



Reduce PAPR in Filtered-CPOFDM using Hybrid Method System

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ABSTRACT

5G multicarrier waveform Filtered Cyclic Prefix Orthogonal Frequency Division Multiplexing (F-CPOFDM) allows for high data speeds and increases in spectrum efficiency. The main drawback of F-CPOFDM is its high peak-to-average power ratio (PAPR), a common element of all multicarrier modulation schemes. In this research is investigate the implementation of a Hybrid strategy to reduce the peak to average power ratio (PAPR) in a F-CPOFDM system and evaluated the impact of employing a Hybrid Technique with Group Codeword Shift (GCS), Median Codeword Shift, Selective Codeword Shift (SCS), and Conventional F-CPOFDM on the reduction of peak to average power ratio (PAPR) in CP-OFDM. The novelty of this research is GCS method integration with WHT Precoding technique for reduce PAPR. Simulation results show that compared to traditional Filtered-CPOFDM, the GCS-WHT method reduces peak PAPR by 59.46 %, while the SCS- method reduces it by 32.43 % and the MCS-WHT method reduces it by 31.53%. Compare to the non-hybrid technique, the GCS only reduce 45.95%, while for SCS and MCS reduce 19.82% and 23.42% respectively. From the results, shows that Hybrid method is better performance compare with non-hybrid method.

1. Introduction

The high PAPR is the main drawback for multicarrier signal and a lot of study and method has been establish to overcome this drawback. This method can be categorized in three main groups [1-5]. Group one which is signal scrambling methods include selective mapping (SLM), partial transmit sequence (PTS), selective codeword shift (SCS), interleaving, tone reservation (TR), tone injection (TI), active constellation extension (ACE) and Precoding. Second group is Signal Distortion Methods Include Clipping and Filtering, Comanding, Peak Windowing, and Envelop Scaling. The third group which is signal coding methods, namely Block coding and Turbo coding.

The research for reducing PAPR method have demonstrated that reducing PAPR is achievable, however, it comes at the cost of other measures, such as processing complexity, efficacy in reducing Bit Error Rate, handling auxiliary data, preserving information percentage, utilizing bandwidth and

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spectrum efficiently, managing computational complexity, and minimizing distortion. Arithmetic coding and Huffman coding are two examples of Block Coding methods. The signal-to-quantization-noise ratio (SQNR) is taken into account while determining the appropriate clipping level to use in order to reduce PAPR [6]. When comparing PTS to SLM and Clipping and Filtering, you can see that PTS considerably lowers the PAPR value [7]. Selected Mapping (SLM) requires carrying out many phase rotations on the cluster spots and then using the one with the smallest amplitude of the duration output.

This objective is achieved by generating a comprehensive collection of variables and thereafter identifying the variable with the minimum Peak-to-Average Power Ratio (PAPR). From a set of sufficiently different signals that all represent the same data, the one with the lowest PAPR is chosen for transmission [4,8]. SLM's advantages include minimal distortion and a free-floating number of carriers, but its disadvantages include unnecessary side information and inefficient BER [9-11]. Because of this shortcoming, a hybrid strategy involved both of SLM and clipping approaches in order to mitigate PAPR [5].

By using a customized SLM with M-QAM strategy raises the PAPR value by about 3.4dB [8]. While the SLM strategy does succeed in lowering the PAPR value, it comes at the expense of a lower data rate and increased computational complexity in the system. Several factors, such as receiver BER degradation, data rate loss, computational complexity, transmitted signal power increase, PAPR reduction capabilities, and bandwidth expansion [12-14], must be taken into account when selecting which strategy may decrease a high PAPR value.

Another method for reducing PAPR is the Selective Codeword Shift (SCS) that has demonstrated a notable enhancement in PAPR reduction in contrast with the initial data and traditional SLM; however, this method can only be used with modulation of more than 4 QAM or more than 2 bits per symbol. Since no phase factor multiplication is performed during the transmission operation, the IFFT block used in this method has a lower computational complexity than SLM [15,16].

