European Scholar Journal (ESJ)
Available Online at: https://www.scholarzest.com
Vol. 2 No. 11, November 2021
ISSN: 2660-5562

A REVIEW PAPER ON PAPR PROBLEM OF THE TRANSMITTED SIGNAL IN OFDM SYSTEMS

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Article history:
Received: 3rd September 2021
Accepted: 6th October 2021
Published: 24th November2021

Abstract:
Orthogonal Frequency Division Multiplexing (OFDM) is a very attractive technique for high-data-rate transmission in wireless applications. This system has some drawbacks, one of the main drawbacks of the OFDM technique is its high peak to average power ratio (PAPR). This problem is complicated because it is generated in time domain. This study proposes a useful information's which relate the input data and output PAPR as a main aim. This aim is accomplished in use of the mathematical and logical approaches with trial and error to study and analyze the effect of PAPR problem in OFDM system. In this research, we will mainly investigate the advantages and disadvantages of OFDM system and PAPR reduction performance with different PAPR reduction methods in OFDM system. The main objective of this work is to enable researchers entering this field become familiar with the problem as well as the techniques to mitigate this problem. We classify OFDM PAPR methods into three categories: Signal Distortion, Signal Scrambling, and Coding. This review discusses each category and its impact on the transmitter and receiver and summarizes the discussion in a table. We also briefly describe some of the methods used to reduce PAPR in OFDM system.

Keywords: Orthogonal Frequency Division Multiplexing (OFDM), OFDM PAPR methods

1. INTRODUCTION

Wireless systems are operating in an environment which has some specific properties compared to fixed wire line systems and these call for special design considerations. In a wired network, there is no fast movement of terminals or reflection points and the channel parameters are changing slowly. In addition, time dispersion is less severe in a wired system, though it might still be a hard problem due to high data rates. In a mobile system the terminals move around, the received signal strength as well as the phase of the received signal may change rapidly. Furthermore, the signal is transmitted over the radio channel and is reflected by buildings and other means of transportation on the ground, leading to different paths to the receiver. If the length of paths differs, the received signal will contain several delayed versions of the transmitted signal according to the channel impulse response. The delays make it necessary to use complex receiver structures. In mobile wireless system, the terminals are of course intended to be portable. Therefore, low complexity and low power consumption are properties that are even more desirable in wireless system than in wire system [1].

Driven by multimedia based applications, anticipated future wireless systems will require high data rate capable technologies with a high speed of mobility. In the third generation (3G) wireless communication system, although the maximum data rate can be 2Mbps, the typical data rate is around 384 Kbps. To achieve the goals of broadband cellular services, it is very appealing to leap to the fourth generation (4G) network [1,2]. The focus of future fourth generation (4G) mobile systems is to support high data rate services and ensure seamless provision of services across a multitude of wireless system and networks, from indoor and outdoor, from one air interface to another, and from private to public network infrastructure. Higher data rates allow the deployment of multi-media applications, which involve voice, data, pictures, and video over the wireless network. At this moment, the data rate envisioned for 4G networks is 1 GB/s for indoor and 100 Mb/s for outdoor environments. High data rate means the signal waveform is truly wideband, and the channel is frequency selective from the waveform perspective, that is, a large number of resolvable multipaths are present in the environment. Orthogonal Frequency Division Multiplexing (OFDM), which is a modulation technique for multicarrier communication systems, is a promising candidate for 4G wireless systems since it is less susceptible to inter-symbol interference introduced in the multipath environment [1,3, 4].

This work suggests a useful information's for the relation between the input data and output PAPR. This aim is satisfied in three points: Studying and analyzing the effect of PAPR problem in OFDM system, that in turn influences directly the value of power amplifier.This research is arranged in four sections. Section one presents an introduction to the subject. Section two gives a description of OFDM system with its problems and focuses on the PAPR problem with its reduction methods. Section three presents analysis and studies of PAPR problem in OFDM system. Then, the general lliterature survey is representation of all possible eventualities of the form and the ideal situation by using appropriate models. Finally, several conclusions and some suggestions for future works are given in section four.

2. SINGLE-CARRIER AND MULTI-CARRIER MODULATION

In a single-carrier system, data symbols are transmitted sequentially and each symbol conveys a number of information bits. In this situation, the delay spread of the multipath may be higher than the symbol rate, which causes severe Inter-symbol Interference. So that the symbol rate must be reduced sufficiently, because the information that can be carried is limited in the presence of multipath, and that leads to degrade the system performance drastically, especially in high bit rate communication systems [5]. In multi-carrier Modulation (MCM) the available transmission bandwidth BW is split into a set of parallel and ideally independent narrowband sub-channels. That means instead of sending data in serial on one channel, data are sent in parallel over N channels, each one being modulated by a low data rate stream. Because all sub-channels are narrow-band, the channels look like almost flat fading, which makes equalization very simple [5, 1].

Multicarrier modulation has become a key technology for current and future communication systems and OFDM is a form of multicarrier modulation. These systems are becoming popular due to the fact that they efficiently use the available frequency band and provide high data rates. In the multicarrier modulation, the available frequency band is divided into a large number of sub bands and the data user is modulated onto many separate subcarriers. These subcarriers are separated from each other and in case of OFDM; the subcarrier is orthogonal to each other [5, 6]. To achieve orthogonality between the different subcarriers, the spacing between the carriers is equal to the reciprocal of the useful symbol period. The spectrum of these subcarriers shows that each subcarrier has a null at the center frequency of the other subcarriers in the system. When the subcarriers are placed in this fashion, then there is no interference between the different carriers [6]. By comparing a multicarrier modulation system (OFDM) with a single carrier modulation system, the multicarrier system has several advantages: Multicarrier system, offers a better immunity for multipath effects, channel equalization is much simpler and timing acquisition constraints are relaxed [6, 7].

