International Journal of Computing Academic Research (IJCAR)
ISSN 2305-9184, Volume 6, Number 2 (April 2017), pp.31-39

http://www.meacse.org/ijcar

Combined DHT Precoding and A-Law Companding for PAPR Reduction in FBMC/OQAM signals

Imad Ahmed Shaheen[1],AbdelhalimZekry[2] ,FatmaNewagy[3] and Reem Ibrahim[4]
[1,2,3]Electronics and Communication Department, Faculty of Engineering, Ain Shams University, Cairo-Egypt
[4]Embedded System Design, Electronics Factory Department, Cairo-Egypt

Abstract

The filter bank multicarrier with offset quadrature amplitude modulation (FBMC/OQAM) is being studied by researchers as preferable waveforms support the fifth generation (5G) wireless communication. However, a non-constant envelope with high peaks is a main disadvantage of FBMC. The peak power of a signal is an analytical intention factor for communication systems and it is necessary to reduce it as much as possible. In this paper, hybrid schemes are investigated with the combination of the discrete Hartly transform (DHT) Precoding technique and A-Law companding technique to reduce PAPR in FBMC systems. The numerical results verify that the FBMC systems with all Precoding technique with using A-law companding can improve PAPR performance of the signals greatly with satisfying the performance of BER condition.

Keywords:FBMC/OQAM,PAPR,Companding, Precoding.

1.Introduction

Multicarrier techniques have been used to support high data rate in wireless systems, Orthogonal frequency division multiplexing (OFDM) technique is one of the most recognized types of multicarrier system. But due to used cyclic prefix (CP) in transmission symbol sacrifices spectral efficiency Moreover, the use of rectangular pulse shaping on each subcarrier will lead to high out of band radiation. To overcome these drawbacks of OFDM. A new Multicarrier techniques namely filter bank multicarrier with offset quadrature amplitude modulation technique has been established as a candidate multicarrier system for the fifth wireless generation[1]. Precoding transform technique used for reduced PAPR in multicarrier modulation system, because it reduces the autocorrelation of the input stream. However, the Precoding transform technique is based on the relationship between correlation characteristic of the input stream and PAPR of the signal[2]. The average power of the input data sequence used to find the peak value of the autocorrelation of the signal. Therefore, the peak value of autocorrelation provided the number of sub carriers remainsconstant. Moreover it also not requires sending side information to the receiver. However there are many advantages of using Precoding technique in the communication system like the absence of bandwidth expansion, no data rate loss, improve the performance of BER and distortion of the signal is very short therefor it used for reducing PAPR. However, the nonlinear companding technique is one of the most attractive schemes because it provides good BER performance, low implementation complexity, and no bandwidth expansion

[3-4-5]. In this paper, we proposed a hyprid scheme to reduced PAPR for FBMC system by using the combination of DHT Precoding technique which used in the frequency domain and A-Law companding techniques used in the time domain. The rest of paper is organized as follows: in section II, FBMC/OQAM modulation with explaining prototypes filter design using square root raised cosine filter (SRRC) then section III, introduced PAPR theory in FBMC system, then in section IV, Precoding transform techniques are explained, in section V, A-law nonlinear companding scheme explained, then in section VI, Proposed Hybrid schemes with DHT Precoding and A-law companding system is explained in transmitter and receiver side, in section VII results are presented in this section. Last section VIII concludes the paper.

2. FBMC/OQAM system

The FBMC/OQAM modulator is shown in fig.1 .firstly, the input complex signal is modulated with using OQAM modulation block then signal follows to synthesis filter bank then signal lead to transmitted block to thetransmitter through the wireless channels. The FBMC/OQAM can transmit offset symbols. However,the input data at the transmitter side denoted by At the transmitter each input complex data symbol denoted by $S_{k,n}$,for k=0, 1,….M-1, and it can transmit at rate F=1/T Where $d_{k,n}$ denoted the transmitted symbols at the transmitter side, at the kth subcarrier also, let f[m] be a prototype filter with length Lg [7,8,9].

$$Lg = KM \qquad (1)$$

where K is the overlapping factor and M is the total subcarriers.the transmitted discrete baseband signal can be written as [1,8]

$$s_n = \sum_{k=0}^{M-1} \sum_{n=-\infty}^{+\infty} a_{k,n}\, g\left[m - nM/2\right] e^{j\frac{2\pi k}{M}\left(m-\frac{D}{2}\right)} e^{j\varnothing_{k,n}} \qquad (2)$$

