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Research paper

PAPR reduction using combination of SAS preprocessed and WHT precoding for MIMO system of FBMC/OQAM transceiver

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Abstract

FBMC/OQAM is Filter Bank Multicarrier with Offset Quadrature Amplitude Modulation system characterized by bandwidth efficiency, high data rate and more immunity to fading channels However, the combination of FBMC/OQAM system with Multiple Input and Multiple Output (MIMO) technology will increase the capacity of the system which may be used as the best scheme for next wireless communication system 5G . Unfortunately, one of the major drawbacks of MIMO FBMC/OQAM system is its high peak to average power ratio (PAPR) of the transmitted signals, resulting in signal distortion and reduced system performance. This paper proposes a new PAPR reduction method for MIMO FBMC/OQAM system based on the iterative addition and subtraction of FBMC/OQAM symbols which is known as Successive Addition Subtraction (SAS) followed by the WHT precoding. Simulation results show that the proposed schemes can improve the performance of the transceiver.

Keywords: *FBMC/OQAM; MIMO; PAPR; 5G; STBC; Precoding.*

1. Introduction

In order to improve the diversity gain and increase the capacity of Orthogonal Frequency Division Multiplexing (OFDM) system, the OFDM system is combined with multiple-input-multiple-output (MIMO over the time variant frequency-selective channels[1]. Moreover, the OFDM is a multi-carrier modulation (MCM) scheme technique used for 4th Generation (4G) wireless communication[2], but in case of next wireless communication system (5G) [3], therefore many researchers has been suggested new modulation technique, one of them is known as Filter bank multicarrier with offset quadrature modulation scheme (FBMC/QOAM) system which has many advantages such as High spectral efficiency, immunity to intersymbol interference and capability of handling very strong multipath fading[4].
Multiple-Input Multiple-Output (MIMO) system is the use of multiple antennas at both the transmitter and receiver to improve wireless communication performance[5]. FBMC/OQAM system combined with MIMO technology with the use of the space-time coding (STBC) to support high capacity, improve spectral efficiency and robustness to multipath fading [6]. Therefore, it may be used as the high-speed data multicarrier transmission in future wireless communication network systems [7-10]
However, a major drawback of MIMO technology combined with the FBMC/OQAM system is that the transmitted signals on different antennas might exhibit a high peak-to-average power ratio (PAPR) [11].
Many methods have been proposed to mitigate the MIMO technology with FBMC/OQAM system PAPR by acting on the signal itself. The simplest ones use clipping and filtering techniques. However, these methods may increase the BER of the system since clipping is a nonlinear process, tone reservation, nonlinear transformations, coding, Moreover, some method is already done for OFDM system like selecting mapping (SLM) and partial transmit sequence (PTS)[12]. However, the computational complexity is still remaining unsolved totally.
The main concept of the PAPR reduction in MIMO FBMC/OQAM system can be recognized as reallocation of the peak power of the signal over all the antennas [13-15].
In this paper, we propose to use a combination of STBC coding techniques (Alamonti) in MIMO FBMC/OQAM system, with reduction techniques to better discriminate the PAPR reduction based on iterative addition and subtraction of FBMC/OQAM symbols which known as Successive Addition Subtraction (SAS) followed by WHT Precoding operation. However, in the MIMO scheme, we used two scenarios, the first one with used two antennae for the transmitter and the second scenario we used three antennas for the transmitter.
The organization of this paper is as follows: in section 2, we introduced the FBMC/OQAM Transceiver system, in section 3, introduced the FBMC/OQAM system with MIMO technology, then in section 4, we introduced the concept of the PAPR Theory in MIMO Technology, in section 5, we explain in details the Proposed method based on the combination of the Preprocessing SAS followed by the Walsh-Hadamard Transform Precoding techniques to reduce the PAPR. The computational complexity is analyzed in section 6. In section 7, the simulation results are presented. Last section 8 concludes the paper.

Table 1: List of Symbols

$s(t)$	Baseband continuous time FBMC/OQAM signal
$a_{m,n}$	transmitted symbol
F_0	Frequency
τ_0	Time offset
$g_{m,n}(t)$	pulse shape prototype filter
$\phi_{m,n}$	The phase term
M	the number of subcarriers
m	sub-carrier index
n	symbol index
Re (.)	real part of a complex number
(m_0,n_0)	first order neighboring points
$a_{m,n}$	demodulated symbol at receiver side
N_t	transmit antennas
N_r	receive antennas
H	channel matrix
*	complex conjugate operation
x	transmitted signal vector
y	received signal vectored
w	noise vector
$f_{z_m}(z)$	Probability Density Function (PDF)
Z_{max}	the crest factor (CF),
$\tilde{F}_{Z_{max}}(z)$	complementary cumulative distribution function (CCDF)
WH_{ij}	Walsh Hadamard matrix
u	matrix order
T	transpose operation

2. FBMC/OQAM transceiver system

Figure 1 shows the FBMC/OQAM Transmitter using nonlinear companding the transmitter consists of the OQAM preprocessing, IFFT follows by PolyPhase filter bank and companding technique. Consequently, the FBMC/OQAM system used to transmit the OQAM instead of transmitting QAM data[16]. Tabe I illustrated the List of symbols .