3. OVERVIEW OF OFDM SYSTEM

OFDM becomes a very popular multi-carrier modulation technique for the transmission of signals over wireless channels. It converts a frequency-selective fading channel into a collection of parallel flat fading subchannels, which greatly simplifies the structure of the receiver [8]. When orthogonality is maintained between different subchannels during transmission, then it is possible to separate the signals very easily at the receiver side. Classical or conventional FDM which ensures by inserting guard bands between sub-channels. These guard bands keep the subchannels far enough so that separation of different subchannels is possible. Naturally, inserting guard bands results in an inefficient use of spectral resources [8, 9, 10,11]. Orthogonality makes it possible in OFDM to arrange the subcarriers in such a way that the sidebands of the individual carriers overlap and still the signals are received at the receiver without being interfered by inter-carrier interference (ICI). The receiver acts as a bank of demodulator, translating each subcarrier down to DC, with the resulting signal integrated over a symbol period to recover raw data [12, 13]. Hence, the available bandwidth is utilized very efficiently in OFDM system without causing the ICI. By combining multiple low-data-rate subcarriers, OFDM system can provide a composite high-data-rate with long symbol duration. That helps to eliminate the inter-symbol interference (ISI), which often occurs along with signals of short symbol duration in a multipath channel. Simply speaking, the advantages and disadvantages of OFDM system can be listed, as follows [10,12,14,15,16,17]: -

Advantages of OFDM system are:

1- High spectral efficiency.
2- Simple implementation by FFT (fast Fourier transform).
3- Low receiver complexity.
4- Robust ability for high-data-rate transmission over multipath fading channel.
5- High flexibility in terms of link adaptation.
6- Low complexity multiple access schemes such as orthogonal frequency division multiple access.

Disadvantages of OFDM system are [10]:

1- Sensitive to frequency offsets, timing errors and phase noise;
2- Relatively high peak-to-average power ratio compared to single carrier system, which tends to reduce the power efficiency of the radio frequency (RF) power amplifier.

4. LITERATURE SURVEY

It is well known that one of the main disadvantages of OFDM is that the time-domain signals exhibit a high peak-to-average power ratio (PAPR). Several methods were presented to reduce the PAPR of OFDM transmissions. They are classified according to the data of publication. In 1997 [5], S. H. Müller proposed a very effective and flexible peak power reduction scheme for Orthogonal Frequency Division Multiplexing (OFDM) called Partial Transmit Sequences (PTS). In PTS, the information bearing subcarrier block is subdivided into pairwise disjoint carrier subblocks, each subblock carries information which are already represented in another subblock which is set to zero. Then, a rotation factor introduced for each subblock and the modified subcarrier amplitude vector represents the same information that actually used.

In 1998 [6], Jayalath proposed methods using coding which are limited methods such as Block Coding Schemes, Sub Block Coding and Block Coding with error correction. In 1999 [18], E. Lawrey and C. Kikkert proposed a technique that combines selective mapping and cyclic coding. A reduction in the PAPR is achieved by adding extra carriers referred to as Peak Reduction Carriers (PRC). The phase and amplitude of the PRCs is varied to minimize the overall PAPR. The original information carriers are unaffected and can be decoded normally. In 2002 [19], Seung Hee Han and Jae Hong Lee proposed a novel PAPR reduction technique based on signal set expansion. In the proposed technique, original signal set is expanded to a signal set with more signal points. Each point in the original signal set is associated with two or more points in the expanded signal set. A symbol in an OFDM data block is mapped into a point among associated points in the expanded signal set so that PAPR is reduced. Proposed technique is very simple and does not require any side information to be transmitted from the transmitter to the receiver.

In 2003 [20], Serdar Sezginer and Hikmet Sari proposed a very simple scheme based on constellation shaping. Peak power reduction in the proposed scheme is based on a simple metric calculation for the input symbols and does not need any optimization or iterative search. In 2004 [21], Masoud Olfat and K. J. Ray Liu proposed the cyclic shifts of low PAPR codes used in OFDM transmission. They comprise a superclass of Golay Complementary Codes (GCC) with the same level of PAPR (viewed by the discrete OFDM symbols). These codes achieve higher information rate at the expense of lower error correction capabilities. For constructing a framework is proposed, these codes out of GCC. The framework can be applied to obtain the cyclic shift of any code represented by Boolean algebraic functions.

In 2008 [22], Ashraf A. Eltholth and others proposed the use of Huffman coding to reduce the PAPR of an OFDM system as a distortion less scrambling technique, and utilized the amount saved in the total bit rate by the Huffman coding to send the encoding table for accurate decoding at the receiver without reducing the effective throughput. It was found that, the use of Huffman coding reduces the PAPR by about 6 dB. Also, they investigated the effect of PAPR reduction due to Huffman coding through testing the spectral spreading and the inband distortion due to HPA with different IBO values [23]. In 2009 [24], by Robert F.H. Fischer and Christian Siegl a new scheme for PAPR reduction in OFDM was presented. In contrast to the existing approaches of designing codes for a specific situation, general purpose channel codes, in particular Reed–Solomon codes are employed to create a number of candidates, from which the best—any possible criterion is selected. The codes are arranged over a number of OFDM frames rather than over the carriers. Thereby, the use of coding and the strategy of alternative signal representations and selection are combined. Significant gains can be achieved with this very flexible and versatile method.

In 2010 [25], precoding method of OFDM signals is addressed for the reduction of the peak-to-average power ratio with less complexity, it is proposed by Namitha.A.S and Sudheesh.P. In precoding method, multiplying the modulated data of each OFDM block by a precoding matrix is carried out before giving to IFFT block. Precoding is a new method which has less complexity compared to the other power reduction techniques and also it can reduce PAPR considerably and results in no distortion.

5. OFDM SYSTEM PROBLEMS

Like anything else, OFDM is not perfect. It is very complex, making it more expensive to implement. However, modern semiconductor technology makes it pretty easy. OFDM is also sensitive to carrier frequency variations. To overcome this problem, OFDM systems transmit pilot carriers along with the subcarriers for synchronization at the receiver. Another disadvantage is that an OFDM signal has a high peak to average power ratio. As a result, the complex OFDM signal requires linear amplification. That means greater inefficiency in the RF power amplifiers and more power consumption. The most important problems in OFDM system can be explained in the following points.

