PAPR Reduction in OFDM using Combination of Statistical Transformation Distribution and Selected Mapping Method

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Abstract

Orthogonal Frequency Division Multiplexing (OFDM) offers a high spectral efficiency, smooth operation and effectiveness against multipath fading as its modulation technique. This modulation technique advancement is to increase the number of subcarriers to enhance efficiency. Despite of the number of subcarriers increases, certain time domain OFDM coefficients are likely to acquire unwanted high magnitudes of PAPR. This high PAPR cause the limit of the transmitter power efficiency. Therefore, cause spectral to spread and reduce the bit-error-rate (BER) performance. In order to allay these potential performance problems, a computationally efficient and low cost PAPR reduction method were proposed. The new method presents a combination of Statistical Redistribution Method (SRM) with Selected Mapping Method (SLM). The proposed scheme takes advantage of Selected Mapping (SLM) followed by the companding SRM technique to amplify the reduction of the PAPR of the OFDM signal. Simulation results indicate that about 5 dB reduction in PAPR is achieved compared with the conventional SLM algorithm.

Keyword : Orthogonal Frequency Division Multiplexing(OFDM), Peak-to-Average Power Ratio(PAPR), Statistical Redistribution Method (SRM), Quadrature Amplitude Modulation(QAM).

1. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is a parallel and multicarrier transmission scheme. OFDM is implemented in a lot of famous standards these days such as, 802.11a, Wi-Max, DSL, LTE and others due to its numerousness advantages. OFDM offer some features such as high spectral efficiency, high data transmission bitrate, immunity to inter symbol interference (ISI) and its effectiveness against multipath fading (Han and Lee 2005, Al-Azzo, Ali et al. 2007).

Despite the fact that OFDM is a great technology for high data transmission bitrate, this technique experience of high peak-to-average power ratio (PAPR) and this problem is considered as the major drawback. Another drawback of the features offered by the OFDM technique is it increases the complexity of OFDM system, cost, and power usage which is lead to high peak-to- average power ratio (Lim, No et al. 2005).

Due to the parallel transmission scheme used in OFDM, the total number of all subcarriers signal will emerge in some very high peaks in the output signal. Those high peaks cannot be easily amplified linearly by the final power amplifier connected to the transmission line which will distort the OFDM signal and will lead to a lot of issues as a result of this distortion. In order to solve this problems, very advanced and complex power amplifier system that can maintain linearity is required but this solution is very costly. (Zhou, Zhu et al. 2010).

PAPR reduction technique is divided into three main categories which is signal distortion technique, special forward-error correcting code set and scrambling each OFDM symbol with different scrambling sequences and selecting that sequence that gives the smallest PAPR. Despite of the PAPR can be reduced by using these three methods, there are disadvantage for each categories. Distortion technique is symbols with a large PAPR suffer more bit error rate. For the second categories, it is depend on the code words in order to control the reduction or the level of PAPR. The higher the reduction of PAPR, the larger the code words. While for the third categories, symbol scrambling will decrease the probability that high PAPR occurs but it does not give a clear value of a PAPR ration below some low level.(Nee and Prasad 2000, Lim, Heo et al. 2006).

PAPR should be reduced in order to reduce the system complexity, costs and power inefficiency of OFDM based systems. There are lots of techniques has been proposed for this idea. The suggested techniques to reduce PAPR that can be considered distortion technique such as clipping or distortion-less technique such as SLM, PTS, coding, tone reservation and injection (Jayalath and Tellambura 2000, Jiang and Wu 2008). In similar experiment, a new companding algorithm has been designed give improvement in terms of BER and minimize the out of band interference (OBI) while PAPR can be reduce effectively(Jiang 2010). The Experimental result shows that the new scheme proposed produces OBI almost 3 dB lower than the exponential companding technique and 10 dB lower than μ-law algorithm.

The paper has been organized into the following sections: Section II talks about PAPR. Section III presents the concept of statistical redistribution technique. Section IV show the discussion of the results obtained from the proposed technique and OFDM. Finally, section V concludes this study.

