Journal of Advanced Research in Applied Sciences and Engineering Technology 34, Issue 2 (2024) 246-255

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Reduction of PAPR for STFBC MIMO F-OFDM using Enhancement Asymmetric Arithmetic Coding Scheme

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ARTICLE INFO

Article history:
Received 20 July 2023
Received in revised form 15 November 2023
Accepted 23 November 2023
Available online 7 December 2023

ABSTRACT

The advancement of mobile communications has rapidly expanded in recent years, with the invention of transmitting and receiving system technology. The use of multiple antennas, also known as Multiple-Input Multiple-Output (MIMO) technology, is a key feature in modern wireless communication systems such as 5G. MIMO utilizes multiple antennas at both the transmitter and receiver to improve the system's performance in terms of data rate, link reliability, and spectral efficiency. In this paper, a block coding technique, was deployed to enhance the reliability of data transmission and introducing redundancy and error correction capabilities. These techniques involve encoding data into blocks and adding redundancy bits, which allow the receiver to detect and correct errors that may occur during transmission. The encoding technique, called the Asymmetric Arithmetic Coder (AAC), and it is supported in 5G system to provide high speed signal transmission in multiple users' environment. For retrieving a smooth signal at the receiver, a filter was introduced to improve its efficiency of the wireless link. However, the existing filter in the system, caused the increasing of the peak-to-average-power-ratio (PAPR) at the transmitter system. Thus, the block coding technique was implemented to increase the efficiency and reduced the power ratio. The most common block coding technique for wireless communication is AAC technique. The AAC technique was founded to reduce the power ratio and further improve the signal diversity. Recently, for the application of 5G, the AAC was enhanced by adding the number of symbol and improved the PAPR. It is called the Enhancement Asymmetric Arithmetic Coding (EAAC) technique. The EAAC contributes to the lower value of the PAPR. With the use of EAAC as the block coding technique, the transmitter is said to support the system and thus improved the PAPR measurements by 5.5%. Lastly, the reduction of PAPR contributes to minimize the distortion and enhanced spectral efficiency for wireless communication system.

Keywords:

PAPR; 5G; Multiple Input Multiple Output; Enhancement Asymmetric Arithmetic Coding; Antennas

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https://doi.org/10.37934/araset.34.2.246255

1. Introduction

Wireless communications have become a prominent medium that provides massive signal transmission services to retrieve information for the past few years. Moving towards high-speed data transmission, considering 5G, is idealized to have a good voice quality, tolerance to noise, higher network capacity, low latency and more practical in real-time environment [1]. However, 5G is still suffering from signal interference that affects the performance of the system, which involved signal losses due to multipath propagation [2]. For a general, multicarrier modulation has commonly been used to enhance the system. Currently, a technique named filtered Orthogonal Frequency Division Multiplexing (F-OFDM) is proposed for 5G network [3].

F-OFDM is a technique that extended from OFDM with the operation of converting the signals in frequency domain before transmitting [4]. F-OFDM uses a filtering technique to reduce the out-of-band radiation that can cause interference with other wireless systems. The filter is applied to the OFDM signal to shape the spectral response of each subcarrier, which reduces the power of the subcarriers outside the desired frequency band [5]. This results in improved spectral efficiency and reduces the potential for interference with other wireless systems.

Thus, the transmitter shows a good performance for speed diversity. Diversity is a technique that improved multipath propagations by enhancing the reliability of the received signals. F-OFDM produces large PAPR during its transmission and somehow minimizing the performance of the wireless link [6]. Efficiency of signals transmission involved data encoding. The process of encoding data has many techniques such as Arithmetic Coding (AC) and Huffman Coding (HC). Both coding techniques show their compression abilities. HC determines a bit to each symbol. Meanwhile AC assigned a random serial numbers factorization to block codes accordingly [7]. However, these two coding techniques encountered losses of bit during data compression [8]. Losses of data during transmission reduced the system's performance. Asymmetric Numeral System (ANS) has been introduced to overcome this problem. The ANS showed the symmetrical coding bit with a single natural number as the state, instead of two as compared to AC. Besides, the ANS is simpler as compared to Arithmetic and Huffman coding.

This research proposes the development of filter with OFDM and the enhancement of ANS coding technique. It is called the Enhancement Asymmetric Arithmetic Coding (EAAC). EAAC is the joint method of ANS and AC. The detailed operational EAAC is discussed in the paper. This technique will minimize the values of PAPR and increase the reliability of wireless communications [9].