5.1 Orthogonality

Orthogonality is a property that allows multiple information signals to be transmitted perfectly over a common channel and detected, without interference. Loss of orthogonality results in blurring between these information signals and degradation in communication. OFDM signals are made up from a sum of sinusoids, with each corresponding to a subcarrier. The baseband frequency of each subcarrier is chosen to be an integer multiple of the inverse of the symbol time, resulting in all subcarriers having an integer number of cycles per symbol. As a consequence, the subcarriers are orthogonal to each other, as shown in Figure (1) [2, 26, 27].

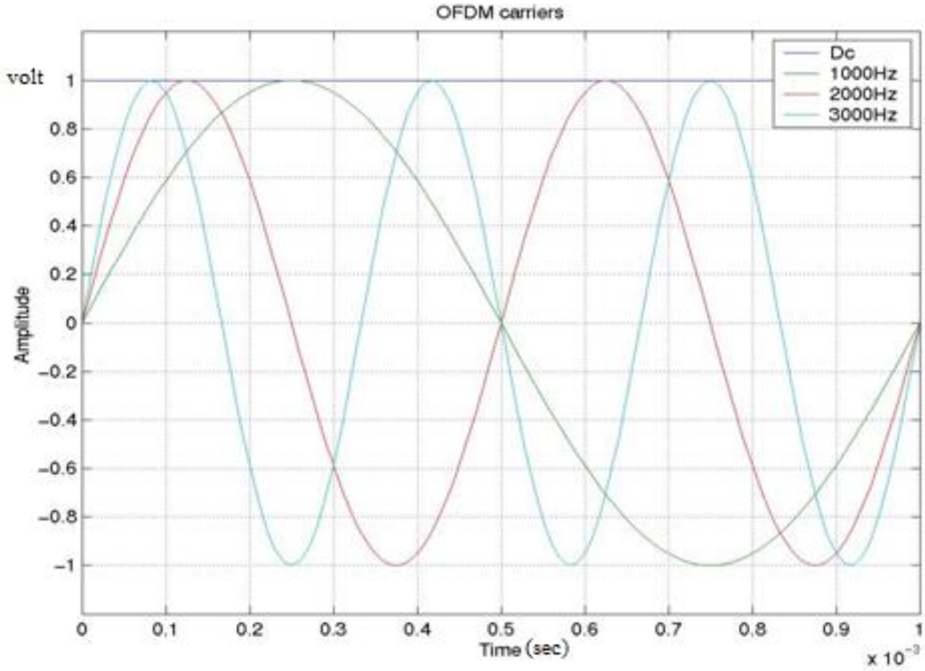

Fig. 1. OFDM waveform in time domain

Another way to view the orthogonality property of OFDM signals is to look at their spectrum. In the frequency domain, each OFDM subcarrier has a *sinc* function, (sin(x)/x), frequency response. The *sinc* shape has a narrow main lobe, with many side lobes that decay slowly with the magnitude of the frequency difference away from the center [28]. Each carrier has a peak at the center frequency and nulls evenly spaced with a frequency gap equal to carrier spacing. The orthogonal nature of the transmission is a result of the peak of each subcarrier corresponding to the nulls of all other subcarriers [2, 26, 27].

5.2 Synchronization

One of the crucial problems in the receiver is to sample the incoming signal correctly. If the wrong sequence of samples is processed, the FFT will not correctly recover the received data on the carriers. If the signal transmitted is really time domain periodic, as required for the FFT to be correctly applied, the effect of the time displacement is to modify the phase of all carriers by a known amount. This is due to the time shift theorem in convolutional transform theory. The effect of the time shift would then be not only to add the phase shift, but also to add some inter-symbol interference with adjacent symbols. This interference could hardly degrade reception. One technique used to obtain good synchronization is to add between each OFDM symbol a null (zero samples) symbol. This technique is used in DAB for time synchronization [8, 29, 30,31].

5.3 Phase Noise

At the receiver, a local oscillator can add phase noise to an OFDM signal. The phase noise could so have two effects those are: Common Phase Error (CPE) due to a rotation of the signal constellation and, Inter Carrier Interference (ICI), similar to additive Gaussian noise.CPE arises simultaneously on all carriers. Indeed, the signal constellation within a given symbol is subject to the same rotation for all carriers and this effect can be corrected by using reference information within the same symbol [8, 27, 32]. ICI is more difficult to overcome, due to additive noise, which is different for all carriers. This difference can be interpreted as a loss of orthogonality.

5.4 Frequency Error

An OFDM system is subjected to two types of frequency errors. They are Frequency offset (as might be caused by the tolerance of the local oscillator frequency) and, Error in the receiver master clock frequency (which will make the spacing of the demodulating carriers different from those transmitted). Both of these error situations have been analyzed so; a frequency offset affects most carriers equally, with the very edge carrier less affected. ICI, resulting from a fixed absolute frequency offset, increases with the number of carriers, if the system bandwidth is kept constant. About error in the receiver clock frequency, in absence of frequency offset, it affects carriers unequally (the center carrier suffers a little, while the worst affected carrier lies close to, but not at the edge) [32].

5.5 Peak- to- average Power Ratio (PAPR)

When the phase of different subcarriers adds up to form large peaks, an important complication comes in OFDM system. This problem is called Peak to Average Power Ratio (PAPR) and it is defined for each sampled OFDM signal by the following formula [32]:

$$\chi_n = \frac{\max_k |x_n[k]|^2}{E\{|x_n[k]|^2\}} \tag{1}$$

In OFDM system, PAPR can have very high values for certain input sets of sample $(X_n[k])$ and overload non-linear characteristics of systems, causing inter-modulations among different carriers and undesired out-of-band radiation.

