Simulation Analysis of Partial Transmit Sequence on Palm Date Leaf Clipping for PAPR Value Reduction

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***Abstract*—FFT, as the key concept in the OFDM system, produces a high PAPR value. Several techniques can be implemented to reduce it, such as the Palm Date Leaf clipping and the Partial Transmit Sequence. Previous researchers have evaluated each technique individually. This paper proposes to evaluate the PAPR value as the effect of combining the Partial Transmit Sequence (PTS) with the Palm Date Leaf (PDL) clipping technique. The evaluation is done with several modulation techniques, such as QPSK, 8-PSK, 16-PSK, 8-QAM, and 16-QAM. Since low PAPR performance is not advantageous if the signal's BER value worsens, thus the evaluation also considers the BER performance. In this case, the Authors focus on the BER performance over the AWGN channel. The result shows that in all of the scenarios, the PTS technique could improve the signal's BER and PAPR performance for low CR values such as 5 dB and 7 dB. Additionally, for higher CR values such as 10 dB and 20 dB, the BER performance is similar to the normal OFDM signal. Even so, it provides a consistent PAPR reduction of approximately 3 dB. Do note that the PAPR is evaluated at CCDF of 10^{-3}. This way, the PTS technique always provides an improvement in signal BER performance. As for the PAPR performance, the PTS technique can improve all cases except for 8-QAM and 16-QAM signals with clipping technique at low clipping ratio such as 5 dB. However, the PTS technique still requires Side Information (SI), and it has high computational complexity.**

Keywords— BER, OFDM, Palm Date Leaf Clipping, PAPR, PTS.

I. Introduction

The signal processing is crucial in wireless communication. With the proper technique, the data transmitted across the wireless channel can become efficient. One way to transmit a huge amount of data is to use the proper modulation technique. For instance, PSK technique modulates the carrier wave's phase in order to carry the information across the wireless channel. On the other hand, QAM provides a way to modulate the phase and amplitude of the signal simultaneously. The signal will then be modulated to a carrier wave before transmitted through a wireless channel. The modulation can have several levels of it. The higher the level corresponds to a more efficient modulation, but leads to a signal that is prone to error, especially when it comes to the fading channel.

One way to overcome the fading channel is to use the OFDM. It utilizes several nearby frequencies that have orthogonal nature with each other. In short, it saves bandwidth usage and provides a stronger signal through fading channel compared to the single carrier signal.

Combining the PSK or QAM with OFDM provides a way to have a high data rate and also have a stronger signal through fading channel at the same time. However, the usage of OFDM demands a high power in its implementation. The FFT technique that becomes the key in OFDM creates a high PAPR value for the signal. Practically, it can go as high as 10 dB, which is not efficient for the amplifier of the system [1]. There are several PAPR reduction techniques, one of them is the clipping technique [2], and the other one is the Partial Transmit Sequence (PTS) [3]. The clipping technique itself has several different types. The simplest one is the classical method. It allows the system to reduce any part of the signal that exceeds a certain threshold. Another type is known as Palm Date Leaf (PDL) clipping. It has been shown to be superior compared to several other clipping methods [4].

Previous researchers conducted the analysis of PTS technique and the PDL clipping technique separately. Since these techniques are applied on different part of the structure (either in transmitter or receiver), thus it is possible to combine both of them. Considering that they are meant for PAPR reduction, thus it is hoped that PAPR value can go low.

In this research, the combination of them is simulated with MATLAB 2014b, and the effect of using PTS technique along with PDL clipping is discussed. Additionally, the PTS technique is aided by the implementation of PSO algorithm to reduce its complexity in searching optimal phase factor. The OFDM signal is combined with the usage of several modulation techniques such QPSK, 8-PSK, 16-PSK, 8-QAM, and the 16-QAM. Therefore, a wide range of signals are evaluated within this research. In order to simulate its BER performance, the AWGN channel is chosen due to its simplicity compared to fading channels such as Rayleigh. The AWGN channel distorts the signal randomly around its mean [5]. On the other hand, fading channel distorts the signal in a worse way, where one frequency might suffer worse distortion compared to the other (in the frequency selective fading).

This research analyses two parameters of the signal. The first one is the PAPR value and its reduction from normal FFT-based OFDM signal. To have a better analysis, the BER value is also monitored, because it will not be practically useful if the signal has the lowest PAPR but worse BER performance.

