International Journal of Engineering Research and Technology.
ISSN 0974-3154 Volume 11, Number 4 (2018), pp. 575-593

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Performance evaluation of Peak-To-Average-Power Ratio Reduction techniques in OFDM

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Abstract

The high demand of using wireless communication leads to establish a new technique of modulation to enhance the throughput of the system and to have a high data rate communication. One of the modern wireless modulation techniques is the Orthogonal Frequency Division multiplexing (OFDM) which considered a suitable technique of modulation in modern wireless application. But there is an important issue to make into consideration when designing OFDM which is the Peak to Average Power Ratio Reduction (PAPR). This study provides a full comparison between using several techniques of PAPR reduction like Clipping and Filtering, Partial Transmit Sequence, DFT Spreading, and Selective Mapping techniques. These techniques are simulated and the PAPR results are obtained for each technique. The comparison between results is also obtained and verified experimentally using MATLAB. The simulation results show that Clipping and filtering technique is the simplest technique of reducing PAPR ratio of the OFDM signal, it depends on the clipping level that satisfies the Signal to Quantization Noise Ratio SQNR. They also show that the partial transmit and selective mapping techniques depends on dividing the OFDM signal into subsignals which the result of transmission these subsignals is nearly to that obtained for the base band signal transmission. The use of Selective Mapping technique (SLM) leads to a PAPR reduction in the simulation from nearly 18 for normal OFDM signal to 12.8 for SLM-OFDM signal. The PAPR ratio from the clipping and filtering technique is 9.5 while the PAPR from SLM is 16.4. The efficiency obtained from the simulation of the SLM technique and clipping and filtering technique are 28.6 and 58.4 respectively.

Keywords - DFT, OFDM, PAPR, Partial Transmit Sequence, SLM

I. INTRODUCTION

Because of the increasing demand of wireless applications due to the increase of tablets and Internet of things, and because the need for high data rat transmission and using the spectrum available in an efficient way, the Orthogonal frequency division multiplexing (OFDM) is considered one of modern techniques used to satisfy this demands [1]. OFDM is a form of modulation using multicarrier signals. It is a combination of modulation and multiplexing. The carrier in OFDM is first split into independent signals modulated by data and then re-multiplexed to create the OFDM carrier as shown in fig 1.

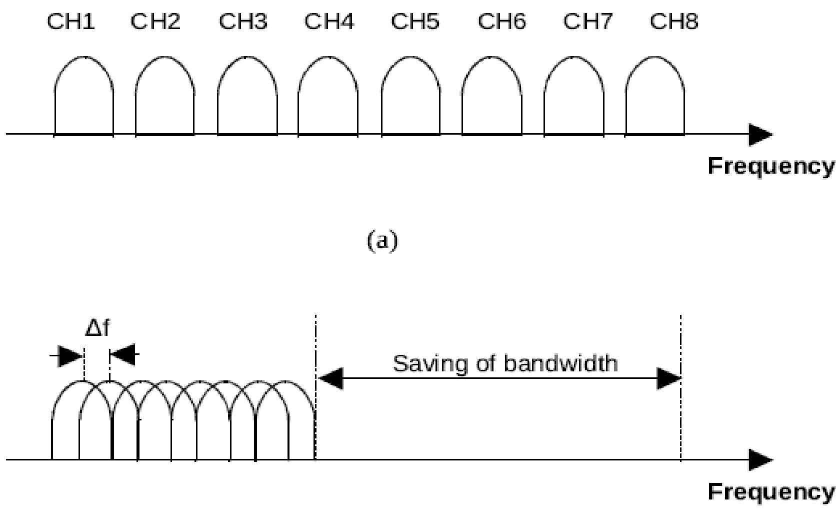

Fig 1. Subcarrier of the OFDM signal [3]

The first condition of using OFDM is the linearity of the transmitting and receiving systems since any non-linearity ill cause interference between the carriers as a result of inter-modulation distortion which impair the orthogonality of the system [2].

The Advantages of using OFDM as a modulation scheme are:

- Immunity to selective fading: OFDM divides the overall channel into multiple narrowband signals that are less affected by the selective fading [4].
- Less interference: Because of the subdivided of the overall channel.
- Spectrum efficiency: Using the available spectrum to send several signals because of the concept of orthogonality.
- Less ISI: Because the low data rate on each of the sub-channels [5].

- Simpler channel equalization: Using multi-channel in OFDM results on less equalization required and the equalization process become much simpler [6].

However, the OFDM has some disadvantages and they should be into consideration when using OFDM process. The disadvantages are:

- High PAPR: The amplitude variation of the sub-carriers results a high PAPR value. This impacts the linearity of the RF amplifier efficiency [7].
- Sensitive to carrier offset and drift: Each carrier should has a specific offset and drift to satisfy orthogonality.

Fig 2 shows the block diagram of the OFDM transmitter and receiver, the process starts from transforming the input bit stream from serial to parallel and then mapped to the suitable sub-carrier [8]. To create the OFDM symbol and to be sure that it is orthogonal to other symbols, IFFT process is obtained by the equation below.

$$c(t) = \sum_{n=1}^{N} m_n(t)\sin(2\pi nt) \tag{1}$$

The channel is to be determining according to the surrounding environment and the receiver performs the inverse operations of the transmitter as shown in fig 2. That is, the receiver starts from down converter and A/D [9]. the FFT process is then performed to recover the transmitted symbols by applying the equation below:

$$x(k) = \sum_{n=0}^{N-1} x(n)\sin\left(\frac{2\pi kn}{N}\right) + j\sum_{n=0}^{N-1} x(n)\cos\left(\frac{2\pi kn}{N}\right) \tag{2}$$