6. PAPR EQUATIONS

The crest factor of the discrete-time representation *s(n)* is defined as the ratio of the peak magnitude value and the square root of the average power of this signal. As it has been seen, in OFDM signaling, the *T*-spaced samples *s (n)* within the symbol period associated with OFDM symbol *m* are directly obtained from the sequences s_m with elements $s_{n',m}$. Thus, the crest factor can be written as [33]

$$\zeta = \frac{\max\limits_{\forall n'} |s(n')|}{\sqrt{E\left\{|s(n')|^2\right\}}} = \frac{\max\limits_{\forall m, 0 \le n' < N_u} |s_{n',m}|}{\sqrt{E\left\{|s_{n',m}|^2\right\}}} \tag{2}$$

where $E\{\cdot\}$ denotes the expected value. Note that the PAPR, widely used in literature, is simply the square of the crest factor, $\zeta^2 = PAPR$ .The maximum amplitude which has to be encountered in an OFDM signal is:

$$\max_{\forall m, 0 \le n' < N_u} |s_{n',m}| = \frac{1}{N_u} \cdot N_u \cdot \max_{X \in \chi} |X| = \max_{X \in \chi} |X| \tag{3}$$

Assuming the same signal constellation χ for modulation in each subcarrier. The mean-squared magnitude σ_x^2 of the sequence $s_{n',m}$ is calculated according to Parsevals's theorem for power signal, resulting in

$$\sigma_x^2 = E\left\{|s_{n',m}|^2\right\} = \frac{N_u}{N_u^2}\sigma_X^2 = \frac{1}{N_u}\sigma_X^2 \tag{4}$$

because, N_u carriers with $\varepsilon\left\{|X_{k,m}|\right\} = \sigma_X^2$ are used for transmission. In addition, it has proved to be useful to define an OFDM symbol-related crest factor defined as [33]

$$\zeta_m = \frac{\max\limits_{0 \le n' < N_u} |s_{n',m}|}{\sqrt{\varepsilon\left\{|s_{n,m}|^2\right\}}} = \frac{\max\limits_{0 \le n < N_u} |s_{n',m}|}{\sqrt{\sigma_x^2}} \tag{5}$$

Or

$$\zeta_m = \frac{N_u \cdot \max\limits_{0 \le n' < N_u} |s_{n',m}|}{\sqrt{\sigma_X^2}} \tag{6}$$

7. STATISTICAL DISTRIBUTION OF PAPR

This is subsequent analysis and calculation of the probability that the crest factor of an OFDM symbol exceeds a certain threshold. With this, the distribution of ζ_m can be approximated. The *Central Limit Theorem* will help in approximation. The Central Limit Theorem is the probability density of the sum of a large number of independently distributed quantities approach Gaussian probability density function, regardless of the form of distribution of the individual components. The time-domain samples of the OFDM signal are the sum of *Nu* nonzero carrier amplitudes $X_{k,m}$ which can be interpreted as independent zero mean random variables with variance σ_X^2 .The multiplication with complex factors $\exp\left(j\frac{2\pi}{N_u}km\right)$ does not affect the variance of the individual components, due to the central limit theorem, and assuming that *Nu* is sufficiently large, $s_{n',m}$ is a zero-mean complex near Gaussian distributed random variable with variance $\sigma_x^2 = \frac{1}{N_u} \cdot \sigma_X^2$. Introducing the variable , and the Rayleigh distribution for the probability density function of the OFDM signal magnitude:

$$p_u(u) = \frac{2u}{\sigma_x^2} \exp\left(-\frac{u^2}{\sigma_x^2} \right) \tag{7}$$

$$\Pr\{|s| \le a_0\} = \int_0^{a_0} p_u(u) du = 1 - \exp\left(-\frac{a_0^2}{\sigma_x^2} \right) \tag{8}$$

Now, assuming $s_{n',m}$, $0 \le n' < N_u$ to be statistically independent, the probability that the magnitude value of an entire OFDM symbol which does not exceed a certain magnitude threshold can be approximated by CDF.

$$\begin{aligned} CDF &= \Pr\left\{ \max_{0 \le n' < N_u} |s_{n',m}| \le a_0 \right\} \\ &= \Pr\left\{ |s_{0,m}| \le a_0, \ldots\ldots, |s_{N_u-1,m}| \le a_0 = \left(\Pr\{ |s_{n',m}| \le a_0 \} \right)^{N_u} \right\} \\ &= \left(1 - \exp\left(-\frac{a_0^2}{\sigma_x^2} \right) \right)^{N_u} \end{aligned} \tag{9}$$

The Complementary Cumulative Distribution Function (CCDF) of the PAPR denotes the probability that the PAPR of an entire OFDM symbol that at least one magnitude exceeds a given threshold.

$$\Pr(PAPR > \zeta_0) = 1 - CDF = 1 - \left(1 - \exp\left(-\frac{a_0^2}{\sigma_x^2} \right) \right)^{N_u} \tag{10}$$

In other words, the theoretical expression of the probability $P_\zeta(\zeta_0)$ that the crest factor of one OFDM symbol at time *m* exceeds a certain crest factor threshold $\zeta_0 = \frac{a_0}{\sigma_x}$ follows from the above as:

$$P_\zeta(\zeta_0) = \Pr\{\zeta_m > \zeta_0\} = 1 - \left(1 - \exp\left(-\zeta_0^2\right)\right)^{N_u}, \zeta_0^2 = PAPR \tag{11}$$

Due to the approximation, the probability of the occurrence of OFDM symbols having a crest factor ζ_m higher than a given threshold ζ_0 is merely a function of the IDFT length N_u used in the given OFDM transmitter [34].

