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Performance of PAPR for Different Modulation Technique Using Cluster Scrambling Codeword Shifting Technique in F-OFDM Systems

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ABSTRACT

Filtered-OFDM (F-OFDM) is one of the proposed 5G system candidates. In order to achieve service diversification, it must be able to support a large number of asynchronous subband transmissions. However, the transmitted signal in a multi-carrier transmission system with different subcarriers has a high peak-to-average power ratio (PAPR). Therefore, the main problem of F-OFDM systems is the high PAPR in the system, which leads to poor performance and excessive power consumption due to numerous distortions. This study introduces a technique based on codeword structure manipulation known as Cluster Scrambling Codeword (CSC) to achieve better reduction of PAPR with the evaluation of the performance of QAM and APSK modulation. This is a new formulation of the bit data sequence shifting approach that can reduce PAPR more effectively than the conventional scheme. Simulation results show that CSC with 256 QAM modulation scheme provides a PAPR reduction better than the conventional F-OFDM system.

1. Introduction

The 5G network system has recommended a new multi-carrier modulation technique called filtered-OFDM (F-OFDM), which can support multiple asynchronous sub-band transmissions and be employed to expand diversification in future services. The system bandwidth is divided into many sub-bands up to a particular width, and each sub-band is filtered independently by Yu [1]. A 5G system's fundamental design could also include capabilities such reduced out-of-band emissions and synchronization relaxation by Shah [2]. The main challenge with the F-OFDM system is that the high PAPR value and poor performance of the BER within the system, that may be a crucial drawback with any multicarrier modulation approach that causes performance degradation and high-power consumption due primarily to various distortions.

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A high-speed transmission known as an OFDM signal is made up of several separate modulated sub carriers. Due to the addition of several subcarrier components in an OFDM system, the transmit signals may experience high peak values during an Inverse Fast Fourier Transform (IFFT) operation. It is therefore well known that OFDM systems have higher PAPR than single-carrier systems. High Peak to Average Power Ratio (PAPR) and poor bit error rate (BER) in fading situations, when summed up coherently, are significant limitations in the overall performance of OFDM systems. Filtered-OFDM (F-OFDM) was developed to support diversity in future services and will be implemented using a 5G network device due to the proper filtering criteria, including flat pass-band over the subcarriers inside the sub-band, sharp transition band that reduces the guard bands, and sufficient stop-band attenuation, Zhang [3]. With the F-OFDM network system, this will benefit in terms of reduced PAPR and improved BER degradation. The F-OFDM system's purpose is to achieve high spectrum efficiency for ultra-reliable, low-latency communication with increased intercarrier spacing, as described by Rajasekharl [4].

To optimize performance for high PAPR and low BER, a variety of techniques can be used. Peak windowing, selective mapping (SLM), clipping and filtering, block coding approaches, and others are all mentioned by Shukla [5]. In terms of PAPR reduction, various strategies have been proposed by researchers which is Selective Mapping (SLM) [6-7], Partial Transmit Sequence (PTS) [8–11] and codeword shifting [12–19]. These are some implementations of the multiple signaling approach and the probabilistic method. According to previous findings, this is a distortion-free PAPR reduction solution for OFDM systems since it is based on the symbol scrambling approach. Before the modulation process, data is scrambled at the bit data stream. Multiple signaling is a strategy that focuses on permutating multicarrier signals and adopting the signal with the lowest PAPR value for transmission, whereas probabilistic signaling focuses on modifying control criteria in OFDM signals and optimizing them to obtain better PAPR reduction., by Rozaini [14]. These approaches are designed to reduce PAPR significantly without adding distortion effects.