The rest of this paper is organized as follow. Chapter 2 discusses more about the literature review, especially for the PTS technique and the PDL Clipping technique. Then it is followed by chapter 3, which describes the proposed structure. Then chapter 4 discusses the result obtained from the simulation. Ultimately, chapter 5 will conclude the research.

II. Literature Review

Before proceeding to the discussion of the result, the PTS and the PDL clipping technique would be first elaborated. As a PAPR reduction technique, PTS is applied directly after the IFFT, while the clipping technique is applied after the PTS technique. In short, if one would like to combine these techniques, the sequence will be PTS technique followed by the PDL clipping technique.

A. Partial Transmit Sequence

The OFDM signal has several sub-carriers. Each sub-carrier has a distinguish frequency, and all of the signal's frequencies have an orthogonal nature. Before transmission, each sub-carrier is partitioned into M sub-blocks by the Partial Transmit Sequence. Each part of the partition is multiplied by a certain phase factor to modify its phase. The phase factor is normally limited to a certain value such as $0, \pi/2, \pi$, and $3\pi/2$. After all of the part has been multiplied, they will be summed back to form the full signal with new phase orientation. This way, the PAPR can be changed. The technique can be expressed mathematically as Eq. 1.

$$X_{new} = \sum_{i=1}^{M} b_i X_i \tag{1}$$

With X_{new} is the signal after the process, X_i is the original signal, and b_i denotes the phase factor. Each combination of the phase factor is implemented, and the combination that provides the lowest PAPR is chosen. This way, the PAPR of the signal can be reduced. The higher the subblocks, the greater the reduction. However, the reduction is achieved at the cost of increasing the system's complexity, and normally the value is taken to be either 4 or 8 where 8 performs better than 4 at the cost of system's complexity [3].

To improve the performance of this technique, an algorithm known as Particle Swarm Optimization can be implemented. It creates a way to find the best phase factor's combination without having to go through each of them one by one.

The procedure of doing the algorithm can be simplified as follow. First, initialize the array of particles in a population. Each of them will have their own position and velocity to move from one point to another. The initialization is done randomly. Next, calculate the fitness of the particle. The fitness function is a condition that determines whether the particle is the best one or not. The evaluation is done by storing the first fitness value as the local best, then try to move the particle with the first velocity. After that, measure the fitness value again, and compare it with the previous one. The better one is stored as the global best. The velocity is then adjusted following the distance between the local best and the global best. Furthermore, a threshold can be specified to simplify the algorithm [6]. This way, the PTS technique does not evaluate all of the phase factor's combination to find the best one, thus, simplifying the technique. Eqs. 2 and 3 show the formula to calculate the velocity and the position of the particle [7].

$$\begin{aligned} v_i(t+1) = \chi w v_i(t) + c_1 r_1\left(x_i^P(t) - x_i(t)\right) \\ + c_2 r_2\left(x^G(t) - x_i(t)\right) \end{aligned} \tag{2}$$

$$x_i(t+1) = x_i(t) + v_i(t+1) \tag{3}$$

Where x denotes the position of the particle, t denotes the time, v denotes the velocity, c_1 and c_2 denotes the local and global coefficient, r denotes the random variable with uniform distribution in the range of between 0 to 1 [8]. ω denotes the inertia weight of the particle and χ is a dimensionless variable that is scaling the inertia weight [7]. The x with a superscript of p is denoting a local best and the x with a superscript of g denotes a global best.

B. Palm Date Leaf Clipping

Clipping technique cuts the signal that exceeds a certain level. The process is done by multiplying the signal with a certain scaling factor. There are several scaling factors that can be implemented, depending on the clipping method that is used. The PDL clipping has a scaling factor and the clipping function express in Eq. 4 and Eq. 5.

$$P_\beta^A = \frac{A}{\cosh\left(\frac{r-A}{\beta}\right)} \tag{4}$$

$$f(r) = \begin{cases} x(t), & |x(t)| \le A \\ P_\beta^A(x(t))e^{i\phi(x(t))}, & |x(t)| \ge A \end{cases} \tag{5}$$

