simulations and investigation reveal that the suggested SW-PTS can get dramatic computational complexity reduction and much like PAPR reduction operation compared to O-PTS.

Naresh Kumar, Balwinder S. Sohi (2016) [15], presented simple effective hybrid system for decrease in ICI from multicarrier modulations and proposed wavelet established OFDM along side self indulgent and windowing way to decrease ICI. At wavelet transform orthogonality provided is way better, which leads in improved performance of this system. Simulation results reveal suggested hybrid technique performs a lot better compared to traditional system using self-cancellation technique.

Luv Sharma and Shubhi Jain (2016) [16], examined and studied that the total result of this PAPR decrease inside the spectral efficiency (SE) and energy efficiency (EE) within OFDM system thinking about the class-a higher power amplifier (HPA).with that the PAPR decrease, the ability efficiency of this HPA is tremendously enhanced, and also the non linear distortion noise resulting from the HPA is paid off into remarkable level. Ergo, the end result is obtained together with the contrast of this initial OFDM strategy without PAPR decrease, the OFDM system using PAPR decrease can achieved advanced level data speed with very low energy intake. For that reason, both SE and EE performances might be significantly enhanced by lowering the PAPR of their OFDM signs. Additionally PAPR decrease fulfills the dependence on non power in smart apparatus.

Panca Dewi Pamungkasari, Yukitoshi Sanada (2016) [17], Cyclic-selective mapping (SLM) for wireless OFDM systems where unites a first signal and its own cyclic altered signal to decrease a PAPR over time domain. But unwanted information (SI) about to the quantity of the cyclic shift is called for at the recipient, and also how to carry it's but one of the very challenging dilemma of SLM strategy since it reduces the throughput of wireless OFDM procedure. The postponed significance based estimate strategy is suggested in this paper in order to prevent the transmission of this SI. This strategy divides the correlation between a shield period arrangement and also a received signal with wait to gauge that the sum of the perceptible shift in the recipient side. Numerical results gained through computer simulation demonstrate that the suggested strategy can gauge the delay using a precision in excess of 0.99 in an Eb/No of both 8db and also get the PAPR that's the same as the traditional SLM whereas BER degradation is a bit different from this using flawless shift estimation.

Z. Esat Ankarali, H¨useyin Arslan (2016) [18], suggested two book technique that the very first technique is constructed on a CP decision plan as the 2nd one is situated on randomizing the emblem time. Cyclic prefix (CP) deploying processes like orthogonal frequency division multiplexing (OFDM) and only company frequency domain equalization (SC-FDE) offer advantages concerning real-time dispersive consequence of wireless station at the cost of a moderate spectral redundancy. But, CP introduces perceptible qualities to the signal that may likewise be manipulated to signal interception, blind parameter estimation and synchronization, and so, undermine the safety of this signal against eavesdropping attacks.

Chi Dinh Nguyen, Jaejin Lee (2016) [19], suggested modulation code, a simulation model is completed at a bit-patterned media documenting BPMR technique. The outcomes reveal that the suggested modulation code provides an advantage of approximately 2 dB over that of something with no programming. Specifically, a profit of approximately 1 dB is got on this of a 6/8 modulation code concerning exactly the very same signal speed.

Faisal Nadeem, Muhammad Zia, Hasan Mahmood, Nazar A. Saqib (2016) [20], presented a frequency-spread time-encoded (FSTE) mehod to get OFDM modulation, which divides multipath diversity and accomplishes target energy-per-bit to noise spectral density Eb/N0 in low SNR regime by dispersing differentially encoded information symbols together OFDM subcarriers. They explore the effects of dispersing on bit-error speed (BER) and throughput under comparative mobility and multi path fading scenarios. As a way to maximise the throughput of this suggested method, in addition they maximize dispersing variable and modulation order. The simulation results reveal substantial BER and throughput performance advantage when compared with existing differential encoding methods [21].

Dongwan Kim, Sunshin An (2015) [22], established a hybrid peak-windowing strategy that choose the best PAPR reduction strategy in line with this PAPR pattern, also assessed its performance with a true LTE evaluation bed.

Our evaluation results reveal that the projected scheme outperform the present strategy concerning error vector magnitude (EVM) and adjacent channel leakage ratio (ACLR) and energy intake.

1.6 Conclusion and Future Works

Multicarrier transmission such as OFDM is one of the most attractive techniques for both wired and wireless applications due to its high data rates, robustness to multipath fading and spectral efficiency. However, it has a major drawback of generating high peak to-average ratio. Lots of PAPR reduction techniques are proposed in literature and discussed in this review paper. All of proposed schemes have the potential to reduce PAPR substantially but at the cost of loss in data rate, transmit signal power increase, BER increase, computational complexity increase and so on. Thus, the PAPR reduction technique should be carefully chosen according to various system requirements. In the future works we will focus on new optimization based techniques for reducing PAPR in OFDM systems.

