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Performance Improvement for PAPR Reduction in OFDM with Frequency Domain Technique

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Abstract- OFDM is a most democratic procedure of data transmission for high speed communication system. Transmission technique of OFDM is multiple-carrier where single richly data rate stream is sub divided into many low data rate stream and transmitted over a number of sub-carriers. The basic theme of OFDM is disunited the overall transmission bandwidth into a figure of orthogonal sub-carriers this phenomenon reduces the ISI, Power consumption and gain the capacity and efficiency of the system, Fading effect is reduced by multipath propagation this is the merit of OFDM .But in OFDM system problem occur in time domain , it consist growth of PAPR, the major limitation of OFDM is PAPR which degrade the system efficiency and increase the cost of RF power amplifier which cause ISI, non-linear distortion and out of band radiation. To deal with this problem various technique developed but in this paper, we will trim the PAPR performances with two different frequency domain technique- SLM &PTS and also, we compare these two-frequency domain techniques with each other. In this paper QPSK modulation technique is used.

Index Terms- OFDM, PAPR, FFT, IFFT, AWGN, BER, CCDF, PTS, SLM, IDFT

1. INTRODUCTION

In today era communication is one of the important panorama of life and its maturing day by day. One new modulation scheme which is a form of multiple-carrier modulation become more popular over a last few years is called OFDM. The first OFDM scheme was suggested by CHANG in1966[1][3]. OFDM is used multiple-carrier modulation method and multiplexing scheme is frequency division, where the complex data symbol is transmitted in parallel mode after modulating them over orthogonal sub-carrier. In parallel transmission N complex data is channelize over N sub carrier where as in single carrier(SC)one complex data is channelize using one carrier[2].OFDM has most popular now day and concept of OFDM has been around for several year. OFDM has many wired and wireless application such as-(BRAN)Broad cast Radio Access Network, (DAB)Digital Audio Broadcast, (DVB)Digital Video Broadcast, (ADSL)Audio Digital Subscriber Line, Wireless-max and LTE. Now these days OFDM consider as significant assets of 4G mobile communication [3]. OFDM is multiple-carrier system, In multiple-carrier system available bandwidth is divided by many sub-carriers, whereas single carrier(SC)system, it occupies entire bandwidth, So multiple-carrier(MC) has smaller bandwidth as compare to single carrier (SC)system. OFDM handle high data rate. The lowest level data rate for 4G is anticipate to be 10-20mbps and in moving vehicle at least 2mbps [4].The basic design of OFDM is it disunited the entire transmission bandwidth into a figure of orthogonal sub-carriers. This phenomenon reduces the ISI, Power consumption, and gain the capacity and efficiency of the system. The ability of OFDM is fight multipath fading channel by using Cyclic prefix and Guard interval, Fading effect is reduced by multipath propagation this is the advantages of OFDM .As comparing with single carrier(SC)system it provide high data rate and high spectral efficiency[5].However OFDM suffer from serious problem of fluctuation of amplitude in large amount is called PAPR .To channelize the signal with such high PAPR, it necessitate very high power scope for power amplifier and reduce the (HPA)High Power Amplifier efficiency. These type of amplifier is very expensive and have low efficiency cost. PAPR occur at the output of IFFT in transmitter section. If the amplitude fluctuation is too giant then it could be out of the range of linear power amplifier then occur non-linear distortion which degrade the system performance, to minimize this problem various technique developed. Some of them Amplitude clipping, Filtering, Coding, Tone reservation, Tone injection, (PTS)Partial transmit sequence, (SLM)Selective Mapping. [6]. Here we can be going to investigate reduction performance of PAPR two different Frequency Domain Technique (Signal Scrambling Technique) such as- PTS (Partial Transmit Sequence, SLM (Selective Mapping). We simulate all result in MATLAB environment and then we will compare result based on reduction in PAPR ratio.