Where is time delay D/2 depends on the length of the prototype filter used [5] , Where

$$D = L_g - 1 \qquad (3)$$

The phase $\varnothing_{k,n}$ is used for the phase shift of $\pm\pi/2$ between transmitted symbols along the time and frequency axes and can be given by

$$\varnothing_{k,n} = \frac{\pi}{2}(n+k) - \pi kn \qquad (4)$$

the discrete-time baseband signal at the transmitter side can be written as:

$$s_n = \sum_{k=0}^{M-1} \sum_{n=-\infty}^{+\infty} a_{k,n}\, g_{k,n}[m] \qquad (5)$$

Where $g_{k,n}[m]$ is defined by

$$g_{k,n}[m] = g\left[m - nM/2\right] e^{j\frac{2\pi k}{M}\left(m-\frac{D}{2}\right)} e^{j\varnothing_{k,n}} \qquad (6)$$

The demodulated symbol can be determined using the product of S_n and, Then the received signal can write as

$$r_{k,n} = d_{k.n} + \sum_{k',n' \neq k.n} d_{k',n'} \sum_{n=-\infty}^{+\infty} d_{k',n'}[n] g^{*}_{k',n'}[n] \qquad (7)$$

$$r_{k,n} = d_{k.n} + I_{k.n} = d_{k.n} + j\, u_{k.n} \qquad (8)$$

Where $I_{k.n}$ is denoted the inter symbol interference

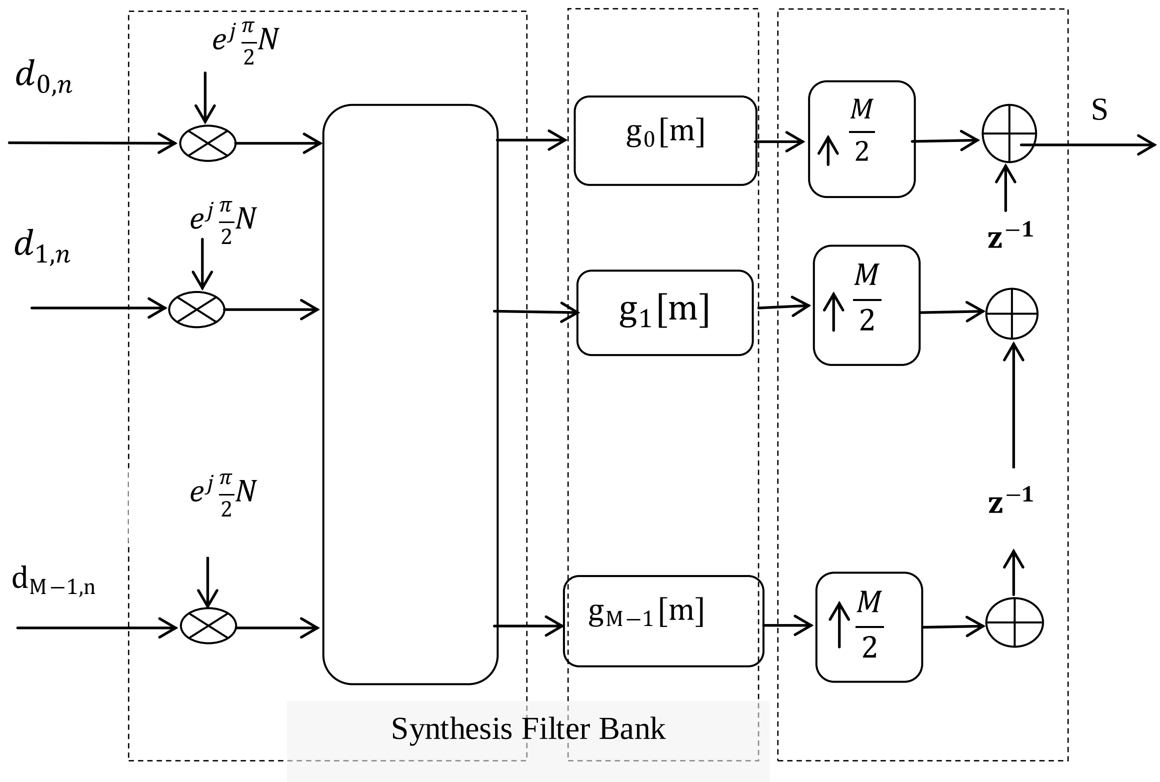

Fig.3. FBMC/OQAM modulator system

2.1 SRRC Prototype filters

We chose the prototype filter, using SRRC filter. However, the frequency response of SRRC filter is defined by[10]

