PAPR Reduction in FOFDM System Using Group Codeword Shifting Technique

Azlan Yusof, Azlina Idris* and Ezmin Abdullah

Abstract— **Filtered Orthogonal Frequency Division Multiplexing (FOFDM) system is one of 5G multicarrier waveform that provide high data rate and capable improve spectral efficiency. The main disadvantage for FOFDM is high peak to average power ratio (PAPR) that faced by every multicarrier modulation technique. This paper we investigate used of a Group Codeword Shifting (GCS) method for peak to average power ratio (PAPR) reduction in FOFDM system. Beside that we also comparing result of peak to average power ratio (PAPR) reduction with low complexity in FOFDM used a Group Codeword Shifting (GCS) method with Median Codeword Shift (MCS), Selective Codeword Shift (SCS) method and Conventional FOFDM. The simulation result show that the Group Codeword Shifting (GCS) method is 45.5 % reduction compare with Conventional FOFDM, while 21.8% better than Median Codeword Shift (MCS) and 19.1% better than Selective Codeword Shift (SCS) method for peak PAPR reduction**

Index Terms— **Group Codeword Shifting (GCS), Median Codeword Shift (MCS), Selective Codeword Shift (SCS), Filtered Orthogonal Frequency Division Multiplexing (FOFDM), Peak to average power ratio (PAPR)**

I. Introduction

FOFDM knowns as Filtered Orthogonal Frequency Division Multiplexing is defined as one of the waveforms used in 5G technology.F-OFDM offers various distinguishing characteristics, including the ability to allow asynchronous transmission, low latency, and may help to improve spectrum efficiency in comparison to OFDM, which supports multiple asynchronous sub-band transmissions. The primary disadvantage of adopting the F-OFDM system is the high PAPR generated when the signal travels through the receiver's non-linear high power amplifier (HPA). When the F-OFDM has a big dynamic signal and a large number of subcarriers with the PAPR, the non-linear impact will be more sensitive. While there are several strategies for overcoming a high PAPR[1,2,3,4].Many studies and technique has been proposed to overcome on high PAPR value, by introduce few techniques for reduce the high PAPR value that can be divided into three main approach [5,6,7,8,9]. First the Signal Scrambling Techniques can be classified as Selective Mapping (SLM), Partial Transmit Sequence (PTS), Selective Codeword Shift (SCS), Interleaving, Tone Reservation (TR), Tone Injection (TI) and Active Constellation Extension (ACE). Secondly the Signal Distortion Techniques can be classified as Clipping & filtering, Companding, Peak Windowing and Envelop Scaling.

Thirdly Signal Coding Techniques can be classified as Block Coding and Turbo Coding. On the past research show the potential in PAPR reduction but they had to face with the trade off with some of the problem such as high computational complexity, degrade bit error rate (BER) performance, side information, loss data rates, bandwidth, loss spectral efficiency and distortion. In Block Coding technique it can be divide into two such as Arithmetic coding and Huffman coding, the Arithmetic coding is better on reducing PAPR by 32% compare Huffman only 30.6% [10]. The Clipping & Filtering technique is the simplest technique to reduce PAPR and it is depend on clipping level that satisfies the signal to quantization noise ratio (SQNR) [11]. PTS technique is better in reduce PAPR value compare with SLM and Clipping and filtering technique [12].If your paper is intended for a conference, please contact your conference editor concerning acceptable word processor formats for your particular conference.

The Selected Mapping (SLM) technique is multiple phase rotations are applied to the constellation points and the one used that minimizes time signal peak is used and selective mapping involve to generate a large set of vector with lowest resulting PAPR is selected. This technique actual transmit signal lowest PAPR is selected from set of sufficiently different signal which all represents the same information [8,13]. The advantage of SLM such as no distortion is introduced and Independent number of carrier while the disadvantage such as side information and degrade BER performance [14,15,16]. Due to this disadvantage the combination of SLM and clipping technique been applied to reduce PAPR [9]. The modified of SLM with M-QAM technique improve the PAPR value nearly 3.4dB [12].

In SLM technique it reduces PAPR value but at the same time it compromises the data rate of the system and also the computational complexity. For to choosing which technique that can reduce high PAPR value few criteria need to taking into account such as BER degradation at receiver, data rate loss,

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computational complexity, power increment in transmitted signal, PAPR reduction capability and bandwidth expansion [17,18,19]. The Selective Codeword Shift (SCS) and Median Cordword Shift (MCS) technique has shown significant improvement reducing PAPR compared to original signal and conventional SLM, however this technique only effective for modulation higher than 4 QAM or higher than 2 bits per symbol. The advantage of this technique are low computational complexity as compared to SLM technique in term of IFFT block used and no multiplication of phase factor involve in transmission process [20,21].