2. BASIC OF OFDM SYSTEM

2.1. *Principle of Orthogonality*

As we know that multicarrier system occupies smaller bandwidth channel. This smaller bandwidth channel reduces the frequency space between carrier is obtained only when they are orthogonal to each other. When time average integral product of two signals should be zero then it is orthogonal. [2] Mathematically expression of orthogonality of two signals-

$$\frac{1}{T}\int_{t_1}^{t_1+T} f_k(t)\times f_l(t)dt = 0, \text{ if } k \neq l \tag{1.1}$$

Where $f_k(t)$ and $f_l(t)$ are any two signals over the time interval $[t_1, t_1+T]$, T is a signal time period. When product of time average integral of two signals should be one then it is orthonormal. Mathematically, orthonormal expression of two signals can be expressed as [2]-

$$\frac{1}{T}\int_{t_1}^{t_1+T} f_k(t)\times f_l(t)dt = 1, \text{ if } k = l \tag{1.2}$$

For equation (1.1) & (1.2) orthogonality of OFDM system is expressed [2] –

$$\frac{1}{T}\int_0^T e^{j2\Pi f_k t}\times e^{-j2\Pi f_l t}dt$$

$$=\frac{1}{T}\int_0^T e^{\frac{j2\Pi kt}{T}}\times e^{\frac{-j2\Pi lt}{T}}dt$$

$$=\frac{1}{T}\int_0^T e^{\frac{j2\Pi(k-l)t}{T}}dt \tag{1.3}$$

Solve equation (1.3) we get [2]

$$\frac{1}{T}\int_0^T e^{j2\Pi f_k t}\times e^{-j2\Pi f_l t}dt = \begin{cases}1, k = l\\ 0, k \neq l\end{cases} \tag{1.4}$$

Taking discrete sample with the sampling instances at $t = n\ TS = n\ T/N$, where n =(0,1,2,.......... N -1) equation (1.4) can be written in discrete time domain as [2]-

$$=\frac{1}{N}\sum_{N=0}^{N-1} e^{\frac{j2\Pi k}{T}nTS\times} e^{\frac{-j2\Pi k}{T}nTs}$$

$$=\frac{1}{N}\sum_{N=0}^{N-1} e^{\frac{j2\Pi(k-l)}{N}n} = \begin{cases}1, k = l\\ 0, k \neq l\end{cases} \tag{1.5}$$

The ability of OFDM system, it efficient utilize the frequency spectrum through oversampling sub-carriers [2].

2.2. *OFDM System Model*

The diagram of discrete time base-band OFDM system is shown in figure .It consist Transmitter, Channel & Receiver block

2.1.1 Transmitter

In this diagram input bit stream are passed to the modulator block. In this transmitter section different type of modulator used depending upon system requirement (e.g. M- PSK, M- QAM etc.).After modulation N such symbol are transferred by serial to parallel converter(S/P) [7].By using modulation technique complex parallel data symbol are obtained and given to N point IFFT block as shown in figure2.1Complex envelope of base-band transmitted OFDM signal can be expressed [2]

$$x(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k\, e^{(j2\Pi f_k t)}, 0 \leq t \leq NT \tag{2.1}$$

N =Total no. Of sub-carrier, X_k, k = (0,1,.... N -1) block of N input bits (symbols). $f_k = k\Delta f$, where Δf =1/(NT), T is original symbol period. Generally, the complex data are uncorrelated as shown below-

$$E[X_k X_l^*] = \begin{cases}1, k = l\\ 0, k \neq l\end{cases} \tag{2.2}$$

(X_l^*) represent complex conjugate of (X_l)

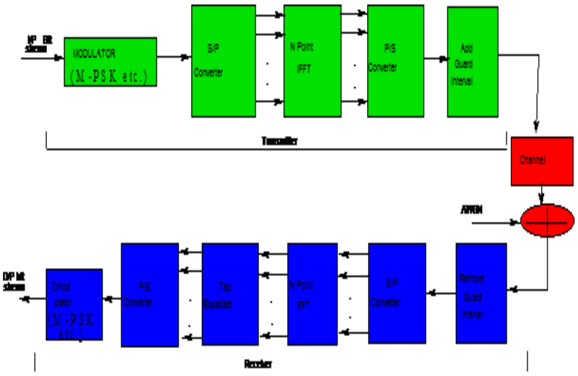


Figure-2.1: Block Diagram of OFDM System

Discrete time of OFDM signal $x(n)$ is expressed as-

x(n)= $\frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X(k)e^{\frac{j2\Pi kn}{N}}$,for n =0,1,2..N -1(2.3)

Equation (2.3) can be obtained by taking the (IDFT) Inverse Discrete Fourier Transform & IDFT can be comfortably & thoroughly obtained by IFFT [2]

Addition Of Guard Band-In OFDM system, ISI(Inter-Symbol Interference) occur, ISI is introduced between sequentially OFDM symbol. To remove ISI we use guard band interval [8].Guard band interval can be used two ways-1.Zero padding (ZP) 2.Cyclic extension. Cyclic extension can be extended in two ways-1.cyclic prefix (CP) 2.Cyclic suffix (CS)[2].