Wireless communication is a type of transferring information and signal wirelessly and increase the speed of signal transmission [1]. Increasing the speed of the signal transmission will contribute to the increasing of PAPR due to the filter of the multiplexer [7]. The PAPR is the entity that can affect the performance of the transmitter model of the wireless system that is measured in decibel (dB). The value of PAPR has been reduced to increase the performance of the system by using Eq. (1), considering the values of square peak value divided by the root mean square (RMS) value. Clearly stated as the PAPR formula, and it is shown in Eq. (1).

$$PAPR = \frac{\max\,[x(t)]^2}{E[x(t)]^2} \tag{1}$$

where, $\mathbf{max}\left|\,\mathbf{x}\,(\mathbf{t})\right|^{\mathbf{2}}$is the peak signal power and $\mathbf{E}\left[\left|\,\mathbf{x}\,(\mathbf{t})\right|^{\mathbf{2}}\right]$ is the average signal power. On the general overview of the wireless system, Figure 1 is considered to contributes to the reduction of the PAPR of the signal at the transmitter system.

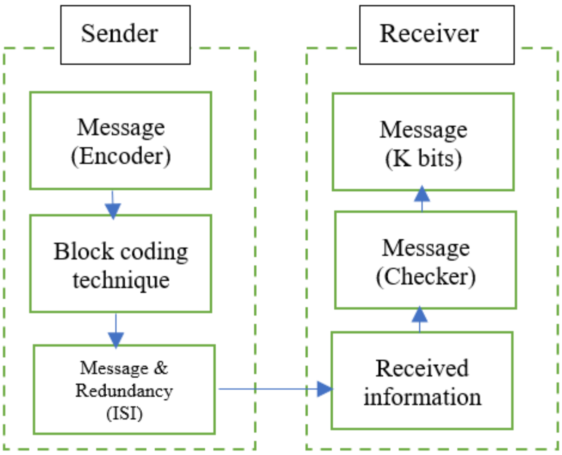

Fig. 1. Overview of wireless system

Considering the modern wireless communication system, as shown in Figure 1. It is stated the process of the information transfer from sender to receiver. Basically, the process involved the block coding technique to improve the technology of maintaining the signal to be transmitted. By the era of technology changes, the block coding (coder) is referring to a technique that can convert a signal into a reliable signal to be transmitted [10].

Further in detail, this research deployed F-OFDM system to overcome the issues of OFDM which is the high PAPR as well as having high side lobes in the frequency [4]. Besides, F-OFDM has been proposed in order to fulfil the characteristics needed for 5G networks which have the ability to provide massive connectivity for wireless access. F-OFDM offers an increment in the number of multiple users that the system can accommodate. Hence, the proposed F-OFDM technique to the system, is mainly to accommodate massive users with better PAPR reduction and maximize the BER degradation as compared to OFDM system. Occasionally, the F-OFDM in the system produces high PAPR, which degrades the efficiency of the power amplifier in the transmitter. Filtering is a straightforward way to suppress Out-of-Band (OOB) emissions by applying a digital filter with prespecified frequency response [11]. Since, F-OFDM considering Inverse Fast Fourier Transform (IFFT) and cyclic prefix (CP), it is said that the signal imposes a size of channel to protect from overlapping [12]. Thus, the signal is in frequency domain during its transmission. It is said that the signal has better efficiency of transmission.

Multiple transmit and receive antennas are used to form multiple-input multiple-output (MIMO) channels to increase the capacity and data rate of any wireless system.

The researchers improved the orthogonal space-time frequency block codes (OSTFBC) in frequency selective channels for 2x1, 2x2, 4x1, 4x2 MIMO-OFDM systems [2]. However, the research is not focusing on multiuser interference reduction. Also, the gap on the combination of the diversity technique with the multi-user (MU)- MIMO downlink system.

At the receiver part of F-OFDM, the signal is received and passed through the filter, f*(-n) which matches the filter at the transmitter. Then, the output signal received from the filter passes through the regular OFDM receiver. At the receiver, the filtered signal is subdivided into a number of consecutive OFDM symbols and encounters channel equalization. Mitigation of the signal interference (remove CP) shows its capacity and capability to get PAPR and BER degradation [13]. Finally, the data symbols are processed in AAC decoder to refine STFBC MIMO F-OFDM decoded by the extraction from the corresponding subcarriers. The system has the potential to reduce computational complexity.