In the SCS method, the codeword undergoes circulant shifting, which takes more time to complete because of the codeword's longer route. This means that the SCS approach's PAPR and BER reductions will be less than optimal. Due of weakness of SCS method, the Group Codeword Shifting (GCS) is designed a method for expedited codeword switching achieved by partitioning the codeword into two groups, A and B.

The SLM, SCS and MCS technique is the effective technique for reduce PAPR in the F-CPOFDM system compare to another method because this technique utilises various signalling and probabilistic methods, specifically based on the interleaving method. The MCS and SCS technique are under multiple signalling and probabilistic technique. The Selective Codeword Shift (SCS) and MCS technique has demonstrated remarkable breakthroughs in decreasing Peak-to-Average Power Ratio (PAPR) when compared to the original signal and standard Selected Mapping (SLM) technique.

This study introduces the Group Codeword Shifting (GCS) technique, which involves dividing the codeword into two segments (part A and part B) to enable codeword shifting. The PAPR approach shows a lower value compared to the SCS and MCS methods when applied to the GCS. The Precoding WHT method has been selected to be integrated with GCS, SCS, and MCS methods due to its ability to decrease system complexity and greatly reduce the Peak-to-Average Power Ratio (PAPR). No previous research has been conducted on the combination of precoding WHT method with GCS, SCS, and MCS methods for the purpose of minimizing PAPR.

2. Methodology

This section discusses on filtered cyclic prefix orthogonal frequency division multiplexing (F-CPOFDM), Walsh Hadamard Transform (WHT) precoding and hybrid method on F-CPOFDM.

2.1 Filtered-Cyclic Prefix Orthogonal Frequency Division Multiplexing (F-CPOFDM)

Another multicarrier modulation strategy that could clear the way for 5G's introduction is filtered cyclic prefix orthogonal frequency division multiplexing (F-CPOFDM). Although F-CPOFDM may retain only the properties of the OFDM used in 4G, it shows significant flexibility in spectrum utilization depending on a variety of application scenarios, backward and forward stability, and enhanced OOB [17-19].

At first, the F-CPOFDM receiver signal is filtered using the reception trims, which is the same as the broadcaster filter. The receiver's filter eliminates information from surrounding transmissions. The receiver filter attenuates interference from other signals to guarantee that the F-CPOFDM data is sent with little interference from other signals [20,21]. To enable parallel transmission and reduce latency [20,21] the filter is introduced to the transmitter to limit the excessive OOB value of the OFDM system.

The system's spectrum effectiveness is improved as a result, has led to its compliance with the requirements for 5G technology. The F-CPOFDM system may have difficulties when dealing with a large peak-to-average power ratio (PAPR), as the dimension of the filter surpasses the cyclic prefix (CP) duration during transmission. Consequently, this results in an amplification of power distribution throughout the samples. As a result of this process, the mean energy of the signal is reduced, and the gap between the peak and average power of the F-CPOFDM signal widens. As a result, PAPR in the F-CPOFDM system is higher than in the OFDM system [20,21].

To achieve signal frequency localization and greater flexibility between time and frequency localization, filter layout is key in F-CPOFDM. This is due to the divergence in the time domain brought on by the targeted frequency-domain focus. The filter design that strikes a suitable middle position between temporal and frequency localization. In certain cases, a time-domain window with gradual changes is used to perform a soft truncation of a filter [22-24].

Some of the criteria on the list, like a flat passband for the sub-carriers, must be present in the filter used for the F-CPOFDM. To reduce the filter's consumption of guard bands, it must have a fast transition. Thirdly, there needs to be enough attenuation in the stop band [24,25]. The sinc filter, frequently referenced as an exemplar of an ideal minimal band filter, demonstrates all of these attributes. The rectangular-function filter effectively reduces frequencies over the threshold frequency. An IFFT is performed on the frequency response of a sinc filter to get its impulse response [24,25].

