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BER Analysis of Filter Bank Multicarrier for 5G Wireless Communications

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ABSTRACT--- In recent years, the world is looking for higher data rate along with the support of machine to machine communication, internet of things(IoT) in the 5G mobile communications, the limitations of conventional orthogonal frequency division multiplexing(OFDM) have less spectral characteristic due to the out of band emission and high peak to average power ratio(PAPR). Future generation wireless communications needs the better spectral properties and high spectral efficiency. Offset quadrature amplitude modulation based filter bank multicarrier is one of the waveform candidature to meet the requirements of future wireless configuration. In this paper, we proposed OQAM based FBMC with reduced bit error rate characteristics as close as to theoretical results with moderate complexity. It is simulated with Matlab Software, and the simulation results shows the better BER with respect to SNR as compared with the traditional methods.

Keywords – OFDM, FBMC, Cyclic Prefix, QAM, OQAM, BER.

I. INTRODUCTION

Fifth generation wireless communication systems are expected to meet the higher data rates due to the tremendous increase of the smart devices. Cisco's Visual Networking Index (VNI) predicted that the maximum number of devices connected in the cellular network are smart devices by the end of 2019[1]. On an average each and every mobile user is expected to download around 1 TB of data yearly by the end of 2020[2]. Tremendous usage of the smart devices resulting an enormous growth of the mobile user traffic. However, the current researchers are exposed to the new emerging applications like IoT, Device to Device communications, M2M communications, vehicular communication E-healthcare and tactile internet usage of the large number of devices. Some of the basic requirement of the 5G systems are [3]

- Large network speed in terms of Gbps (≥1Gbps), which means that the time required to download the movie may be less than second.
- Low latency
- Can be able to handle the huge number of devices simultaneously
- Long battery life time
- 100% of the connectivity for any place and anywhere

Current cellular technology is unable to handle the extreme and ever increase of the data rate and providing simultaneous connectively to the huge number of users. 4G LTE systems are unable to handle such type of rapid growth of the data rate and the connectivity of the more number of devices due to the out of band emission and high PAPR. Future wireless communication systems are expected to meet the massive and the tactile internet connected devices compared to the existing systems [4].

FBMC attracts the researchers and industry towards the next generation wireless communication. Currently , filter bank multicarrier (FBMC) with offset quadrature amplitude modulation is an alternative waveform contender for the orthogonal frequency division multiplexing for 5G mobile communication to achieve the basic requirements of high data rates and better spectral properties [5,6]. FBMC technique is having a number of advantages compared to conventional techniques. Few important advantages are (i). Less radiation outside the required bandwidth (ii) signal must be transmitted without cyclic prefix (iii) environmental robustness is high. FBMC have lower spectral side lobes compared with the conventional OFDM systems due to the employment of the pulse shaping filters, which means that the FBMC have the abilities of adjustable parameters and of asynchronous transmission [7-9]. The filters used in OQAM-FBMC can satisfies the orthogonality property only in the real domain. In OQAM, real and imaginary part of the symbols are delayed by the half of the symbol period [10, 11]. OQAM-FBMC systems are the potential for physical layer technique in 5G communication systems.*Bouhadda et al* [12], have investigated the performance of OQAM-FBMC investigated in terms of bit error rate by considering phase error and the intrinsic interference represented in terms of probability distribution in the discrete domain. This BER analysis was implemented with 4-OQAM and the noise present in the channel was considered as additive white Gaussian noise. *Zakaria et al*[13] has given the symbol error rate expression by considering the probability density of Gaussian one , for 2^m pulse amplitude modulated data mapping function and constant phase error only for channel has additive white Gaussian noise. *Hanen Bouhadda et al* [14] introduced analytical study of high-power amplifier and nonlinear distortion impact on BER on both the multicarrier modulation techniques: FBMC/OQAM and OFDM systems.In this paper, we identified a significant improvement in the performance of bit error rate in the FBMC waveforms with OQAM. We provided the simulation results between signal to noise ratio (SNR) and the bit error rate(BER) for different values of the subcarrier which are compared with theoretical results as well as the traditional methods.

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The subsequent sections of this paper is arranged as follows. Introduction of basic OFDM model is provide in section II. In section III, basic model of OQAM based FBMC transceiver followed by the subcarrier mapping in QAM and OQAM. Simulation results are discussed and compared with conventional techniques in section IV. Lastly, conclusion of the paper presented in section V.

II. OFDM SYSTEM MODEL

OFDM is basically the current dominant technology for broadband multicarrier communications. The basic principle of OFDM is to divide the large data sequence into the smaller data streams. These data streams are passed through the number of subcarriers are as close as possible, which reduces the interference between the subcarriers by introducing the orthogonality between the spectra of the signals.