Digital modulation process starts with the carrier signal carrying out modulation of the converted analogue to digital signal. Then, the carrier wave will act as a switch in order to create a signal pulse to be modulated. The signal that has been modulated depends on the parameter of the carrier wave such as the amplitude, frequency or phase [14]. The process of digital modulation helps the system to achieve high data capacity, better data security and increase system availability [15]. Furthermore, digital modulation provides numerous advantages to the system such as allowing for high bandwidth availability, high permissible power, and also high noise immunity.

This paper presents the reduction of PAPR for STFBC MIMO F-OFDM by using the EAAC scheme by compression and error correction and characterized by using CCDF. Hence, the system introduced IFFT block and CP converted in frequency domain for the transmission reliability. The EAAC in the context of a 5G system with MIMO allowing for high-speed signal transmission in the presence of multiple users and environment. This leads to improve reliability and quality of the received signal, even in challenging wireless environments with fading, interference, or noise.

2. Methodology

2.1 System Parameter

This section provides the methodology adopted throughout the implementation of the research which includes the simulation parameters, formulations, and developments of the proposed technique as well as the methods used to collect and analyse the data from literature reviews and simulations.

The flow chart shown in Figure 2 shows the operation sequence order to measure the PAPR reduction, typically starting with generating random codeword. The EAAC block coding technique is chosen to compress the random bits with a digital modulator. Thus, data was modulated with APSK modulation that offers a trade-off between spectral efficiency, complexity, and robustness against noise and channel impairments. The PAPR values of an STFBC MIMO F-OFDM is characterized by using the CCDF.

The simulations parameters are shown in Table 1. It includes the type of modulation (APSK), the FFT sizes, the number of symbols, CP, and the number of subcarriers. The chosen APSK modulator has the capability to support high-speed data transmission in wireless communications [16].

The Channel type chosen for this research is COST 207 Typical Urban (TU) because this channel is most suitable for the real environment. Besides, TU is more inter-operable because this research focuses on non-stationary environment. The number of symbols captured in Table 1, stated the reliable values to determine the PAPR at the complementary cumulative distribution function (CCDF) 10^{-2}.

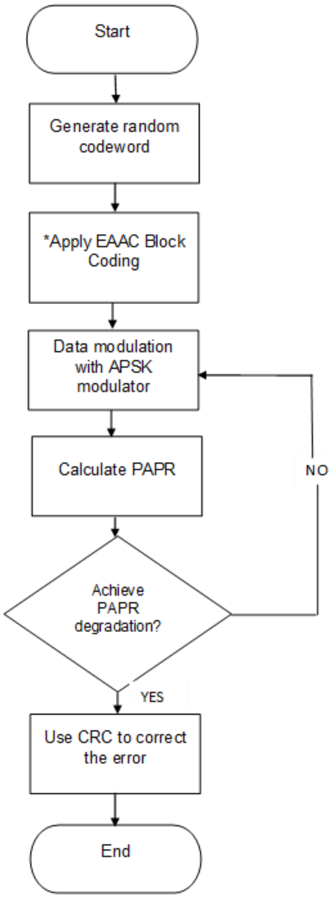

Fig. 2. The flow chart of the wireless system

Table 1
F-OFDM PHY based on IEEE 802.11 [17]

Parameter	Values
Modulation	APSK
FFT size	1024
Number of symbols	700
Cyclic Prefix	256
Number of subcarriers	128

Figure 3 shows the input data symbol, encoded by Space Time Frequency Block Codes (STFBC) encoder into a proper format to ensure the transmission efficiency. The EAAC encoder encoded symbols into a suitable form to maintain the process of signal transmission. The F-OFDM was previously proposed to overcome the drawbacks of OFDM which includes the high PAPR as well as having high side lobes in the frequency by Athija *et al.,* [3]. At the transmitter, the capacity of digital modulator could modulate random codeword and convert the time domain into frequency domain by IFFT. The CP acts as a method to eliminate the noise during its transmission. Next, at the receiver, the FFT process involves much more complex operations of addition and multiplication of data. The signal was converted into a time domain to suit the format. Removing CP provided access to individual subcarriers or frequency components to ensure accurate detection. A digital demodulator extracted and separated the desired signal and estimated the carrier frequency, to compose the signal which may contain multiple channels or interference.