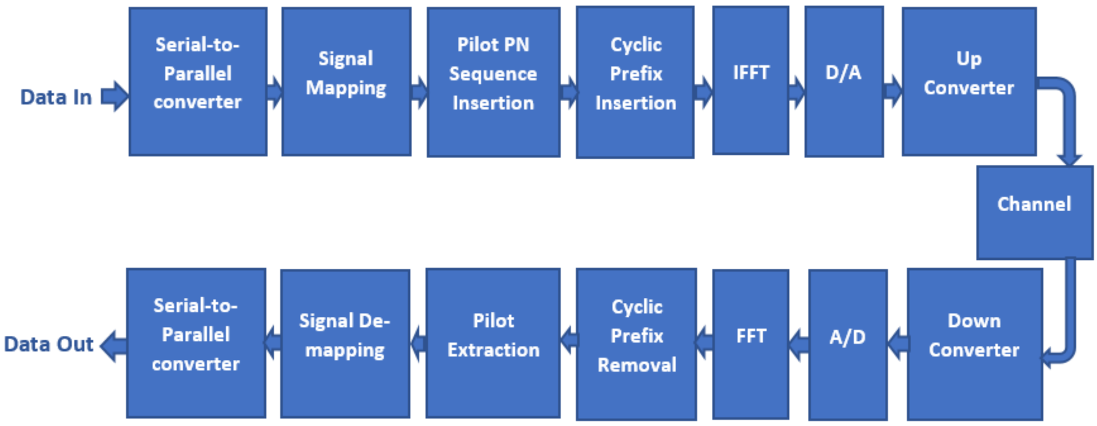

Fig 2. OFDM block diagram

The multiple access of the OFDM is the OFDMA which is a scheme used to provide a multiple access capability when using OFDM technologies, and also used to reduce the PAPR value [10]. There are several techniques used to reduce PAPR, these techniques are:

I.I Clipping and filtering technique

This technique is the simplest technique of reducing PAPR ratio of the OFDM signal, it depends on the clipping level that satisfies the signal to quantization noise ratio SQNR and the oversampling level L which is normally greater than or equal to 4 to meat Nyquest rate [11] of the up sampling signal as shown in fig 3.

The passband modulated signal Xp[m] with carrier frequency fc is transformed to the clipped and filtered signal Xcp[m] which expressed as:

$$X_c^p[m] = \begin{cases} -A & X^p[m] \leq -A \\ X^p[m] & |X^p[m]| < A \\ A & X^p[m] \geq A \end{cases} \qquad (3)$$

where the clipping level is A and the clipping ratio to have a powerful transmission of clipped OFDM is (CR) which equal:

$$CR = \frac{A}{\sigma} \qquad (4)$$

where σ is the RMS amplitude of the OFDM signal and equal to $\sigma = \sqrt{N/2}$

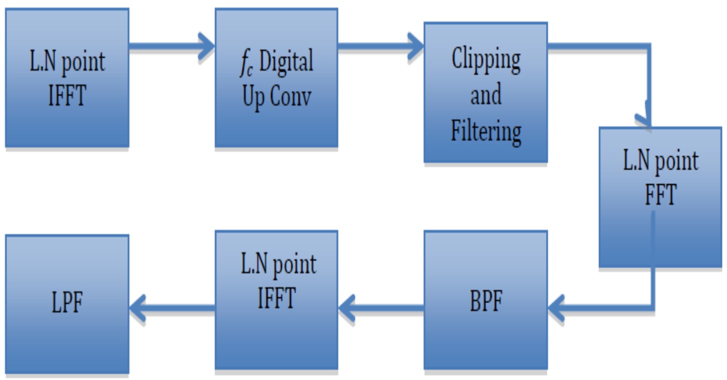

Fig 3. Block diagram of clipping and filtering technique

I.II Partial Transmit Sequence

The OFDM signal X is entered the process of the Partial Transmit Sequence (PTS). The X signal is partitioned into V disjoint subblocks as follows:

$$X = [X0, X1, X2, \ldots\ldots., XV\text{-}1]T \tag{5}$$

All subblocks are combined with each other by applying the phase rotation factor bv=ejΦ to the IFFT. The transmitted signal X will be X' as:

$$X'(b) = \sum_{v-l}^{M} b_v x_v \tag{6}$$

Fig 4 shows the block diagram of the PTS technique which used in the simulation.

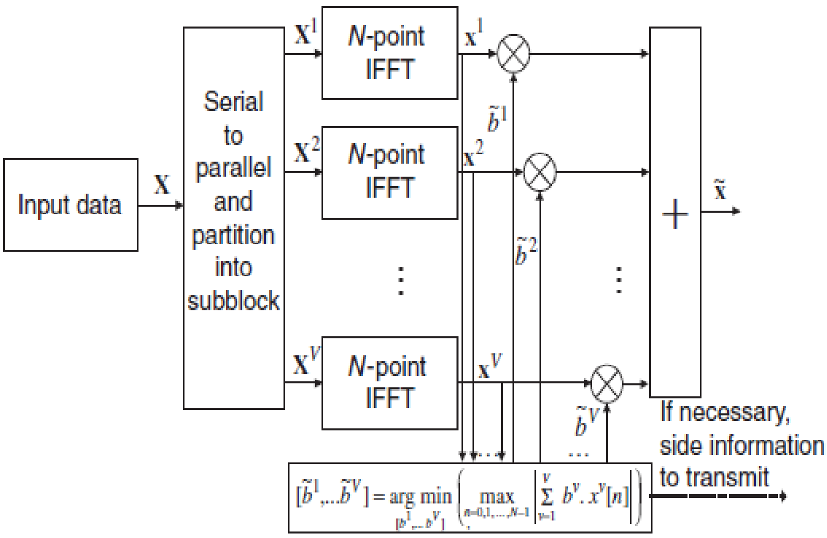

Fig 4 Block diagram of Partial Transmit Sequence (PTS)

I.III DFT spreading

This technique is the technique which deals with passband signal as a baseband one by converting the OFDM signal to OFDMA one which depends on transmitting the subcarriers one after the other in serial communication instead of the parallel form of the OFDM [12]. The result PAPR of the OFDM signal after using this technique is near to that obtained from the SC-FDMA. The DFT spread system as shown in fig 5 consists of serial to parallel converter, DFT and IDFT, parallel to series operation, cyclic prefix and A\D converter [13].