8. Different PAPR Reduction Schemes

Several techniques have been proposed in the literature to reduce the PAPR. Basically, there are two main approaches to deal with PAPR in OFDM, by preventing the problem or by correcting the problem [35]. Some methods as examples can be classified depending on the above approaches, as shown in Figure (2)

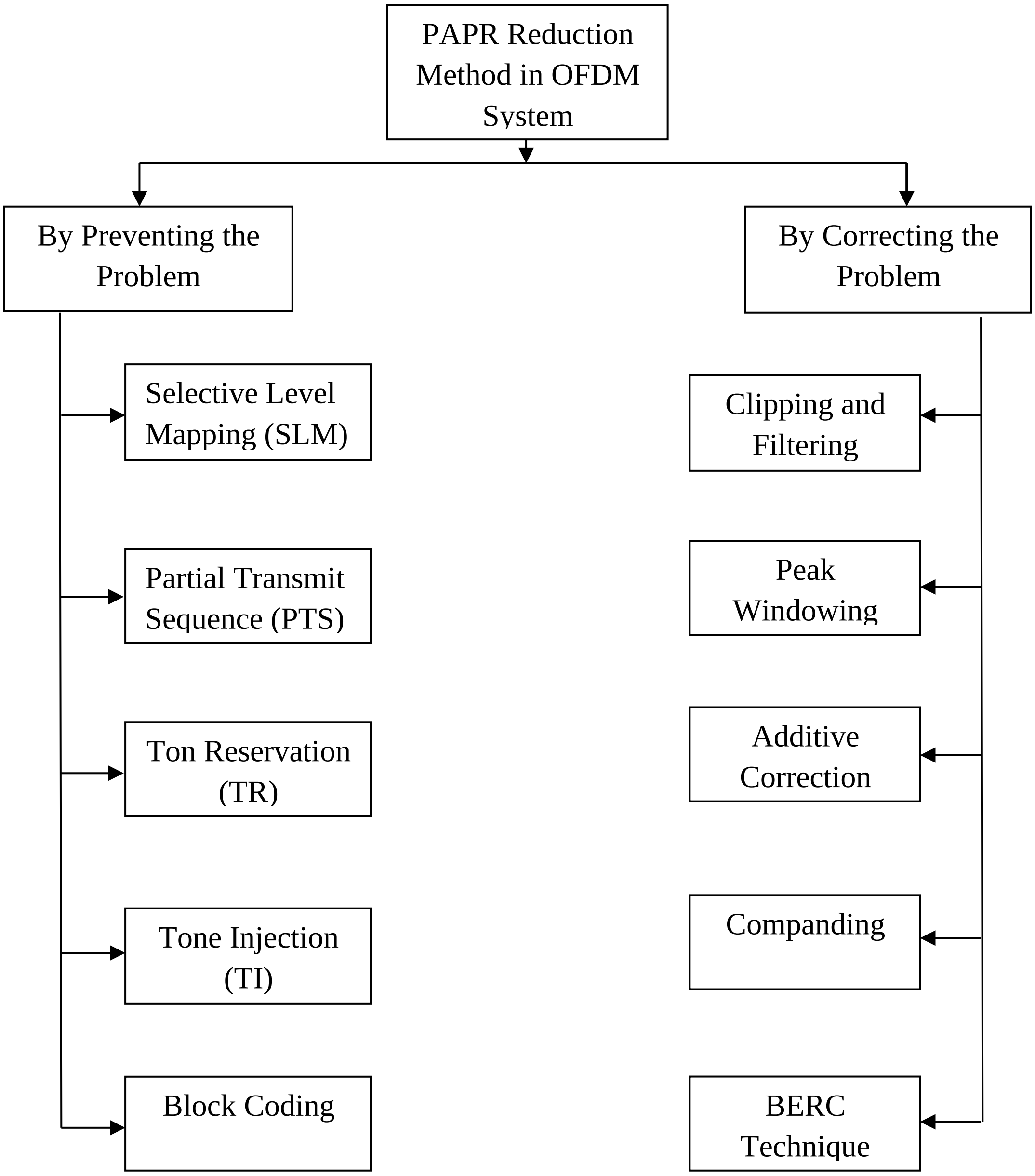

Fig. 2. Different PAPR Reduction Methods

8.1 Selective Level Mapping (SLM)

This method is proposed to reduce a wide range of variation of an OFDM signal. SLM takes advantage of the fact that the PAPR of an OFDM signal is very sensitive to phase shifts in the frequency-domain data. This approach assumes that U statistically independent alternative OFDM symbol $s_m^{(u)}$ which represents the same information. Then, that symbol, which exhibits the lowest crest factor, is selected for transmission. Mathematically, it will be written as:

$$\tilde{u}_m = \arg\min_{1 \le u \le U} \left(\max_{0 \le n' < Nu} \left| s_{n',m}^{(u)} \right| \right) \tag{12}$$

and that sequence $\tilde{s}_m = s_{n',m}^{(\tilde{u}_m)}$ with the lowest crest factor, denoted as $\tilde{\zeta}_m$, is transmitted. Note that the *argmin (.)* operator yields the argument for which the expression in brackets achieves the global minimum. Assuming a set of statistically independent OFDM symbols, the probability that exceeds is simply given by:

$$\Pr\left\{\tilde{\zeta}_m > \zeta_0\right\} = \left(\Pr\left\{\tilde{\zeta}_m > \zeta_0\right\}\right)^U = \left(P_\zeta\left(\zeta_0\right)\right)^U \tag{13}$$

Hence, the reason why the name *Selected Mapping* is used, because of the varying assignment of data to the transmitted signal, or by properly selecting a priori the phase-shifts. Now, the question is how to generate this set of OFDM symbols, each representing the same information. Here, it presents one possible, very promising solution. Define *U* distinct, fixed vectors:

$\mathrm{P}^{(u)} = [\; P_1^{(u)},....., P_{Nu}^{(u)} \;]$, with $P_k^{(u)} = e^{j\vartheta_k^{(u)}}$, $\vartheta_k^{(u)} \in (0,2\pi), 1 \le u \le U$.