2.2.2 Channel Model

In channel model, the phenomenon of noise & multipath environment can be prefigured. Noise can be cause by attach few random data to the OFDM symbol& generation of multipath environment can be done by adding delayed copies and attenuated of the OFDM signals. For wireless channels, impulse response $h(\Gamma - t)$ is given by [9]-

$$h(\Gamma - t) = \sum_{l=0}^{L-1} h_1(t)\,\delta(t-\Gamma) \quad (2.4)$$

Where $h_1(t)$ and Γ are the tap coefficient or complex amplitude & propagation delay. The tap coefficient $h_1(t)$,l=(0,1,2,......, L -1) are model as zero means complex Gaussian random variable having variance 1.Proper environment of wireless signal provide a Rayleigh fading model.[9].Amplitude of wireless signal followed the Rayleigh distribution because of multipath environment & its(PDF)Probability Density Function is given as[10]-

$$f(r) = \frac{r}{\sigma^2}\exp\left\{-\frac{r^2}{2\sigma^2}\right\}, r\geq 0 \quad (2.5)$$

Where r is envelope of received signal & σ^2 is variance of envelope of received signal. After multipath fading $h(\Gamma, t)$,The received signal $y(t)$ is expressed as-

$$y(t) = \sum_{l=0}^{L-1} h_l(t)\; x_{ext}(t-\Gamma) + n(t) \quad (2.6)$$

Where, $n(t)$ is Additive White Gaussian Noise.

2.2.3 Receiver

At the receiver side, the process is done by the inverse of transmitter. Firstly the guard interval is removed, then unguarded OFDM symbols is passed to(S/P) serial to parallel converter & then is passed through FFT block and FFT convert these parallel data stream into a frequency domain[11].output of FFT is expressed as[2]-

$$X(k) = F(k)x(k) + w(k), \text{for } 0\leq k\leq N-1 \quad (2.7)$$

Where w(k) is AWGN component in frequency domain& F(k) is denotes the FFT which is expressed as[2]-

$$F(k) = \frac{1}{\sqrt{N}}\sum_{l=0}^{L-1} h_l e^{\frac{-j2\Pi kn}{N}}, k = 0,1,.....N-1 \quad (2.8)$$

Single tap frequency domain equalizer are recovered $x(k)$ complex data received symbols and expressed as-

$$G(k) = \frac{1}{F(k)} \quad (2.9)$$

tap coefficient of filter are calculated based on channel information [12].

Finally recovered data is passed to P/S converter. P/S converter convert the data into serial stream and then demodulated the stream by using scheme like(M-PSK,M-QAM) to base band.

- *Advantages Of OFDM*- 1.saving bandwidth 2.Easy to implement modulation and demodulation 3.Easy equalization 4.Susceptible to frequency selective fading 6.Protection against ISI[2]

- *Application*- Application of OFDM dived by two categories-wire line and wireless application. The wire line application- 1.ADSL (Asymmetric Digital Subscriber Line) broad band access through (POTS) Plain Old Telephone Service copper wiring [13]2. MOCA (Multimedia Over Coax alliance) home networking.[14].

The wireless application such as-1. IEEE802.a/g/n 2. IEEE 802.15.3a 3. IEEE 802.16d 4. IEEE 802.20 5.DAB (Digital Audio Broadcast) 6.DVB (Digital Video Broadcast) terrestrial TV systems 7. HIPERLAN/2[2].

- *Major Drawback Of OFDM System*- OFDM system has major problem like-1.PAPR (Peak Average Power Ratio) 2.Synchronization(Timing and Frequency)at receiver. This paper mainly focused on PAPR problem in OFDM.