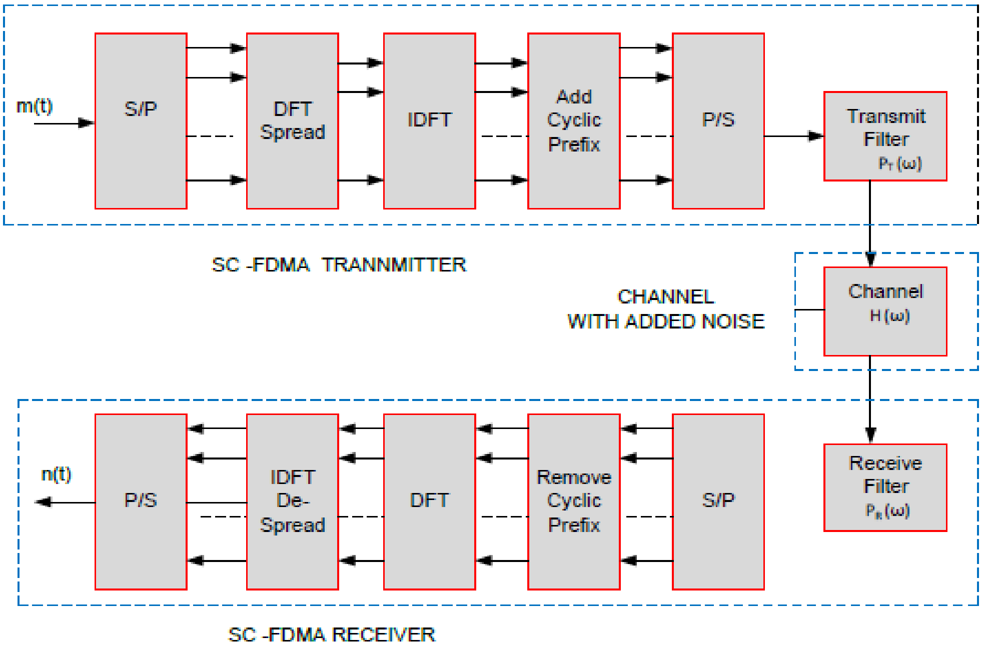

Fig 5 Block diagram of DFT spread technique

I.IV Selective Mapping technique (SLM)

Selective Mapping technique is the technique which depends on transforming the normal OFDM signal into a signal multiplied by a phase shift between each sub-carrier [14]. The efficiency of this technique is directly proportional to the number of phase different used. But when the phases increased the simulation computation is also increased and this is considered a drawback of this technique [15]. The block diagram of the SLM technique is shown in fig 6.

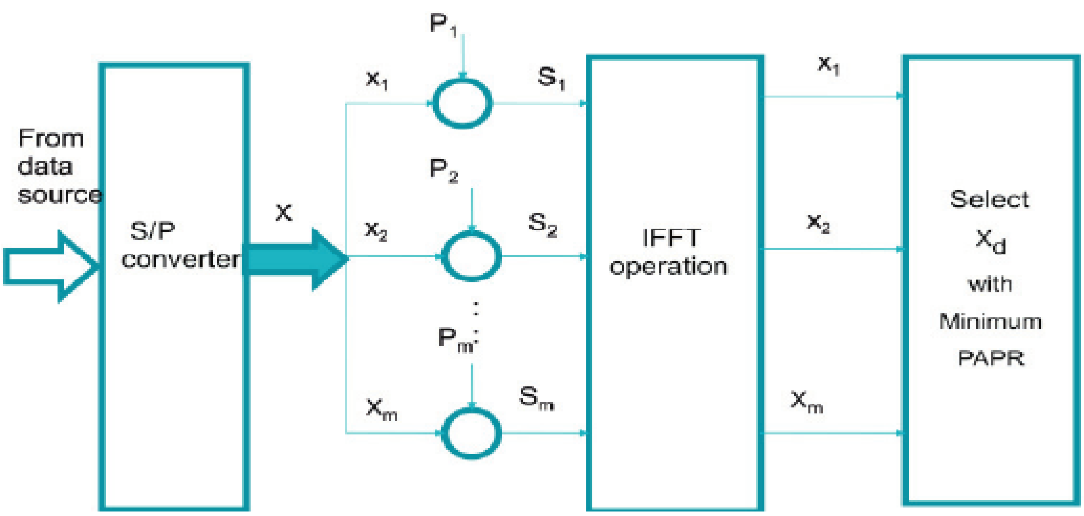

Fig 6 The process of SLM-OFDM signal transmission

II. METHODOLOGY

The simulator used in this comparative study is the MATLAB simulator. The simulation process starts from initializing the OFDM signal and calculating its initial PAPR. The second simulation is the PAPR comparison between the baseband signal and the passband signal to show the need of PAPR reduction technique of the passband one to be near of this obtained of baseband signal. The third section of simulation is the simulation of some PAPR reduction techniques and the comparsion between them. The simulation parameters is as listed in Table 1