The parameter β denotes the smoothness factor, which will affect the clipping result. Researcher [4] suggested the value of 5 to have the best performance. As for parameter A, it is the threshold value which can be calculated by using the clipping ratio (CR) and the RMS value of the signal. The equation is expressed in Eq. 6.

$$CR = \frac{A}{\sigma} \tag{6}$$

The value of CR and the threshold is proportional. Thus, a lower clipping ratio leads to a lower value of threshold. A low threshold value means that the signal will be clipped hoarsely, and the PAPR can be reduced greatly. However, the reduction comes with the cost of the signal's BER performance. Note that the clipped signal has a different wave form compared to the original one, because the part that exceeds the threshold value will be multiplied by a certain function, and the consequence is that it leads to an error in the receiver side because the form is no longer recognized as the initial one. In short, a low CR value leads to a greater PAPR reduction but also a higher BER value. While a higher CR value performs the other way around. Normally, the CR is used below 10 dB, and the performance below 7 dB has a bad BER performance [4].

III. PROPOSED STRUCTURE

To simulate the system, several parameters are set as shown in Table 1. Additionally, the simulation block diagram is shown in Fig. 1. Since it is known that PAPR value gets worse at a higher order of modulation, the Authors decided to analyse several bit modulations such as QPSK, 8-PSK, 16-PSK, then followed by 8-QAM, and finally the 16-QAM. As previously discussed in chapter 2, the PTS technique is performed with 8 sub-blocks, and the PDL clipping has 5 as the value for its smoothness factor. Various clipping ratios are used to have a good range of analysis. In this case, the performance of relatively low CR such as 5 dB is covered, and also the relatively high value such as 20 dB is also covered.

The proposed structure is quite similar to the normal OFDM system, but different in some way. First of all, the information is generated, then undergoes the PSK or QAM modulator. Then it flows into the IFFT block. Next, PTS is done. After that, PDL is performed before transmission. After passing the AWGN channel, the signal has to recover the PTS technique, before it can be demodulated, and converted into bits.

The usage of PTS and clipping in the block diagram is not a must. The simulation is designed to be done several times. To have a better evaluation for the effect of the PTS technique, there are three scenarios in each simulation. First, the normal OFDM is simulated. Then followed by the clipped OFDM signal, and finally the clipped signal with PTS technique.

TABLE 1. SIMULATION PARAMETERS

Parameter	Value
Number of sub-carriers	128
Number of OFDM frame	1000
PTS subblocks	8
Smoothness Factor	5
Clipping Ratio	5 dB, 7 dB, 10 dB, 20 dB
Channel	AWGN

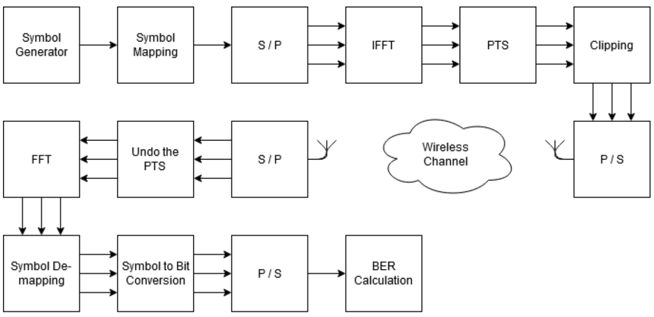

Fig. 1. Simulation Block Diagram

IV. RESULT AND DISCUSSION

In this section, the results are presented in the following order. The BER performance results are shown prior to the PAPR results. The evaluation itself is done by considering three cases of signals. First, the normal OFDM signal without any PAPR reduction technique is denoted as the "Normal" signal. Then it is followed by the "clipped" signal, which denotes the signal with PDL clipping, but without PTS technique applied. Finally, the OFDM signal with PTS and PDL clipping technique applied is denoted as "Clipped with PTS". These signals' labels can be seen in the graph's legend of each presented result.

First of all, the result is showing the performance of QPSK modulation. The BER result is shown in Fig. 2 and Fig. 3.