Due to limited availability of resources in wireless networks, quadrature amplitude modulation (QAM) and amplitude-phase shift keying (APSK) modulation are being considered for future mobile radio systems in order that could save bandwidth while maintaining improved error rate performance [20–22]. By comparing these two modulation techniques, QAM can outperform APSK under Rayleigh fading conditions by Sapari [23]. High order modulation schemes are significantly more sensitive to channel conditions, Wei [24], however these modulation techniques are advantageous because they allow higher bit rates, therefore increases the number of applications as mentioned by Baldi [20]. The total performance of the F-OFDM system as a potential advancement of the 5G network will be evaluated and analyzed throughout this study. To support the diversified use and high-speed data transmission demands of today's consumers, one of the major qualities required is the deployment of a system that can enhance effective spectral efficiency at an optimum price. particularly compared to the current 4G OFDM system as a result, an efficient technique is required to perform a significant PAPR reduction with low computational cost, improved BER performance, and consideration of the signal data rate loss problem.

This study aims to contribute to this growing area of research by exploring substantial method in order to deal with the high PAPR drawback, a novel strategy known as the Cluster Scrambling Codeword (CSC) shifting methodology was introduced in this study. PAPR performance of this approach using different modulation techniques was also explored. It is possible to further enhance this approach by manipulating the arrangement of the codeword's structure before returning to pass the shifting process by applying the shifting method on the codeword while maintaining the original codeword's structure alone. As a result, there are more options available for how the bit position will be set up to obtain alternate codewords with a lower PAPR. The main methodological approach is to manipulate the codeword structure, and the key to achieving higher PAPR reduction is to use the permutation method. A new bit sequence technique may be effective in decreasing high PAPR within the F-OFDM system because it is capable of generating alternative codewords by modifying the codeword structure and shifting process.

2. Methodology

The phenomenon known as the carrier frequency offset is caused by frequency mismatch at the receiver, whereas high peak-to-average power ratio is caused by the summation of several sinusoids at the transmitter. The PAPR is the ratio of a sample's maximum power to the average power of a particular OFDM transmit symbol. The PAPR is the ratio of a signal's peak power to its average power. It is expressed in decibels (dB) of volume. When the several sub-carriers in a multicarrier system are out of phase with one another, PAPR occurs. At each instant they are different with respect to each other at different phase values. When all of the points reach their maximum value at once, the output envelope will suddenly accelerate, creating a "peak" in the output envelope. Whereas an OFDM system has a large number of independently modulated subcarriers, the peak value of the system may be extremely high when compared to the average of the overall system. Peak-to-Average Power Ratio refers to the ratio of peak to average power value.

2.1 Peak Peak-To-Average Power Ratio (PAPR)

The transmit signal in multicarrier transmission systems with different subcarriers does indeed have a high PAPR. The high value of the PAPR signal introduces non-linear distortion in the transmitter of the front-end high-power amplifier (HPA), leading in HPA saturation [25]. As a consequence, high dynamic range amplifiers are required, increasing the system cost as stated by Naeiny [26]. If the PAPR is high, the conversion of OFDM signals from A/D and D/A will be saturated, to reduction of power consumption efficiency. In addition, the transmit power amplifier must operate in its linear region to avoid spectral growth of the multi-carrier signal in the form of intermodulation between subcarriers and out-of-band emissions. Thus, these results in inefficient power conversion.

The IFFT of OFDM modulated subcarriers signal equation may be written as

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X_k . \exp\ (j2\pi f_k t) \tag{1}$$

where X_k is OFDM symbol frequency at f_k while $e^{j2\pi f_k t}$ is IFFT sinusoid. The ratio of peak output power to average output power is used to calculate the PAPR of OFDM signals [16]

$$PAPR(dB) = 10 \log \left\{ \frac{P_{peak}}{P_{avg}} \right\} \tag{2}$$

The complex baseband signal's PAPR mathematical equation defined throughout time interval is represented by

$$PAPR\ (dB) = \frac{max_t |x(t)|^2}{E_t[|x(t)|^2]} \tag{3}$$

where $max|x(t)|^2$ is the maximum signal power and $E[|x(t)|^2]$ is the average signal power. Whereas the average signal power of an OFDM system is computed by

$$E = \frac{Sum\ of\ magnitude\ of\ all\ OFDM\ symbol}{No.\ of\ OFDM\ symbol\ (N)} \tag{4}$$

For discrete time signal

$$PAPR = \frac{max_n|x(n)|^2}{E_n[|x(n)|^2]} \tag{5}$$

The time domain samples of the output from the inverse fast Fourier transform (IFFT) are x_n, which represent the transmitted OFDM signals obtained after passing through the IFFT operation process on modulated input symbols. The input signal to the amplifier in the OFDM system is an analogue signal [15].

$$x_n = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k W_N^{nk} \tag{6}$$

where N is number of OFDM symbol and $W(k)$ is Additive White Gaussian Noise (AWGN) in frequency domain.