The signal in a multicarrier transmission system with M subcarriers is composed of real-valued symbols $a_{m,n}$ transmitted shifted in time by τ_0, which is the duration of one real symbol, and in frequency by F_0, which is the spacing between two successive carriers [6]. The baseband continuous time FBMC/OQAM signal can be written as:

$$s(t)=\sum_{n=-\infty}^{+\infty}\sum_{m=0}^{M-1}a_{m,n}g_{m,n}(t) \quad (1)$$

Where $g_{m,n}(t)$ is design pulse shape prototype filter signal used for pulse shaping which can be written as [18]

$$g_{m,n}(t)=g(t-n\tau_0)e^{j2\pi mF_0t}e^{j\phi_{m,n}} \quad (2)$$

The phase term $\phi_{m,n}$ can be written as

$$\phi_{m,n}=\phi_0+\frac{\pi}{2}(m+n) \quad (3)$$

Where m is means sub-carrier index, n is means symbol index and ϕ_0 is an additional phase[19]. With given rate T_0 on each subcarrier, the real (Re) and imaginary (I'm) are transmitted separately at a rate $\tau_0=T_0/2$, with a time-offset of τ_0. $F_0=1/T_0=1/2\tau_0$, which means either the real or the imaginary part is delayed by one half-symbol duration. The constraint is to keep a phase difference of $\pi/2$ between adjacent symbols in time and frequency which are known as a staggering rule[20].

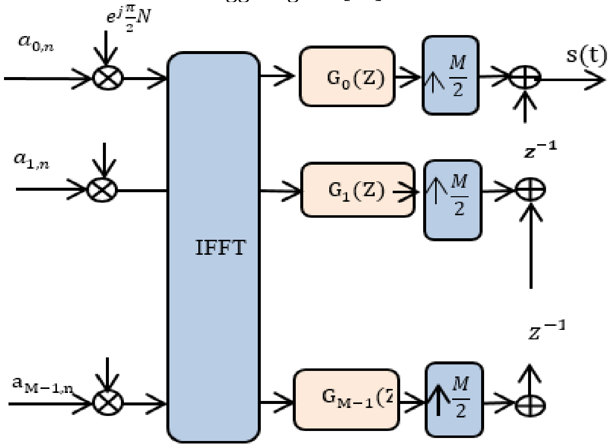

Fig. 1: The FBMC/OQAM Transmitter.

We assume a distortion-free channel to transmit signals, then the perfect reconstruction of real symbols can be obtained from the following real orthogonality condition

$$\mathrm{Re}\left\{\int_{-\infty}^{+\infty}g^{*}_{m,n}(t)g_{m_0,n_0}(t)dt\right\}=\delta_{m,m_0}\delta_{n,n_0} \quad (3)$$

Where * denotes the complex conjugation, Re (.) denotes the real part of a complex number and (m0,n0) denote the first order neighboring points.

In the absence of fading and noise, the demodulated symbol corresponding to the m-th subcarrier and n-th symbol can be expressed as[21]

$$a_{m,n}=\int s(t)g^{*}_{m,n}(t)dt+A_{m,n} \quad (5)$$

Where

$$A_{m,n}=\sum_{(n',m')\neq(n,m)}a_{n',m'}\int g_{n',m'}(t)g^{*}_{n,m}(t)dt \quad (6)$$

3. FBMC/OQAM system with MIMO system

To enhance the channel capacity of the wireless communication system, the concept of the Multiple Input and Multiple Output (MIMO) system has been established using multiple transmitter and receiver antennas exploiting multipath propagation with used multipath propagation[22]. Moreover, the spatial multiplexing (SM) is used to for diversity gain where the high rate signal is divided into multiple rate stream, then each stream is transmitted using different antenna by using same frequency channel, then in the receiver side, the received stream will be separated into the parallel channel. however, the SM diversity provides higher channel capacity at the higher signal to noise ratios (SNR). Figure 2 shows the MIMO channel model with a different transmitter and receiver antenna [23].

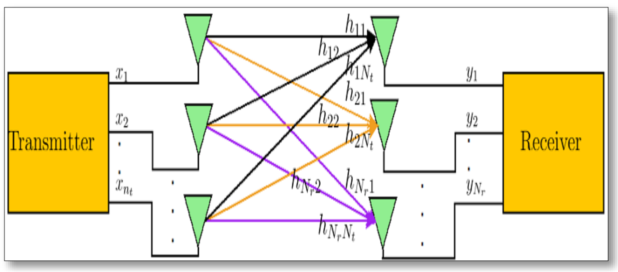

Fig. 2: The MIMO Channel Model.

The maximum number of spatial streams is limited by the number of transmitter and receiver antennas used If the N_t and N_r are the number of transmitting and receiving antennas, then we can denote the number of spatial streams will be $\min(N_t, N_r)$.

Spatial multiplexing can be used without Channel State Information (CSI) at the transmitter, but can be combined with precoding if CSI is available. Spatial multiplexing can also be used for simultaneous transmission to multiple receivers, known as space-division multiple access or multi-user MIMO, in which case CSI is required by the transmitter [4]

3.1. MIMO channel model

In MIMO systems, a transmitter sends multiple streams by multiple transmit antennas. The transmit streams go through a channel which consists of all $N_t N_r$ paths between the N_t transmit antennas and N_r receive antennas. The receiver gets the received signal vector by the multiple receive antennas and decodes the received signal vectors into the original information[4]. A MIMO communication system can be simplified by the following equation:

$$y = Hs + w \tag{7}$$

Where s is the transmitted signal vector with the dimension of Nt*1, y is received signal vectored with a dimension of Nr*1, H means the channel matrix and w means noise vector. In our paper, we have used the Alamouti space-time coding to achieve spatial diversity in MIMO systems[1]. In Alamouti space-time block coding (STBC), every two continuous transmit symbols, s1 and s2, are coded into a transmit symbol matrix as follows:

$$s = \begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix} \tag{8}$$

Where (*) indicates the complex conjugate operation, and s is the space-time code with its columns representing space dimension while the rows representing the time dimension[24]. It takes two time slots for transmitting two symbols; where in the first time slots, the two symbols s_1 and s_2 is transmitted from the two antennas simultaneously, and during the second time slot, $-s_2^*$ and s_1^* is transmitted from the two antennas. Figure 3 shows the Alamouti encoder system for two transmitters and receiver antenna