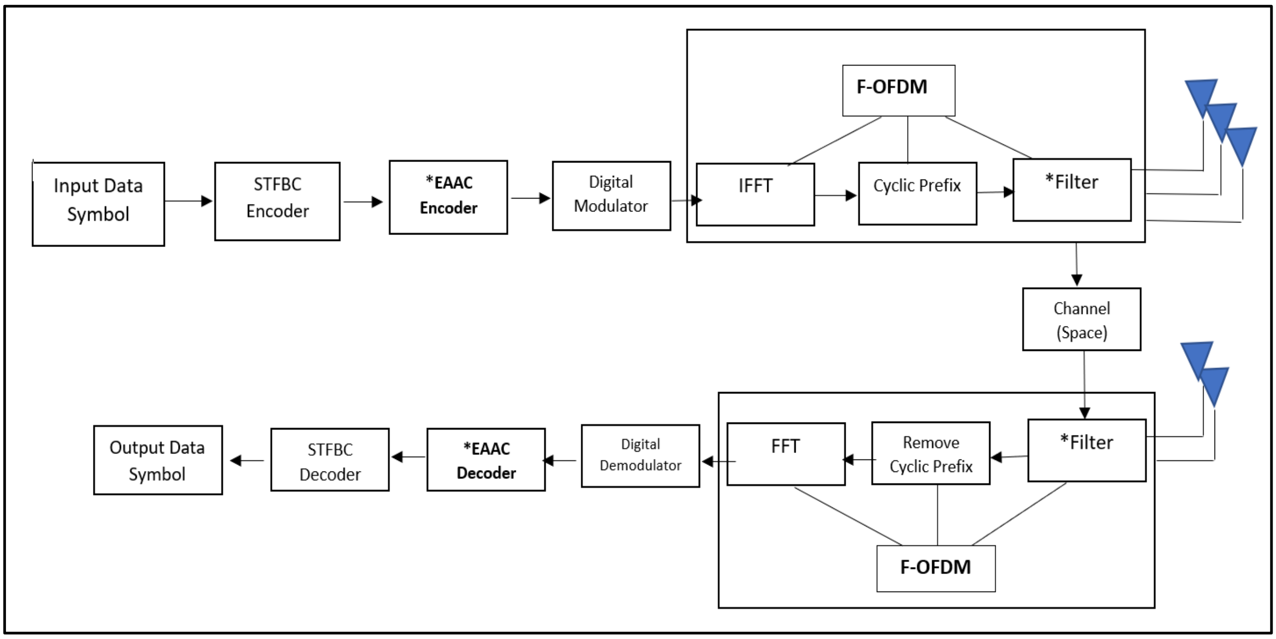

Fig. 3. Block diagram for STFBC MIMO F-OFDM system

In detail, for a typical OFDM symbol $s(n)$ is expressed as Eq. (2).

$$s(t) = \sum_{i=0}^{N-1} direct\ (t - ts - \frac{T}{2})e^{i2\pi fi(t-ts)} \tag{2}$$

where N is the number of subcarriers, di denotes the complex data symbol. T is the symbol of duration. Meanwhile, fi is the subcarrier frequency. $Rect$ is the rectangular function. For time, it is stated that $t_s \leq t \leq t_s + T$.

For the filter design (F-OFDM), the signal is obtained as shown in Eq. (3).

$$\tilde{s}(n) = s(n) * f(n) \tag{3}$$

where $\tilde{s}(n)$ is the signal passing through $s(n)$ combined with filter $f(n)$. F-OFDM has the reduce signal interleaving (a technique used in digital communication systems to transmit multiple signals over a channel. It divides a single high-speed data stream into multiple lower-speed streams, which are transmitted in an interleaved fashion over the channel.

3. Analysis of Results

This section discussed the results obtained from the MATLAB 2021Rb simulations. There are 4 iterations simulated with AC, HC in OFDM and F-OFDM, respectively shown in Figure 4. The simulated system with different coding scheme used to validate and verify the suitable signals. The signal with the lowest PAPR value has contribute to the system efficiency used in STFBC MIMO F-OFDM.