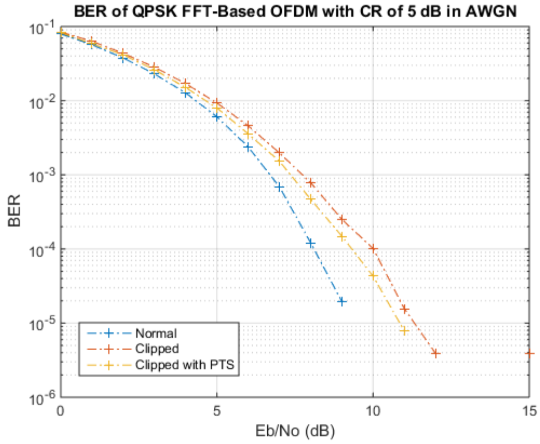

Fig. 2. Result of QPSK with CR of 5 dB

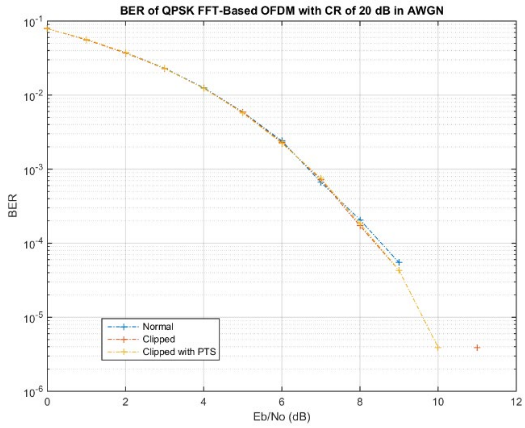

Fig. 3. Result of QPSK with CR of 20 dB

The first scenario is implementing 5 dB as the clipping ratio. It is shown that the PTS technique is able to provide a better BER performance for the signal, even though the normal signal is still the best. The usage of PTS technique can lower the Eb/No value by approximately 0.5 dB in this case. As for the usage of 20 dB as the clipping ratio, all of the signals perform similarly. So far, we could see that PTS could improve PDL clipped signal for a low clipping ratio value.

As for the PAPR, ─for the clipping ratio of 5 dB─ the usage of PDL clipping only provides a reduction of 4.62 dB, while its usage with PTS has a better reduction with the value of 5.08 dB. Besides, in the usage of 20 dB as the clipping ratio, PDL clipping provides almost 0 dB of reduction for the signal's PAPR, while PTS technique could provide up to 3 dB of reduction.

Even though in the presence of high clipping ratio, where PTS provides minor improvement in BER performance of the signal, it still reduces the PAPR. Next, the result for the simulation of 8-PSK is shown in Fig. 4 and Fig. 5. The result is ─as expected─ similar to the performance of QPSK. The 5 dB clipping ratio scenario shows that PTS technique could improve the performance of PDL clipped signal. The value varies with Eb/No value. However, the normal OFDM signal still has the best BER performance. As for the implementation in 20 dB of clipping ratio, all of the simulated signals show a similar result in BER performance.

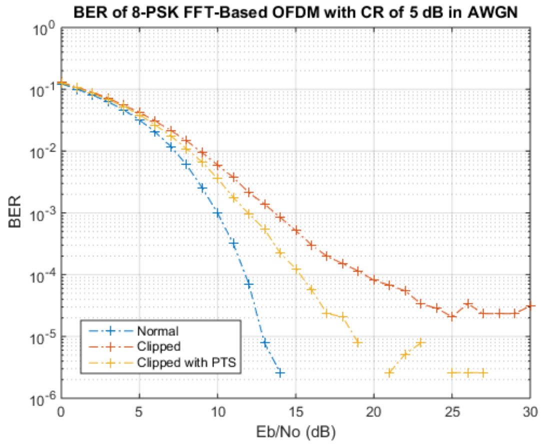

Fig. 4. Result of 8-PSK with CR of 5 dB

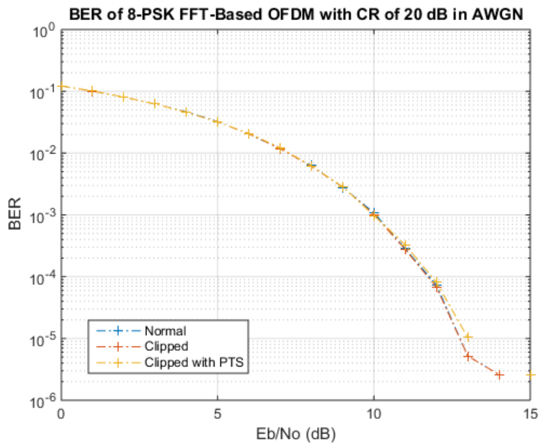

Fig. 5. Result of 8-PSK with CR of 20 dB

For the PAPR performance, the addition of PTS could make 5 dB of total reduction for the clipping ratio of 5 dB, and 3 dB of total reduction for the clipping ratio of 20 dB. The PDL clipping alone could provide PAPR reduction of 4 dB in CR of 5 dB, but 0 dB in CR of 20 dB.