The signals of the space dimension are orthogonal [25] by the validity of the following relation:

$$\begin{bmatrix} s_1 & -s_2^* \end{bmatrix} . \begin{bmatrix} s_2 & s_1^* \end{bmatrix}^H = 0 \tag{9}$$

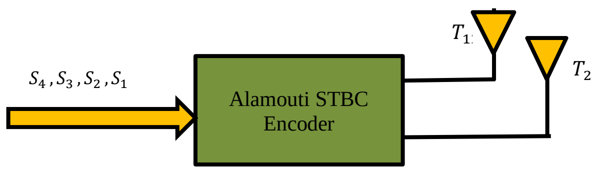

Fig. 3: Alamouti STBC with 2×2 System.

For the STBC with half rate complex transmission matrices achieving full diversity for 3 transmitted antennas scenario are given as

$$s_{3,1/2} = \begin{bmatrix} s_1 & s_2 & s_3 \\ -s_2 & s_1 & -s_4 \\ -s_3 & s_4 & s_1 \\ -s_4 & -s_3 & s_2 \\ s_1^* & s_2^* & s_3^* \\ -s_2^* & s_1^* & -s_4^* \\ -s_3^* & s_4^* & s_1^* \\ -s_4^* & -s_3^* & s_2^* \end{bmatrix} \tag{10}$$

$E\{|s(t)|^2\}$

$$s_{3,3/4} = \begin{bmatrix} s_1 & s_2 & \frac{s_3}{\sqrt{2}} \\ -s_2^* & s_1^* & \frac{s_3}{\sqrt{2}} \\ \frac{s_3^*}{\sqrt{2}} & \frac{s_3^*}{\sqrt{2}} & \frac{(-s_1 - s_1^* + s_2 - s_2^*)}{2} \\ \frac{s_3^*}{\sqrt{2}} & -\frac{s_3^*}{\sqrt{2}} & \frac{(s_2 - s_2^* + s_1 - s_1^*)}{2} \end{bmatrix} \tag{11}$$

Where the code can achieve a rate of ½ and ¾ respectively

4. PAPR theory in MIMO technology

The PAPR is defined as the ratio of maximum power to the average power of the complex signal[26]. Mathematically it can be presented as

$$PAPR(s(t)) = \frac{\mathrm{Max}\{|s(t)|^2\}}{E\{|s(t)|^2\}} \tag{12}$$

In the FBMC/OQAM system, the maximum amplitude will appear when all subcarrier become in the same phase then PAPR=M. For instance, let us consider an FBMC/OQAM system which is the sum of the multiplied sinusoidal having frequency separation 1/Ts[27].

The PAPR is usually calculated through cumulative distribution function (CDF) which is a probabilistic approach. Complex FBMC/OQAM symbols are composed of real parts and imaginary parts. [28]. Hence, the amplitude of FBMC/OQAM symbols follows Rayleigh distribution.

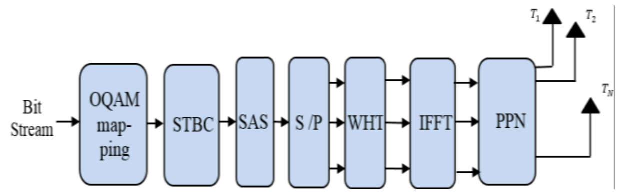

Fig. 4: Proposed STBC Alamouti MIMO FBMC Transmitter Block Diagram.

Assuming that the average power of s(t) s equal to one, = 1; then z_m are Rayleigh random variables normalized with its own average power will have Probability Density Function (PDF)

$$f_{z_m}(z) = \frac{z}{\sigma^2} e^{-\frac{z^2}{2\sigma^2}} = 2z\, e^{-z^2} \tag{13}$$

Where $E\{z_m^2\} = 2\sigma^2 = 1$, then CDF of Z_{max} can be presented as

$$F_{Z_{max}}(z) = P((Z_{max}) < z) \tag{14}$$

$$= (1 - e^{-z^2})^M \tag{15}$$

Where Z_{max} is known as the crest factor (CF), which is used to find the probability that exceeds z of the complementary CDF (CCDF)[29]; then CCDF can be given by

$$CCDF = \tilde{F}_{Z_{max}}(z) = P((Z_{max}) > z) = 1 - P(Z_{max} \le z) = 1 - F_{max}(z)$$
$$= 1 - (1 - e^{-z^2})^M \tag{16}$$

Where $\tilde{F}_{Z_{max}}(z)$ is the complementary cumulative distribution function (CCDF). The CCDF in MIMO for the FBMC/OQAM transceiver system with $M \times N_t$ is then given by

$$CCDF = \Pr(PAPR < z) = 1-(1-e^{-z^2})^{MN_t} \tag{17}$$

Where M is the number of subcarriers for FBMC/OQMA system and N_t is the transmitter antennas[30].

5. Proposed method

The block diagram of the FBMC/OQAM transmitter with the proposed method of PAPR reduction is shown in figure 4 while figure 5 shows the flow chart explaining the operation of each block of the transmitter given in Figure 4.

The proposed method is based on a combination of SAS preprocessed with WHT precoding to reduce PAPR for FBMC/OQAM transceiver. However, the principle of the SAS method is to change the phase of each successive symbols of the FBMC/OQAM frame. For M number of subcarrier there will be also M symbols which can be denoted $m = 0,1,2,3, \ldots \ldots M-1$ symbol [31].