In an OFDM system with sub-carriers, the peak power of received signals is N times the average power when the phase values are the same. The Rayleigh distribution-based cumulative distribution of the amplitude of OFDM signals given as [15]

$$F(\gamma) = 1 - \exp\ (\gamma) \tag{7}$$

Probability of PAPR that is below certain threshold level, γ expressed as

$$\Pr\{PAPR < \gamma\} = \ (1 - [exp\ (-\gamma)]\ )^N \tag{8}$$

Complementary Cumulative Distribution Function (CCDF) is commonly presented for PAPR performance, as the number of subcarriers, N increases, PAPR CCDF is increases too

$$CCDF(PAPR) = Prob(PAPR > PAPR_0) \tag{9}$$

$$CCDF\ (\gamma) = \Pr\{PAPR > \gamma\} = 1 - (1 - [exp\ (-\gamma)]\ )^N \tag{10}$$

2.1.1 Cluster scrambling codeword shifting method

This study proposes a new PAPR reduction approach that generates a scrambled data sequence employing the permutation process (circulates shift). In order to reduce the PAPR, CSC is emphasizing on the codeword structure and bit layout. The two parameters can be changed to generate a unique codeword with a lower PAPR, as according CSC. Finally, it will be decided to transmit the alternative F-OFDM signal with the lowest PAPR value.

This proposed technique is inspired by the Artificial Bee Colony (ABC) algorithm as studied in [27-31]. This novel clustering intelligent evolutionary algorithm have been proposed by Karaboga [32], which is an algorithm for numerical optimization problems. The ABC is a swarm-based optimization algorithms that having a good PAPR reduction performance, Taspinar [27]. It is simulated based on the behavior of honeybee mining colonies.

A food source location in the ABC method is indicates a potential solution to the problem to be solved, and the nectar amount of a food source correlates to the quality (fitness) of the associated solution. The primary goal of the ABC algorithm is to search the neighborhoods for the best solutions that have a mutation operator. A new food source is investigated by hired bees, and when the honey of the new food source outperforms that of the existing food source, it is saved as one of the possible optimal options, Boontra [29]. On the other hand, this idea also being used in CSC as this proposed technique will select codeword that has the best PAPR value to be transmitted.

The generation of an OFDM signal for N subcarriers begins with the serial-to-parallel block process of converting input data into information symbols. the information symbol can then be modulated using the desired modulation technique and mapped onto the constellation point. Finally, the modulated symbol is converted into an OFDM signal using the Inverse fast Fourier transform (IFFT) as shown in Figure 1.

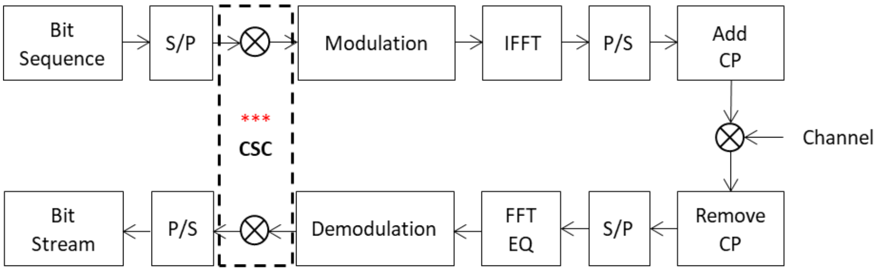


Fig. 1. Block diagram of CSC technique

As shown in Figure 2, C represents the binary sequence codeword having z total number of input bits and can be indicated as $C = [C_1, C_2, \dots, C_z]$. A serial to parallel converter will divide the codeword sequence into p number of sub-blocks denoted by $C' = [C'_1, C'_2, \dots, C'_p]$. and each sub-block will have n is representing the number of sub-block and the number of bits per symbol respectively where $p = z/n$. Constructing a few cluster groupings out of the codeword's structure as the first step. At that point, the divided codeword in each sub-block can be written in the following pattern $C_1 = [C_1, \dots, C_n]$, $C_2 = [C_{n+1}, \dots, C_{2n}]$ and so on until C_n.

