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Improvement of Bit Error Rate Using Novel Precoded Techniques

K. Pramidapadma[1*], Chandra Mohan Reddy Sivappagari [2]

[1]ECE Department, JNTUA College of Engineering, Pulivendula, Andhra Pradesh, India
[2]ECE Department, JNTUA College of Engineering, Pulivendula, Andhra Pradesh, India

[*]Corresponding Author: yours.pramida@gmail.com, Mob: +91-9676305094

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Abstract — The objective of the next generation communication system is to construct a "global information village", which encompasses a range of components at different scales extending from global to pico cellular size. The Circular Filter Bank Multicarrier Communication (C-FBMC) is an innovative transmission method that works by linking the standard FBMC with circular convolution. This arrangement is in the form of a block and acquires orthogonality amongst subcarriers. This research paper employs a Walsh-Hadamard precoding system to the C-FBMC system in order to manipulate frequency levels within a channel that is multipath in nature. The hypothetical estimation for the subsequent BER arrangement is derived with the help of this method in the paper. The performance and working of the arrangement is compared with the pre-coded Generalised Frequency Division Multiplexing (GFDM) arrangement. Results of the paper highlight that the results drawn are quite similar or matching to the outcomes of simulation and the amount or frequency of WHTC-FBMC is quite higher in comparison to the WHT-GFDM**.**

Keywords — C-FBMC, Orthogonality, Subcarriers, Walsh and Hadamard Precoder, Bit Error Rate (BER), GFDM.

I. Introduction

Mobile communication, these days have become an indispensable part of living and life without it seems hopeless. The first generation of cellular systems were rudimentary in nature but they allowed their users to transfer their voices from one place to another. This transformed the nature of human communication which became more personal and distances became just a number. The second generation digitalized the mobile device and improvised the system capacity, offered better battery time to its users and provided high-quality and efficient services. Short Message Service was introduced by this generation, which altered the way people communicated with one another.

The third generation offered amenities such as internet access and better data rates to its users that were not far behind the wired solutions available at that time. They introduced mobile phones that had higher storage capability and better processing systems, had larger HD mobile screen and good quality mobile cameras and also allowed to build networks and communicate with each other through social networking websites. This transformed the users of media into content suppliers and providers and pushed the fourth generation towards a throughput that was much higher than all the previous mobile generations. The needs of the fifth generation have been forecasted as much higher than previous users in terms of data rates. 5G mobile networks are Machine Type Communication (MTC) however previous communication medium still holds prominence and relevance [1].

The generation of 5G cellular networks is approaching. The main requirement of this fifth generation of mobile users is to have data rates that are 1000 times higher than the present 4G users [3].

The paper is organized in the form of sections. In Section II, related work of the system. In Section III, methodology for WHT-C-FBMC is presented and introduced by the researcher for a clear understanding. The results and discussions are presented in Section IV whereas the conclusion and future work is put forth in Section V by the researcher.

II. RELATED WORK

R. Datta, N. Michailow, M. Lentmaier, and G. Fettweis rigorous research has been carried out on this physical layer and the waveform design is still being developed due to the increasing demand of the fifth generation. OFDM technology is related to the utilization and incorporation of 4G networks, and is a better option for the 5G networks due to a number of reasons including effective employment, singular tap equalization for each subcarrier, and easy and efficient in order to combine with Multi Input Multi Output (MIMO). GFDM is proposed for 5G network air interface [4].

B. Farhang-Boroujeny, distinguish the relationship between OFDM and filter bank multicarrier. FBMC modulation is also

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an efficient alternative source for 5G networks [5]. This technique detaches multifarious data into real and imaginary data symbol categories and gives a π/2 counterweight to the sequential symbols to the next in line time slots and the subcarriers.

Recently, [6] and [7] propose that the incorporation of Cyclic Prefix (CP) within FBMC can assist in simplifying the equalization task on the receiver's end while operating across a Frequency Selective Channels (FSC).

Y. P. Lin, S. M. Phong and P. P. Vaidyanathan proposed filter Bank transceivers for OFDM systems. Linear convolution needs CP length in order to adapt the channel that is multipath in nature, along with the distance and length of the transmit filter to achieve an Inter Block Interference that is free in nature (IBI) [8]. For the IBI to reach a state that is free without escalating the length of the CP, the linear convolution that is incorporated within a circular convolution FBMC, leading to a new arrangement that is named as C-FBMC. Reference [9] links C-FBMC with the GFDM on the grounds of bit error rate and the convolution of the application across an AWGN channel.