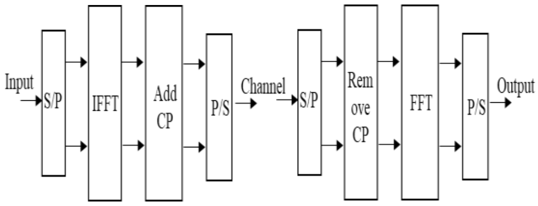


Fig. 1. OFDM system model [15]

OFDM symbol is basically the sum of multiple modulated exponential subcarrier signals. However these subcarriers are orthogonal to one another. OFDM has high capacity and more resist to inter symbol interference due to the orthogonality of the subcarriers.OFDM uses the rectangular window, which results the poor frequency localization. In OFDM system, a set of symbols are mapped with OQAM and these symbols are modulated with IFFT on N parallel subcarriers and add cyclic prefix(addition of a copy N_{cp} of the end symbol) for each OFDM symbol, which are represented in fig.1

Mathematical representation of the OFDM signal as expressed equation 1 & 2:

$$x(t)= \sum_{m=0}^{M-1} x_m(n+m(N+N_{cp})) \quad (1)$$

$$\text{where } x_m(\text{n})=\sum_{k=0}^{N-1} X_{m,k}\, e^{\,j2\pi kn/N} \quad (2)$$

Here $X_{m,k}$ represents data symbols, k represents the number of subcarriers and OFDM symbols are represented by M

To obtain the required signal at the output of the receiver, an inverse operation is performed on subsequent stages.

$$y_n=h_n * x_n + w_n \quad (3)$$

$$y_n= \sum_{m=0}^{L} h_n\, x_m\left(n-m+N_{cp}\right)+ w_n \quad (4)$$

Where y_n is the received signal, h_n is the impulse response of the channel, L - length of h_n and w_n - time domain representation of the noise. Multiple-input and multiple-output play a greater role for improvement of the capacity and the communication system reliability. The accessibility of 5G waveforms candidates to MIMO technology is the key point for the assessment of the any modulation scheme. OFDM is compatibility with MIMO, which allow the applications of the MIMO techniques by use of QAM and maintains the orthogonality constraint in the complex plane.

III. FBMC SYSTEM MODEL

FBMC is best suitable technique considered among the different multicarrier modulation schemes for future generation wireless communications. OFDM and FBMC are mostly differ in the selection of the filter. In case of OFDM, rectangular filter is used to pass the each subcarrier where as in FBMC the pulse shaping filter is used in order to give the better spectral characteristics by reducing the radiation in the out of band.

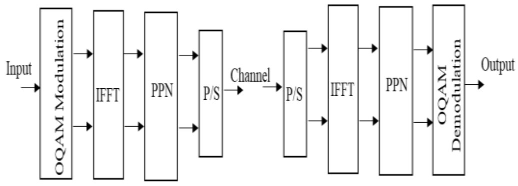


Fig. 2. FBMC polyphase network model [15]

Mathematical representation of the FBMC the transmitted signal is

$$x(t)=\sum_n \sum_{k=0}^{N-1} s_k\,[n]p_k\,(t-\tfrac{nT}{2}) \quad (5)$$

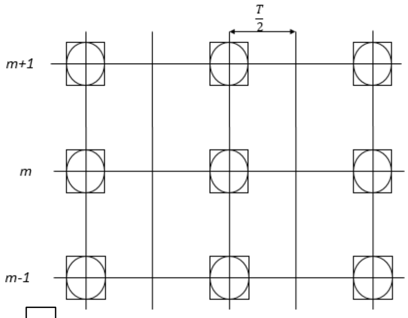
$$\text{here } p_k(t) =p(t)\, e^{j2kFt} e^{j(k+n)/2} \quad (6)$$

Where p_k is filter of k^{th} subcarrier and s_k represents the symbol.

In this, a group of the data symbols are passed through the set of synthesis filter bank after OQAM pre-processing. Adjacent spectral leakage and frequency localization can be controlled by proper selection of the prototype filter. At the receiver side, these signals are passed through the set of analysis filter bank followed by OQAM post processing to achieve the perfect reconstruction of the signal. The compatibility of the FBMC with MIMO is somewhat difficult because of the self-interferences. This will compatibility with MIMO when the interference can be managed.

OQAM

In OFDM systems orthogonality must be satisfied by all the subcarriers. In case of FBMC, orthogonality condition holds between the adjacent subcarriers. In OQAM, the complex signal is divided into real and imaginary parts. These are separated in the time domain by half of the symbol period and hence the spectral efficiency is increased.