3. PAPR

3.1 Impact of PAPR On the System

In transmitter side, to obtain maximum output power efficiency (HPA) High Power Amplifier use the radio system. HPA are normally operate in saturation in region. HPA non-linear characteristics is very sensitive to the difference of the signal amplitude.

OFDM amplifier difference is very large with high PAPR. In HPA, high PAPR will introduce interference into the system &inter-modulation between different sub-carriers. Interference reduce BER performance. PAPR forces the amplifier having for having high Back-off power for linear amplifier of the signals. This type of amplifier has poor power efficiency[15].
Major impact of high PAPR are-
1.Increase complexity in the ADC&DAC.
2.Efficiency reduced of RF amplifier.

3.2 Definition Of PAPR

PAPR is define as, Continuous time base-band OFDM transmitted signal x(t) is the ratio of the maximum instantaneous power and the Average power [2].

$$PAPR = \frac{\max[x(t)]^2}{E\{|x(t)|^2\}} \text{,for} 0 \leq t \leq NT \qquad (3.1)$$

Where, $E\{.\}$ denotes expectation operator and $E\{|x(t)|^2\}$ is average power of $x(t)$ and T is symbol period.

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) e^{j2\Pi f_k t} \text{,} 0 \leq t \leq NT \qquad (3.2)$$

For discrete OFDM signal $x(n)$,PAPR is calculate from L time Over sample OFDM signal as[16].-

$$PAPR = \frac{\max[x(n)]^2}{E\{|x(n)|^2\}} \text{,for} 0 \leq n \leq NL\text{-1} \qquad (3.3)$$

$E\{|x(n)|^2\}$ is average power of $x(n)$.In OFDM signal, oversampling is required to prevent aliasing. $x(n)$ is the discrete form of OFDM signal and $x(n)$ can be represented as-

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) e^{\frac{j2\Pi kn}{N}} \text{,for } n = 0,1,2\ldots,N\text{-1} \qquad (3.4)$$

3.3. Parameter Influencing PAPR

-The number of subcarrier (N)
-Modulation scheme
-Oversampling rate

3.4. Distribution Of PAPR

To calculate the efficiency of PAPR technique most systematically used framework is (CDF) Cumulative Distribution Function. Normally (CCDF) Complementary Cumulative Distribution Function is used rather then CDF to measure the probability[2].

CDF of the amplitude of signal sample is given by [17]-

$$F(Z) = (1 - e^{-z^2}) \qquad (3.5)$$

Z is a magnitude of complex samples .
The CCDF of PAPR for non-over sampling data block is given as [2][17]-

$$P(PAPR > z) = 1 - F(Z)^N = (1 - e^{-z^2})^N \qquad (3.6)$$

N is number of sub carrier , For oversampling data block CCDF of PAPR is obtain by multiply this equation with N and some constant α, which is expressed as [2][17]-

$$CCDF = P(PAPR > z) \approx 1 - (1 - e^{-z^2})^{N\alpha} \qquad (3.7)$$

$CCDF$ is generally used to estimate the boundary of PAPR.
-Why PAPR Reduction in OFDM System?
PPAR is one of the major limitation of the OFDM system. signal of OFDM consist large amount of independent modulated sub-carriers which create issue of PAPR.it has not workable to convey high peak amplitude signal to transmitter .Therefore we reduce peak in transmitter side. So we have to decrease PAPR before transmitting [2].

4. PAPR Reduction Method

High PAPR is the major disadvantages of OFDM System. To overcome this problem various technique developed. All the technique are different to each other in complexity & performance [2][17].PAPR reduction can divided in two domain method- 1.Frequency domain 2. Time domain [18].In signal scrambling technique, before IDFT block it grow the cross-connection of the input message& decrease the IDFT peak value at the output. Frequency domain scheme are-Selective Mapping(SLM),Partial Transmit Sequence(PTS), pre-coding etc., and basic concept of Time domain method is reduce PAPR by disfigure the signal before amplification added of extra signals. Time domain scheme are -Clipping, Filtering, Peak windowing etc.. Time domain method is very simple method but it introduces distortion &increase out-of -band radiation and degrade BER performance. When we compare these two method Frequency domain method is very efficient, It reduce PAPR without distorting the signal and also not introduce In-band-distortion and out-of-band radiation in OFDM signal. In this paper, we will investigate the reduction performance of PAPR with two different Frequency domain technique such as- SLM &PTS.
Frequency Domain method is mostly used to reduction of PAPR (i. e Signal scrambling & Pre-coding) because they are distortion less.