2. METHODS

2.1 Peak-To-Average-Power-Ratio

By using inverse discrete Fourier transform (IDFT), the OFDM output signal can be represented as

$$x(t) = \frac{1}{N}\sum_{k=0}^{N-1} X_k . e^{j2\pi k\Delta f t} \quad ,0 \le t \le T \qquad (1)$$

Where N is the number of subcarriers, X_k is the input data symbol, Δf is the difference of frequency between adjacent subcarriers, and T=1/Δf is the symbol duration. OFDM continuous time signal can also be calculated using matrix multiplication like below

$$x = F^{-1}.X \qquad (2)$$

Where x is time domain signal sequence of OFDM, F^{-1} is inverse Fourier matrix of N×N size and X is input data sequence with size of N×1. Representation of the inverse Fourier matrix used in Equation 2 is defined by

$$F^{-1}{}_{xy} = \frac{1}{N} e^{j2\pi x\Delta f y} \; ; x, y = 0,1,..,N-1 \qquad (3)$$

Where x and y=t defined column and row index respectively. Therefore, generally it represented as

$$x = IDFT(X) \qquad (4)$$

The term PAPR is defined as the ratio of peak power to average power of signal. The equation below is used to calculate the PAPR value of OFDM signal

$$PAPR = \frac{Max|x_k|}{E[|x_k{}^2|]} \quad ; k = 0, \dots NL-1 \qquad (5)$$

Where E is average and L is the oversampling value.

PAPR value can be viewed in dB so that:

$$PAPR(dB) = 10\, log_{10}(PAPR) \qquad (6)$$

When the input data X is equal to the maximum permitted for all input, the maximum PAPR for OFDM signal can be obtained. Since the input data of OFDM is usually a complex data, the value of X should have the same for all inputs to generate its maximum PAPR. Therefore, for OFDM signal

$$PAPR(dB)_{max} = 10\;\; log_{10}(N) \qquad (7)$$

There are lot of proposed technique to reduce PAPR. To figured out the effectiveness of a proposed techniques, Complementary Cumulative Distribution Function (CCDF) is used (Pradhan, Yadav et al. 2014). CCDF is a probability distribution function used to describe how often the random variable is above a particular value and CCDF for PAPR indicate the rate of occurrence of the PAPR of OFDM output signal of random inputs is higher than value of PAPR. The more data used for calculating CCDF, the more genuine the result. CCDF is calculated by using the following equation

$$CCDF = \Pr(PAPR > PAPR_0) \qquad (8)$$

2.2 Statistical Redistribution Method (SRM)

High value of PAPR might cancel out all of the potential assets of the OFDM system, and consequently becomes biggest problem of the development of OFDM systems in future technology. This kind of problem also can cause a major barrier against widespread acceptance of OFDM systems (Wang and Chen 2014). The advantages of the OFDM systems is known that it motivate lot of researchers to find solutions to reduce the PAPR by using the main categories according to the domain operation, time, frequency and data. Time domain processing is the simplest implementation at the moment. This implementation processed the complex signal output from IFFT into discrete before sending it to D/A converter. As a result, symbol distortion exist if the processing operations change the amplitude values of processed samples. This situation occurred in both clipping and companding techniques (Lim, Heo et al. 2009, More and Somani 2013), while partial transmit sequence (PTS) does not cause any distortion since the only changes is the phase factor of the discrete time domain samples (Wang, Guo et al. 2009).

Consider an OFDM block N symbols {S(k)=k=0,1,2,…N-1} where N is the number of subcarriers. The output *s(n)* can be expressed as the following equation after undergo IFFT operation (Zhou, Zhu et al. 2010)

$$s(n) = s(n)^R + js(n)^I$$

$$= \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x(k) exp\left(j\frac{2\pi nk}{N}\right),$$

$$n = 0,1,\dots,N-1 \qquad (9)$$

where $s(n)^R$ and $s(n)^I$ is the real and imaginary parts of s(n), respectively. The probability density functions (PDF) of $s(n)^R$ and $s(n)^I$ is shown as

$$f_{s(n)^R}(x) = f_{s(n)^I}(x) = \frac{1}{\sqrt{2\pi\sigma^2}} exp\left(-\frac{x^2}{2\sigma^2}\right) \qquad (10)$$

The amplitude distribution of original OFDM signals has a Rayleigh distribution, which means a high PAPR level and its PDF is as follows,

$$f_{|s(n)|}(x) = \frac{2x}{\sigma_s^2} exp\left(-\frac{x^2}{\sigma_s^2}\right), \quad x \geq 0 \qquad (11)$$

Let f_g denote the PDF of Gaussian (normal) distribution and can be written by

$$f_g(x) = \frac{1}{\sqrt{2\pi\sigma^2}} exp\left(-\frac{x^2}{2\sigma^2}\right) \qquad (12)$$