So, each odd symbol is multiplied by $+1$ while each even symbol is multiplied by -1. After that, the symbols are arranged in a matrix according to equation (20) with M rows [17] .

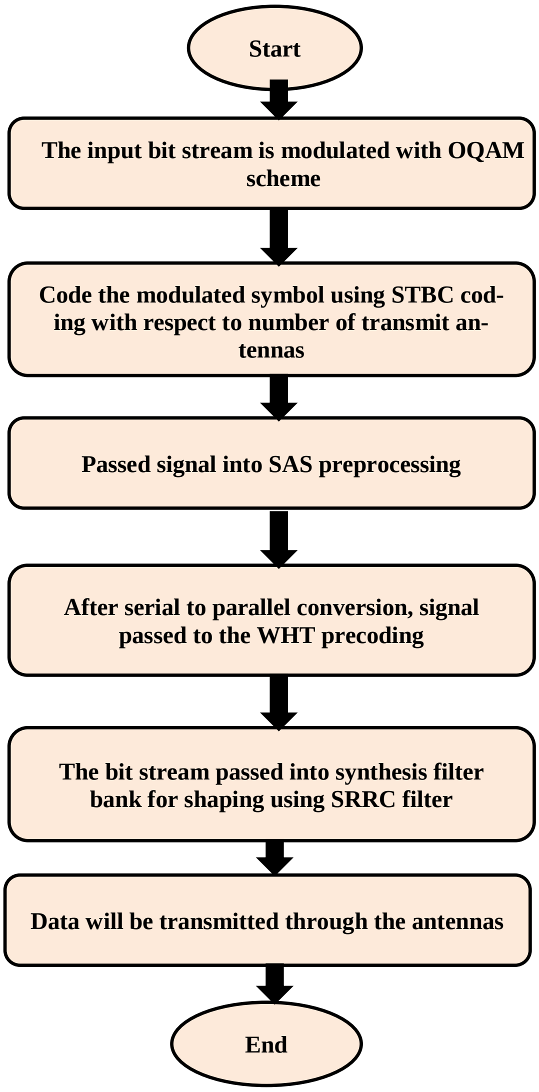

Fig. 5: PAPR Reduction Algorithm Techniques.

Mathematically the SAS process is given by the formula,

$$S_i(k) = \begin{cases} \sum_{i=even}^{K=k} S(i) - \sum_{i=odd}^{K=k} S(i) & for\ k = 1,2,3,\ldots..M-1 \\ S(k) & for\ k = 0 \end{cases} \tag{18}$$

In matrix representation, the process block S_t can be expressed as

$$S_t = \begin{bmatrix} 1 & 0 & 0 & 0 & \cdots & 0 \\ 1 & -1 & 0 & 0 & \cdots & 0 \\ 1 & -1 & 1 & 0 & \cdots & 0 \\ 1 & -1 & 1 & -1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & & \vdots \\ 1 & -1 & 1 & -1 & \cdots & -1 \end{bmatrix} \begin{bmatrix} S(0) \\ S(1) \\ S(2) \\ S(3) \\ \vdots \\ S(M-1) \end{bmatrix}_{M\times 1} \tag{19}$$

$$S = \begin{bmatrix} S(0) \\ S(0)-S(1) \\ S(0)-S(1)+S(2) \\ S(0)-S(1)+S(2)-S(3) \\ \vdots \\ \vdots \\ S(0)-S(1)+S(2)-S(3)-\cdots\ S(M-1) \end{bmatrix}_{M\times 1} \tag{20}$$

After getting the transformed M symbols, the WHT of the transmitted signal is taken place[17]. Then it is passed to IFFT block. However, the Walsh Hadamard transform (WHT) precoding is applied for reducing the autocorrelation in the data sequence[32]. The Walsh Hadamard transform is real, symmetric, and orthogonal transform. Its elements are equal to ± 1 which make the hardware implementation requires only addition operation[33]. The Walsh Hadamard matrix can be given by

$$WH_{ij} = \frac{1}{\sqrt{M}}(-1)^u \tag{21}$$

$$u = \sum_x i_x * j_x \tag{22}$$

Where i , j are the element indices of the WHT matrix, and u is matrix order, moreover, the symbol (*) denotes a binary operation between bits of binary element indices i and j, respectively while x is the length of the binary digits of i_x and j_x . For example, a WHT matrix of order 2 can be written as

$$\mathrm{WHT}_2 = \begin{bmatrix} \mathrm{WH}_{1,1} & WH_{1,2} \\ \mathrm{WH}_{2,1} & WH_{2,2} \end{bmatrix} = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \tag{23}$$

Alternatively, the matrix can be constructed recursively by defining Hadamard identity [34]as

$$\mathrm{WHT}_M = \frac{1}{\sqrt{2}}\begin{bmatrix} \mathrm{WH}_{M/2} & \mathrm{WH}_{M/2} \\ \mathrm{WH}_{M/2} & -\mathrm{WH}_{M/2} \end{bmatrix} \tag{24}$$

Since, the WHT matrix is real, symmetric and orthogonal, it follows that

$$\mathrm{WHT}_M = \mathrm{WHT}_M^* = \mathrm{WHT}_M^T \tag{25}$$

$$\mathrm{WHT}_M \mathrm{WHT}_M = I_M \tag{26}$$

Where * stands for complex conjugate, T for transpose operation, and I_M is an identity matrix with a dimension of $M \times M$