In order to customize this impulse reaction, its need to utilize a window that converts the infinite impulse reaction into a finite one and produces a nice insignificant changeover at all sides. Multiple waves can be seen in the output of the reduced sinc function. To mitigate these sine waves, a low-pass tone-offset filter with longer lobes is required. Tone offset is the surplus of subcarriers in the final signal [25,26].

A fitting filter is used in the receiver section to link an identified signal with an unidentified signal in an effort to recover the desired signal. Both the targeted signal and the Rayleigh are present in the received signal. To isolate the target signal from the noisy background, a fitting filter is applied. In the given context, the signal-to-noise ratio (SNR) experiences enhancement due to the prevailing

condition where the strength of the disturbance surpasses that of the signal. To enhance the signal-to-noise ratio, F-CPOFDM employs a fitted filter in the receiver [25,26].

2.2 Walsh Hadamard Transform (WHT) Precoding

In order to reduce the interference caused by the presence of several users in the F-COFDM system and to get a signal with minimized PAPR, the following section details precoding approaches that can be employed. It is crucial that PAPR mitigation strategies account for the HPA's nonlinearities before proceeding. The Walsh Hadamard Transform (WHT) is a linear transform that is orthogonal, but non sinusoidal. The incoming signal is processed by WHT in a linear, orthogonal form.

WHT transforms a signal into a set of primitive operations. Walsh functions, which are square waves in nature, can take on either a +1 or -1. The high peaks may be less common with the suggested WHT technique than with the original F-CPOFDM system. WHT eliminates the need for auxiliary data by decreasing input sequence autocorrelation, which in turn lessens the PAPR problem. Precoding-based approaches have the advantages of requiring neither additional bandwidth nor additional power, losing neither data rate nor BER, and reducing the amount of distortion in the signal. The kernel of the WHT acts as a pre-coding matrix P of dimension $N=L*L$, as given in the following equations [27,28]:

$$H_1 = [1] \quad (1)$$

$$H_2 = \frac{1}{2} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (2)$$

$$H_{2N} = \frac{1}{2N} \begin{bmatrix} H_N & H_N \\ H_N & H_N^{-1} \end{bmatrix} \quad (3)$$

To reduce the F-CPOFDM system's peak, precoding techniques employ numerous transformations or matrices. Before the IFFT block, the modulated symbol is multiplied by the precoding matrix. Linearity characterizes the Walsh Hadamard Transformation. There is no increase in system complexity as a result of WHT.

Square waves, or Walsh functions, can take on either a +1 or -1 value. The strong auto-correlation attribute of the IFFT block is the primary cause of the high PAPR. WHT may be used to reduce the autocorrelation of the input sequence, which in turn reduces the number of high peaks without compromising the transmission of any additional information [29,30].

2.3 Hybrid Method on F-CPOFDM

The main novelty of this research is GCS technique that has been develop to reduce PAPR by enhancement SLM technique. Another novelty on this paper is hybrid technique that combination between GCS technique and WHT precoding technique.

The combination of two or more techniques will produce a hybrid technique that has a good PAPR reduction and BER. Normally the Walsh-Hadamard Transform (WHT) technique is used in hybrid due to its simplicity compared to other techniques. In this research, the hybrid technique is combining between WHT method with the GCS, MCS, SCS and Original F-CPOFDM to reduce the value of PAPR and BER more efficient.

F-CPOFDM signals for N subcarriers are built from the base up using a serial-to-parallel symbol translation of the incoming data. The 64-QAM modulation process will subsequently be used to send

the information symbol to the constellation node. The technique of Group Codeword Shifting is employed in this research to develop novel codewords through the modification of codeword patterns. Subsequently, a permutation process, namely a circulant shift, is applied to construct a scrambled data sequence that exhibits an enhanced decrease in Peak-to-Average Power Ratio (PAPR). To reduce PAPR, this Group Codeword Shifting technique concentrates on adjusting the codeword's physical layout and its underlying bit architecture.