This research paper employs WHT to C-FBMC to expand its BER performance over FSC. This performance can be affected due to the operation of poor subcarriers and can experience a deep fade as well. WHT precoder is chosen and implemented as it consists of elements that have equal magnitude levels and hence can be employed by making some additions [10]. The estimation for the BER of the subsequent scheme is drawn in the process. Its performance is linked with the performance of the precoded GFDM so that a comparison can be made.

III. METHODOLOGY

In the WHT-C-FBMC system given below, the symbols are managed in the form of blocks, where each of the block is linked or related with K subcarriers and M time slots. Let $s_{k,m} = s^R_{k,m} + j s^I_{k,m}$ be the complex QAM data symbol linked with the k^{th} subcarrier and m^{th} time slot. To allow offset modulation, the portions of the symbols are detached from one another and are organized in a K ×2M matrix as mentioned below:

$$A = \begin{bmatrix} a_{0,0} & a_{0,1} & \cdots & a_{0,2M-1} \\ a_{1,0} & a_{1,1} & \cdots & a_{1,2M-1} \\ \vdots & \vdots & \ddots & \vdots \\ a_{k-1,0} & a_{k-1,1} & \cdots & a_{k-1,2M-1} \end{bmatrix}$$

$$= \begin{bmatrix} s^R_{0,0} & s^I_{0,0} & \cdots & s^R_{0,M-1} & s^I_{0,M-1} \\ s^R_{0,0} & s^I_{0,0} & \cdots & s^R_{0,M-1} & s^I_{0,M-1} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ s^R_{0,0} & s^I_{0,0} & \cdots & s^R_{0,M-1} & s^I_{0,M-1} \end{bmatrix} \quad (1)$$

The diagram of the transmitter is given in the Fig. 1, where the data streams inputs K are shown in the K rows of the matrix A. This structure offered in [7], except that a precoder is utilised.

The WHT is used for each column of A as

$$\tilde{a}_m = W_K a_m \quad (2)$$

Where a_m the m^{th} column of A is, W_K is a K ×K Walsh Hadamard matrix and $\tilde{a}_m$ is the mth precoded column vector.

$$W_K = \frac{1}{\sqrt{K}} \begin{bmatrix} W_{K/2} & W_{K/2} \\ W_{K/2} & -W_{K/2} \end{bmatrix}, W_2 = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (3)$$

In this, the phase offsets are given to both of the mechanisms in relation to symbols that are given to different subcarriers in the following manner:

$$b_m = J_m \tilde{a}_m \quad (4)$$

Where $J_m = diag\left(\left[j^m, j^{m+1}, \ldots, j^{m+K-1} \right]\right)$. Then, the transmitted signal is given as mentioned in [6].

In this channel that is multipath in nature, the C-FBMC uses the length L in order to acquire an IBI that is free. As long as V −1 ≤ L, free IBI is certain at the end of the receiver. The signal that is received after removing the CP can be shown as

$$y = Hx + n \quad (5)$$

Where H is a KM×KM circulant matrix whose first column is h appended with KM − V zeros, and n is a vector of Additive White Gaussian Noise (AWGN) samples.

A method has been given in Fig. 1 in order to demodulate the data [7]. First, an equalizer S is employed to the signal y that is received in order to eliminate the interference effect. Then, the vector is handled in this as well. This output can then be utilized to spot the symbol of the data for the mth time slot. To make sure that the reconstruction is faultless within the FBMC, combined reactions from the received and transmit filter should be a Nyquist pulse [11]. A standard Square-Root Raise Cosine (SRRC) filter is incorporated as it fulfils this condition and is mostly incorporated for FBMC.