Table 1: Simulation parameters

Parameters	Value
Clipping ratio	1.2
Modulation order	QPSK
Number of subcarriers	128
Carrier frequency	2 MHz
Sampling frequency	8 MHz (to make oversampling)
Bandwidth	1 MHz
Number of guard interval samples	32
Interpolation L	4
Number of subblocks V	1 to 16
Roll of factor for pulse shaping	0 to 1

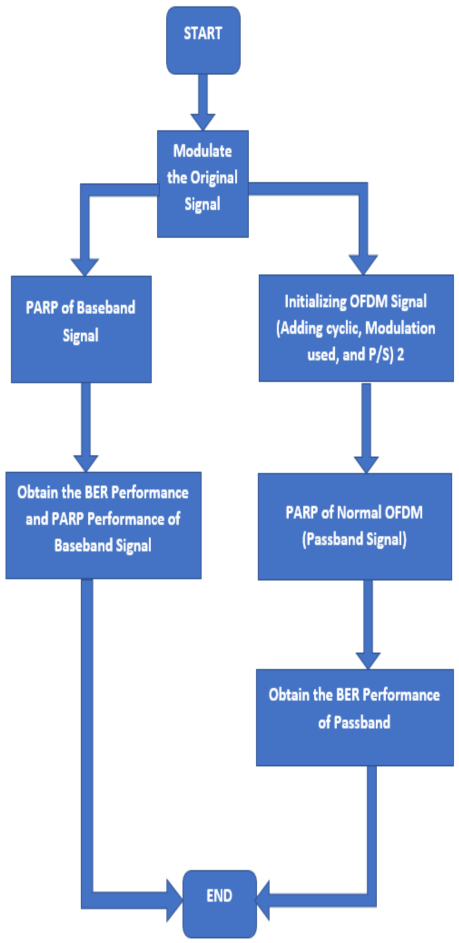

Fig 7. The flow chart of the first section of simulation.

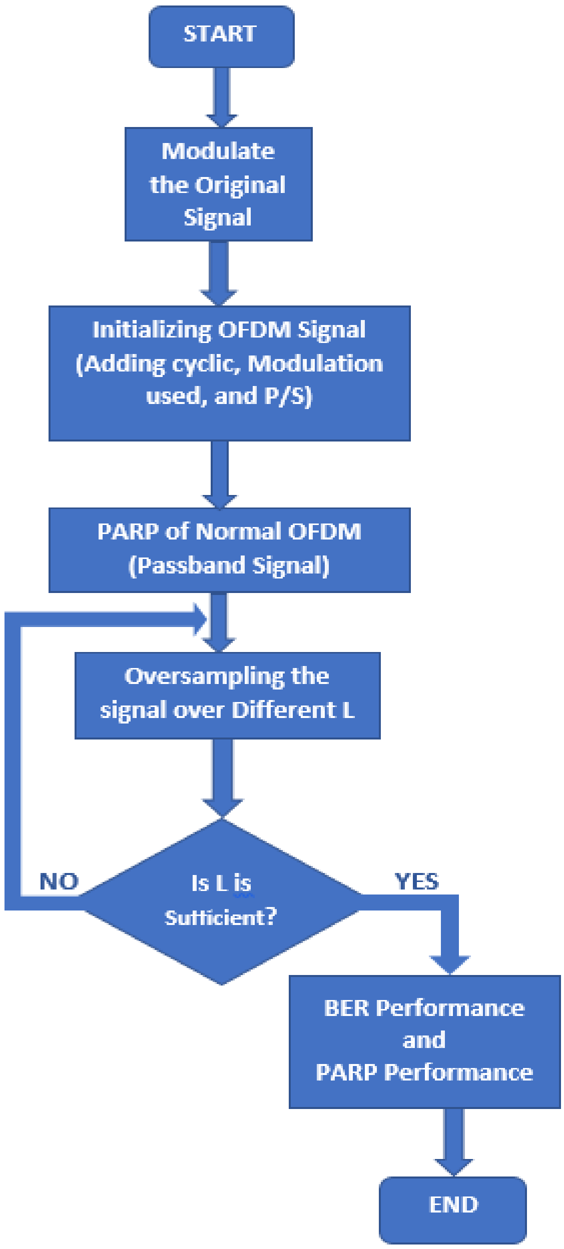

Fig 8. The flow chart of the second section of simulation.

The flow chart of the comparative simulation section is as shown in fig 9:

Fig 9. The flowchart of the comparative simulation as

III. SIMULATION RESULTS AND DISCUSSION

To initialize the simulation to have an experimentally overview about the response of PAPR in OFDM, the generation of OFDM signal is obtained in fig. 10 and 11 and the complementary CDF of OFDM is in fig. 12.