$$g(f) = \begin{cases} T & \text{for } 0 \leq |f| \leq \frac{1-r}{2T} \\ \frac{T}{2}\left[1+\cos\frac{\pi T}{r}\left\{|f| - \frac{1-r}{2T}\right\}\right] & \text{for } \frac{1-r}{2T} \leq |f| \leq \frac{1+r}{2T} \\ 0 & \text{for } |f| \geq \frac{1+r}{2T} \end{cases} \qquad (9)$$

Where T is symbol period and the symbol rate is $f=1/T$,where r is the roll-off parameter $0 \leq r \leq 1$ however the impulse response of the SRRC filter in the continuous time domain is expressed as

$$g(t)=\frac{\sin\left((1\text{-}r)\frac{\pi t}{T}\right)+\frac{4rt}{T}\cos\left((1+r)\frac{\pi t}{T}\right)}{\frac{\pi t}{T}\left(1\text{-}\left(\frac{4rt}{T}\right)^2\right)} \qquad (10)$$

3. THE PEAK TO AVERAGE POWER RATIO (PAPR)

the PAPR of FBMC/OQAM signal $s_n$is defined as the ratio of the peak power of transmitted signal to its average power. The PAPR of FBMC transmitting signal can be written as [5]

$$\text{PAPR}=10\log_{10}\frac{\text{Max}\left\{|s_n|^2\right\}}{E\left\{|s_n|^2\right\}}\ \text{dB} \qquad (11)$$

Where $E\{\ .\}$ express the expectation operation.

4. Precoding Techniques

The efficient and flexible ways to reduce the PAPR in the multicarrier system are the Precoding techniques. In the Precoding technique, each of data input block is multiplied by a Precoding matrix to spread the energy of symbols. However, the data must be independent to avoid block optimization also theprecoding works with a random number of subcarrier moreover its provide good BER performance and also the provide acceptable implementation complexity moreover they are no need to handshake between the transmitter and receiver. However, the main concept of used Precoding matrix to spread the energy of symbols over the subcarriers assigned to the user. Precoding matrix can be written as:

$$P=\begin{bmatrix} P_{00} & \cdots\cdots & P_{0(N-1)} \\ P_{10} & \cdots\cdots & P_{1(N-1)} \\ M & M & M \\ P_{(N-1)0} & \cdots\cdots & P_{(N-1)(N-1)} \end{bmatrix} \qquad (12)$$

Where P is a Precoding Matrix of size N ×N

4.1 The discrete hartly transform

The DHTis a linear transform. In DHT, N real numbers$s_0, s_1, \dots\dots. s_{M-1}$ are transfomed into N real numbers $H_0, H_1, \dots\dots, H_{M-1}$ for the N point DHT can, be defined as follows[11]

$$y_n=\sum_{k=0}^{N-1}s_n\left[\cos\frac{2\pi nk}{N}+\sin\frac{2\pi nk}{N}\right] \qquad (13)$$

$$H_k=\sum_{n=0}^{N-1}s_n\left[cas\,\frac{2\pi nk}{N}\right] \qquad (14)$$

For $k=1,2,\dots\dots,N\text{-}1$ and $cas\ \theta=\cos\theta+\sin\theta$

5. Non-Linear Companding Technique

The companding transform technique used to perform compression of the signal at the transmitter and expansion the signal at the receiver also the others advantages of using the companding technique to keep the signal level above the noise level during companding process. also, it is used to increases the signal to noise ratio (SNR) when the input signal is very low therefore it reduces the effect of a system's noise. However, the A-law companding is used in this paper. For given the input sequence signal, the companding function can be given as[12]

$$C\{Y_n\}=\mathrm{sgn}(Y_n)\begin{cases}\dfrac{A\left|Y_n\right|}{1+\ln(A)}, & \text{if } |y|<\dfrac{\left|Y_n\right|_{max}}{A}\\ \dfrac{1+\ln(A\left|Y_n\right|}{1+\ln(A)}, & \text{if } |y|\geq\dfrac{\left|Y_n\right|_{max}}{A}\end{cases} \quad (15)$$