In Figure 1, $R = [R_1, R_2, \dots, R_r]$ represents the binary series codeword with r cumulative input bits. The serial-to-parallel converter will partition the codeword sequence into z blocks, denoted by $R = [R_1, R_2, \dots, R_z]$, each containing y symbols with r bits per symbol. Each subcodeword block is therefore described as follows: $R_1 = [R_{1,1}, R_{1,2}, R_{1,3}, \dots, R_{1,y}]$; $R_2 = [R_{2,1}, R_{2,2}, R_{2,3}, \dots, R_{2,y}]$; and so, on up to R_z .

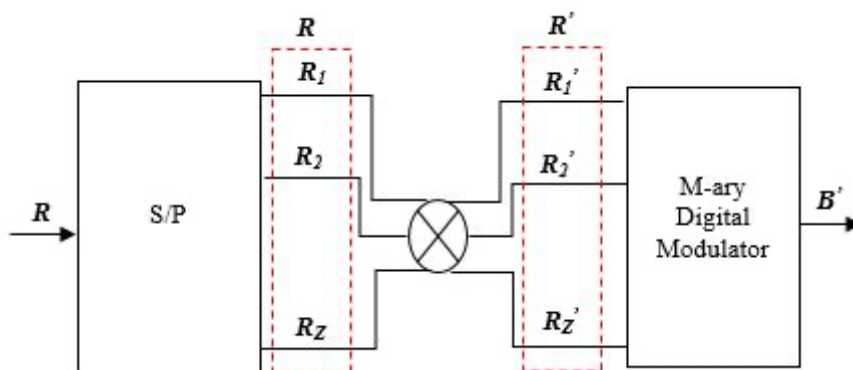


Fig. 1. GCS sub-block [8]

The first step of the group codeword shifting method is to split the codeword into two halves, A and B, as shown in the Figure 2. During the subsequent stage of development, the generation of the novel codeword is achieved through the independent execution of the circulant shift operation on sections A and B.

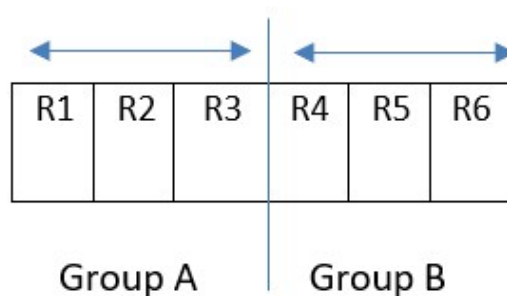


Fig. 2. Group codeword shifting structure [8]

The positions of bits following a specific shift action are presented in Table 1 for the purpose of enhancing clarity. Codeword $R_{1,0}$ represents the first bit position in the codeword. As a result of the exchange of bits in parts A and B, the new position of bit A will be represented by Codeword $R_{1,1}$. The modernized option codeword sequence is expressed by the expression $R' = [R_1', R_2', \dots, R_z']$. Transmission will be prioritized to the Filtered-CPOFDM signal with the lowest PAPR.

Table 1
 Bit arrangement of codeword for group codeword shifting method [8]

Sub-block codeword bits, $R_{z,\delta}$	Position of bits
Codeword, $R_{1,0}$	R1, R2, R3, R4, R5, R6
Codeword shift 1, $R_{1,0}$	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

The efficiency of GCS's PAPR will be assessed computationally. Using 64-QAM modulation, the simulation generates and maps $N = 128$ symbols of random input. Once the modulated symbol is complete, the input signal N is complex vector transformed by WHT matrix ($N = PX$). Then IFFT operation is performed on Y like: $y = \text{IFFT}(Y)$, where $y = [y(1), y(2), \dots, y(n)]^T$. The transmission path will be a Rayleigh channel. At the receiver end FFT transform is applied to the signal $y^{\wedge}(n)$, i.e., $Y^{\wedge} = \text{FFT}(y^{\wedge}(n))$. Where $y^{\wedge} = [y^{\wedge}(1), y^{\wedge}(2), \dots, y^{\wedge}(N)]^T$. Then inverse WHT transform is applied to the signal Y^{\wedge} i.e., $X^{\wedge} = P^T Y^{\wedge}$. Then the obtained signal X^{\wedge} is de-mapped to bit stream. To mitigate InterSymbol interference (ISI), the Filtered-CPOFDM symbols also have a cyclic prefix of length 1/4. Figure 3 depicts the full process and all simulation-related settings are summarized in Table 2 and in Figure 4 show the flowchart of the simulation process for Hybrid Method.