After mapping the information to the carrier amplitudes $X_{k,m}$, each OFDM symbol is multiplied carrier wise with the *U* vectors $\mathrm{P}^{(u)}$, resulting in a set of *U* different OFDM symbols $X_m^{(u)}$ with components:

$$X_{k,m}^{(u)} = X_{k,m} \cdot P_k^{(u)} \quad , 0 \le k < N_u \quad ,1 \le u \le U \tag{14}$$

Then, all *U* OFDM symbols are transformed into time-domain to get $s_m^{(u)} = IDFT\{X_m^{(u)}\}$ and again that sequence $\tilde{X}_m$ with the lowest crest factor $\tilde{\zeta}_m$ is selected for transmission. The drawbacks of SLM is that it introduced side information required to locate some carriers that carry this information, which leads to decrease the bit rate. Also, increasing the number of rotations angles, results in that the additional gain becomes smaller and smaller for each extra angle. Finally, the complexity of SLM needs additional transformation the same as the value of U [36, 37, 38].

8.2 Partial Transmit Sequence (PTS)

The same authors of SLM proposed a technique that is based on the same principle, called PTS. The main idea of the following scheme is, that the information bearing subcarrier set X_m of the OFDM symbol is partitioned into *V* pairwise disjoint subblocks $X_m^{(v)}$, $v = 1,.....,V$. In other words, every used subcarrier within the OFDM symbol X_m is represented in exactly one of these *V* subblocks $X_m^{(v)}$. Thereby, the total number of subcarriers included in any one of these subblocks $X_m^{(v)}$ is arbitrary. All carrier positions in $X_m^{(v)}$, which are represented in another subblock, are set to zero. Figure (3) shows one possible example. Mathematically, X_m is then simply given by $X_m = \sum_{v=1}^{V} X_m^{(v)}$. Now, complex-valued rotational factors $b_m^{(v)}$ with $\left|b_m^{(v)}\right| = 1$, are introduced $b_m^{(v)} \in \{\pm 1, \pm j\}$.
Then, a modified vector with subcarrier amplitudes

$$\tilde{X}_m = \sum_{v=1}^{V} b_m^{(v)} \cdot X_m^{(v)} \tag{15}$$

is obtained, which represents the same information as X_m , if the current set $[\; b_m^{(v)}, v = 1,...,V]$ is known (side information). Actually, simply a rotation of all sub carriers comprised in the subblock *v* by the same angle $\arg\left(b_m^{(v)}\right)$ is performed. In order to calculate ,the linearity of the IDFT is exploited. Accordingly, the subblocks may be transformed by V separate and parallel IDFTs, yielding:

$$\tilde{s}_m = IDFT\left\{\sum_{v=1}^{V} b_m^{(v)} \cdot X_m^{(v)}\right\} = \sum_{v=1}^{V} b_m^{(v)} \cdot IDFT\{X_m^{(v)}\} = \sum_{v=1}^{V} b_m^{(v)} \cdot s_m^{(v)} \tag{16}$$

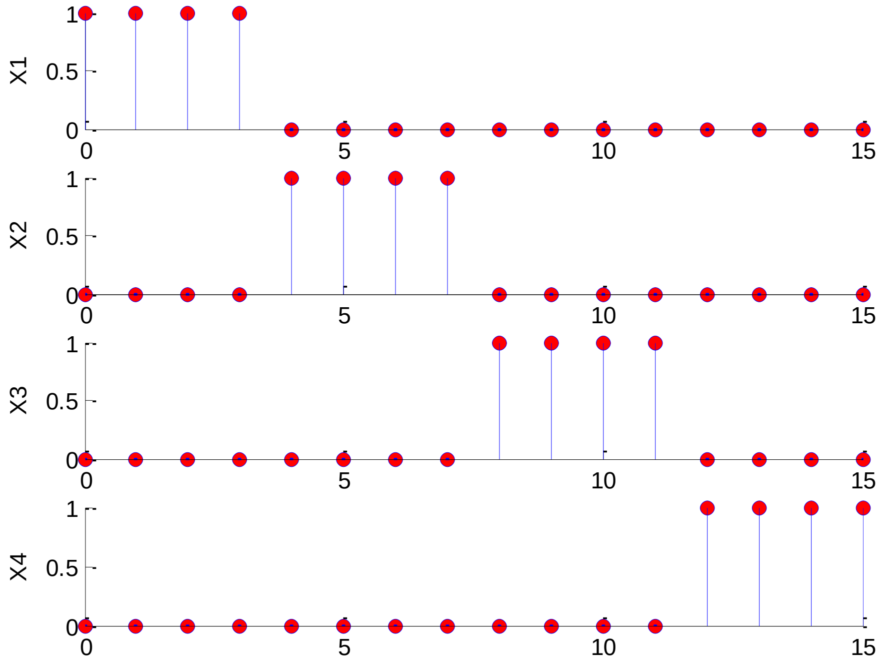

Fig. 3. Example of Dividing the Subcarriers into v=4 Subblocks PTS.

where the V so-called partial transmit sequences (PTS) $s_m^{(v)} = IDFT\left\{X_m^{(v)}\right\}$ have been introduced. The combination of such blocks with different phase-shifts gives the wanted different alternatives possible symbols for transmission. Ideally, the optimized rotation parameter set reads:

$$\left[\ \tilde{b}_m^{(1)},....,\tilde{b}_m^{(V)}\ \right] = \underset{\left[\ \tilde{b}_m^{(1)},...,\tilde{b}_m^{(V)}\ \right]}{\arg\min}\left(\max_{0\le n'<Nu}\left|\sum_{v=1}^{V} b_m^{(v)} \cdot s_{n',m}^{(v)}\right|\right) \qquad (17)$$

Resulting in the optimum transmit sequence

$$\tilde{s}_m = \sum_{v=1}^{V} \tilde{b}_m^{(v)} \cdot s_m^{(v)} \qquad (18)$$

which has the lowest crest factor of all alternative transmit sequences which can be generated by this approach. The addition of $s_m^{(v)}$ is done component wise, and the multiplication with the scalar values $\tilde{b}_m^{(v)}$ affects each component in the same way. Again, it is obvious, that the receiver has to gain knowledge about how the transmitted OFDM signal is generated in symbol period m. Thus, the set of the rotation factors or any appropriate and unambiguous representation of it has to be transmitted to the receiver. In spite of the several advantages of PTS, two main drawbacks are recorded about this method. Because of the linearity of IDFT, PTS divides the sequence into subblocks and that increases the computational load and requires more time for the selection of the sequence to be transmitted. Another difficulty for PTS is that side information must be introduced for each subblock instead of the entire symbol in the case of SLM [36, 37, 39].