Where A is the compression parameter ratio, This parameter used to control Companding function and $sgn()$ is means sign of the input .however at receiver side inverse companding expression is done by the following function

$$F^{-1}\left(r_n\right)=\mathrm{sgn}(r_n)\begin{cases}\dfrac{\left|r_n\right|(1+\ln\left(A\right))}{A}, & \text{if} \left|r_n\right|<\dfrac{\left|r_n\right|_{max}}{1+\ln(A)}\\ \dfrac{\exp(\left|r_n\right|\left(1+\ln\left(A\right)\right)\text{-}1)}{A}, & \text{if } \left|r_n\right|\geq\dfrac{\left|r_n\right|_{max}}{1+\ln(A)}\end{cases} \quad (16)$$

6. Proposed Hybrid Scheme

FBMC/OQAM Transmitter with proposed schemes are shown in figure 2 with two technique to reduced PAPR. The first technique is DHT Precoding technique, and second technique is the A-Law companding which applied on the transmitter end. However, the modulated data sequence is transformed to Precoding matrix then, it passed to the IFFT unit. A companding technique is adopted after the analysis filter bank to further reduce the PAPR of the signal. However, The prototype filter is based on the SRRC filter with roll-off equal to 0.5, a block diagram of transmitter FBMC/OQAM system with Precoding transform technique used after OQAM modulation and Companding transform technique used after PolyPhase network is shown in fig 4.

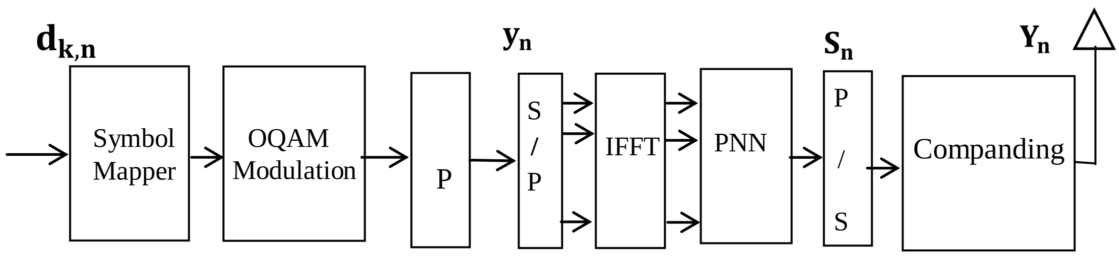

Fig 2. FBMC/OQAM Transmitter with proposed schemes

The algorithm explains signal processing step is described as:

Step 1: The input sequence is passed through the OQAM modulation

Step 2: The output of modulation system is fed to Precoding block.

$y_n = P\{s_n\}$ (17)

Where P is a preceding matrix

Step 3: output of the Precodingy_n} is applied to the IFFT as

$Y_n = IFFT\{y_n\}$ (18)

Where $y=[y(1)\ y(2),\ldots\ldots\ldots,y(N)]^T$ (19)

Step 4: the output of IFFT is passed to the PNN for shaping, then it passed to parallel to serial conversion

Step5: A companding function (A-Law) is then applied to**,**as$S_n = C\{Y_n\}$(20)

At the receiver side, the inverse operation is done at each block as shown in figure 3. However, the A block diagram of the FBMC/OQAM system with deprecoding technique P^{-1} and decompanding transform technique is shown in fig 5.The algorithm explains signal processing step is described as:

Step 6: received signal$r(n)$ is fed to inverse companding function

$\hat{y}_n = C^{-1}\{r_n\}$ (21)