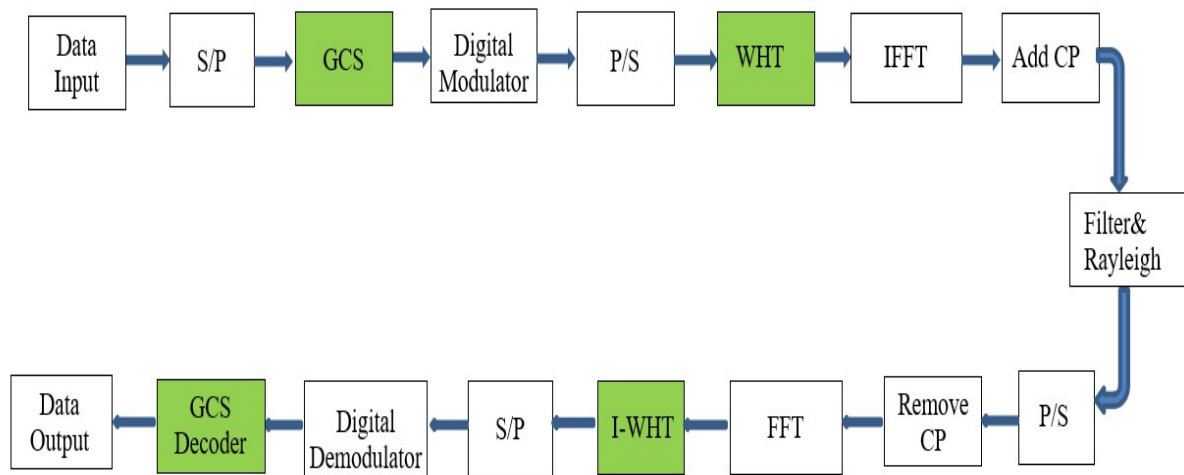
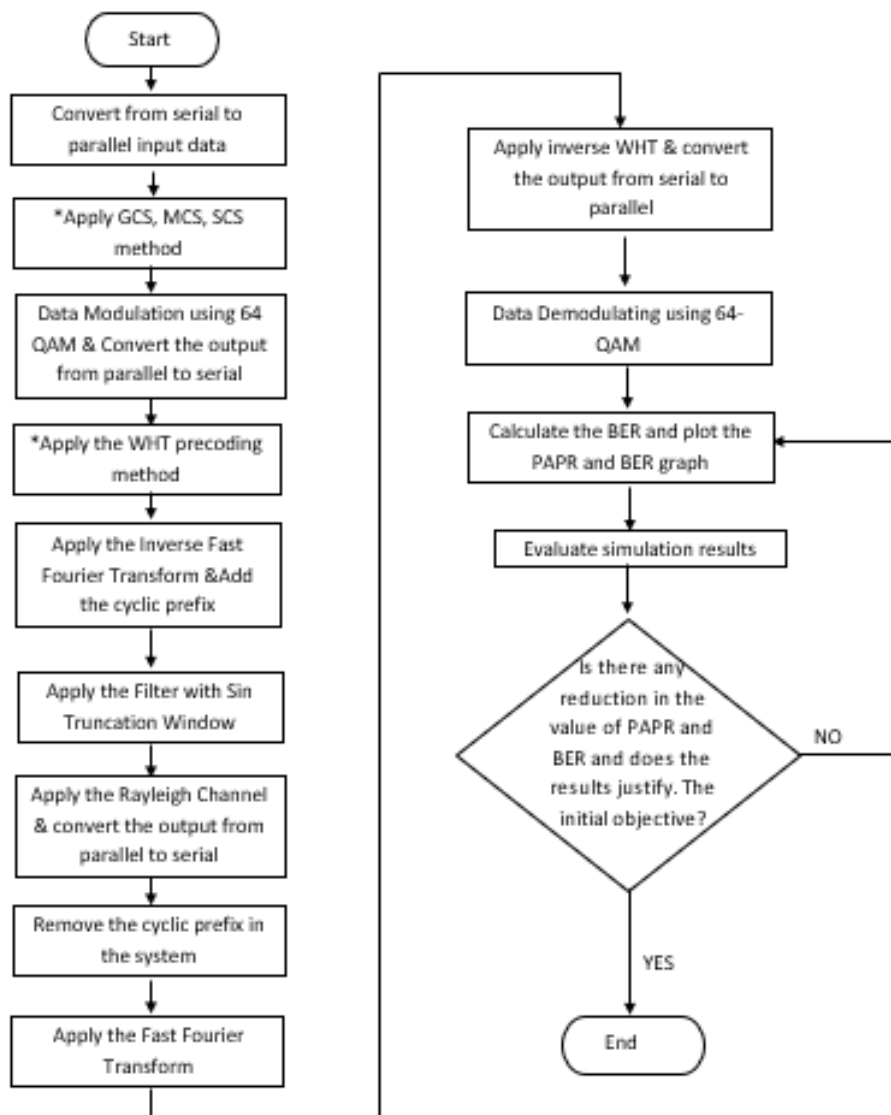