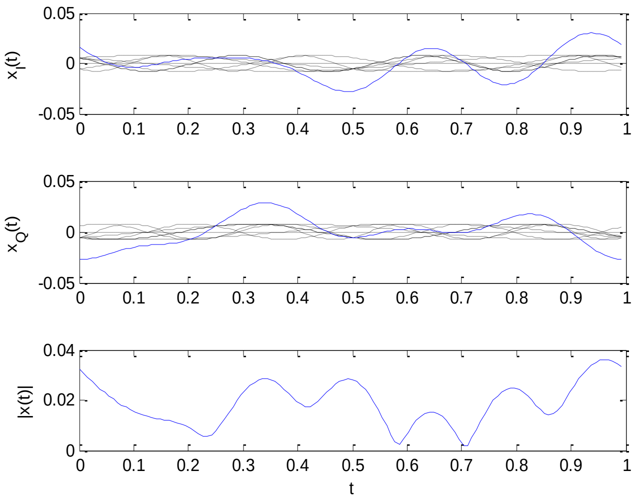

Fig 10 Time domain OFDM signal with N=16 and QPSK as modulation

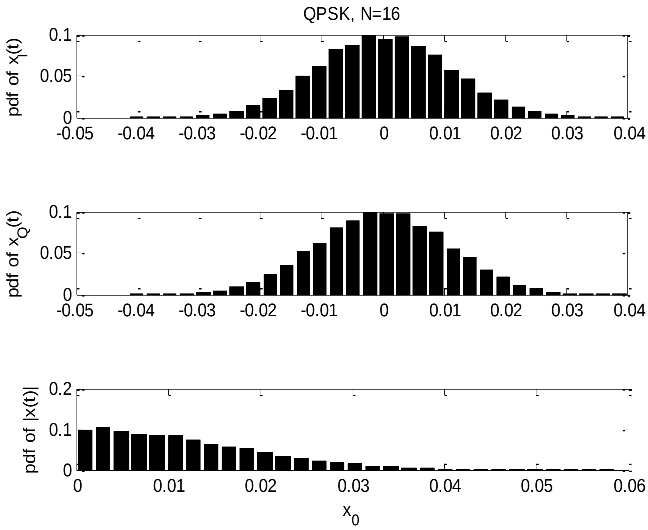

Fig 11. OFDM Magnitude distribution

From fig. 10 and fig. 11, the PAPR response of OFDM is increased as N increase. Meanwhile, figure 11 shows that the distribution of the OFDM signal x(t) follows a Gaussian distribution while the magnitude of x(t) |x(t)| follows a Rayleigh distribution.

Fig. 12 shows the complementary CDF of OFDM to show the effect of N in the OFDM signal. As said before, the PAPR response increases as N increase [16]. Fig.12 shows the response of N equals 64, 128, 256, 512, and 1024 respectively. The response shows that there are 1 dB difference from N=64 and N=256 and so on.

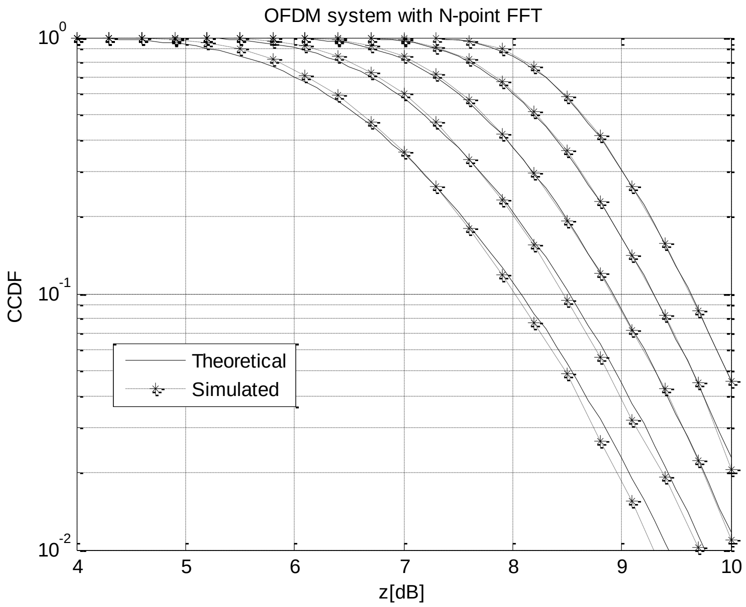

Fig 12. OFDM signals distribution with different values of N (64, 128, 256, 512, and 1024).

The PAPR distribution of Orthogonal FDM increases as a pass band signal, while the PAPR distribution of the base band signals is usually equals zero [17].

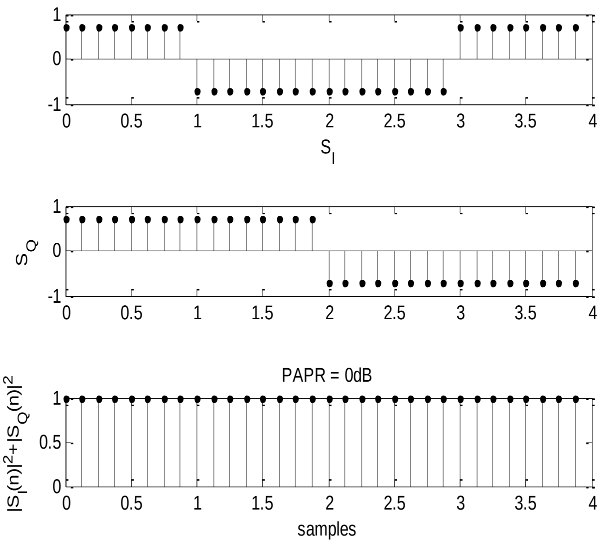

Fig 13. Baseband signal for QPSK-modulated symbols.

This simulation shows that the PAPR response is appeared when the transmitted signal is modulated. Fig. 13 shows the base band distribution of the transmitted signal of a single carrier (N=1) while fig. 14 shows the pass band distribution of the transmitted signal. The modulation used is QPSK with carrier frequency fc = 1[Hz].

The result shows that the baseband signal has the value of PAPR reaches 0dB while the pass band signal has a 3.01 dB of PAPR value. In general, and unlike OFDM, the modulation scheme can used to predict the value of PAPR in the single carrier system directly.