8.3 Tone Reservation (TR)

The most efficient technique to reduce the PAPR is the one proposed by Jose Tellado called, tone reservation (TR). The basic idea is to reserve a small set of tones for the PAPR reduction signals. These reserved tones are not used for data transmission instead; they are reserved for anti-peak signals and they are orthogonal to the other tones which bear data. The goal is to find the time domain signal $c(n)$ to be added to the original time domain signal $s_m(n)$, to cancel large peaks. Figure (4) shows the operation of TR technique in discrete time domain. If the vector $C(k) = IDFT\{c(n)\} = [C_0, C_1, ..., C_{Nu-1}]^T$ is added to $X_m(k)$ in the frequency domain, the new time domain signal can be represented as

$$\tilde{s}_m(n) = s_m(n) + c(n) = IDFT\{X_m(k) + C(k)\} \qquad (19)$$

The new PAPR of the additive signal $\tilde{s}_m(n)$ is defined as:

$$PAPR = \frac{\max\left|\tilde{s}_m(n)\right|^2}{E\left[\left|s_m(n)\right|^2\right]} = \frac{\max\left|s_m(n) + c(n)\right|^2}{E\left[\left|s_m(n)\right|^2\right]} \qquad (20)$$

Tellado's original technique reduces peaks in the time domain by iterative subtraction of Dirac-like functions and the algorithm to compute or and reduce the PAPR of the OFDM signal will be presented in the following [40, 41]. In the TR technique, the reserved anti-peak signals are taken from the total number of subcarriers, that leads to decrease the system data rate, which is the only the drawback of this method.

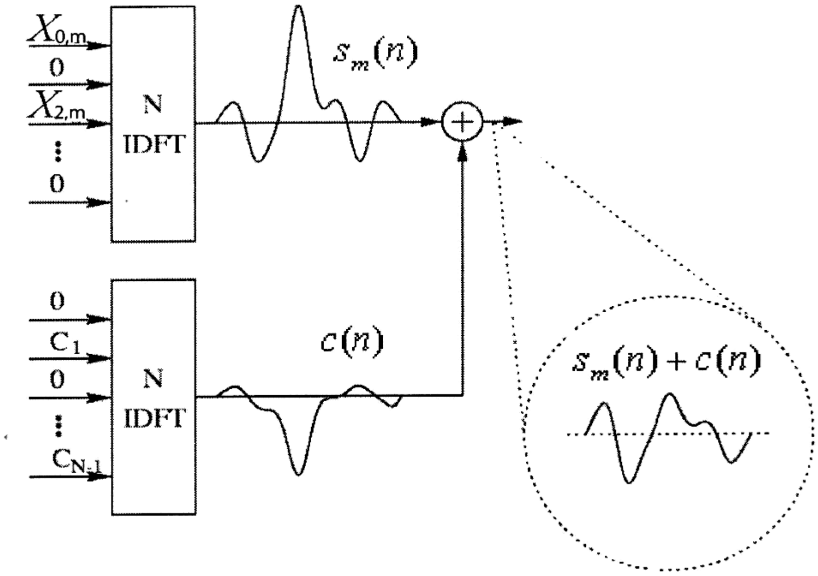

Fig. 4. Operation of the Tone Reservation Technique [40].

8.4 Tone Injection (TI)

In this method, a tone of the appropriate frequency and phase in the multicarrier symbol is injected. The basic idea is to expand the constellation points from the original constellation to one of its corresponding points in the extended constellation. The constellations are separated by a distance *D*, so that $d_{\min}$ ($d_{\min}$ is the minimum distance between the points in the constellation) for the extended constellation is the same as the original $d_{\min}$. If it is done properly, this rearrangement will lead to a PAPR reduction.

The clever trick is that the receiver can recover which constellation point a received extended point corresponds to by taking the modulo-*D* of the in-phase and quadrature-phase components of the received signal. Thus, no side information is necessary to recover the original signal from the PAPR reduced signal. Figure (5) shows the original constellation and the expanded constellation for a 16QAM.The modifying of the real and/or imaginary part of $\tilde{X}_{k,m}$,is by using $\tilde{X}_{k,m} = X_{k,m} + pD + jqD$ where *p* and *q* are any integer values and *D* is a positive real number known at the receiver. Note that, if we want the receiver to be able to recognize which $\tilde{X}_{k,m}$ has been transmitted without ambiguity, *D* must be chosen in such a way that new $\tilde{X}_{k,m}$ does not overlap to other points of the constellation. It is furthermore important that minimum distance among different points is preserved, so as not to increase the received error probability.