Furthermore, since the WHT matrix is symmetric, both the forward and inverse transformation is identical. The one dimensional Walsh Hadamard transforms for a sequence s_m is given as[26]

$$S_k = \sum_{m=0}^{M-1} WH_{k,m} s_m \qquad for \ k = 0,1,2,.......,M-1 \tag{27}$$

Where $WH_{k,m}$ is an element of the WHT matrix.
Also, other main advantages of using WHT precoding beside PAPR reduction help the system to restore orthogonality before IFFT operation due to the process of successive addition and subtraction, Hence, the FBMC/OQAM signal after IFFT is presented as

$$s(m) = IFFT\{WHT\{S_k\}\} \tag{28}$$

6. Computational complexity

In our proposed scheme, the computational complexity can be divided into two parts. The first part deals with the SAS preprocessing computational complexity and the second deals with the number of computation required in the IFFT stage.

i) Complexity of SAS preprocessing

Our proposed method deals with addition and subtraction of FBMC/OQAM symbols with respect to the number of subcarriers used at the system, therefore the complexity of the proposed scheme can be found in two-step:

- The first step for SAS preprocessing: the complexity of the SAS is given by the same number of the subcarrier which is required for SAS process
- The second step is to deal with the complexity of the WHT precoding which given by $M \log_2 M$

ii) Complexity in the IFFT process

For M point IFFT, it requires complex multiplications and $M \log_2 M$ additions. Here, the computational complexity of different algorithms at the IFFT stage is calculated. Therefore, the computational complexity of the different number of transmitter antenna of the proposed scheme is given in table 2

Table 2: Complexity Analysis of Proposed Schemes With M_t the Transmitter Antenna

Multiplications	Additions
$M_t \frac{M}{2} \log_2 M + M_t \frac{M}{2} \log_2 M$	$(M + M \log_2 M) M_t$

We can observe that the IFFT requires more complexity, but the computational complexity of the PAPR reduction of the proposed scheme depends on the number of the subcarriers used of FBMC/OQAM system.

7. Simulation results

In this section, the simulation results are introduced for the proposed transceiver of STBC MIMO FBMC/OQAM systems with used space diversity. To evaluate the performance of the proposed schemes, we used different number of subcarriers and different number of transmit antennas under two scenarios as follows:

i) 2*2 MIMO FBMC/OQAM Transceiver
ii) 3*3 MIMO FBMC/OQAM transceiver

We employed a different number of subcarriers as 64,128,256, and 512 for both scenarios with the detailed system parameters given in Table 3

Table 3: The Parameter Used in the Simulation for MIMO FBMC System

	Parameters	value
1	Number of subcarriers	128,256,512,1024
2	SNR range	0-30
3	MIMO Scheme	STBC
4	Modulation Technique	OQAM
5	Prototype filter	SRRC
6	Roll-off factor	0.55
7	Precoding scheme	WHT
8	sampling factor	8

7.1. Performance under scenario 1

In this section, we analyzed the PAPR for MIMO FBMC/OQAM Transceiver having two transmitters antennaes and two receiver antennas with STBC technology. The complementary cumulative distribution function (CCDF) is used to evaluate PAPR reduction performance, which measures the probability that the PAPR exceeds a certain threshold (z). For a given threshold, a lower CCDF indicates better PAPR performance.
Fig.6 Illustrates the CCDFs of 2*2 MIMO FBMC/OQAM signal (scenario 1) with a different number of subcarriers and combined scheme consisting of SAS preprocessing with WHT precoding to reduce PAPR. While Table 4 depicts the PAPR at CCDF = 10^{-4} . Clearly, from figure 6 and Table III, we observe that when we use the proposed scheme, The PAPR appreciably improves. At clip rate of 10^{-4} , we can observe that our proposal can achieve PAPR gain of 2.02, 2.79, 3.4, and 4.81 dB for 128, 256, 512 and 1024 subcarriers, respectively.

Table 4: PAPR Performance of Proposed Schemes under Scenario 1

No. of subcarrier	PAPR of conventional FBMC system	PAPR of FBMC with the Proposed scheme
1024	11.12	6.31
512	9.28	5.81
256	8.02	5.23
128	7.03	5.01

Fig. 7 illustrates the BER over an AWGN channel for 2*2 MIMO FBMC/OQAM signal (scenario 1) with a different number of subcarriers and combined scheme consisting of SAS preprocessing with WHT precoding. We can observe that fortunately that the proposed scheme has provided appropriate BER performance.

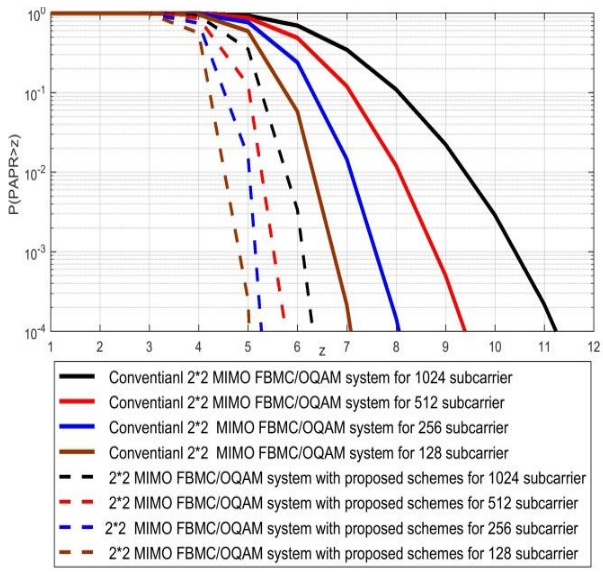

Fig. 6: PAPR Performance of 2*2 MIMO FBMC/OQAM Systems with A Proposed Scheme.