□ real segment of the symbol
○ imaginary segment of the symbol

Fig. 3. FBMC/QAM symbol mapping on subcarriers [15]

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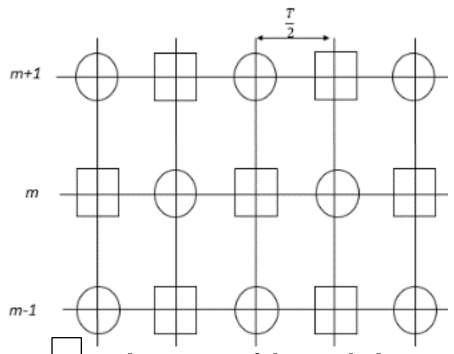

□ real segment of the symbol
◯ imaginary segment of the symbol

Fig. 4. FBMC/OQAM symbol mapping on subcarriers [15]

In this paper, we employ polyphase network for FBMC using the PHYDYAS project [16], the prototype filter designed to filter the each subcarrier using the frequency sampling technique [17]. Considering the overlapping factor K=4. The coefficients of the prototype filter are expressed as follows [14]:

$$P(m)=1+\sum_{k=1}^{K} 2P_k \cos(2\pi K/KM(m+1)) \quad (7)$$

Here m = 1,2,….L and P_k are the coefficients that satisfies the following expression:

$$\frac{1}{K}\sum_{k=-K+1}^{K-1} |P_k|^2 = 1 \quad (8)$$

IV. SIMULATION RESULTS

In this paper, various results are investigated to justify the basics discussed in the prior sections. An average BER for OQAM-FBMC is considered for different subcarriers and results are compared with the theoretical values. We can notice that the simulation results are very nearer to the theoretical results. The proposed FBMC with OQAM gives the improved bit error rate when compared with the simulation results of cyclic prefix OFDM and coded FBMC-OQAM[18-19]

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Number of Subcarriers	64,128,256
Modulation	OQAM
FFT	256
Filter Coefficients for FBMC	H_1=0.971960, H_2=0.7070 H_3=0.235147

The presence of errors in the frequency synchronization effects the orthogonality between the subcarriers, which results the degradation of the OFDM system performance. In this point, FBMC technique reduces inter symbol interference and intercell interference by proper design of pulse shaping filter.

From simulation results we can understood that, BER is as nearer to the theoretical results by increasing the number of subcarriers from 64 to 256.Enhanced characteristics of BER with respect to SNR values.

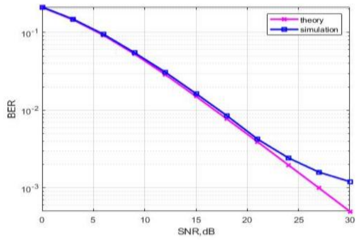

Fig. 5. OQAM-FBMC with 64 subcarriers

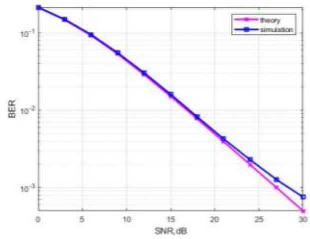

Fig. 5. OQAM-FBMC with 128 subcarriers

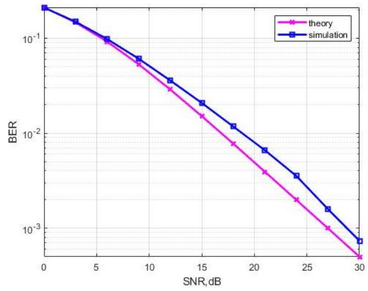

Fig. 6. OQAM-FBMC with 256 subcarriers

The following table shows the BER verses SNR of the proposed method and the conventional methods. From the analysis BER is improved compared to the traditional methods.

TABLE 2: COMPARISON OF BER

SNR	BER		
	CP-OFDM[18]	FBMC-QAM[19]	Proposed Method
10	0.033	0.166	0.025
15	0.016	0.100	0.011
20	0.005	0.012	0.003
25	0.002	0.011	0.001
30	0.001	0.001	0.0005

V. CONCLUSION

In this paper, BER analysis for 256 subcarriers has been implemented using the concepts of FBMC with OQAM and prototype filter. Achieved results shows an improvement in BER with respect to the SNR. From the simulation results we can depict that the proposed OQAM-FBMC is best suited for the emerging 5G technology when compared to cyclic prefix-OFDM and FBMC-QAM.Spectrum efficiency can be increased by implementing FBMC for multiple-input and multiple output technique at the same time the challenges of complexity and high PAPR need to be addressed.