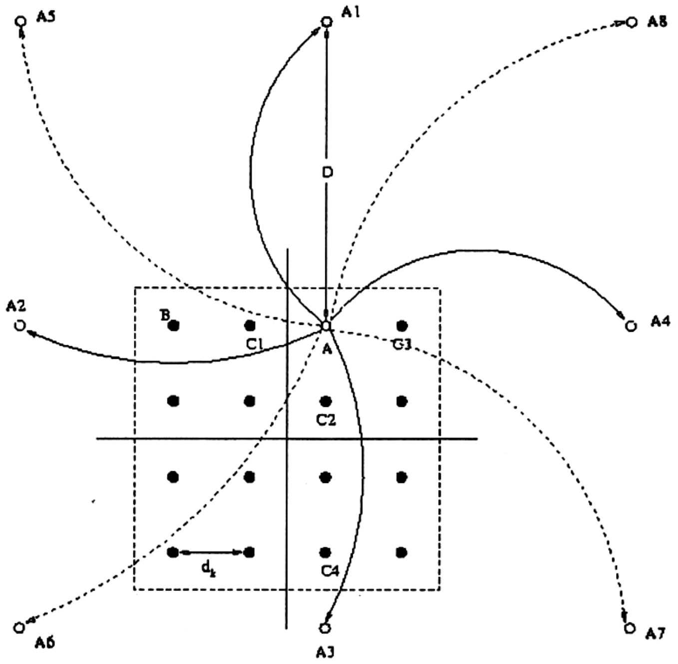

Fig. 5. Scheme of Constellation Expansion According to TI Technique.

The transmitted vector is chosen from the following set:

$$\tilde{s}_m(n) = \frac{1}{N_u} \sum_{k=0}^{Nu-1} \left(X_{k,m} + p_k D_k + j q_k D_k \right) e^{j2\pi kn/Nu} \qquad (21)$$

At the receiver side, constellation is shrunk back to its original size to obtain the original point [37, 38, 39, 40]. TI deals with the increase in average power more than in the decrease in peak power, and in some cases peak power could lead to another peak power. In practice, the large increment in average power is not desired, because it limits the gain of PA and leads to inefficient amplification.

8.5 Block Coding

A block coding scheme for the reduction of PAPR, is to find code words with minimum PAPR from a given set of code words and to map the input data blocks of these selected code words. Thus, it avoids transmitting the code words which generate high peak envelop power. But, this reduction of PAPR is at the expense of a decrease in transmission rate, and it is only available for a small number of carriers (4 to 16). A Golay sequence is one of several codes based on this criterion, in which the information is transmitted by mapping each data word with a complementary Golay sequence. When the length of the symbol is large, it is difficult to select sequences to be complementary between them. So, it is not suitable for higher order bit rate or large number of carriers [41, 42, 43].

8.6 Clipping Method

Clipping is a type of Transparent Method. Clipping too large peaks is a simple solution to the PAPR problem. Clipping belongs to the group of techniques that reduces large peaks by nonlinearly distorting the signal. It does not add extra information to the signal and too large peaks occur with low probability so the signal is distorted. The maximum peak power allowed is determined by the system specifications, usually by the linear region of the power amplifier [4,6]. A maximum peak amplitude **A** is chosen so that the OFDM signal does not exceed the limits of this region, and symbols that exceed this maximum amplitude, will be clipped. The clipping is performed in digital time domain, before the D/A conversion and the process is described by the following expression [6].

$$x_k^c = \begin{cases} x_k & |x_k| \le A \\ A e^{j\phi(xk)} & |x_k| > A' \end{cases} \quad 0 \le k \le N-1 \qquad (22)$$

where x_k^c is the clipped signal, x_k is the transmitted signal, **A** is the clipping amplitude and $\phi(x_k)$ is the phase of the transmitted signal x_k. The clipping ratio (CR) is defined as:

CR **= A /** · (23)

In the following discussion, a normalized clipping level will be used, which is called the clipping ratio (where · is the rms level of the OFDM signal) [4,6].

8.7 BERC Technique Method

It is a Bandwidth Efficient Reduction of the Crest Factor. The OFDM envelope S (t) is multiplied by a weighting function b (t) ,Ś (t) = S (t) b (t) where b (t) is composed of a sum of Gaussian pulses [35].

$$b(t) = 1 - \sum_{-\infty}^{\infty} a_n g(t - t_n) \quad (24)$$

where $g(t) = e^{\gamma t^2}$, γ: Optimization factor and t_n denote the position of the local maximum of the envelope above a certain threshold (Tr) that is normalized to the root mean square value $S_{Eff}(t)$. The coefficients a_n are chosen so that the envelope Ś (t) does not cross the threshold Tr [35].

$$a_n = 1 - \frac{Tr.S_{Eff}(t)}{S(t)} \quad (26)$$

9. CONCLUSION

This review is an overview of the orthogonal frequency division multiplexing (OFDM). Also, it discussed the advantages and disadvantages of OFDM system through the analysis and compare it with other traditional adjustment plans. In this work, we focus the review on investigating one of the drawbacks of OFDM, viz., high peak to average power ratio (PAPR) of the output signal, and discuss how to reduce it by various effective algorithms. Among the various proposals, we focus primarily on three techniques (Signal Distortion, Signal Scrambling, and Coding. Simultaneously, we are getting some guidance and meaningful conclusions through a comparative analysis of these results as well as simulation. A comparison of some optimistic proposals with estimate to proportional factors is given in Table 1.

Table. 1. Comparison of adaptable PAPR reduction suggestions

Techniques	Data Rate Loss	Power Increase	Distortion	Requirements in TX & RX
Clipping	No	No	Yes	TX: Clipping. RX: None
Coding	Yes	No	No	TX: Coding. RX: Decoding
PTS	Yes	No	No	TX: K Times IFFTs. RX: Side information extraction and inverse PTS
SLM	Yes	No	No	TX: K Times IFFTs. RX: Side information extraction and inverse SLM

One of the main conclusions is that most researchers and developers are focusing on traditional methods, the SLM and the PTS algorithms. A string of outcomes detailed comparison of these two schemes in terms of performance to minimize the PAPR, and redundancy of additional information, as well as the system complexity. OFDM as a multi-carrier modulation method is particularly suitable for high-speed wireless communication. The review focuses mainly on our assessment of the various methods for PAPR reduction in OFDM system. Nevertheless, there are still several technical problems to be solved despite the excellent properties exhibited in almost all aspects of wireless communications. In this review, all the results obtained under ideal conditions, but in fact, the OFDM system has a lot of practical problems, such as channel estimation and synchronization, Thus, to realize a more complete and effective system, one can add channel estimation and synchronization techniques for OFDM systems.

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