Then, the result of 16-PSK is shown in Fig. 6 and Fig. 7. The result is similar to the first two simulations. However, the performance seems to be worse in this scenario, which can be justified by a relatively great difference between the performance of normal OFDM signal and the other signals, especially in high Eb/No value.

The PAPR reduction provided in CR of 5 dB is 4 dB and 5 dB for the usage without and with PTS technique respectively. As for the CR of 20 dB, PDL clipping provides 0 dB of reduction while PTS still consistently provides 3 dB of PAPR reduction. This way, —at any level of PSK— the PTS technique could provide a better performance of signal either in terms of BER and PAPR for low CR value, and in terms of only PAPR for the high CR value.

Fig. 8 shows the performance of 16-PSK in various CR values.

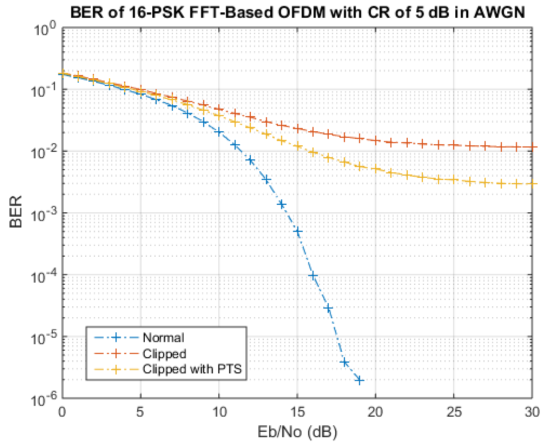

Fig. 6. Result of 16-PSK with CR of 5 dB

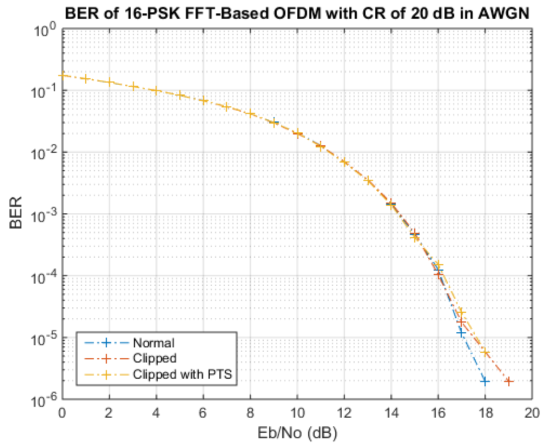

Fig. 7. Result of 16-PSK with CR of 20 dB

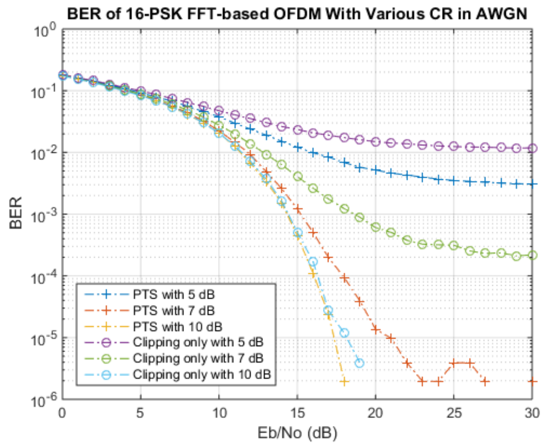

Fig. 8. Result of 16-PSK with various CR

The performance of PTS technique is confirmed to be able to improve PDL clipped OFDM signal. The fact that the BER performance shown in Fig. 8 is always better when PTS technique is implemented justified the statement. In fact, the usage of PTS in 7 dB of clipping ratio could match up with the usage of PDL clipping without PTS technique in 10 dB of clipping ratio. As for the PAPR performance, the previous three results show that PTS is able to provide a greater reduction.