In principle, there are two ways to transform the OFDM signal (Zhou, Zhu et al. 2010). One is transform the amplitude of |*s(n)*| directly while remaining the phase angle unchanged, namely

$$|s(n)'| = C(|s(n)|) \qquad (13)$$

where $s(n)'$ is the signal transformed by the nonlinear function. The other way is to transform respectively, and at the same time their signs remain unchanged. Particularly, the relationship between the original signal and the transformed signal can be given by

$$\begin{cases} \mathrm{Re}\{s[n]\}' = C\,\mathrm{Re}\{s[n]\} \\ \mathrm{Im}\{s[n]\}' = C\,\mathrm{Im}\{s[n]\} \end{cases}$$

(14) where *CRe{s[n]} and CIm{s[n]}* is the nonlinear function and represent the real and imaginary parts of the transformed signal {s[n]} respectively.

This study only considered the first case where the phases of signals remain unchanged. The only variable that been process and modified is the amplitude. The high peaks occur infrequently due to summation of modulated symbol with the same phase because companding method is commonly used in speech processing.

In an OFDM system, the subcarriers transmitting N low data rate streams. Quadrature amplitude modulation (QAM) modulate each of single subcarrier. Modulated scheme converts the one dimensional input real valued data samples into two-dimensional complex symbols due to the mapping process. The subcarrier frequencies are equally spaced with $fk=k\Delta f$, where $\Delta f=1/(NT_s)$. T_s represents the symbol duration (Liu, Xu et al. 2011). The complex signal of OFDM which transmitted into parallel subcarriers using serial-to-parallel (S/P) converter is expressed by

$$s(t) = \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} S_k e^{j2\pi f_k t}, \qquad s(t) 0 \le t \le NT_s \qquad (15)$$

Since IFFT is a linear operation, the transmitted signal $s(t)$ follows a complex Gaussian distribution. For better approximation, sampling factor M are used to oversample the signal $s(t)$.

After sampling frequency $f_s = L/T$ undergo IFFT on the N mapped complex valued data symbols, the OFDM baseband symbol is represented by

$$s_n = \frac{1}{\sqrt{N}} \sum_{K=0}^{N-1} S_k e^{j2\pi \frac{n}{NL} k}, \qquad 0 \le n \le NL-1 \qquad (16)$$

Where,

N = number of sub-carriers

s_n = complex value of IFFT output signal

S_k = complex value of IFFT input signal

s_n and S_k= frequency domain and time domain vector signal.

The larger the number of sub-carriers N, the real and imaginary part of s_n are independent and identically distributed Gaussian random variable with zero mean according to the central limit theorem (Pannu and Singh 2012). Therefore, the amplitude $|s_n|$, phase $\emptyset_n$and its probability density function $f_{S_n}(s)$ of OFDM signal s[n] are calculated by

$$|s_n| = \sqrt{Re^2\{s_n\} + Im^2\{s_n\}} \tag{17}$$

$$s_n = \sqrt{|s_n|}\, e^{j\emptyset_n} \tag{18}$$

Where,

$$j = \sqrt{-1}$$

$$f_{S_n}(s) = \frac{s}{\sigma^2} e^{\frac{s^2}{2\sigma^2}} \tag{19}$$

$f_{S_n}(s)$ = Probability density function

The total value of all input complex valued samples, $s_n = [s_0, s_1, \dots \dots \dots s_{N-1}]^T$ produce variation of amplitude value at the output. This may occur due to the combination of the phases of input samples and IFFT process. Different phases from sample to another produced because of the variation of IFFT phase factors $e^{j2\pi\frac{n}{N}k}$ produce. Hence, envelope fluctuations and develop PAPR affecting the output sequences suffer which may affect power efficiency of OFDM system.