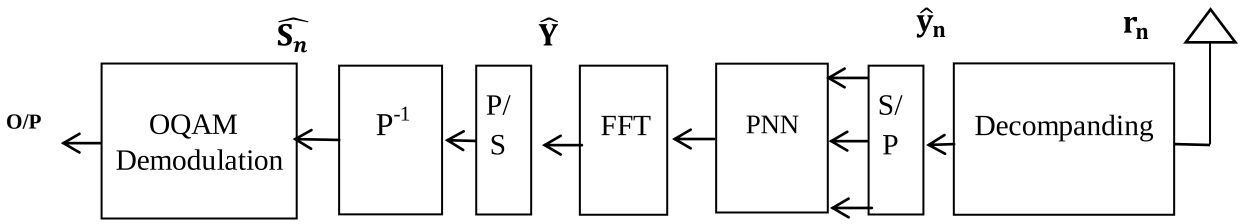

Fig 3. FBMC/OQAM Receiver with proposed scheme

Step 7: then it passed to the PNN before applied to the FFT blockas

$\hat{Y} = FFT(\hat{y}_n)$(22)

Where $\hat{y}_n = [\hat{y}_1\ \ \hat{y}_2 \ldots\ldots\ldots\ldots\ldots \hat{y}_{N-1}\ ]^T$ (23)

Step 8: Then, the signal fed to an inverse Precoding function as

$\hat{S}_n = H^T\hat{Y}$ (24)

Finally, the signal $\hat{S}_n$, is demapped from the bit stream.

7. Simulation Result

We have designed the FBMC/OQAM with 256 subcarriers and we have applied 1500 source bit to be transmitted to OQAM block. In our designed the prototype filter design using SRRC with roll factor equal to 0.5, the length of the filter is chosen to 4T.For the PAPR of FBMC hybrid schemes is implemented with DHT Precoding techniques and A-Law scheme and we chose the commanding ratio A= 50 .we consider additive White Gaussian Noise (AWGN) channel in our simulation.

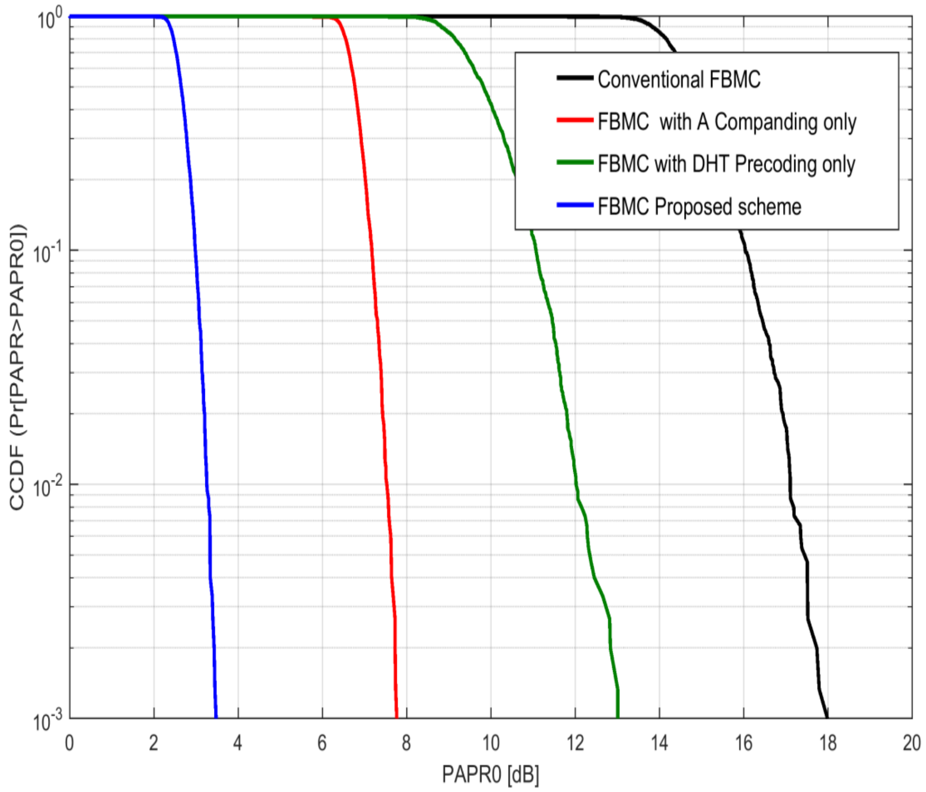

Fig 4. FBMC.OQAM with hybrid scheme consist from discrete Hartley transform and A- Law Companding

Fig.4. Shows the complementary cumulative distribution function (CCDF) performance with using Hybrid scheme consist form the Discrete Hartley Transform (DHT) Precoding with A-Law companding technique for reduced the PAPR in FBMC/.OQAM systems with fixed the value of companding factor A =50, From figure 4 and table I, we can observe that when we used the DHT Precoding with A-companding the PAPR is improve . At clip rate of 10^{-3} , the PAPR is reduced to the 3.45dB when compared with the original system or comparing with using Precoding technique only or using companding technique only.