Table-4.1Comparison Of PAPR Reduction Technique [9] [19]

Methods	**Average-Power Increases**	**Complexity**	**Bandwidth Expansion**	**BER Degradation**	**Side Information**
Clipping &Filtering	No	Low	No	Yes	No
Coding	No	Low	Yes	No	No
PTS	No	High	Yes	No	Yes
SLM	No	High	Yes	No	Yes
Pre-coding	No	Low	Yes	No	No

Frequency Domain method is mostly used to reduction of PAPR (i. e Signal scrambling & Pre-coding) because they are distortion less.

4.1. Partial Transmit Sequence(PTS)

PTS algorithm was first proposed by Muller SH, Huber JB [20]. In PTS, frequency domain symbols order (X) is separated into V disjoint sub-block $X(i)$ Where $1 \le i \le V$,such that -

$$X = \text{Sum}\,(X(i));1 \le i \le V \quad (4.1)$$

& then sub block X(i) are transformed into V time domain Partial Transmit Sequence.

$$x(i) = \text{IFFT}\,(X(i));1 \le i \le V \quad (4.2)$$

After that these series are independent rotated by some phase aspect,

$$b(i) = \exp(j^{*}\varphi_i);1 \le i \le V$$

(4.3)

Then these are combined to provide the time domain OFDM signal packet reverse.

$$x = \text{Sum}\,(b(i)^{*}\,x(i));1 \le i \le V \quad (4.4)$$

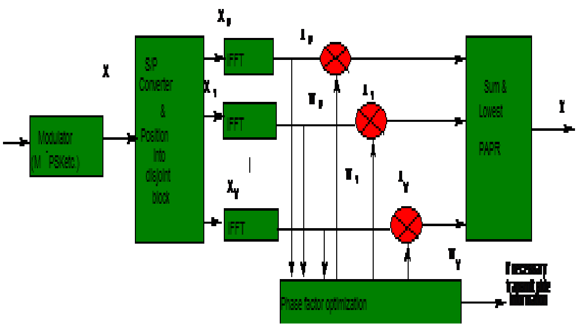


Figure-4.1: Block Diagram of PTS

Sub block Partitioning can be done by 3 method-Adjacent partition, Pseudo random Partition and Interleaved Partition. [21] and each sub-block has equivalent size. PTS technique is affected by not only the figure of sub-block &also the figure of allowed phase vector (w) as well as partitioned of sub blocks.

4.2. Selective Mapping

First SLM plan was introduce by Bauml, Fischer & Huber in 1996[22].The basic idea of this technique is based on Phase rotation. Figure show the bock diagram of SLM scheme [23]-

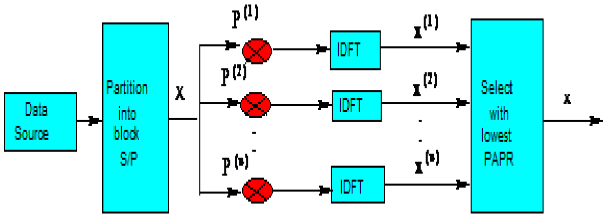


Figure-4.2: Block Diagram of SLM

In SLM, Original input data $X[X_0, X_1, \ldots\ldots\ldots, X_{N-1}]^T$ multiplied with independent phase sequences. $P^{(u)} = [P_0^{(u)}, P_1^{(u)}, \ldots\ldots\ldots, P_{N-1}^{(u)}]^T$ (u =0, 1,..., U -1),Where U is number of phase sequence. N will be the same for both input data &phase sequence &N is the length N (u =0, 1,..., U -1).After multiplication, IFFT will applied on each series to transform signal from frequency dominion to time dominion. The conclusion from multiplication will produce the data block of an OFDM signal that has dissimilar time dominion signal, with length of V and dissimilar PAPR values, $X^{(u)} = [X_0^{(u)} + X_1^{(u)} + \ldots\ldots\ldots X_{N-1}^{(u)}]^T$ .Final stage is comparing the PAPR among the independent data blocks and the signal with the shortest PAPR will be picked for transmission [23].