As shown in Figure 1 is the concept figure of GCS, R represents the binary sequence codeword having r total number of input bits and can be indicated as $R = [R_1, R_2, \dots, R_r]$. The serial to parallel converter will divide the codeword sequence into z number of sub-block denoted by $R = [R_1, R_2, \dots, R_z]$ and each sub-block will have y number of bits per symbol where $z = r/y$.Therefore, the representation for codeword for each sub-block can be written as $R1 = [R1, R2, R3, , \dots, Ry]$, $R2 = [Ry{+}1, Ry{+}2, Ry{+}3, \dots, R2y]$ and so on until Rz. In Group Codeword Shifting (GCS), the amount of sub-block and shifting is higher compare than MCS and SCS. Thus GCS will get more quality value compare than MCS and SCS. This value will indicate the value of PAPR and BER.

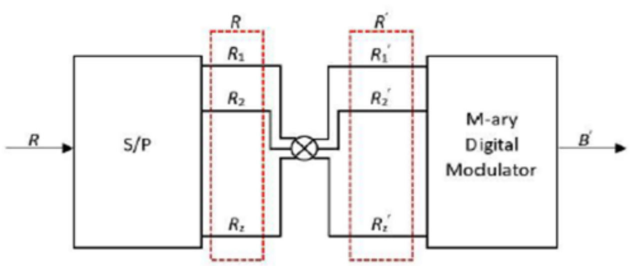

Fig. 1. GCS sub-block.

II. System Model

A. Filtered Orthogonal Frequency Division Multiplexing

Filtered Orthogonal Frequency Division Multiplexing (FOFDM) is another multicarrier modulation technique that has been presented also one of the potential waveforms for the development to 5G. FOFDM not only retains the features of OFDM used in 4G, but also shows significant versatility in spectrum usage based on diverse service situations, backward and forward consistency and also decreased OOBE [22,23,24]. After OFDM processing, the transmitted signal is sent to the transmitter filter which generates the transmitter FOFDM signal. The FOFDM receiver signal is first passed via the receiver filter, which is similar to the transmitter filter. The signal received from surrounding transmissions is filtered out by the receiver's filter. As a result, the receiver filter eliminates other signals' contributions, ensuring that the FOFDM signal is carried along to the next step without disturbance from several other signals [25,26].

The major goal of adding the filter to the transmitter is to limit the OFDM system's high OOBE level in order to facilitate asynchronous transmission and reduce latency [25,26]. As a result, the system's spectral efficiency improves allowing it to meet the 5G technology criteria. The high PAPR might be viewed as a potential obstacle for the FOFDM system, because the filter length exceeds the cyclic prefix (CP) time at the transmitter and the power distribution among the samples increases. This process reduces the signal's mean power and widens the gap between the greatest maximum output and the mean output of the FOFDM signal. As a result, the FOFDM system has a greater PAPR than the OFDM system [25,26].

Filter design is critical in F-OFDM for achieving frequency localization of the signal as well as more versatility among time and frequency localization. This is due to the fact that the intended frequency-domain localisation causes time-domain divergence. The filter structure that can establish a substantial balance in the filter's temporal and frequency localisation. Applying a time-domain window with smooth transitions, the soft truncation of a filter is used in specific [27,28,29]. For appropriate filtering, the filter employed for the filtered OFDM should have some of the qualities listed such as for the sub-carriers a flat passband is required. Secondly a sharp transition is required for the filter in attempt to reduce guard band usage. Thirdly the sufficient stop band attenuation is required [29,30].

The sinc filter, also known as a perfect low pass filter, exhibits all of the aforementioned characteristics. This filter removes all frequency components over a cutoff frequency and reaction is a rectangular function. The inverse Fourier transform (IFT) of the filter's frequency reaction is used to determine the sinc filter impulse reaction [29,30].

This impulse response must be trimmed with a window and the window's goal is to change the limitless impulse response to a limited response and produces a seamless zero transition at both ends. The result of the reduced sinc function has some waves. Stretch both ends of the low pass filter with tone offset to prevent these waves. The excess number of sub-carriers added to the intended output is referred to as tone offset [30,31]. In order to recover the intended signal on the receiver side, a matching filter is utilised in the receiver portion, which correlates a known signal with the unknown signal. The intended signal is combined with AWGN in the received signal. The matching filter's goal is to separate the intended signal from the noisy received signal. Because the noise power is greater than the signal power in this scenario, the SNR value is increased. A matching filter is employed in the Filtered OFDM at the receiver portion to boost the SNR value [30,31].