Table I
PAPR forFBMC/OQAM

N.	**schemes**	**PAPR- dB**
1	Conventional FBMC	18.00
2	FBMC without DHT Precoding and with A Companding	7.74
4	FBMC with DHT Precoding and without Companding	13.31
5	FBMC with Proposed schemes	3.45

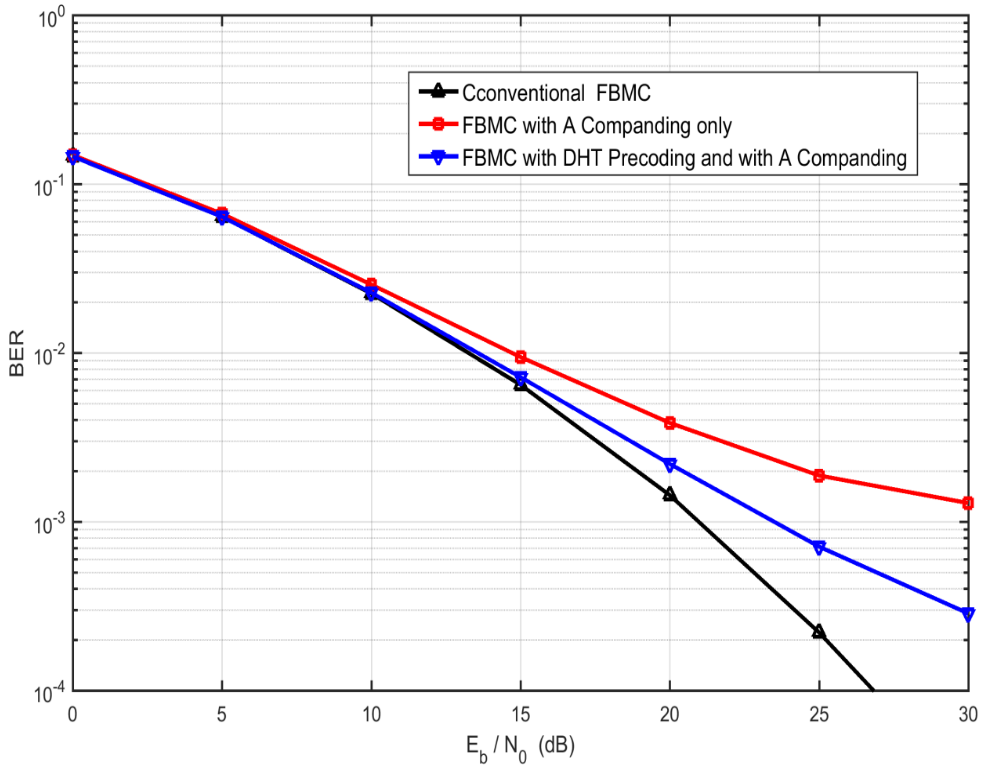

Fig 5 BER performance of FBMC/OQAM

In fig 5 are represented the BER performance of Hybrid scheme applied to reduced PAPR for the FBMC system. we can observe that the hybrid technique based on the DHT Precoding and A-Law Companding given good performance on the term of BER.

8. Conclusion

In this paper FBMC/OQAM system performance based on DHT Precoding and A- law companding techniques are analyzed with CCDF characteristics and BER performances , from our simulation we can satisfy that the hybrid scheme produce the lowest PAPR as compare to conventional FBMC/OQAM also by using Precoding techniques they will not be any signal degradation and do not require any side information to send to the receiver side. However the BER performance of FBMC/OQAM is improving with using the hybrid scheme. Therefore, the proposed scheme has the advantage of maintaining an acceptable average power level. Thus, we can find a justification for using our proposed hybrid schemes for reducing PAPR in FBMC for next generation wireless communication (5G system).

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