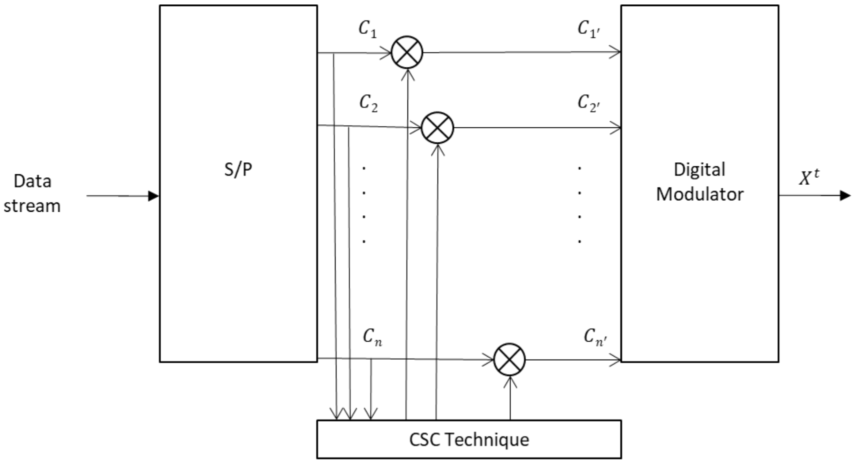


Fig. 2. Block diagram of CSC technique

It begins by rearranging the codeword's structure to a few clusters grouping across two columns. As with the example in Figure 3, it is split up into 2 segments, part A and part B, each of which has 2 columns. By shifting the codeword location in part B while maintaining the codeword on part A idle, the second alternative codeword may then be produced.

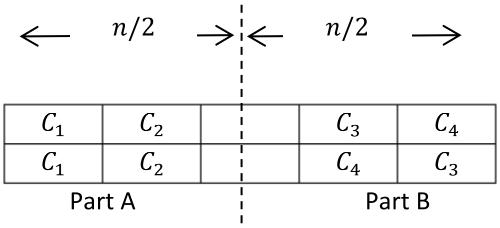


Fig. 3. Example cluster grouping for 4 codeword

Modifications to the codeword structure have a substantial influence on PAPR performance, shorter codeword distances result in improved PAPR reduction. The benefit of the shifting process in CSC is that it provides the system with the flexibility to selecting a signal with a lower PAPR to transmit. Meanwhile, conventional OFDM has only a single output signal. Table 1 shows the alternatives positioning bits of codeword for numbers of shifting processes for better interpretation.

Table 1
Bit arrangement of codeword for CSC technique for 64-QAM (6 Codeword)

Sub block codeword bits	Position of bits
Codeword	$C_1, C_2, C_3, C_4, C_5, C_6$
Codeword Shift 1	$C_1, C_2, C_3, C_4, C_6, C_5$
Codeword Shift 2	$C_1, C_2, C_4, C_3, C_5, C_6$
Codeword Shift 3	$C_1, C_2, C_4, C_3, C_6, C_5$
Codeword Shift 4	$C_2, C_1, C_3, C_4, C_5, C_6$
Codeword Shift 5	$C_2, C_1, C_3, C_4, C_6, C_5$
Codeword Shift 6	$C_2, C_1, C_4, C_3, C_5, C_6$
Codeword Shift 7	$C_2, C_1, C_4, C_3, C_6, C_5$

Therefore, the alternative OFDM transmitted signal given as

$$x'(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} C'_k W_N^{nk} \tag{11}$$

where C'_k is the binary shifted codeword sequence of OFDM signal and $W(k)$ is Additive White Gaussian Noise (AWGN) in frequency domain.