In the SCS and MCS technique the codeword is circulant shifting and the time to complete this circulant shifting is longer because the codeword take a long path to travel. The effect of that, the value of PAPR and BER will not reduce so much in SCS and MCS technique. In this paper the Group Codeword Shifting (GCS) is propose, the codeword is divided into 2 part (part A and part B) so it will make a shorter path for codeword to shifting. The value of PAPR and BER is reduce more compare than SCS technique on GCS.

B. Filtered OFDM Based on GCS

The formation of FOFDM signal for *N* number of subcarriers begin with the conversion of input data into information symbol via serial-to-parallel process. Then, modulating process will be conducted using 64-QAM and mapped the information symbol into the constellation point. Finally, Inverse Fast Fourier Transform (IFFT) will transform the modulated symbol into an FOFDM signal. This whole process is illustrated in Figure 2. In the green box after the serial to parallel process, where the GCS technique has been coded.

In this paper the Group Codeword Shifting technique is generate alternative codeword by altering the codeword structure followed by using permutation process (circulant shift) in order to generate a scramble data sequence for better PAPR reduction. This Group Codeword Shifting technique is aiming on the arrangement of the codeword and the bits structure in reducing PAPR, by manipulating on these two parameters the alternative codeword having lower PAPR will be producing.

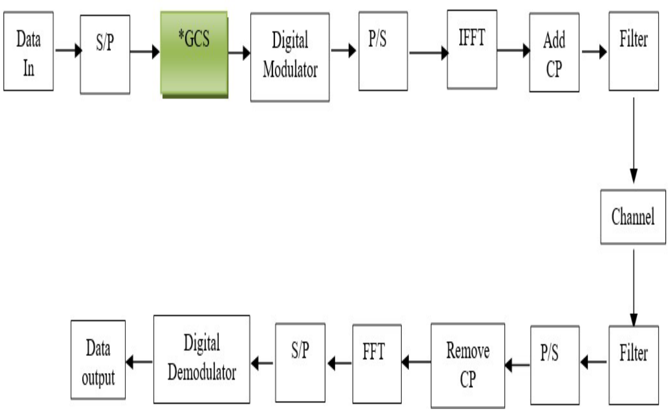

Fig. 2. Block diagram of FOFDM GCS.

The first step performed by group codeword shifting technique is modify the arrangement of the codeword by dividing it into two parts, part A and part B as shown in Figure 4. The second step is the one that will generate the alternative codeword by implementing the circulant shift between part A, and part B one at a time. To get better understanding, the position of bits after δ number of shifting process is show in Table 1. The initial position of the codeword bits is represented by Codeword $R_{1,0}$. When the shifting process took place between part A and part B, its new bit position will be represented by Codeword $R_{1,1}$. The new alternative codeword sequence can be expressed as $R' = [R1', R2', \ldots, Rz']$. Finally, the alternative FOFDM signal with lowest PAPR value will be chosen for transmitted.