Since the results for PSK modulation are consistent, where PTS technique provides improvement to the signal with PDL clipping implemented, then the result of 8-QAM —which is shown in Fig. 9— directly focuses on comparing several values of CR with and without PTS technique implemented.

As the figure shows, clipping ratio of 5 dB and 7 dB improves significantly when PTS technique is implemented. For a higher CR value such as 10 dB, there is almost no improvement in the BER performance of the signal. PAPR reduction of 4.3 dB, 3.7 dB, and 3.4 dB is achieved when PTS technique is implemented in CR of 5 dB, 7 dB, and 10 dB respectively. As for the scenario without PTS technique, the reduction is 4.5 dB, 3 dB, and 1.5 dB for CR of 5 dB, 7 dB, and 10 dB respectively. Even though the reduction provided without PTS technique in CR of 5 dB is higher than when PTS is implemented, the reduction drops significantly when the CR is increased. This way, it makes PTS technique to provide a consistent PAPR reduction while improving BER performance of the signal at the same time, except on 8-QAM with CR of 5 dB where the implementation of PTS with PDL clipping provides 0.2 dB less reduction compared with the scenario that has no PTS technique.

Note that QAM is modulating the phase and amplitude simultaneously. In the case of using CR at 5 dB, the PDL clipping is set to have a lower threshold compared to a higher CR value. The lower threshold makes the clipped signal to have a lower amplitude, thus reducing the PAPR. In the case of using PTS before the clipping, the signals' phase has been optimized, thus the result already has a lower amplitude. It eases the effort of the clipping technique in reducing signal's amplitude, thus making the PAPR reduction made after PTS technique becomes lower.

As for the case in CR of 7 dB and 10 dB, the PDL clipping alone could provide a PAPR reduction that is less significant compared to the CR of 5 dB. This way, the PTS technique could make the attempt of reduction in the first place, then its output signal's PAPR will be further reduced by the PDL clipping. It makes the PTS implementation to be able to reduce the PAPR better than the implementation of PDL clipping only. Note that the reduction is similar when applying PTS with clipping technique at CR of 7 dB and 10 dB. This is because the amount of reduction is relatively small when applying clipping technique at relatively high CR such as 7 dB and 10 dB.

A similar result is shown in 16-QAM, where PTS technique provides an improvement for the simulated signal. From the perspective of PAPR reduction, it could provide 4.6 dB, 4.0 dB, and 3.9 dB in the CR of 5 dB, 7 dB, and 10 dB respectively. In the scenario without PTS technique, the reduction is 5 dB, 2.8 dB, and 1.5 dB for the CR of 5 dB, 7 dB, and 10 dB respectively. A consistent improvement in reduction is shown when PTS technique is implemented, except in the 16 QAM with clipping at CR of 5 dB. Similar to the 8-QAM, the PTS implementation does not improve the PAPR reduction of the system that has PDL clipping technique. This case is similar to the case in 8-QAM. Next, the PAPR reduction for each simulation is compiled into Table 2.

Table 2 shows the PAPR reduction achieved after the implementation of PDL clipping technique only, along with the combination of it with PTS technique. To accommodate the results, the table shows both reductions in one cell with a slash to separate each scenario. For instance, the QPSK at clipping ratio of 5 dB has PAPR reduction of 4.62 dB in the simulation without PTS technique, and the reduction becomes 5.08 dB when the PTS technique is applied. All values are shown in dB unit, but in order to simplify the data presentation, the unit is not shown.

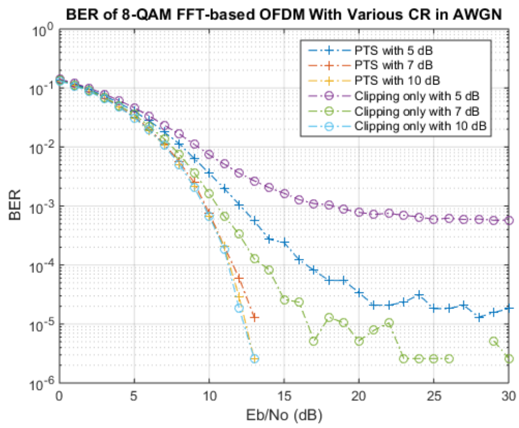

Fig. 9. Result of 8-QAM with various CR

Finally, the result of 16-QAM with various CR is shown in Fig. 10.