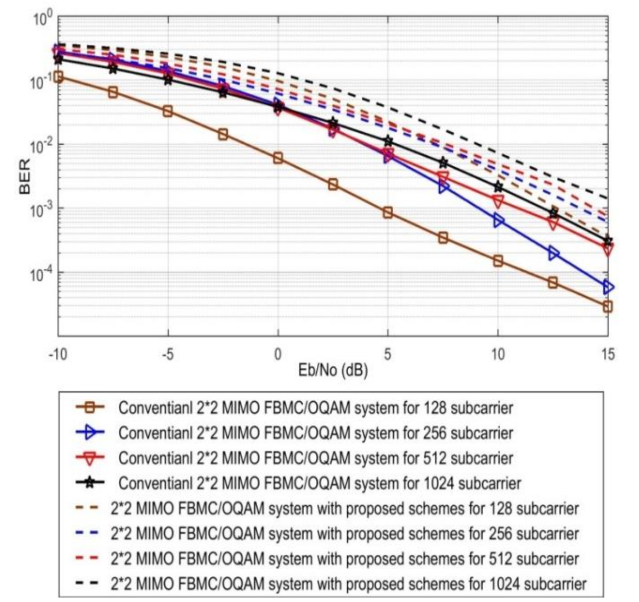

Fig. 7: BER Performance of 2*2 MIMO FBMC/OQAM Systems with A Proposed Scheme under AWGN Channel.

7.2. Performance under scenario 2

In this section, we analyzed the PAPR for MIMO FBMC/OQAM Transceiver with having transmitter antennas and three receiver antennas with STBC technology.

Fig.8 Illustrates the CCDFs of conventional 3*3 MIMO FBMC/OQAM signal (scenario 2) with a different number of subcarriers and combined scheme consisting of SAS preprocessing with WHT precoding to reduced PAPR. While, Table 5 depicts the PAPR at CCDF = 10^{-4}. Clearly, from figure 8 and table IV, we observe that when we use the proposed scheme, The PAPR appreciably improves. At clip rate of 10^{-4} , we can observe that our proposed can be achieved PAPR gain of 1.82, 1.65, 2.4 and 3.35 dB gain for 128, 256, 512 and 1024 subcarriers, respectively.

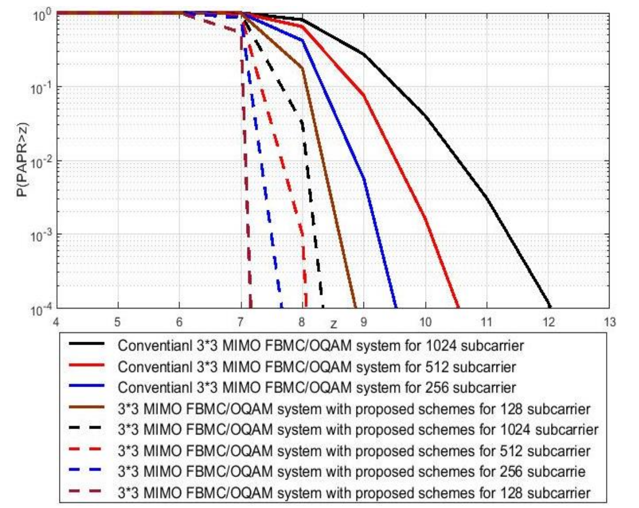

Fig. 8: PAPR Performance of 3*3 MIMO FBMC/OQAM Systems with a Proposed Scheme.

Table 5: PAPR Performance of Proposed Schemes under Scenario 2

No. of subcarrier	PAPR of conventional FBMC system	PAPR of FBMC with the Proposed scheme
1024	12	8.45
512	10.5	8.1
256	9.45	7.8
128	8.84	7.03

Fig. 9 illustrates the BER over an AWGN channel for 3*3 MIMO FBMC/OQAM signal (scenario 2) having different number of subcarriers and combined scheme consisting of SAS preprocessing with WHT precoding. We can observe that fortunately that the proposed scheme has provided appropriate BER performance.

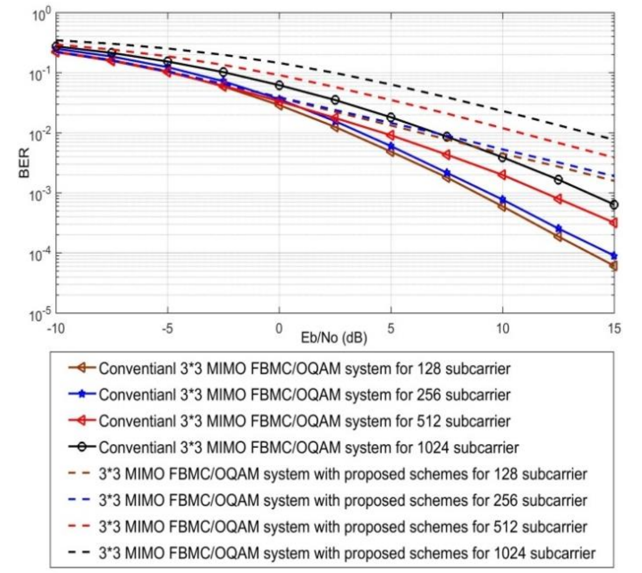

Fig. 9: BER Performance of 3*3 MIMO FBMC/OQAM Systems with A Proposed Scheme under AWGN Channel.