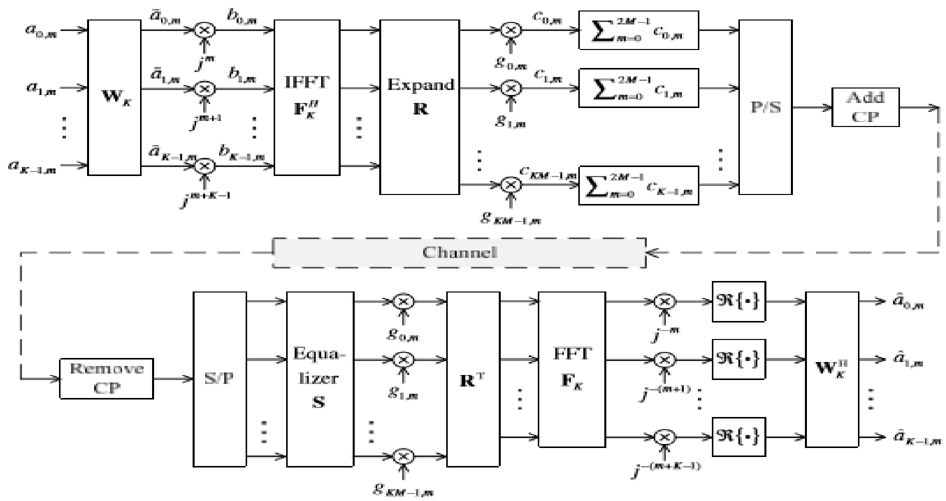

Figure 1: Block diagram for complex base band WHT-C-FBMC system

More lately [12], highlights a pulse that meets the condition of the orthogonality for FBMC and also meets this condition for the CFBMC.

This paper uses a filter that has a length of KM where the coefficients are accurate and symmetric such that,

$$g[n] = g[KM - n].$$

IV. SIMULATION RESULTS AND DISCUSSIONS

This project can be executed with the assistance of MATLAB. The simulation limitations are given in the Table 1. GFDM and CFBMC signals are transferred in the form of blocks, where they are given KM codes. In the process, the length of the time slot (sub symbol) is T = 256 µs. A block of the code is transmitted across a time duration of MT seconds, directing to the sampling phase (period of one symbol) of T_S = MT/KM = T/K = 4 µs.

Table 1: Simulation Limitations

Parameters	Value
Number of Subcarriers(K)	64
Number of Sub symbols(M)	32
Prototype filter	SRRC
Roll-off	0.5
Modulation	4-QAM,64-QAM
FSC	$h[n] \approx c\mathrm{N}\left(0, 10^{-n/V} - 1\right)$

Fig.2 represents the performance of both in channel A, for constellation of 4-QAM.

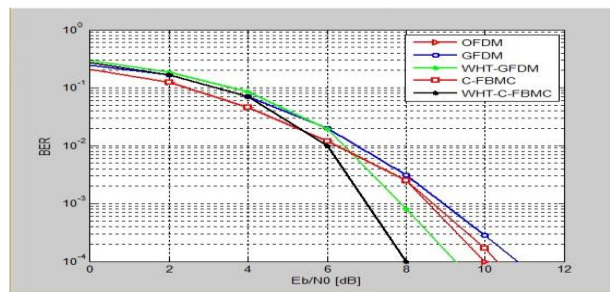

Fig.2 The performance in channel A

The simulation results of fig.2 are given in Table 2.

Table 2: Simulation results

BER (Y-axis)	$E_b/N_0(dB)$ (X-axis)					
	0	2	4	6	8	10
OFDM	0.2	0.12	0.048	0.012	0.0025	0.0001
GFDM	0.25	0.19	0.06	0.02	0.0028	0.0003
WHT-GFDM	0.29	0.19	0.085	0.02	0.0008	-
C-FBMC	0.2	0.12	0.048	0.012	0.0025	0.00018
WHT-C-FBMC	0.28	0.18	0.07	0.01	0.0001	-

Fig.3 represents the performance of channel A, for constellation of 64-QAM.

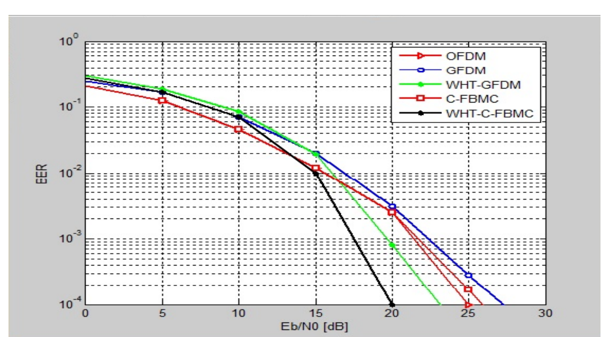

Fig.3 The performance of channel A

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The simulation results of fig.3 are provided in Table 3.