This result can be calculated by using Peak to Average Power Ratio (PAPR). The PAPR of transmitted signal s_n is represented as

$$PAPR = 10\, log_{10} \frac{P_{peak}}{P_{av}} \tag{20}$$

Where P_{peak} is peak power of OFDM symbol and P_{av} denotes the average power of OFDM symbol. P_{peak} and P_{av} are shown as

$$P_{peak} = \max_{0 \le n \le N-1} |s_n|^2 \tag{21}$$

$$P_{av} = \frac{1}{N} \sum_{n=0}^{N-1} |s_n|^2 \tag{22}$$

The maximum amplitude of s_n is equal to crest factor (CF). Let define the crest factor as S_{max}, $S_{max} = \max_{n=0 \dots N-1} S_n$. The cumulative distribution function (CDF) of S_{max} is given as

$$F_{S_{max}}(s) = P(S_{max} < s)$$

$$= \int_0^s f_{h_n}(h)dh \ , \qquad n = 0,1,2 \dots N-1$$

$$= \int_0^s \frac{h}{\sigma^2} e^{\frac{-h^2}{2\sigma^2}} dh$$

$$= P(S_0 < s).P(S_1 < s) \ldots P(S_{N-1} < s)$$

$$CDF = (1 - e^{\frac{-s^2}{2\sigma^2}})^N \quad (23)$$

The probability that the crest factor (CF) outstrip some threshold level, consider following complementary CCDF,

$$\bar{F}_{S_{max}}(s) = P(S_{max} > s)$$

$$= 1 - P(S_{max} < s)$$

$$= 1 - F_{S_{max}}(s)$$

$$CCDF = 1 - (1 - e^{\frac{-s^2}{2\sigma^2}})^N \quad (24)$$

Power efficiency reduced due to the large PAPR. In order to reduce this problem, companding technique is applied to OFDM system to maintain the signal level above the noise. Before being converted into analog waveform, the signal s_n are companded and amplified by the High Power Amplifier (HPA). The companded signal is denoted as t_n and given by

$$t_n = h\ (s_n) \quad (25)$$

Where,

t_n = companded signal of s_n

$h\ (.)$ = companding function

The radio channel are used to transmit the signal. Before transmit it to the receiver, Gaussian noise is added. The received signals r_n are represented by the following equation after converting the signal into analog-to-digital (A/D)

$$r_n = t_n + w_n$$

$$= h\ (s_n) + w_n \quad (26)$$

r_n = signal received

w_n = samples of AWGN signal $n(t)$

The signal are received and combined with AWGN fading fluctuation at the receiver and de-compading operation are applied to the received signal. Then the signal can be calculated by

$$\bar{s_n} = h^{-1}(r_n)$$

$$= s_n + h^{-1}(w_n) \quad (27)$$

A non-linear mathematical operation, surd or square root operation is selected and applied on the OFDM outputs signals. This is only affect the amplitude of the signals while the phases of the complex OFDM symbol are remains the same. It will also affect the peak and average power values and cause the reduction in PAPR value. By applying the square root operation, the statistical distribution can be changed as well as the mean and variance of the signal. Only the amplitudes of the signal are changed while the phases are remains the same. The companded and decompanded SRM signal are processed using,

$$h = \sqrt{s}\ (3.34) \quad (28)$$

$$h' = \left[\frac{1}{2\sqrt{s}}\right] \quad (29)$$

For the probability density function, the equation is changed after surd operation of the amplitude of the signal.

$$f_{H_n}(h) = \frac{f_{S_n}(s)}{h'}$$

$$= \frac{\frac{s}{\sigma^2} e^{\frac{s^2}{2\sigma^2}}}{\frac{1}{2\sqrt{s}}} \quad (30)$$

Where $s = h^2$ whereby the PDF $f_{H_n}(h)$ is

$$f_{H_n}(h) = \frac{2h^3}{\sigma^2} e^{\frac{-h^4}{2\sigma^2}} \quad (31)$$

After SRM is applied to OFDM signal, peak power and average power are computed by

$$P_{SRM\_peak} = \max_{0 \le n \le N-1} |\sqrt{s_n}|^2 \quad (32)$$

$$P_{SRM\_av} = \frac{1}{N} \sum_{n=0}^{N-1} |\sqrt{s_n}|^2 \quad (33)$$

Thus PAPR operation using SRM is expressed as

$$PAPR_{SRM} = 10\ log_{10} \frac{P_{SRM\_peak}}{P_{SRM\_av}} \text{dB}$$

$$= 10\ log_{10}\ N \frac{\max_{0 \le n \le N-1} |\sqrt{s_n}|^2}{\sum_{n=0}^{N-1} |\sqrt{s_n}|^2} \quad (34)$$