8. Conclusion

The FBMC/OQAM system with MIMO technology may be used as one of the best modulation schemes for the next wireless communication system namely as fifth generation (5G) system. Moreover, it can improve the spectrum efficiency, high diversity gain, and system capacity. However, the most disadvantage of MIMO FBMC/OQAM system is high PAPR especially when signal access nonlinear devices, since it may require wide dynamic range, or maybe cause nonlinear distortion so that it degrades the overall performance. This paper presents a new scheme based on the combination of the SAS preprocessing with used WHT precoding for reduced PAPR of the MIMO FBMC/OQAM system and Computational complexity of the proposed scheme was also carried out

From our simulation, we can conclude that our proposed scheme is able to provide a great reduction in PAPR as well as providing acceptable BER performance at different number of subcarriers.

References

[1] SHOWME, N et al. “High competence MIMO-OFDM with generalized led index modulation”. In International Journal of Engineering & Technology, [S.l.], v. seven, n. 2.31, p. 228-230, may 2018. http://dx.doi.org/10.14419/ijet.v7i2.31.13448.

[2] Alamelu, N. and P. Dananjayan, “Performance and capacity improvements of subchannel power-controlled MC-CDMA system under multipath channels”. International Journal of Mobile Network Design and Innovation, 2005. 1(1): p. 34-39. https://doi.org/10.1504/IJMNDI.2005.007934.

[3] .J. G. Andrews et al., “What Will 5G Be?,” in IEEE Journal on Selected Areas in Communications, vol. 32, no. 6, pp. 1065-1082, June 2014. https://doi.org/10.1109/JSAC.2014.2328098.

[4] S. Nandi, A. Nandi and N. N. Pathak, “Performance analysis of Alamouti STBC MIMO OFDM for different transceiver system,” in 2017 International Conference on Intelligent Sustainable Systems (ICISS), Palladam, 2017, pp. 883-887.https:// doi: 10.1109/ ISS1.2017.8389305

[5] Vijaya Kumar, P., & Rao Nandanavanam, V. (2018). “A novel method for joint- PAPR mitigation in OFDM-based massive MIMO downlink systems”. International Journal of Engineering & Technology, 7(3), 1185-1188 http://dx.doi.org/10.14419/ ijet.v7i3. 13009

[6] I. A. Shaheen, A. Zekry, F. Newagy and R. Ibrahim, “Modified Square Rooting Companding Technique to Reduced PAPR for

FBMC/OQAM," in 2017 Palestinian International Conference on Information and Communication Technology (PICICT), Gaza City, 2017, pp. 66-70.

[7] Y. Medjahdi et al., "On the Road to 5G: Comparative Study of Physical Layer in MTC Context," in IEEE Access, vol. 5, pp. 26556-26581, 2017. https://doi.org/10.1109/ACCESS.2017.2774002.

[8] J. Nadal, C. A. Nour and A. Baghdadi, "Design and Evaluation of a Novel Short Prototype Filter for FBMC/OQAM Modulation," in IEEE Access, vol. 6, pp. 19610-19625, 2018. https://doi.org/10.1109/ACCESS.2018.2818883.

[9] R. Nissel, S. Schwarz and M. Rupp, "Filter Bank Multicarrier Modulation Schemes for Future Mobile Communications, " in IEEE Journal on Selected Areas in Communications, vol. 35, no. 8, pp. 1768-1782, Aug. 2017. https://doi.org/10.1109/JSAC.2017.2710022.

[10] A. Skrzypczak, J. Palicot, and P. Siohan. 2012. "OFDM/OQAM modulation for efficient dynamic spectrum access," In Int. J. Commun. Netw. Distrib. System .8, 3/4 (April 2012), 247-266. https://doi.org/10.1504/IJCNDS.2012.046360.

[11] A. Valette, M. Ariaudo, L. Zerioul, S. Traverso, I. Fijalkow and A. Cipriano, " Spectral performances of PAPR reduced FBMC/OQAM signals," 2016 International Symposium on Wireless Communication Systems (ISWCS), Poznan, 2016, pp. 566-570. https://doi.org/10.1109/ISWCS.2016.7600968.

[12] H. Tiwari, R. Roshan and R. K. Singh, "PAPR reduction in MIMO-OFDM using combined methodology of selected mapping (SLM) and partial transmit sequence (PTS)," 2014 9th International Conference on Industrial and Information Systems (ICIIS), Gwalior, 2014, pp. 1-5. https://doi.org/10.1109/ICIINFS.2014.7036495.

[13] J. Gao, J. Wang and Z. Xie, "Decomposed selected mapping for peak-to-average power ratio reduction in MIMO-OFDM systems, " in 2008 9th International Conference on Signal Processing, Beijing, 2008, pp. 1900-1903. http://doi: 10.1109/ICOSP. 2008.4697513

[14] Siegl, C., & Fischer, R.F. (2008). "Comparison of partial transmit sequences and selected mapping for peak-to-average power ratio reduction in MIMO OFDM," 2008 International ITG Workshop on Smart Antennas, 324-331. https://doi.org/10.1109/WSA.2008.4475577.

[15] D. Zhu, B. Natarajan and J. S. Dyer, "Peak-to-Average Power Ratio Reduction in MIMO-OFDM with Trellis Exploration Algorithm, " in 2009 Proceedings of 18th International Conference on Computer Communications and Networks, San Francisco, CA, 2009, pp. 1-6. https://doi.org/10.1109/ICCCN.2009.5235316.

[16] Bindiya, T.S. and E. Elias, "Design of FRM-based MDFT filter banks in the canonic signed digit space using modified meta-heuristic algorithms, " International Journal of Signal and Imaging Systems Engineering, 2016. 9(1): p. 20-37. https://doi.org/10.1504/IJSISE.2016.074649

[17] .Zsolt Kollár and Péter Horváth, "PAPR Reduction of FBMC by Clipping and Its Iterative Compensation," in Journal of Computer Networks and Communications, vol. 2012, Article ID 382736, 11 pages, 2012 https://doi.org/10.1155/2012/382736.