Table 3: Simulation results

BER (Y-axis)	$E_b/N_0(dB)$ (X-axis)					
	0	5	10	15	20	25
OFDM	0.2	0.15	0.049	0.012	0.0028	0.0001
GFDM	0.23	0.18	0.07	0.02	0.003	0.00029
WHT-GFDM	0.29	0.19	0.089	0.02	0.0008	-
C-FBMC	0.2	0.15	0.049	0.012	0.0028	0.00018
WHT-C FBMC	0.28	0.18	0.07	0.01	0.0001	-

Fig. 2 and Fig.3 highlights that the system performs 2.5 dB better than that of WHT-GFDM at the BER level of 10^{-4} even with a large constellation such as 64-QAM. That makes the performances of it inferior than the latter system that is WHT-C-FBMC.

Fig.4 represents the performance of both the systems in channel B, for constellation of 4-QAM.

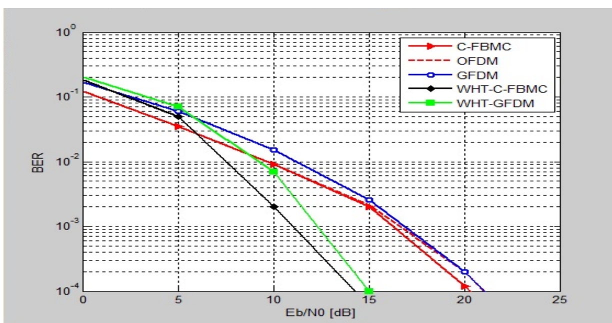

Fig.4 The performance of channel B

The simulation results of fig.4 are given in Table 4.

Table: 4 Simulation results

BER (Y-axis)	$E_b/N_0(dB)$ (x-axis)				
	0	5	10	15	20
OFDM	0.12	0.038	0.009	0.002	0.0002
GFDM	0.18	0.06	0.016	0.028	0.0002
WHT-GFDM	0.02	0.07	0.006	0.0004	-
C-FBMC	0.12	0.038	0.009	0.002	0.0012
WHT-C-FBMC	0.18	0.05	0.002	-	-

Fig.5 represents the performance of both in channel B, for constellation of 64-QAM.

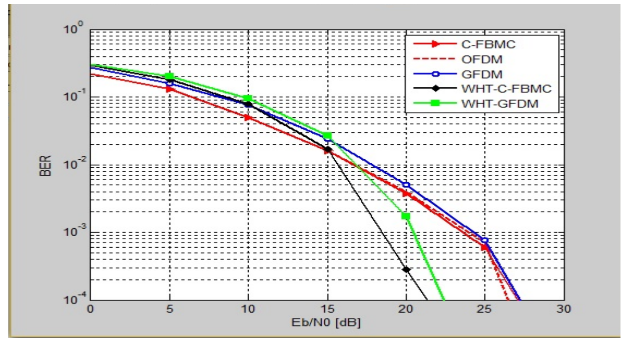

Fig.5 The performance of in channel B

The simulation results of fig.5 are provided in Table 5.

Table 5: Simulation results

BER (Y-axis)	$E_b/N_0(dB)$ (X-axis)					
	0	5	10	15	20	25
OFDM	0.12	0.15	0.05	0.18	0.0039	0.0007
GFDM	0.28	0.18	0.08	0.015	0.025	0.0008
WHT-GFDM	0.3	0.02	0.95	0.029	0.019	-
C-FBMC	0.12	0.15	0.05	0.018	0.038	0.0006
WHT-C-FBMC	0.3	0.19	0.08	0.019	0.0028	-

Fig.6 represents the simulation versus theoretical results of performance in channel A.