3. Results and Discussion

The feasibility of CSC's PAPR reduction will be analysed by simulation in this section. Random input symbols are generated in the simulation, and each one is mapped using a different modulation technique. The Rayleigh channel is being used to transmit the OFDM signal. In order to reduce the effects of ISI, a cyclic prefix with a length of 14 is applied to the OFDM signals. Table 2 contains the parameters that were employed in the MATLAB simulation method in descriptive manner, Zyren [33].

Table 2
Simulation parameter on downlink OFDM modulation [33]

Parameter	Value
Channel Bandwidth	1.25 MHz
Sampling Frequency	1.92 MHz
Sub-carrier spacing	15 kHz
Modulation technique	16 QAM, 64 QAM, 256 QAM 16 PSK, 64 APSK, 256 APSK

3.1 PAPR Analysis of Different Alphabetical Modulation Order for OFDM System

The Figure 4 shows the comparison of PAPR performance between QAM and APSK modulation technique in OFDM system. The PAPR analysis being considered by taking different alphabetical modulation order for 16-QAM/ APSK, 64-QAM/ APSK and 256-QAM/ APSK. By comparing the results obtained, 16-QAM gives better PAPR reduction compared to 16-APSK by 32.17% improvement at 7.8dB and 11.5dB respectively. Meanwhile, 64-QAM have been outperformed 64-APSK where it gives 1.25% improvement at 7.9dB.

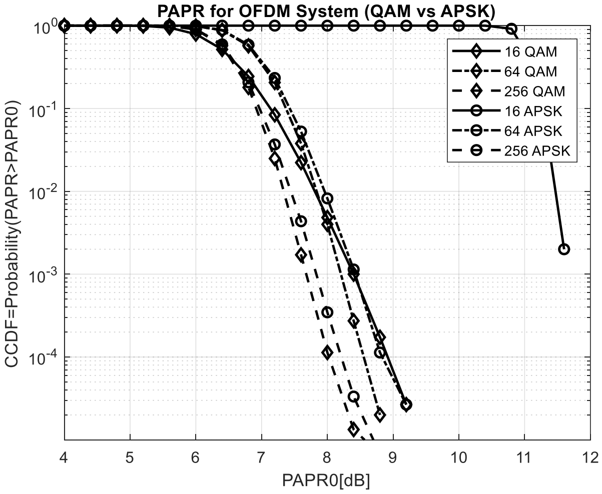


Fig. 4. PAPR Performance between QAM vs APSK for OFDM System

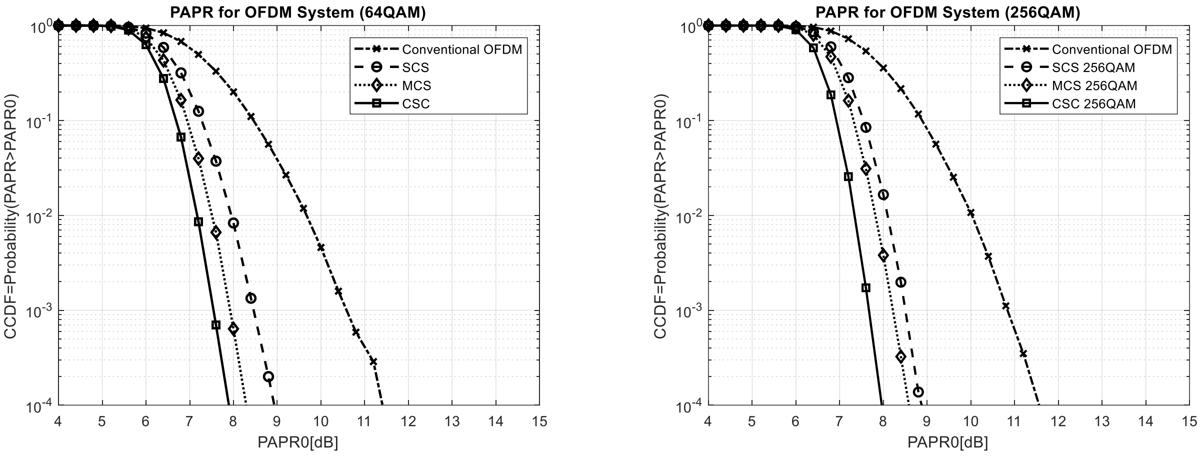
As in Table 3, apparently 256-QAM manage to outperformed the PAPR reduction compared to 256-APSK modulation technique by 1.35% at 7.3dB. Referring to the results, 256-QAM gives better PAPR performance and it is being considered to be implemented as input signal digital modulation for CSC shifting method in overall system.