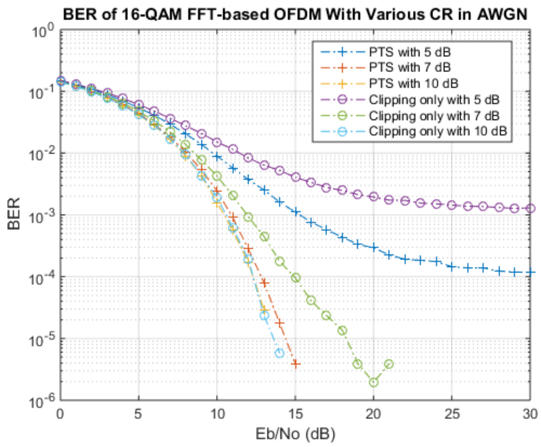

Fig. 10. Result of 16-QAM with various CR

TABLE 2. PAPR REDUCTION FOR VARIOUS CLIPPING RATIO VALUES

Modulation	Clipping Ratio			
	5 dB	7 dB	10 dB	20 dB
QPSK	4.62 / 5.08	-	-	0 / 3
8-PSK	4 / 5	-	-	0 / 3
16-PSK	4 / 5	-	-	0 / 3
8-QAM	4.5 / 4.3	3 / 3.7	1.5 / 3.4	-
16-QAM	5 / 4.6	2.8 / 4.0	1.5 / 3.9	-

Furthermore, the result of PAPR –shown as CCDF plot– is shown below. Fig. 11 shows the PAPR result on QPSK for PDL clipping with CR of 5 dB and 20 dB, as well as its corresponding result when PTS technique is applied to it. Fig. 12 is showing a similar result, but applied for 8-PSK. Then followed by Fig. 13 for 16-PSK in the similar scenarios. Fig. 14 and Fig. 15 shows the result for simulation on 8-QAM and 16-QAM respectively. Note that the PAPR reduction discussed above (e.g., in Table 2), are evaluated based on the PAPR at CCDF of 10^{-3}.

Regardless of the benefits that PTS provides for the signal, it is worth to note that this technique has high computational complexity, especially when finding the best combination for phase factor to minimize the PAPR. Even though PSO algorithm provides relaxation on the process, this technique still requires Side Information (SI) to reconstruct the received signal without providing any distortion.