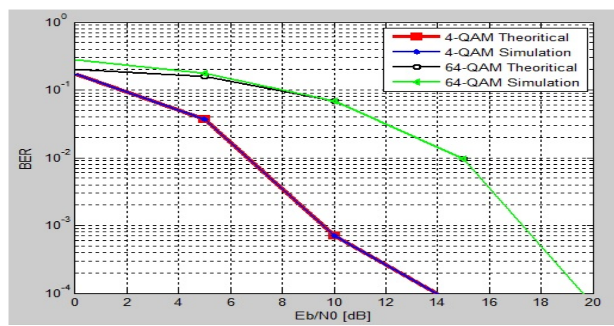

Fig.6 Simulation versus theoretical results of performance in channel A.

The results of fig.6 are provided in Table 6.

Table 6: Simulation results

BER (Y-axis)	$E_b/N_0(dB)$ (X-axis)			
	0	5	10	15
4-QAM Theoretical	0.18	0.039	0.0007	-
4-QAM Simulation	0.18	0.039	0.0007	-
64-QAM Theoretical	0.2	0.18	0.07	0.0095
64-QAM Simulation	0.29	0.19	0.07	0.0095

Fig.7 represents the simulation versus theoretical results of performance of in channel B.

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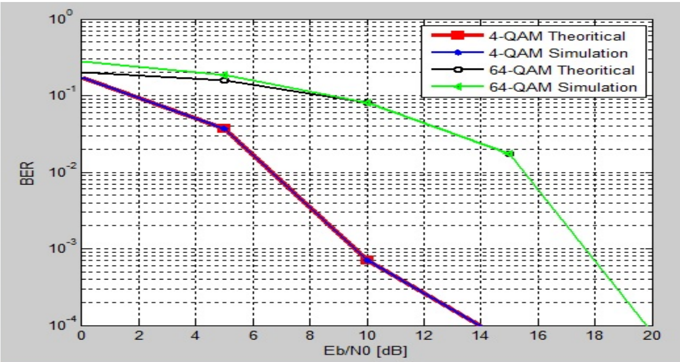

Fig.7 simulation versus theoretical results of performance of channel B

The simulation results of fig.7 are provided in Table 7.

Table 7: Simulation results

BER (Y-axis)	$Eb/N0(dB)$ (X-axis)			
	0	5	10	15
4-QAM Theoretical	0.18	0.39	0.0007	-
4-QAM Simulation	0.18	0.39	0.0007	-
64-QAM Theoretical	0.02	0.18	0.08	0.19
64-QAM Simulation	0.29	0.19	0.08	0.19

Fig. 6 and Fig. 7 highlights that the model can be incorporated effectually. In both of these channels that have 4QAM modulation, the results are similar to one another and matches faultlessly with the simulation outcome for the given SNR value. With 64-QAM modulation, the theoretical estimation is accurate at SNR larger than 7.5 dB.

V. CONCLUSION AND FUTURE SCOPE

For improving the BER performance of C-FBMC within the FSC, this paper proposes a form that is precoded in nature and is named as WHTC-FBMC, which also incorporates the unitary Walsh-Hadamard precoding matrix. WHT-C-FBMC manipulates the multiplicity present within the frequencies by taking an average of the SNR output across each subcarrier. A theoretical estimation or projection of these systems has been given in the paper, which is grounded upon both the channel advances the filter coefficients. Results highlight that WHT-C-FBMC performance is far better if compared with the performance of WHT-GFDM in FSCs. In future work, for the estimation of very low BER Low Density Parity Checking (LDPC) Decoder is used. In LDPC, the Sum of Product algoritm is used.

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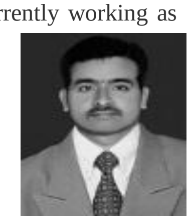
Authors Profile

K. Pramida Padma is currently pursuing the Master of Technology in Digital Electronics and Communication System as Specialization from JNTUA College of Engineering Pulivendula, Andhra Pradesh, India. I pursed Bachelor of Technology in ECE from SKU University, Anantapur, Andhra Pradesh, India in 2016. I have published one research paper in International Research Journal of Engineering and Technology (IRJET).



Dr. Chandra Mohan Reddy Sivappagari is currently working as Associate Professor of ECE, JNTUA College of Engineering Pulivendula, Andhra Pradesh, India since 2006. He is a member of IEEE, life member of IE (I), ISTE and IAENG. He has published more than 40 research papers in reputed both in international and national journals and conferences. His main research work focuses on Signal & Image Processing and Internet of Things. He has 17 years of teaching experience and 8 years of research experience.

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