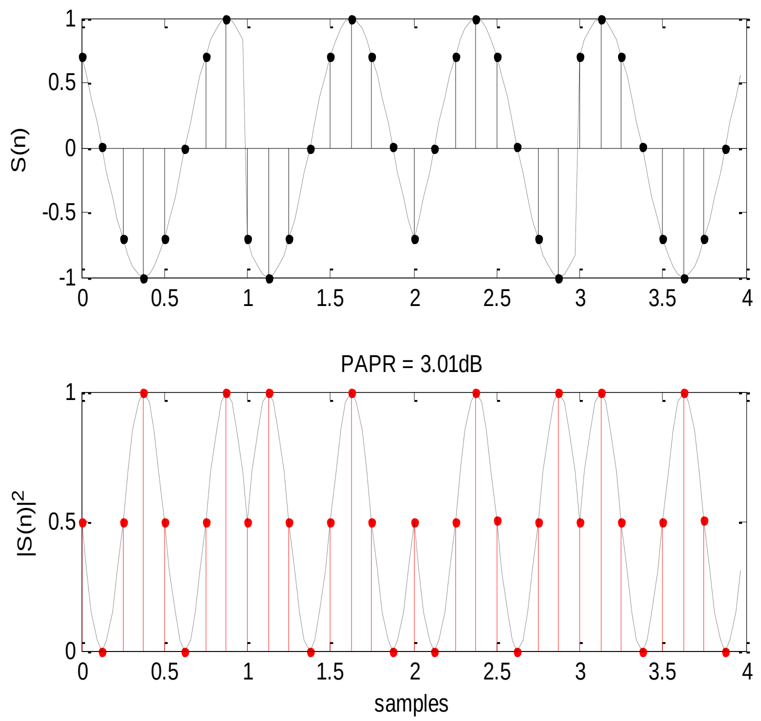

Fig 14. Pass band signal for QPSK-modulated symbols.

To simulate the PAPR of the clipped and filtered signal, Fig. 15(a) is obtained. It shows that the PAPR value of the OFDM signal decreases with the use of clipping/filtering technique. The clipping ratio (CR) and PAPR reduction is directly proportional. That means the smaller CR result a greater PAPR reduction. From Fig. 15(b), the BER performance becomes worse as the CR decreases.

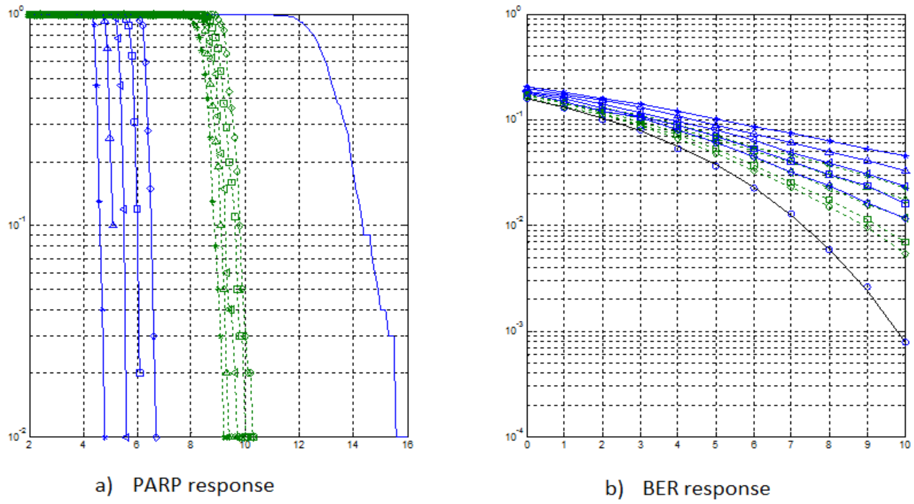

Fig 15. PAPR and BER performance of the OFDM signal with clipping/filtering technique

Fig. 16 shows the PAPR response of this technique using a 16-QAM modulation of the OFDM signal. It is clear that the PAPR performance improves when number of subblocks increases.

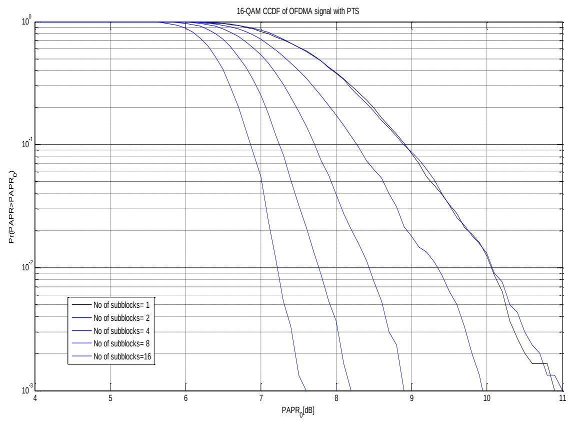

Fig 16. PAPR performance when the number of subblocks varies.

Fig. 17 shows a comparison of several systems used DFT-spreading technique to reduce PAPR. These systems are IFDMA, LFDMA, and OFDMA use QPSK, 16-QAM, and 64-QAM as a modulation technique. The figure shows that the PAPR in the case of 16-QAM at 10-1 are 3.5dB, 8.3dB, and 10.8dB, respectively for IFDMA, LFDMA, and OFDMA with no DFT spreading for OFDMA.

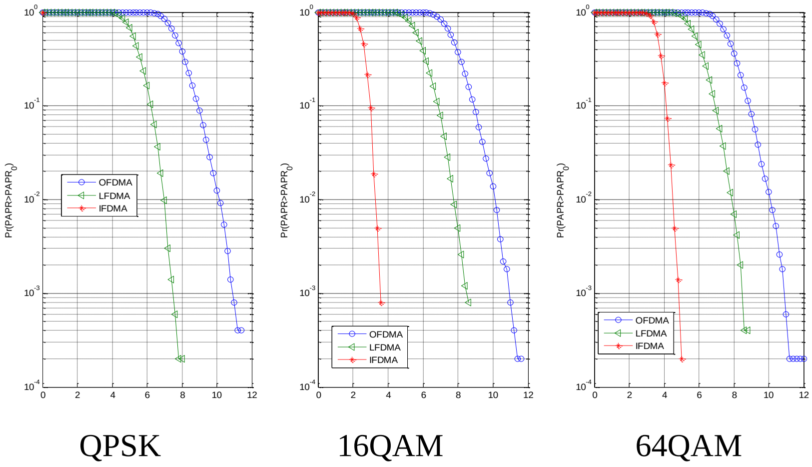

Fig 17. PAPR performances of IFDMA, LFDMA, and OFDMA.