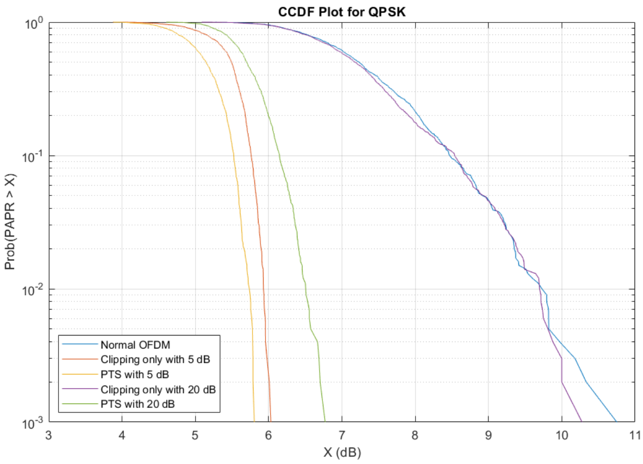

Fig. 11. CCDF plot for simulation on QPSK

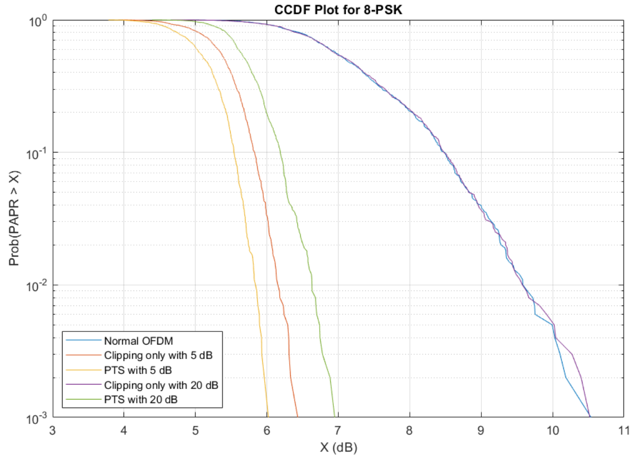

Fig. 12. CCDF plot for simulation on 8-PSK

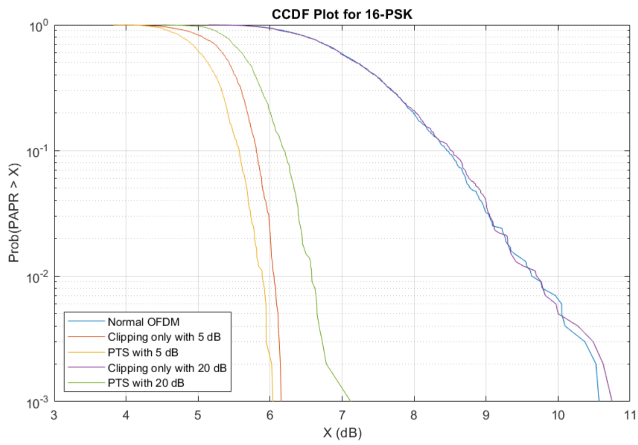

Fig. 13. CCDF plot for simulation on 16-PSK

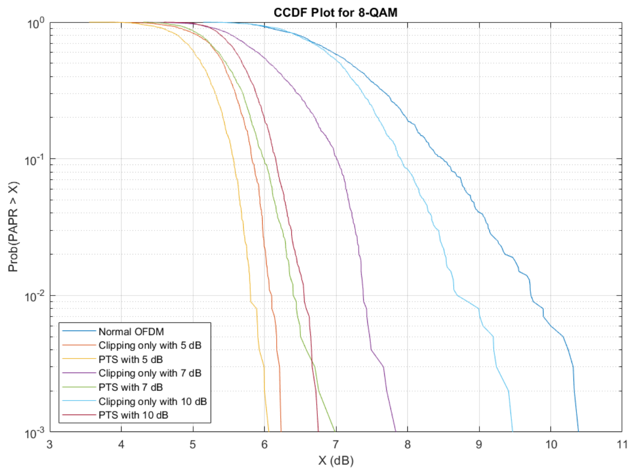

Fig. 14. CCDF plot for simulation on 8-QAM

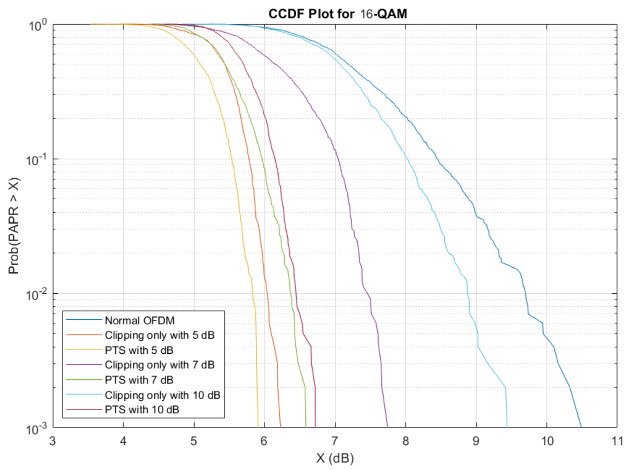

Fig. 15. CCDF plot for simulation on 16-QAM

V. CONCLUSION

To summarize, this research simulates the OFDM signal with QPSK, 8-PSK, 16-PSK, 8-QAM, and 16-QAM through AWGN channel. The effect of PTS technique usage in Palm Date Leaf clipped OFDM signal is discussed. All of the scenarios show that PTS technique could provide improvement in BER and PAPR performance of the signal for a low CR value such as 5 dB and 7 dB. The PAPR is evaluated as per CCDF of 10^{-3}. As for the higher CR value such as 10 dB and 20 dB, the signal's BER performance is similar to the normal OFDM signal, but it provides a consistent PAPR reduction of approximately 3 dB. This way, PTS technique always provides improvement in BER performance of the signal. As for the PAPR performance, PTS technique is able to improve all cases except for 8-QAM and 16-QAM signal with clipping technique at low clipping ratio such as 5 dB. However, PTS technique still requires Side Information (SI), and it has high computational complexity.

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