5. Simulation

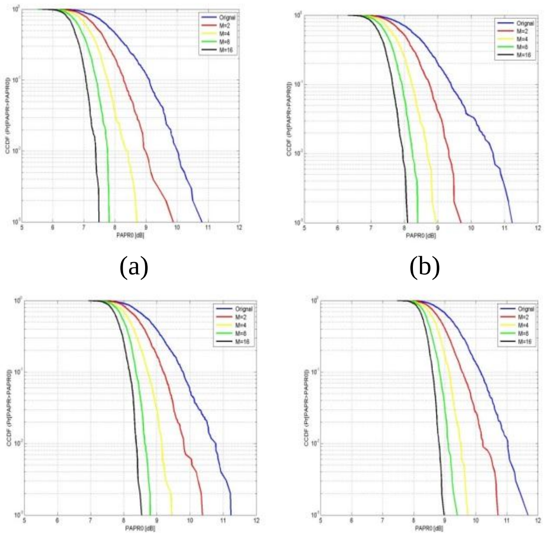
In this zone, an evaluation of factor which could impact the PAPR reduction performance is execute by using MATLAB simulation.

5.1. Simulation of SLM scheme

Construct on the principle of SLM algorithm, it is evidently that the potential of PAPR depletion using SLM is influence by the route number M and sub-carrier number N. Therefore, simulation with different value of M and N will be conducted, and the result exhibit some desired properties of signal representing the same information. Comparison of PAPR reduction performance with different value of M while N is 128, 256, 512, 1024.and rotation factor is $P_{m,n} \in [\pm 1, \pm j]$.

The algorithm executes $1e^3$(1,000) times, over-sampling factor is 8 and QPSK mapping is adopted as modulation scheme in each sub-carrier. Route number M=2, M=4, M=8, M=16 are used. From figure (5.1), it can be observed that the SLM method display better

PAPR reduction performance than the original OFDM signal



(a) (b) (c) (d)

Figure 5.1: Comparison of PAPR reduction performances of SLM where different value of M &different number of subcarrier (a)N=128,(b)N=256,(c)N=512 &(d)N=1024.

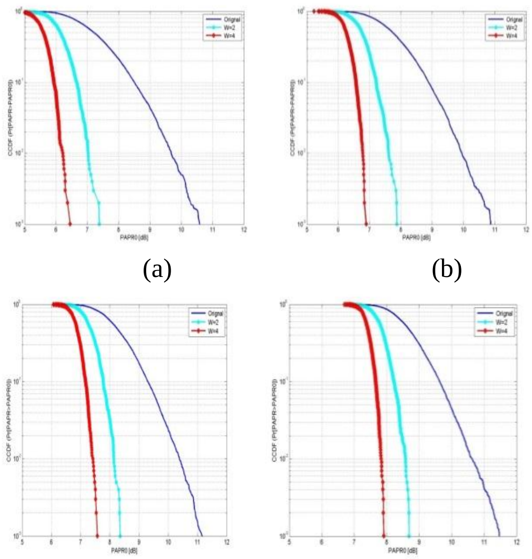
The algorithm executes $1e^3$(1,000) times, over-sampling factor is 8 and QPSK mapping is adopted as modulation scheme in each sub-carrier. Route number M=2, M=4, M=8, M=16 are used. From figure (5.1) , it can be observed that the SLM method display better PAPR reduction performance than the original OFDM signal.

Table5.1: Observation table for SLM technique:

No. of sub-carrier(N)	**(N)**	128	256	512	1024
Max symbols=1e^3	**Route number (M=1)**	10.8	11.1	11.2	11.8
1e^3	M=2	9.9	9.8	10.3	10.7
1e^3	M=4	8.7	8.9	9.5	9.8
1e^3	M=8	7.8	8.4	8.8	9.5
1e^3	M=16	7.5	8.1	8.6	9

5.2. Simulation of PTS scheme

In PTS scheme, there are varying criterion effect the PAPR reduction performance, these are:1) The number of sub-blocks V, which influence the complexity strongly; 2) The number of possible phase value W, which effects the complexity as well; and 3) The sub-block partition scheme. Simulation evaluates the PAPR reduction performance using PTS algorithm with different value of V and W. The simulation result in fig. (5.2) shows the varying PAPR reduction with different W (collection range of weighting factor $W_{v)}$ when using PTS reduction scheme. Simulation specific parameter are: the number of sub-carrier N=128, 256, 512, 1024, QPSK constellation modulation, oversampling factor takes L=8, The number of sub block V=4.