Table 3
PAPR analysis between QAM vs APSK for OFDM system

Alphabetical Modulation Order	PAPR (dB)		Improvement (%)
	QAM	APSK	
16 (4 codewords)	7.8	11.5	32.17
64 (6 codewords)	7.9	8.0	1.25
256 (8 codewords)	7.3	7.4	1.35

3.2 PAPR Analysis of Different Shifting Method

As part of the current study, Figure 5 compares the PAPR performance differences between conventional OFDM, Circulant Shift Codeword (SCS), Median Codeword Shift (MCS) and Cluster Scrambling Codeword (CSC) for 64-QAM modulation. In comparison to conventional OFDM systems, this method has an advantage since the CSC significantly improves PARR reduction performance compared to the other researcher examined method, where CSC produces a 17.59% improvement at 8.9dB. In contrast to SCS, where it provides a 24.07% improvement at 8.2dB, PAPR reduction for MCS has outperformed SCS.



64 QAM Modulation   256 QAM Modulation

Fig. 5. PAPR performance for CSC vs different shifting methods

As shown in Table 4, which evaluates the breakdown of the CCDF of PAPR value, it appears that CSC managed outperform the PAPR reduction in comparing to other shifting methods by 25.93% at 8.0dB. Modifications to the codeword's structure have a substantial influence on how efficiently the CSC technique performs on PAPR values. The performance of PAPR can be improved by reducing the distance at which the codewords are shifted. The shorter the distance of codeword shifted, it gives better PAPR performance. It is an established problem that calls for a better approach with codeword shifting; the proposed CSC method is the shifting distance that is shortest within a codeword.

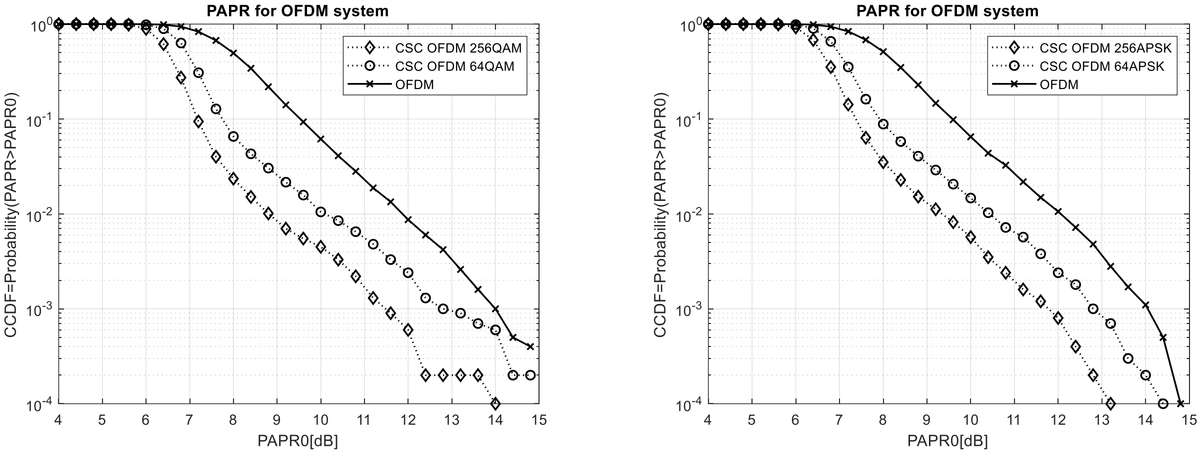
Table 4
PAPR performance on different codeword shifting methods