The maximum amplitude of H_n is equivalent to crest factor (CF). Let define the crest factor as H_{max}, $H_{max} = \max_{n=0 \ldots N-1} H_n$. Now, the cumulative distribution function (CDF) of H_{max} is given as

$$F_{H_{max}}(h) = P(H_{max} < h)$$

$$= \int_0^h f_{S_n}(s)\, ds, \qquad n = 0,1,2 \ldots N-1$$

$$= \int_0^h \frac{2s^3}{\sigma^2} e^{\frac{-s^4}{2\sigma^2}} ds$$

$$= P(H_0 < h).\, P(H_1 < h) \ldots\ P(H_{N-1} < h)$$

$$CDF = (1 - e^{\frac{-h^4}{2\sigma^2}})^N \quad (35)$$

The probability that the crest factor (CF) exceed some threshold level, consider following complementary CCDF:

$$\bar{F}_{H_{max}}(s) = P(H_{max} > h)$$

$$= 1 - P(H_{max} < h)$$

$$= 1 - F_{H_{max}}(h)$$

$$CCDF = 1 - (1 - e^{\frac{-h^2}{2\sigma^2}})^N \quad (36)$$

2.3 Combination of Selected Mapping Method with SRM

PAPR reduction techniques can mainly be categorized into signal scrambling and signal distortion techniques. Signal scrambling techniques are all variations on how to scramble the codes to reduce the PAPR (Vijayarangan and Sukanesh, 2005). Selected mapping (SLM) is a promising PAPR reduction technique. Although SLM is also a scrambling technique, the main idea of SLM is quite different from PTS.

In the SLM technique, the transmitter generates a set of sufficiently different candidate data blocks, all representing the same information as the original data block, and selects the most favorable for transmission (Bauml *et al*., 1996).

Assume that an OFDM data block, $X = [X_0, X_1, \ldots X_{N-1}]^{\mathrm{T}}$, and U different phase sequences, $B^{(u)} = \left[b_{u,0}, b_{u,1}, \ldots b_{u,N-1}\right]^T$ for $u = 1, 2, \ldots U$. Then the U modified data blocks X_u, for $u = 1, 2, \ldots, U$, are generated by multiplying X and all U different phase sequences. Usually the first phase sequence $B^{(1)}$ will be set as an all-one vector of length N to include the original signal into the set of the candidate signals. After U parallel IDFTs, U different time domain candidate signals with different PAPR values is introduced in the system. Among them, the one with the lowest PAPR is selected for transmission. This selecting can be mathematically expressed as (Bauml *et al*., 1996)

$$x = \arg\min\{PAPR(x^u)\}, \quad 1 \le u \le U \quad (37)$$

After applying SLM to X, the OFDM signal becomes

$$x^u(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n \cdot b_{u,n} \cdot e^{j2\pi n\Delta ft} \quad (38)$$

where $0 \leq t < NT, u = 1,2, \cdots, U$ and $\Delta f = \frac{1}{T}$ and T is the duration of data block.

Similar to PTS, the side information of selected phase sequence must be transmitted to the receiver to recover the original data block.

The signal is first processed by the signal scrambling technique. The signal at the output of the first method has a lower PAPR is then processed using the second PAPR reduction method. Figure 3.3 shows the block diagram of the proposed method. Each data block is multiplied by *U* different phase sequences, each of length *N*, resulting in *U* modified data blocks. The autocorrelation of the signal, which has been processed by SLM, is transformed from Rayleigh to Gauss distribution. Among the new modified data blocks $\widetilde{X^{(u)}}, u = 1,2, \ldots U$, the one with the lowest PAPR is selected for transmission. The amount of PAPR reduction for selected mapping depends on the number of phase sequences U.

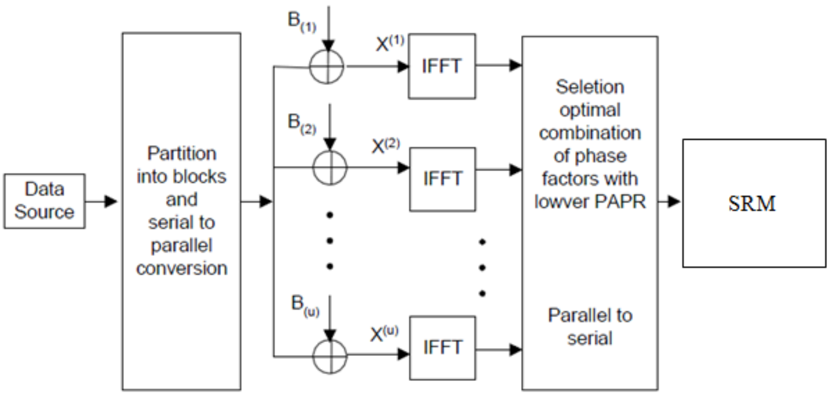

Figure 1. Block Diagram of SRM with Selected Mapping Technique.