[18] Rath, V. and T. Shilpa, "New Physical-layer Waveforms for 5G, in towards 5G: Applications, Requirements and Candidate Technologies," 2017 Wiley Telecom. p. 472. https://doi.org/10. 1002/9781118979846

[19] Chávez-Santiago, R., et al., "5G: The convergence of wireless communications," in Wireless Personal Communications, 2015. 83(3): p. 1617-1642. https://doi.org/10.1007/s11277-015-2467-2.

[20] Chia-Yu Yao and Chiang-Ju Chien, "Design of a square-root-raised-cosine FIR filter by a recursive method, "in 2005 IEEE International Symposium on Circuits and Systems, 2005, pp. 512-515 Vol. 1.https:// https://doi.org/10.1109/ISCAS.2005.1464637.

[21] D. Demmer, R. Gerzaguet, J. B. Doré, D. Le Ruyet and D. Kténas, "Filter design for 5G BF-OFDM waveform, " in 2017 European Conference on Networks and Communications (EuCNC), Oulu, 2017, pp. 1-5. https://doi.org/10.1109/EuCNC.2017.7980688.

[22] B. Farhang-Boroujeny and H. Moradi, "OFDM Inspired Waveforms for 5G, " in IEEE Communications Surveys & Tutorials, vol. 18, no. 4, pp. 2474-2492, Fourthquarter 2016. https://doi: 10.1109/ COMST.2016.2565566

[23] A. I. Pérez-Neira et al., "MIMO Signal Processing in Offset-QAM Based Filter Bank Multicarrier Systems," in IEEE Transactions on Signal Processing, vol. 64, no. 21, pp. 5733-5762, Nov.1, 1 2016. https://doi.org/10.1109/TSP.2016.2580535

[24] .Arthur, A.G. and H.L. Allen, "Digital Communications BER Performance in AWGN and Fading (Convolutional Coding), in Modeling of Digital Communication Systems Using SIMULINK," 2015, Wiley Telecom. p. 416. https://doi.org/ 10.1002/9781119009511.ch11.

[25] M. Surendar and P. Muthuchidambaranathan, "Channel Coded STBC-OFDM Based Transmit Diversity Systems in Multipath Rayleigh-Fading Channels," in 2013 second International Conference on Advanced Computing, Networking and Security, Mangalore, 2013, pp. 160-163. https://doi.org/10.1109/ADCONS.2013.28.

[26] Shaheen, I., Zekry, A., Newagy, F., & Ibrahim, R. (2017). "PAPR reduction for FBMC/OQAM using hybrid scheme of different Precoding transform and mu-law companding," in International Journal of Engineering & Technology, 6(4), 154-162. https://doi.org/10.14419/ijet.v6i4.8326.

[27] Imad A. Shaheen, Abdelhalim Zekry, Fatma Newagy, Reem Ibrahim, "Performance evaluation of PAPR reduction in FBMC system using nonlinear companding transform," in ICT Express, 2018. https://doi.org/10.1016/j.icte.2018.01.017.

[28] I. A. Shaheen, A. Zekry, F. Newagy and R. Ibrahim, "PAPR Reduction of FBMC/OQAM Systems Based on Combination of DST Precoding and A-law Nonlinear Companding Technique," in 2017 International Conference on Promising Electronic Technologies (ICPET), Deir El-Balah, 2017, pp. 38-42. https://doi.org/10.1109/ICPET.2017.13.

[29] Krishna Namani, V., & Arthi, R. (2018). "Zadoff-chu sequence based preamble design of fbmc/oqam for 5g," International Journal of Engineering & Technology, 7(2.12), 193-197. http://dx.doi.org/10.14419/ijet.v7i2.12.11278

[30] S. Patchala and M. Sailaja, "Reducing of PAPR for the MIMO OFDM system," in 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS), Chennai, 2017, pp. 1475-1478. http://doi: 10.1109/ICECDS. 2017.8389690.

[31] X. Zhu, G. Zhu and T. Jiang, "Reducing the peak-to-average power ratio using unitary matrix transformation," in IET Communications, vol. 3, no. 2, pp. 161-171, February 2009. https://doi.org/10.1049/iet-com:20080194.

[32] I. Baig, N. ul Hasan, M. Zghaibeh, I. U. Khan and A. S. Saand, "A DST precoding based uplink NOMA scheme for PAPR reduction in 5G wireless network," in 2017 7th International Conference on Modeling, Simulation, and Applied Optimization (ICMSAO), Sharjah, 2017, pp. 1-4.http://doi: 10.1109/ICMSAO.2017.7934861 https://doi.org/10.1109/ICMSAO.2017.7934861.

[33] M. H. Lee, M. B. Shahab, M. F. Kader and S. Y. Shin, "Spatial multiplexing using walsh-hadamard transform," in 2016 International Conference on Smart Green Technology in Electrical and Information Systems (ICSGTEIS), Bali, 2016, pp. 43-46. https://doi.org/10.1109/ICSGTEIS.2016.7885764.

[34] T. Sravanti and N. Vasantha, "Precoding PTS scheme for PAPR reduction in OFDM," in 2017 International Conference on Innovations in Electrical, Electronics, Instrumentation and Media Technology (ICEEIMT), Coimbatore, 2017, pp. 250-254. https://doi.org/10.1109/ICIEEIMT.2017.8116844.