(a) (b) (c) (d)

FIGURE 5.2: Comparison of PAPR reduction performances of PTS where (Phase value)W=2, W=4 ,&(sub-block)V=4 with different number of subcarrier (a) N=128,(b) N=256,(c) N=512 &(d) N=1024.

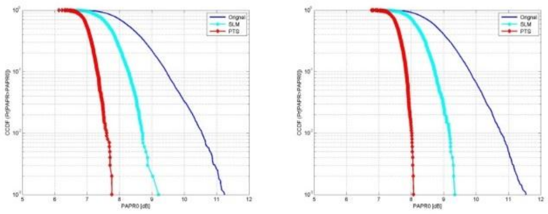
Table 5.2: Observation table for PTS technique when (V=4):

Max symbols =1e^3	**Oversampling factor(L)**	**Number of sub carrier (N)**	**Phase value(W=2)**	**Phase value(W=4)**
1e^3	8	128	7.4	6.5
1e^3	8	256	7.9	6.9
1e^3	8	512	8.3	7.6
1e^3	8	1024	8.7	7.9

We negotiate that in a PTS - OFDM system, the larger W value takes, the superior PAPR performance will be get when the figure of sub-block V is fixed. Similarly, in case of sub-block V, large sub-block V will calculate in small refinement of PAPR reduction performance, but pay for tremendous hardware complexity. Therefore practically, we prefer to choose a suitable value of V to achieve a trade-off in the use of PTS.

5.3. Comparison of SLM and PTS scheme

SLM and PTS algorithm are two classical non-distortion techniques for reducing PAPR in OFDM system. In order to have error-free demodulation in the receiving end, side information must be sent to the receiver, correctly. PTS method demand a higher information redundancy, compare to SLM algorithm. Figure (5.3) show the simulation result of using SLM an PTS method to an OFDM system, separately. In PTS procedure we assign the figure of sub carrier N=256, and N=512 and applying pseudo random partition scheme, for each sub-carrier, choosing QPSK constellation mapping, weighting factor $W_v \epsilon[\pm1,\pm j]$;In SLM method, rotation factor $P_{m,n} \epsilon[\pm1,\pm j]$.Based on the theory ,we know that the IFFT calculation amount of these two methods is same when V=M, but for PTS method, it can provide more signal manifestations, thus, PTS method should provide a superior performance on PAPR reduction. from this figurer5.3 we learned that with the same CCDF probability 1%, The PAPR value equal to 7.6dB &8.2dB when PTS is employed, while the PAPR raise up to9dB & 9.4dB when SLM is employed.



(a) (b)

FIGURE 5.3: Comparison of PAPR reduction performances between PTS algorithm and SLM algorithm for PTS - OFDM system with no. of subcarrier (a)N=256, (b)N=512.It show clearly that PTS method provide a better PAPR reduction performance compared to SLM method. Nevertheless, cost is also payed for sacrificing transmission efficiency and rising complexity. thus, in practical application, a trade-off should be made between good performance and auxiliary information. from the discussion above, we can say that SLM scheme is more suitable if system can tolerate more redundant information, otherwise, PTS scheme is more acceptable when complexity becomes the first considering factor.

6. Conclusion

This paper provides an overview of OFDM. The focus of paper is that we investigate one of the bottleneck problem that exist in OFDM wireless communication system-High Peak Average Power Ratio(PAPR) of OFDM signal, and discuss how to reduce it by different effective algorithms. In this paper two frequency domain technique (signal scrambling technique) such as PTS & SLM are investigated to reduce PAPR, All of these two frequency domain technique have the potential to provide substantial reduction in PAPR. Performance of PTS method is better the SLM method in reducing PAPR.

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