The signal given in equation (38), is passed through SRM and the resultant signal can be written as

$$Y_M^U = \sum_{n=0}^{N-1} P_{m,n} X_n^u \qquad m = 0,1, \ldots N-1 \qquad (39)$$

Where $P_{m,n}$ is the precoding SRM technique.

The signal after performing IFFT becomes

$$X_n^U = \frac{1}{\sqrt{N}} \sum_{m=0}^{N-1} Y_m^u e^{j2\pi \frac{n}{N} m} \qquad n = 0,1,2 \ldots N-1 \qquad (40)$$

As every sample of the IFFT output x_n^u is coming from the summation of all input complex valued sample, then

$$y = \sqrt{X_n^u} \quad and \quad y' = \frac{1}{2\sqrt{X_n^u}} \tag{41}$$

Let $X_n^u = x$ then,

$$y = \sqrt{x} \quad and \quad y' = \frac{1}{2\sqrt{x}} \tag{42}$$

The probability density function (PDF) for the combination scheme ,

$$f_{Y_n}(y) = \frac{f_{X_n}(x)}{y'} = \frac{\frac{x}{\sigma^2} e^{-\frac{x^2}{2\sigma^2}}}{\frac{1}{2\sqrt{x}}} \tag{43}$$

Let $x = y^2$, then the PDF is

$$f_{Y_n}(y) = \frac{2y^3}{\sigma^2} e^{\frac{-y^4}{2\sigma^2}} \tag{44}$$

Now, the cumulative distribution function (CDF) of Y_{max} is given as

$$F_{Y_{max}}(y) = P(Y_{max} < y)$$

$$= \int_0^y f_{X_n}(x)dx, \quad n = 0,1,2 \ldots N-1$$

$$= \int_0^y \frac{2x^3}{\sigma^2} e^{\frac{-x^4}{2\sigma^2}} dx$$

$$CDF = (1 - e^{\frac{-y^4}{2\sigma^2}})^N \tag{45}$$

The probability that the crest factor (CF) exceed some threshold level, consider following complementary CCDF:

$$\bar{F}_{Y_{max}}(y) = P(Y_{max} > y)$$

$$= 1 - P(Y_{max} < y)$$

$$= 1 - F_{Y_{max}}(y)$$

$$CCDF = 1 - (1 - e^{\frac{-y^2}{2\sigma^2}})^N \tag{46}$$

3. RESULTS

3.1 PAPR Performance based on 16 QAM Modulation

The comparison of CCDF between conventional OFDM scheme and SRM for N=64 when communicating in AWGN channel and using 16 QAM modulation scheme are shown in Figure 2. ‘Original’ denotes the CCDF of original PAPR of unmodified OFDM data blocks. It shows that the original PAPR 10.09 dB.

From the result obtained, the PAPR value of 10^{-3} is around 7.602 dB, resulting in 2.480 dB reduction when the new scheme is used. From another view, this study shows that the performances for N= 256, N=512 and N=1024 attain a reduction of more than 2.0 dB in PAPR value.

The overall comparison at 10^{-3} for different number of subcarrier in AWGN channel is shown in Table 1. The table shows that the proposed scheme are able to reduce the PAPR value for any numbers of subcarrier.

Table 1 *Comparison Of Papr Values Between Original And Srm Using 16 Qam At 10^{-3} In AWGN.*

Number of Subcarriers	Peak to Average Power Reduction (PAPR) Comparison (dB)		Reduction in PAPR (dB)
	SRM	ORIGINAL	
64	7.602	10.09	2.48
256	8.479	10.43	1.951
512	8.782	10.87	2.088
1024	9.137	11.29	2.153