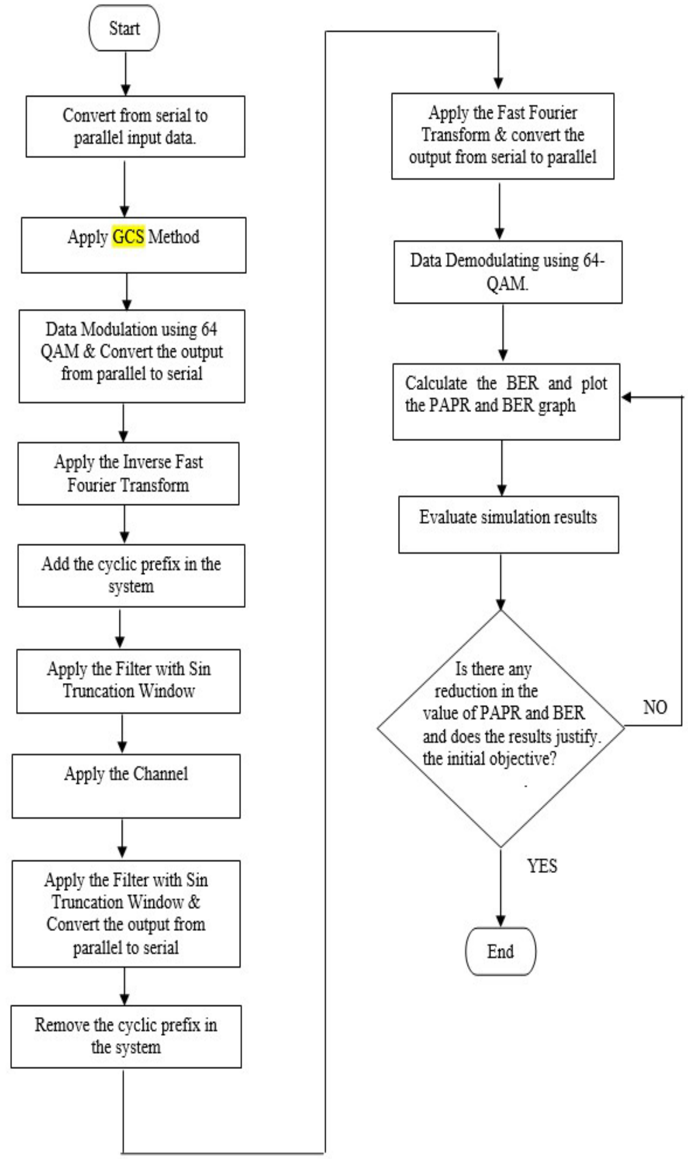

Fig. 3. Flowchart of the simulation process.

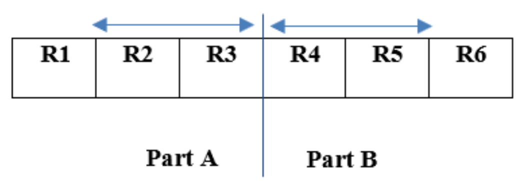

Fig. 4. Group Codeword Shifting structure

TABLE I
BIT ARRANGEMENT OF CODEWORD FOR GROUP CODEWORD SHIFTING METHOD

Sub-block codeword bits, $R_{z,\delta}$	Position of bits
Codeword, $R_{1,0}$	R1, R2, R3, R4, R5, R6
Codeword shift 1, $R_{1,1}$	R4, R2, R3, R1, R5, R6
Codeword shift 2, $R_{1,2}$	R1, R4, R3, R2, R5, R6
Codeword shift 3, $R_{1,3}$	R1, R2, R4, R3, R5, R6
Codeword shift 4, $R_{1,4}$	R5, R2, R3, R4, R1, R6
Codeword shift 5, $R_{1,5}$	R1, R5, R3, R4, R2, R6
Codeword shift 6, $R_{1,6}$	R1, R2, R5, R4, R3, R6
Codeword shift 7, $R_{1,7}$	R6, R2, R3, R4, R5, R1
Codeword shift 8, $R_{1,8}$	R1, R6, R3, R4, R5, R2
Codeword shift 9, $R_{1,9}$	R1, R2, R6, R4, R5, R3

III. RESULT AND DISCUSSION

In this section, the PAPR performance of GCS will be evaluated through simulation. In the simulation, N = 128 random input symbols are generated, and they are all mapped using 64-QAM modulation. The FOFDM signal will be transmitted over AWGN channel. The cyclic prefix with the length of 1/4 is add to the FOFDM symbols for minimize the effect of inter-symbol interference (ISI). All the parameter used in the simulation process are summarized in Table 2.

TABLE II
SIMULATION PARAMETERS [32]

Parameter	Value
Bandwidth (BW)	8068.58 Hz
FFT length	512
Tone offset	2.5
L (filter length)	512
Modulation Technique	64QAM
Cyclic Prefix Length	1/4
Channel Model	AWGN

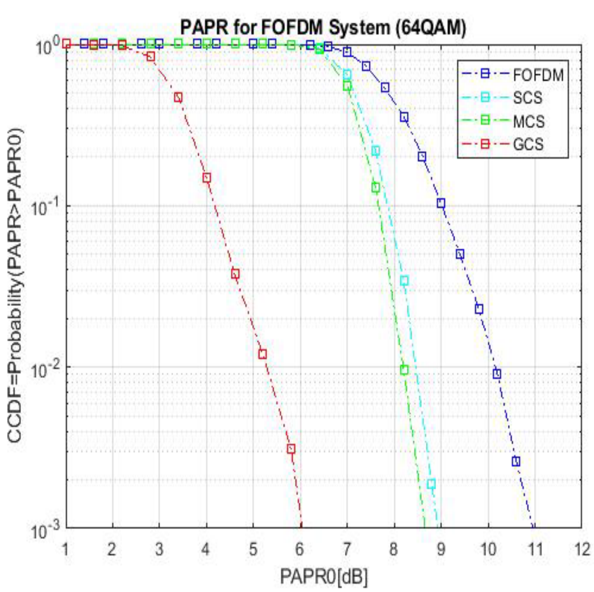

Fig. 5. PAPR Performance for GCS, MCS, SCS and Original on FOFDM.