Method	64-QAM		256-QAM	
	PAPR (dB)	Improvement (%)	PAPR (dB)	Improvement (%)
Conventional OFDM	10.5	-	10.9	-
Selected Codeword Shift (SCS)	8.5	19.05	8.5	20.56
Median Codeword Shift (MCS)	8.0	23.81	8.1	24.99
Cluster Scrambling Codeword (CSC)	7.5	28.57	7.8	27.10

The comparison of PAPR performance for simulation mapping employing 256-QAM modulation using different codeword shifting methods is also presented in Figure 5. Similar parameters for simulation to those listed in Table 4 have been used for this number of modulation orders. Based on results obtained, proposed method CSC give better PAPR reduction with 27.10% improvement at 7.8dB compared to conventional OFDM system. While for SCS and MCS seemingly gives slightly different results with improvement of 20.56% at 8.5dB and 24.99% at 8.1dB respectively. Refer towards PAPR performance between 64-QAM and 256-QAM scheme, higher number of modulation order performed slightly better PAPR values.

3.3 PAPR Analysis of OFDM and F-OFDM System

Meanwhile for simulation mapped for OFDM system on PAPR performance between different modulation scheme have been shown in Figure 6. Based on results obtained, proposed method CSC 64-QAM give better PAPR reduction with 3.85% improvement at 10.0dB compared to CSC 64-APSK OFDM system meanwhile CSC 256-QAM outperformed CSC 256-APSK OFDM system with 4.35% improvement at 8.8dB.



QAM modulation technique APSK modulation technique

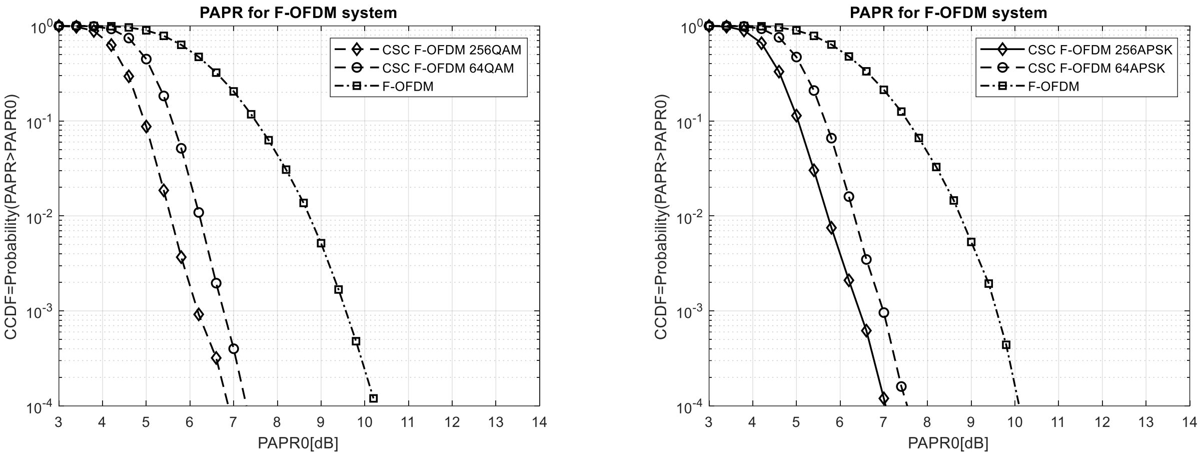
Fig. 6. PAPR performance for CSC OFDM vs conventional OFDM system

While for conventional OFDM seemingly gives slightly different results between QAM and APSK scheme as in Table 5. Output shows good amount of PAPR reduction when number of order increases and compared with original OFDM signal. Refer in the direction of PAPR performance between 64-QAM and 256-QAM scheme, higher number of modulation order performed slightly better PAPR values.

Table 4
PAPR Analysis CSC OFDM technique vs conventional OFDM

Modulation Technique	PAPR (dB)		Improvement (%)
	QAM	APSK	
Conventional OFDM	11.9	12.0	0.83
CSC OFDM (64 QAM/ 64 APSK)	10.0	10.4	3.85
CSC OFDM (256 QAM/ 256 APSK)	8.8	9.2	4.35

From the graph in Figure 7 below, can see that the PAPR performance on conventional F-OFDM vs CSC technique with different modulation scheme.