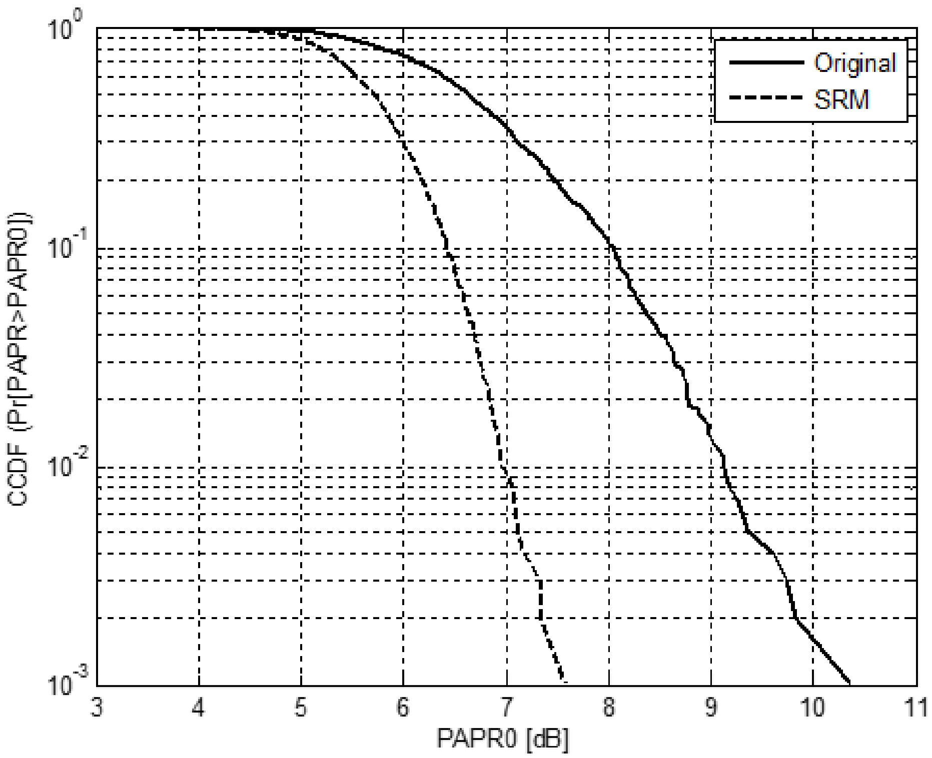

Figure 2. Graph of CCDF against PAPR for $N = 64$ using 16 QAM in AWGN for SRM

3.2 PAPR Performance Based on 64 QAM Modulation

Figure 3 shows the performance of the OFDM system using SRM based on 64 QAM modulation scheme for N=64. The simulation result shows that the SRM at CCDF level of 10^{-3} for N=64, outperforms the original OFDM in terms of PAPR performance with reduction value around 2.800 dB.

Table 2 shows the overall performances based on different number of subcarrier

Table 2 *Comparison Of Papr Values Between Original And Srm Using 64 Qam At* 10^{-3} *In Awgn.*

Number of Subcarriers	Peak to Average Power Reduction (PAPR) Comparison (dB)		Reduction in PAPR (dB)
	SRM	ORIGINAL	
64	7.41	10.23	2.82
256	9.12	11.12	2.00
512	9.14	11.15	2.01
1024	9.32	11.25	1.93