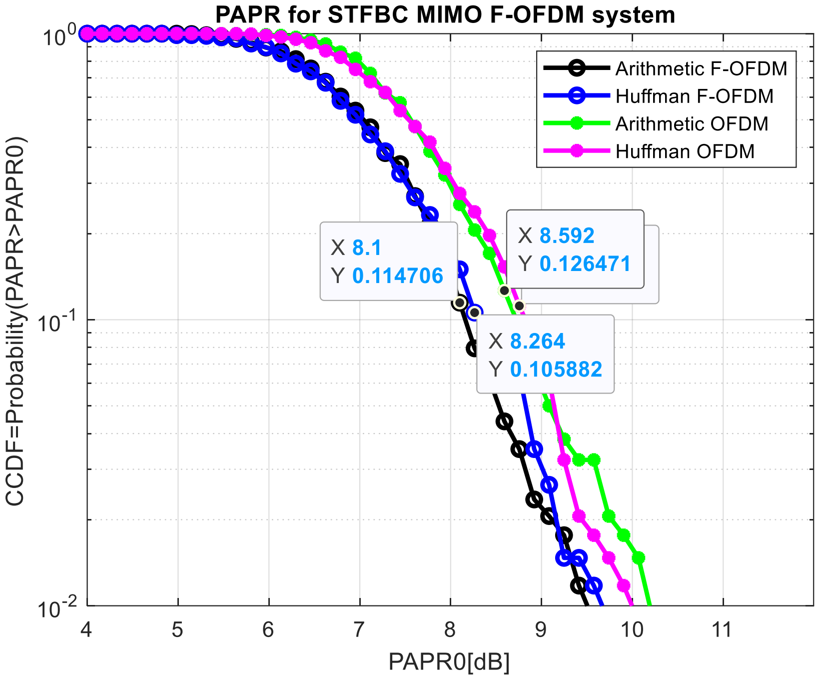

Fig. 4. PAPR values with different block coding scheme

Table 2 stated the measurements for both system with the coding techniques. However, they were simulated at 700 symbols, that is the most common range to observe the PAPR values.

Table 2
Comparison between OFDM and F-OFDM

No	Block coding scheme	CCDF ≈ 10^{-1}	PAPR (dB)
1	AC OFDM	0.126	8.59
2	HC OFDM	0.105	8.79
3	AC F-OFDM	0.114	8.1
4	HC F-OFDM	0.105	8.264

Based on Figure 4, different block coding schemes, were simulated to measure the best system performance. As stated previously, AC F-OFDM perform better at PAPR = 8.1dB as compared to HC F-OFDM at PAPR = 8.264dB, as stated in Table 2. This is because AC F-OFDM achieve better compression ratio and no fixed codeword length while HC F-OFDM uses fixed codeword length to represents symbols. The percentage of improvements is 5.76%. Meanwhile, the AC OFDM and HC OFDM has the same measurements of PAPR that is = 8.59dB and 8.79, respectively. It indicates that without a filter, the system becoming less efficient as the filter acts as a guard band to the signal carrier. Guard band used to mitigate the interference between channel neighbouring and reducing errors.

The simulated results were observed in Figure 5. For EAAC F-OFDM, the PAPR is = 8.24dB and it better as compared to AAC F-OFDM with 8.32dB. Thus, the performance is = 0.96%. This is due to the filtering in OFDM is more sensitive to the recent samples and block coding techniques. For a traditional OFDM EAAC and AAC were having PAPR at 8.72 and 8.88, respectively. The performance is slightly bad due to the increasing value of PAPR (dB). The system measured with the same block coding scheme that is EAAC with AAC for the F-OFDM system, stated that EAAC having better compression efficiency and advanced error resilience to optimize the coding performance, especially in high-speed data transmission. Smaller value of PAPR at CCDF = 10^{-1} can be reduced by introducing EAAC as the block coding technique with F-OFDM for wireless communications technology.