VI. REFERENCES

1. Cisco, “Visual Networking Index,” White paper, Feb. 2015 [Online]. Available: www.Cisco.com.
2. T. S. Rappaport, W. Roh, and K. Cheun, “Wireless engineers long considered high frequencies worthless for cellular systems. They couldn’t be more wrong,” IEEE Spectr., vol. 51, no. 9, pp. 34–58, Sep. 2014.
3. Agiwal, Mamta, Abhishek Roy, and Navrati Saxena. "Next generation 5G wireless networks: A comprehensive survey." *IEEE Communications Surveys & Tutorials* 18, no. 3 (2016): 1617-1655.
4. Shafi, Mansoor, Andreas F. Molisch, Peter J. Smith, Thomas Haustein, Peiying Zhu, P. D. Silva, Fredrik Tufvesson, Anass Benjebbour, and Gerhard Wunder. "5G: A tutorial overview of standards, trials, challenges, deployment, and practice." *IEEE Journal on Selected Areas in Communications* 35, no. 6 (2017): 1201-1221.
5. Zhang, Lei, Pei Xiao, Adnan Zafar, Atta ul Quddus, and Rahim Tafazolli. "FBMC system: An insight into doubly dispersive channel impact." *IEEE Transactions on Vehicular Technology* 66, no. 5 (2017): 3942-3956.
6. Bellanger, Maurice, D. Le Ruyet, D. Roviras, M. Terré, J. Nossek, L. Baltar, Q. Bai, D. Waldhauser, M. Renfors, and T. Ihalainen. "FBMC physical layer: a primer." *PHYDYAS, January* 25, no. 4 (2010): 7-10.
7. Zhang, Jian, Minjian Zhao, Jie Zhong, Pei Xiao, and Tianhang Yu. "Optimised index modulation for filter bank multicarrier system." *IET Communications* 11, no. 4 (2017): 459-467.
8. Zhang, Lei, Ayesha Ijaz, Pei Xiao, Mehdi M. Molu, and Rahim Tafazolli. "Filtered OFDM systems, algorithms, and performance analysis for 5G and beyond." *IEEE Transactions on Communications* 66, no. 3 (2018): 1205-1218.
9. Kaur, Satwinder, Lavish Kansal, Gurjot Singh Gaba, and Nuru Safarov. "Survey of Filter Bank Multicarrier (FBMC) as an efficient waveform for 5G." *International Journal of Pure and Applied Mathematics*, Volume 118, No. 7(2018): 45-49.
10. Shaheen, Imad A., Abdelhalim Zekry, Fatma Newagy, and Reem Ibrahim. "Performance evaluation of PAPR reduction in FBMC system using nonlinear companding transform." *ICT Express* (2018).
11. Patil, Swapnil, and Shruti Patil2and Dr Uttam Kolekar. "Implementation Of 5G using OFDM and FBMC (Filter Bank Multicarrier)/OQAM (Offset Quadrature Amplitude Modulation)." *International Journal of Innovative Science, Engineering & Technology*, Vol. 5 Issue 1, January 2018: 11-15.
12. Bouhadda, Hanen, Hmaied Shaiek, Yahia Medjahdi, Daniel Roviras, Rafik Zayani, and Ridha Bouallegue. "Sensitivity analysis of FBMC signals to non linear phase distortion." In *Communications Workshops (ICC), 2014 IEEE International Conference on*, pp. 73-78. IEEE, 2014.
13. Zakaria, R., and D. Le-Ruyet. "SER analysis by Gaussian interference approximation for filter bank based multicarrier system in the presence of phase error." In *IEEE International Conference on Communications (ICC)*. 2015.
14. Bouhadda, Hanen, Hmaied Shaiek, Daniel Roviras, Rafik Zayani, Yahia Medjahdi, and Ridha Bouallegue. "Theoretical analysis of BER performance of nonlinearly amplified FBMC/OQAM and OFDM signals." *EURASIP Journal on Advances in Signal Processing* 2014, no. 1 (2014): 60.
15. Bedoui, Abla, and Mohamed Et-tolba. "A comparative analysis of filter bank multicarrier (FBMC) as 5G multiplexing technique." In *Wireless Networks and Mobile Communications (WINCOM), 2017 International Conference on*, pp. 1-7. IEEE, 2017.
16. (2008) Phydyas project fp7.[Online].Available:http//www.ict-phydyas.org/
17. Bellanger, “Digital signal processing-Theory and Practice." ser.Four volumes. Wiley,1999, Chichester,NY,USA.
18. Baltar, Leonardo G., and Josef A. Nossek. "Multicarrier systems: a comparison between filter bank based and cyclic prefix based OFDM." In *OFDM 2012, 17th International OFDM Workshop 2012 (InOWo'12); Proceedings of*, pp. 1-5. VDE, 2012.
19. Nissel, Ronald, and Markus Rupp. "OFDM and FBMC-OQAM in doubly-selective channels: Calculating the bit error probability." *IEEE Communications Letters* 21, no. 6 (2017): 1297-1300.

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