Pulse shaping of the DFT-spreading affects the PAPR performance as shown in fig. 18. The fig. shows that the pulse shaping improving the performance of IFDMA as α increased from 0 to 1 as the roll-off factor. But this improving does not appears in LFDMA.

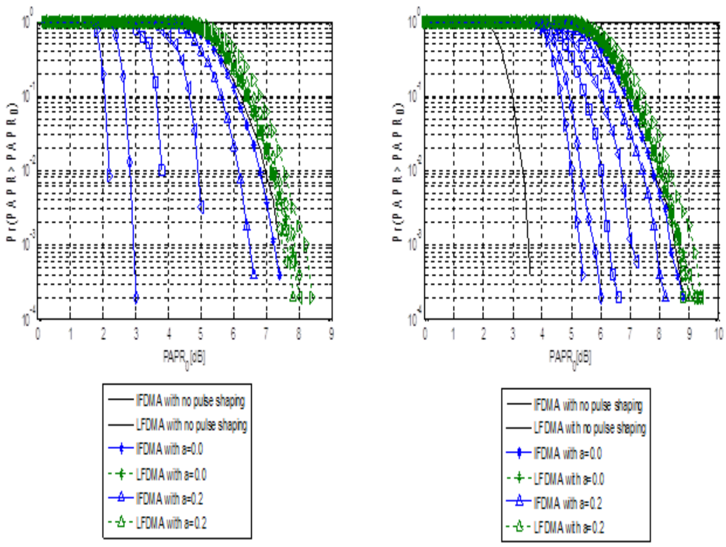

Fig 18. PAPR performances of pulse shaping DFT-spreading for QPSK and 16QAM.

As mentioned before, the PAPR performance is increased as the number of subcarrier increase. By applying this term to the DFT-spreading technique, fig. 19 shows that the PAPR performance of DFT-spreading technique is degraded as number of subcarriers increase.

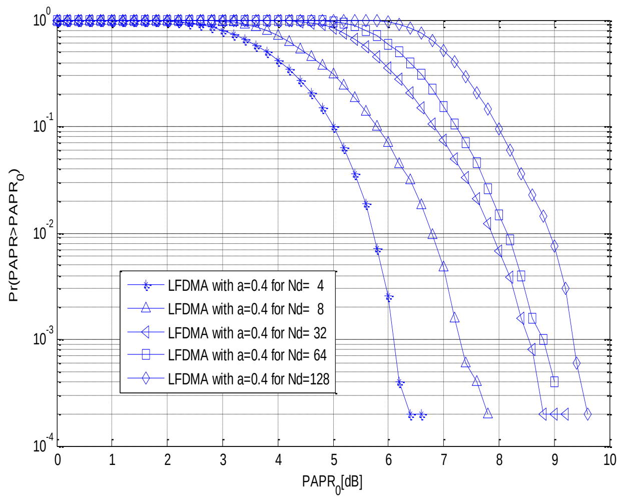

Fig 19. PAPR performance of DFT-spreading technique when subcarriers vary.

Fig. 20 shows the output of the OFDM signal amplitude for 64 FFT sequence before and after the PAPR reduction using selective Mapping. The fig. shows that all amplitudes of the OFDM signal are reduced to less than 0.1 which leads a PAPR reduction from nearly 18 for normal OFDM signal to 12.8 for SLM-OFDM signal.

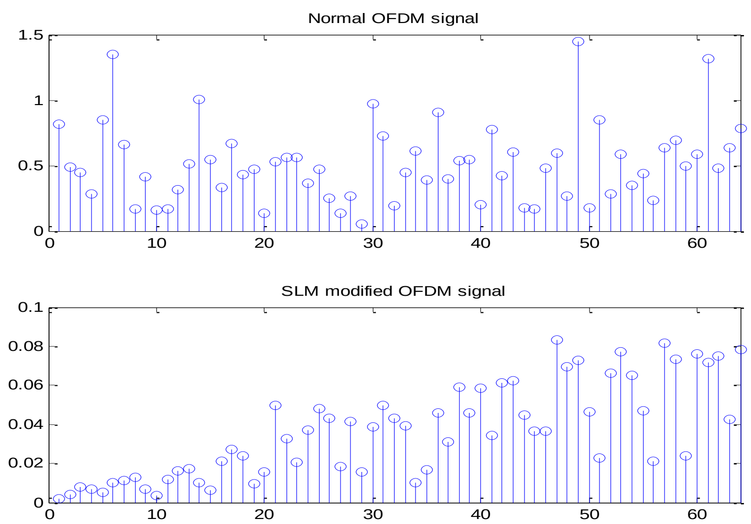

Fig 20. Comparison between normal OFDM signal PAPR with SLM-OFDM signal.

As the number of phases set increases, the efficiency of the SLM method is also increases. This is in general considered a drawback of the SLM technique because increasing the phase amount will increase the computation at the transmitter's and receiver's sides. Another drawback of SLM appears from that the receiver must know phases' sets. It means that the transmitter should send extra sets besides the transmitted signal to let receiver knows the original one.

These drawbacks do not appear in the clipping and filtering technique because this technique depends on only the level of clipping the order of filtering. Also depends on the oversampling ratio L.