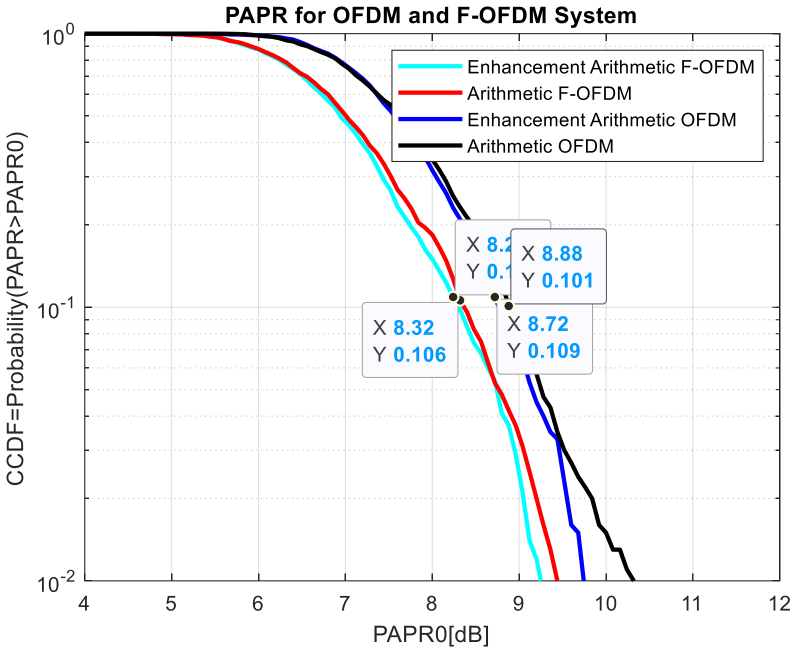

Fig. 5. Comparison of OFDM and F-OFDM with AC and HC series

It contributes to the performance of the systems' improvement of 5.5% by referring to Table 3. This is due to the implementation of filter in at the transmitter, which increases the value of PAPR. The EAAC block coding together with STFBC MIMO is able to improve by generating random codeword and compressing the number of bits to be encoded.

Table 3
Comparison of PAPR for different coding techniques

No	Block Coding Scheme	CCDF ≈ 10^{-1}	PAPR (dB)
1	EAAC F-OFDM	0.109	8.24
2	AAC F-OFDM	0.106	8.32
3	EAAC OFDM	0.109	8.72
4	AAC OFDM	0.101	8.88

OFDM is widely used in various communications system due to its available spectrum divided into multiple orthogonal subcarriers. However, considering Figure 6, OFDM has the PAPR = 8.4dB and F-OFDM = 9.2dB as depicted in Table 4.

Table 4
PAPR measurements for different modulators

No	Modulator	CCDF ≈ 10^{-1}	PAPR (dB)
1	OFDM	0.110	8.4
2	F-OFDM	0.108	9.2

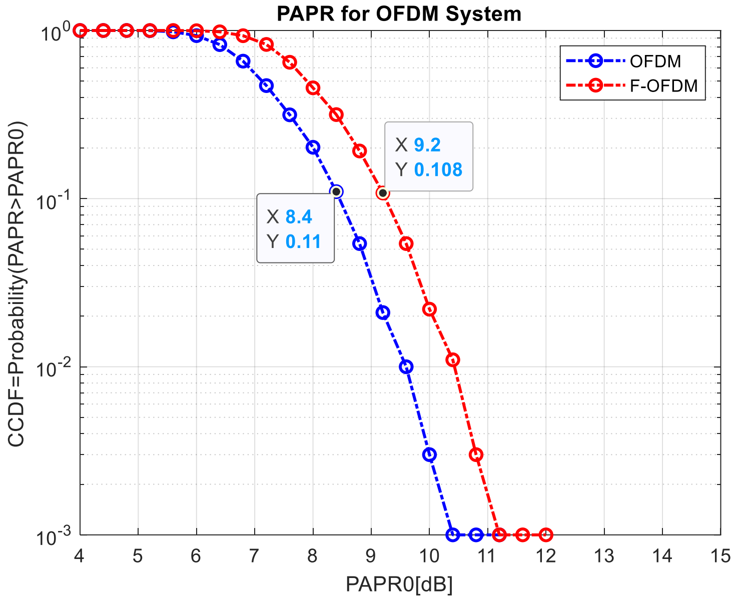

Fig. 6. PAPR comparison with different modulators

The difference of both is = 0.8dB. F-OFDM aims to mitigate spectral leakage issues associated with traditional OFDM, improving spectral efficiency (SE) and coexistence with other systems. F-OFDM incorporates a filtering operation on the transmitted signal to shape the subcarriers and reduced out-of-band (OOB) emissions. Thus, F-OFDM was used with block coding scheme to improve the overall performance, such as complexity, pulse shaping, filtering, and spectral leakage.

4. Conclusions

In a nutshell, this research proves that the STFBC MIMO F-OFDM with the combination of EAAC technique had reduced the PAPR values and further improved the system efficiency. It showed the reduction method in measuring the PAPR of an F-OFDM is characterized by using the CCDF function. It has huge potential in supporting 5G systems in signal transmission processes. It also helps the users in retrieving signals with minimum interference. The problem of high PAPR has been overcome to achieve the objective of the research work. The future of the research may consider the hybrid method of block coding technique at the transmitter to produce a refine measurement of PAPR and BER. Moreover, the block coding technique can be improved to suit the 6G networks [18]. The most prominent for 6G networks is to have great flexibility for its large residual timing error.

Acknowledgement

This research was funded by an internal conference grant (UniKL/code: 41302) from Universiti Kuala Lumpur, Malaysia. I would like to extend my gratitude to the wireless communication technology research group of Universiti Teknologi MARA, Shah Alam, Selangor for the guidance and support.

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