Fig. 3. Block diagram of hybrid system

Table 2
 Simulation parameters for 3rd Generation Partnership
 Project Long Term Evolution (3GPP-LTE) System [35]

Parameter	Value
Bandwidth (BW)	1.25MHz
Sampling frequency	1.92MHz
Sampling time	5.208×10^{-7} sec
IFFT size	128
Used subcarrier	76
Modulation technique	64QAM
Cyclic prefix length	1/4
Channel model	Rayleigh



*Proposed Hybrid method

Fig. 4. Flowchart of the simulation process for Hybrid Method

3. Results

In this article we evaluate the efficiency of the hybrid and non-hybrid method for lowering PAPR and BER. Figure 5 illustrates the PAPR performance of the hybrid WHT precoding technique combined

with SCS, MCS, GCS, and F-CPOFDM, compared to the original SCS, MCS, GCS, and F-CPOFDM without the WHT precoding technique combination.

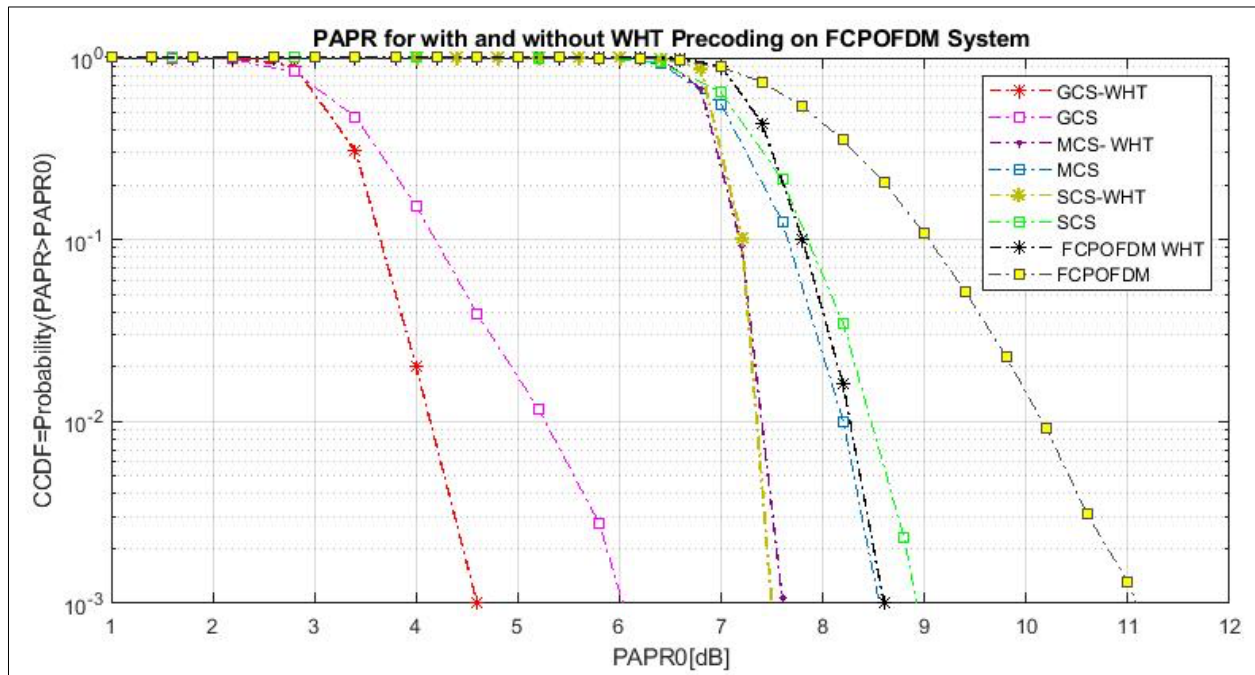


Fig. 5. PAPR performance for various techniques with and without WHT Precoding

The graph at CCDF 10^{-3} in Table 3 indicates that the original value of F-CPOFDM is 11.1 dB, while the Hybrid WHT precoding of F-CPOFDM is 8.50 dB at CCDF Probability 10^{-3} . This is a significant improvement of 23.42% for the hybrid WHT precoding technique compared to the original value of F-CPOFDM. The Hybrid WHT precoding combination, when used in conjunction with the SCS and MCS approach, demonstrates improvements of 32.43% and 31.53% respectively, compared to the original SCS and MCS technique. Moreover, the Hybrid WHT precoding combination with GCS technique show a significant enhancement of 59.46% when compared to the Hybrid WHT precoding combination with SCS and MCS technique. Additionally, it achieves the lowest PAPR value at 4.50 dB. The outcome is affected by the random layout, which contributes to a variety of potential lowest PAPR