Fig. 21 and fig. 22 show the output result of the SLM technique and clipping and filtering technique respectively. Fig. 21 shows the SLM output where all OFDM signal amplitudes lie behind the 0.04 which reduces the PAPR ratio. But there are samples of transmission, and when the samples increase the computational process also increases.

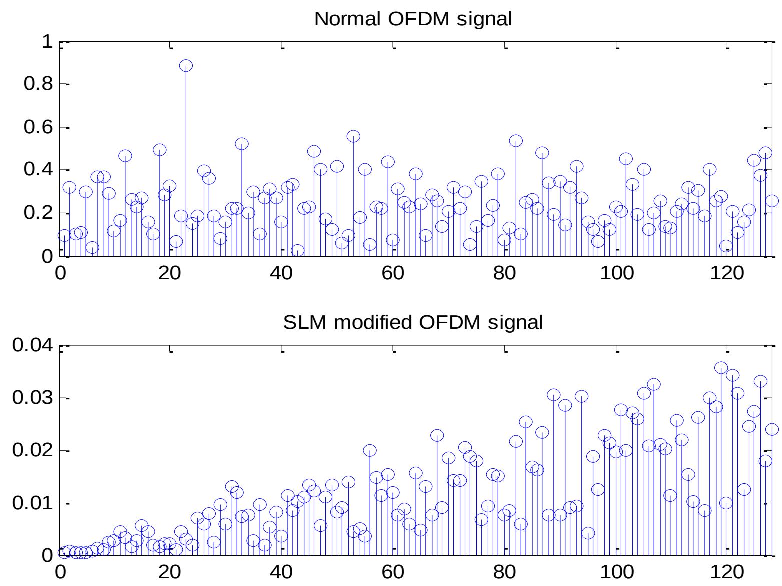

Fig 21. SLM-OFDM signal

In fig. 22 technique; the output shows that the amplitudes of the output signal lies below 0.2 but there are more samples than SLM. The output from the simulation shows that the PAPR reduction obtained from the clipping and filtering ratio of 128 FFT sequence is less than this obtained from the SLM technique. The PAPR ratio from the clipping and filtering technique is 9.5 while the PAPR from SLM is 16.4. The efficiency of the SLM technique and clipping and filtering technique are 28.6 and 58.4 respectively.

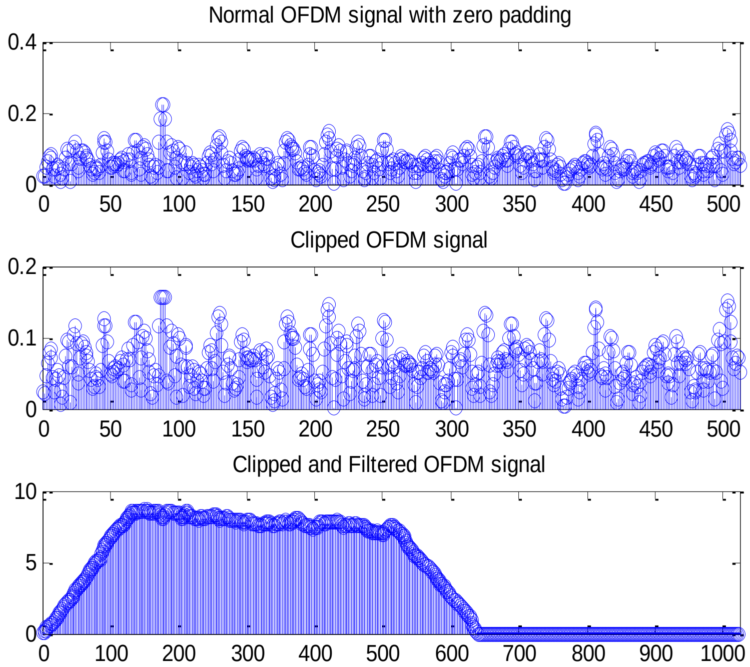

Fig 22. Clipping and filtering of OFDM

IV. CONCLUSION

The goal of this thesis is to make a full comparison study about the PAPR reduction in OFDM. It uses several techniques for reducing PAPR in the OFDM system. This thesis generalized the concept of PAPR reduction of OFDM instead of single-carrier in most PAPR reduction techniques. In addition, this thesis also makes a comparison of PAPR reduction in single- carrier signals as a base band signal and an OFDM signal as a passband signal, and how to transform the passband to base band signal to reduce PAPR. The simulation results shows that the clipping and filtering technique is the simplest technique to improve PAPR, it depends on how to choose the suitable value of clipping to reduce clipping distortion and improved PAPR. In the other hand, the partial transmit sequence is considered a high technique of reducing PAPR, it depends on how the whole signal subdivided into subsignals to transmit each subsignal individually and this subdivided transmission is generalized to selective Mapping technique. Using OFDMA concept transfer the transmission of OFDM to be like transmission a single-carrier signal which means reduction of PAPR. This transformation performed by using the phenomena of DFT which cancelled IFFT virtually. All supposed techniques of reducing PAPR are simulated and their results are compared together. There are several possible future works like reducing the out-of-band radiation which affects the transmitted signal in a way without using filtering, enhance the trade-off between PAPR reduction, BER and spectral spreading, Using the PAPR reduction techniques in different channel response like fading channel and compared the results and Using hybrid techniques by combining two or more methods of PAPR reduction together.

ACKNOWLEDGEMENTS

This work was supported by UTeM Zamalah Scheme. The authors would also like to thank Center for Research and Innovation Management (CRIM), Centre of Excellence, UTeM, UTeM’s research grant JURNAL/2018/FKEKK/Q00001 and Universiti Teknikal Malaysia Melaka (UTeM) for their encouragement and help in sponsoring this study.

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