1.7 References

[1]. Armada, A. G. (2001). Understanding the effects of phase noise in orthogonal frequency division multiplexing (OFDM). IEEE transactions on broadcasting, 47(2), 153-159.

[2]. Li, Y. G., & Stuber, G. L. (Eds.). (2006). Orthogonal frequency division multiplexing for wireless communications. Springer Science & Business Media.

[3]. Bohara, V. A., & Ting, S. H. (2009). Analytical performance of orthogonal frequency division multiplexing systems impaired by a non-linear high-power amplifier with memory. IET communications, 3(10), 1659-1666.

[4]. Rahmatallah, Y., & Mohan, S. (2013). Peak-to-average power ratio reduction in OFDM systems: A survey and taxonomy. IEEE communications surveys & tutorials, 15(4), 1567-1592.

[5]. Kumari, N., & Kaur, S. (2015). A Survey on Various PAPR Reduction Techniques in OFDM Communication Systems. International Research Journal of Engineering and Technology (IRJET), 2(06).

[6]. Bisht, M., & Joshi, A. (2015). Various techniques to reduce PAPR in OFDM systems: A survey. International Journal of Signal Processing, Image Processing and Pattern Recognition, 8(11), 195-206.

[7]. Han, S. H., & Lee, J. H. (2004). PAPR reduction of OFDM signals using a reduced complexity PTS technique. IEEE Signal Processing Letters, 11(11), 887-890.

[8]. Malode, M. V., & Patil, D. B. (2010). PAPR reduction using modified selective mapping technique. Int. J. of Advanced Networking and Applications, 2(02), 626-630.

[9]. Kang, S. G., Kim, J. G., & Joo, E. K. (1999). A novel subblock partition scheme for partial transmit sequence OFDM. IEEE Transactions on broadcasting, 45(3), 333-338.

[10]. Baig, I., & Jeoti, V. (2010, June). DCT precoded SLM technique for PAPR reduction in OFDM systems. In 2010 international conference on intelligent and advanced systems (pp. 1-6). IEEE.

[11]. Wang, Y. C., & Luo, Z. Q. (2010). Optimized iterative clipping and filtering for PAPR reduction of OFDM signals. IEEE Transactions on communications, 59(1), 33-37.

[12]. Siming Peng, Zhigang Yuan, “A novel criterion for designing of nonlinear companding functions for peak to average power ratio reduction in multicarrier transmission system,” Wireless network, august 2016.

[13]. Md. Sakir Hossain, Tetsuya Shimamura, “Low-complexity null subcarrier-assisted OFDM PAPR reduction with improved BER,” IEEE Comm. Letter.,2016

[14]. R.Chandrasekhar, M. Kamaraju, K. Rushendra Babu and B. Ajay Kumar,”Optimization of PAPR using Novel code for OFDM system,” S.C. Satapathy et al. (eds.), Microelectronics, Electromagnetics and telecommunications, lecture notes in electrical engineering 372, 2016

[15]. Ling-Yin Wang, Hua Yuan and Li-Guo Liu, “Seletive weighting PTS PAPR reduction scheme in OFDM system,” A.Hussian (ed.), Electronics, communications and networks v, lecture notes in electrical engineering 382, 2016

[16]. Naresh Kumar, Balwinder S.Sohi, “Evaluation of conventional and wavelet based OFDM system for ICI cancellation,” wireless pers comm., 2 august 2016.

[17]. Luv Sharma, Shubhi Jain, “Consequence of PAPR reduction in ofdm system on spectrum and energy efficiencies using modified PTS algorithm,” S.C.Satapathy et al. (eds.), Proceedings of the internatonal congress on information and comm.. technology, advances in intelligent systems and computing 438, 2016.

[18]. Panca Dewi Pamungkasari, Yukitoshi Samada,”Shift estimation with delayed correlation cyclic selective mapping (Cyclic-SLM) PAPR reduction in OFDM system,” Wireless pers comm.., 5 july 2016.

[19]. Z. Esat Ankarali, H¨useyin Arslan,” Cyclic feature suppression for physical layer security,” Physical Communication (2016).

[20]. Chi Dinh Nguyen, Jaejin Lee,” Elimination of two-dimensional intersymbol interference through the use of a 9/12 two-dimensional modulation code, ”The Institution of Engineering and Technology , Vol. 10, Iss. 14, pp. 1730–1735, 2016.