values. The GCS approach is capable of generating a larger number of candidates, hence increasing the available options. Nevertheless, excessive shifting does not have an impact on the PAPR outcome. Another contributing element is the increased number of candidates, which leads to a greater degree of randomness in the arrangement of the bits and their shifting. The greater the arrangement of shifting the desirable value of PAPR will be obtained.

Table 3

PAPR evaluation of various techniques on with and without WHT Precoding (PAPR = 10^{-3})

	PAPR	% of Improvement
F-CPOFDM	11.10	-
SCS	8.90	19.82
MCS	8.50	23.42
GCS	6.00	45.95
F-CPOFDM WHT	8.50	23.42
SCS WHT	7.50	32.43
MCS WHT	7.60	31.53
GCS WHT	4.50	59.46

Figure 6 indicates the BER performance for the hybrid WHT precoding Technique combination with SCS, MCS, GCS, and F-CPOFDM against the original SCS, MCS, GCS and F-CPOFDM without combination with WHT precoding technique. Summarize from graph show the hybrid approach for GCS WHT is lowest by $30 \times 10^{-4.3}$, MCS WHT is $30 \times 10^{-3.9}$, SCS WHT is $30 \times 10^{-3.7}$ and F-CPOFDM WHT is $30 \times 10^{-3.2}$. While for non-hybrid for GSC is $30 \times 10^{-3.2}$, SCS is $30 \times 10^{-2.9}$, MCS and F-CPOFDM is $30 \times 10^{-2.8}$. It is show that hybrid approach is better BER compare non-hybrid, the result is influenced by random arrangement contribute the several number of lowest BER possibilities. The GCS technique capable to provide more candidate, so that more choice can be used. However too far shifting doesn't affect the BER result. Another factor is the random arrangement of the bits, when having more candidates there is a more random arrangement of shifting. The more arrangement of shifting the good value of BER will get.