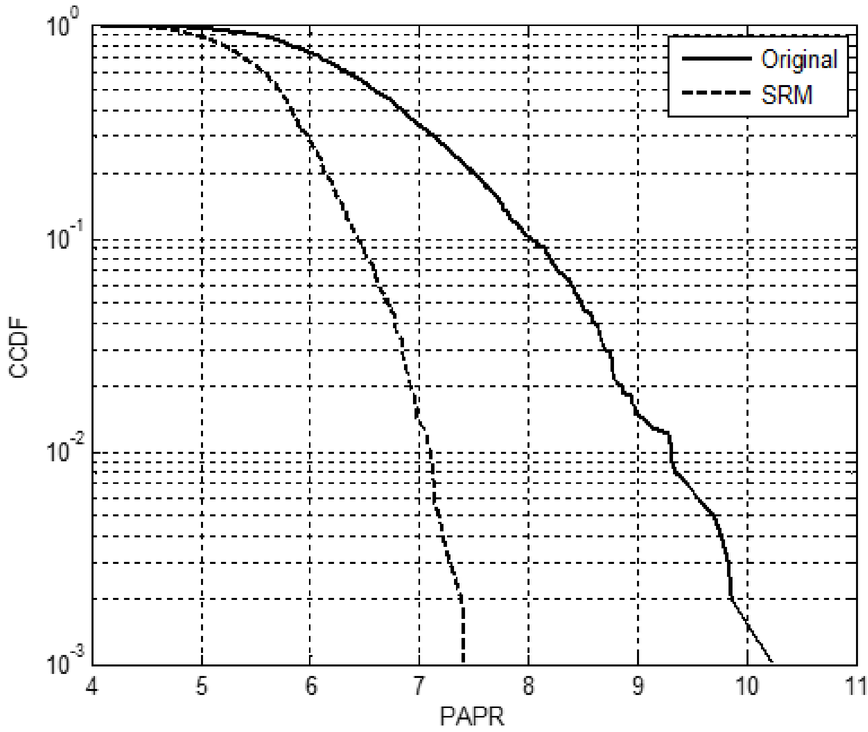

Figure 3. Graph of CCDF against PAPR for $N = 64$ using 64 QAM in AWGN for SRM

3.3 Bit Error Rate (BER) Performance

The relationship between the BER and SNR for both statistical redistribution method and original OFDM system when communicating over AWGN channel are shown in Figure 4. From the figure, BER of 10^{-3} is achieved at 5.5 dB for original OFDM while 7.0 dB for SRM implying a 1.5 dB degradation in BER performance.

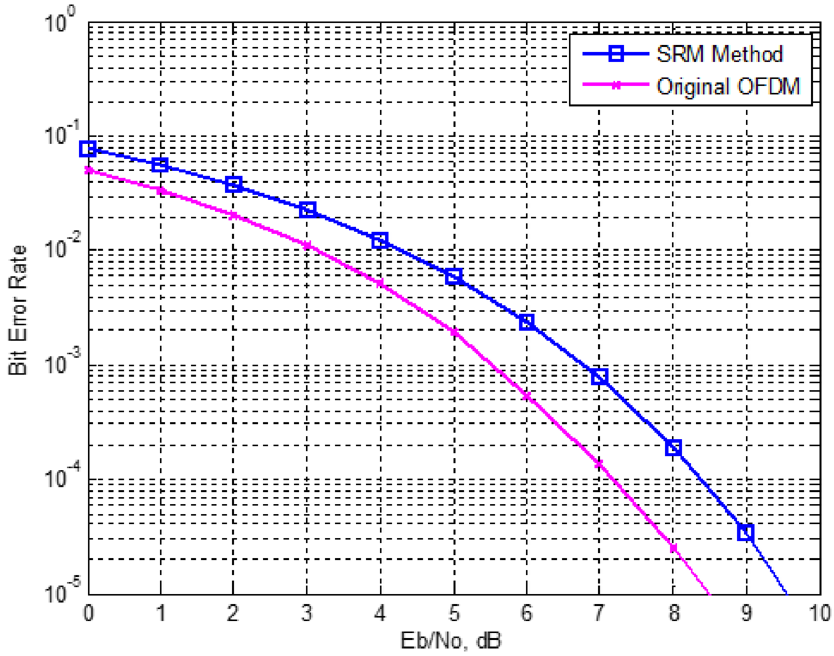

Figure 4. BER Performances of SRM and Original OFDM. N=64, 16 QAM in AWGN

4. CONCLUSION

From the result obtained, PAPR reduction techniques which proved to be reliable for implementation in the OFDM system carrier out in this study resulting a promising result. The method that has been proposed is more suitable for OFDM applications that do not have sophisticated processor because it can be done by using a low computational complexity but at the same time reduce the PAPR value significantly. There are only slight degradation in term of performance which is a good trade-off. Another improvement that has been achieved from this study is a combination scheme between selected mapping method with SRM technique. Different number of subcarrier, modulation scheme and channel noise are used to determine the performance of the PAPR reduction. Despite the fact that PTS and SLM are important to reduce PAPR, SLM has been known as a technique that can produce multiple time domain OFDM signals that are asymptotically independent. For the alternative OFDM, signals are generated by PTS interdependent. Furthermore, the required bits of the side information in PTS are larger compared to SLM. That is the essential objective in this study, selected mapping is chosen for the combination scheme. From the result obtained, selected mapping method (SLM) shows a better performance compared to the hybrid scheme. For 64 QAM OFDM systems with 512 subcarriers, a 5.1 dB reduction in PAPR value was obtained compared to 4.8 dB reduction for the hybrid scheme with a trade-off of 0.8 dB difference in SNR at 10^{-3} BER.

But the performance of PAPR reduction technique always cost a tradeoff of BER performance. BER performance is reducted as the PAPR value is reducted. This is due to the disturbance of modification implemented before the signal being transmitted. This cause some of the data are lost. Hence, the BER performance is affected.

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