TABLE III
PAPR ANALYSIS OF GCS, MCS, SCS AND ORIGINAL FOFDM

	PAPR	% of Improvement
Original	11	-
SCS	8.9	19.1
MCS	8.6	21.8
GCS	6.0	45.5

Figure 5 indicate the PAPR performance between SCS and GCS on Original FOFDM. While the data on table 3 shown the PAPR analysis for FOFDM on SCS, MCS and GCS. The original value of FOFDM is 11dB, the percentage of improvement for SCS against FOFDM is 19.1% at 8.9dB while for MCS is 21.8% improvement at 21.8dB and GCS is manage achieved higher than SCS and MCS with 45.5% of improvement at 6.0dB. By shifting the codeword structure given the impact on GCS PAPR performance, beside that more candidate of bits also give more chance to get more quality value. Another factor is random arrangement, when have more candidate there is more random arrangement of shitfting. The more arrangement of shiting the good value of PAPR and BER will get.

Figure 6 indicates the BER performance between MCS,SCS and GCS on Original FOFDM. While the data on Table 4 shown the PAPR analysis for FOFDM on MCS, SCS and GCS. The original value of FOFDM is 14.1dB, the percentage of improvement for MCS, SCS against FOFDM is 0% at 14.1dB while for GCS is manage achieved higher than MCS, SCS and Original FOFDM with 3.5% of improvement at 13.5dB. By shifting the codeword structure given the impact on GCS BER performance,beside that more candidate of bits also give more chance to get more quality value. Another factor is random arrangement, when have more candidate there is more random arrangement of shitfting. The more arrangement of shiting the good value of PAPR and BER will get.

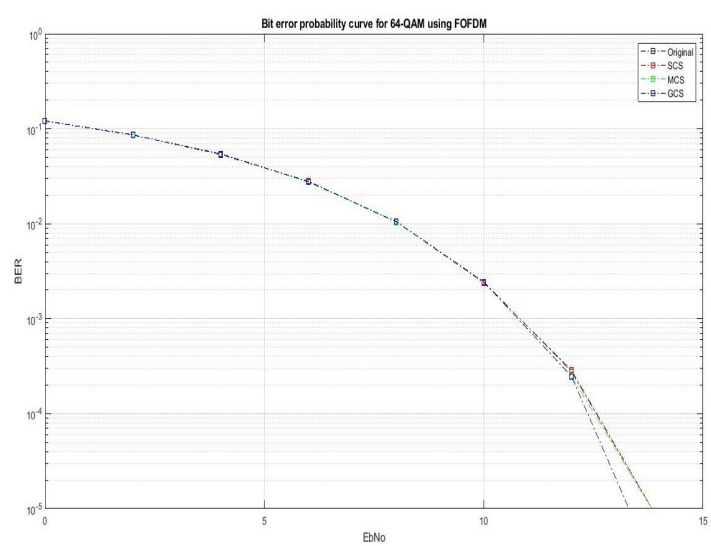

Fig. 6. BER Performance for GCS, MCS, SCS and Original on FOFDM

TABLE IV
PAPR ANALYSIS OF GCS, MCS, SCS AND ORIGINAL FOFDM

	BER	% of Improvement
Original	14.1	-
SCS	14.1	-
MCS	14.1	-
GCS	13.5	3.5

IV. CONCLUSION

In this paper, a GCS method has been proposed to reduce PAPR that the major problem of FOFDM systems. The GCS has shown a significant improvement in reducing high PAPR when comparing with MCS, SCS and original signal FOFDM. However, this method has a limitation that only effective for modulation higher than 4 QAM or higher than two bits per symbol. The advantage of GCS method is low computational complexity by reducing the usage of IFFT block in the system compare than MCS, SCS and original FOFDM. The applications of this GCS method will be apply at the transceiver. Further research needs to be carried out to evaluate the PAPR performance of GCS scheme in different modulation techniques for other applications.

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