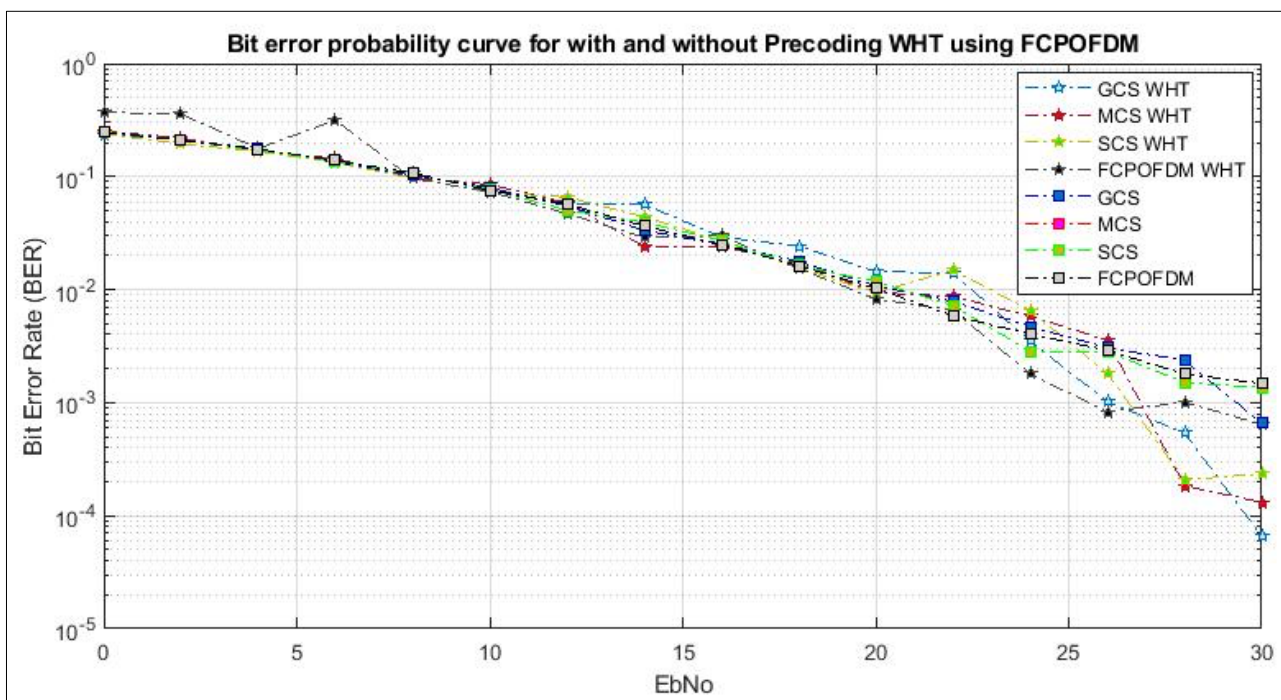


Fig. 6. BER reliability for various techniques with and without WHT Precoding

4. Conclusions

In Figure 5 and Figure 6, we compare the PAPR and BER performance of hybrid and non-hybrid of MCS, SCS and GCS on the fundamental drawback of all multicarrier modulation techniques is their

inability to reduce PAPR and BER in the system, however the results of this study demonstrate that the hybrid GCS- WHT shows a superior approach compared to the MCS-WHT, SCS-WHT, and the original signal Filtered-CPOFDM. The computational cost of the GCS-WHT is lower than that of the SCS-WHT, MCS-WHT, and the original Filtered-CPOFDM because fewer IFFT blocks are used; this helps to reduce the PAPR by 59.46% and achieve the lowest possible BER. However, this method is only effective for modulations with more than 4 QAM or more than 2 bits per symbol. The transceiver will perform the tasks required by this GCS approach. More research is needed to examine the PAPR performance of the GCS system in alternative modulation ways and for alternative objectives. For the future work, hybrid technique should be applied for another multicarrier signal such as Universal Filter Multi Carrier (UFMC) and Filter Bank Multi Carrier (FBMC).

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