QAM modulation technique APSK modulation technique

Fig. 7. PAPR performance for CSC F-OFDM vs conventional F-OFDM system

Based on results obtained, proposed method CSC 64-QAM give better PAPR reduction with 3.17% improvement at 6.1dB compared to CSC 64-APSK OFDM system meanwhile CSC 256-QAM outperformed CSC 256-APSK F-OFDM system with 3.51% improvement at 5.5dB as shown on Table 6. By dividing the codeword structure into lower codeword distance, this may lead to better PAPR reduction compared to conventional system. As the shifting process in CSC can generate alternative codeword, it gives flexibility to the system to select the one with the lowest PAPR for transmission and PAPR performed better for higher number of modulation order.

Table 5
PAPR Analysis CSC F-OFDM Technique Vs Conventional F-OFDM

Modulation Technique	PAPR (dB)		Improvement (%)
	QAM	APSK	
Conventional F-OFDM	8.8	8.9	1.12
CSC F-OFDM (64 QAM/ 64 APSK)	6.1	6.3	3.17
CSC F-OFDM (256 QAM/ 256 APSK)	5.5	5.7	3.51

3.4 PAPR Analysis of QAM vs APSK Modulation Technique

As in Figure 8 shows the summarize of PAPR performance on conventional OFDM and CSC F-OFDM (with 256-QAM) vs CSC F-OFDM (with 256-APSK) scheme technique. The graph shows that there has been a slight improvement in the performance of PAPR reduction of QAM scheme.

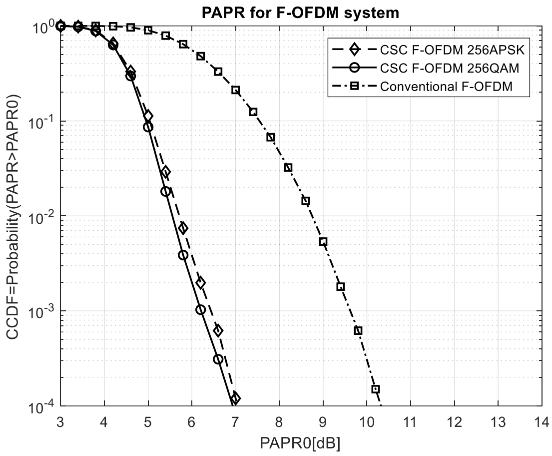


Fig. 8. PAPR performance for CSC F-OFDM (256 QAM & 256 APSK) vs conventional F-OFDM system

Since PAPR performed better for higher number of modulation order, with this proposed method, the PAPR performance with QAM scheme outperformed the conventional F-OFDM by 37.50% at 5.5dB while CSC F-OFDM with APSK scheme gives better performance compared to the conventional F-OFDM by 35.22% at 5.7dB as shown on Table 7. By dividing the codeword structure into lower codeword distance, this may lead to better PAPR reduction. As the shifting process in CSC can generate alternative codeword, it gives flexibility to the system to select the one with the lowest PAPR for transmission.

Table 6
PAPR analysis between QAM vs APSK for CSC F-OFDM system

Modulation Technique	PAPR (dB)	Improvement (%)
Conventional F-OFDM	8.8	-
CSC F-OFDM (256 APSK)	5.7	35.22
CSC F-OFDM (256 QAM)	5.5	37.50

4. Conclusions

The Cluster Scrambling Codeword (CSC) shifting methodology has been performed and analysed in this study to dealing with the high PAPR problem in F-OFDM systems. This section evaluates the effectiveness of QAM modulation and compares it to the APSK modulation method. The following conclusions can be drawn from the present study, when compared to the conventional OFDM and F-OFDM schemes, the proposed methodology may significantly enhance the performance of the PAPR value. Simulation results demonstrate that the proposed algorithm outperforms other evolutionary computation techniques with 256-QAM scheme implementation by providing a better PAPR reduction of the 5.5dB with 37.50% improvement compared to conventional F-OFDM system.

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