FBMC Modulation Schemes for 5GMobile Communications

[1]Dr. A . Naveena, [2]K. Pranathi

[1] Assistant Professor, Dept of ETE, G. Narayanamma Institute of Technology and Science (for women).

[2] PG-Student, Dept of ETE (WMC), G. Narayanamma Institute of Technology and Science (for women).

[1] naveenaambidi@gmail.com, [2] kpranathi26@gmail.com

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ABSTRACT— MCM (multicarrier Modulation) works on the concept of splitting a data stream into many bitstreams, each with a significantly low bit rate, and modulating the several carriers with sub-streams. Multicarrier modulation schemes such as FBMC and OFDM systems are used. Spectral efficiency of the FBMC system is higher than the OFDM system. The simulation results are used to examine the framework, argumentation, and evaluation of FBMC-OQAM (Filter bank multicarrier and Offset QAM), and its comparison with the OFDM (Orthogonal Frequency Division Multiplexing) system is observed. Furthermore, a higher throughput that is similar to the achievable rate is obtained, and the results of this study show that Filter bank multicarrier provides better performance than the OFDM system.

KEYWORDS:- Channel estimation, FBMC-OQAM, Multipath carrier, OFDM.

1. INTRODUCTION

OFDM is the prevalent wireless communication strategy today, and it is expected to continue to be applicable in the future. The key flaw in the OFDM system is that it involves the use of a CP (Cyclic Prefix). The main drawback of the OFDM method is that the subcarriers are not spectrally localized, resulting in spectral leakage and interference with the unsynchronized signal [1]. FBMC seems to be a good strategy for overcoming OFDM shortcomings and to meet 5G specifications. OFDM has increased demand and faced many problems in diverse networks as a result of the widespread use of the MCM technique in many wireless standards. A further disadvantage of OFDM is its unsustainable out-of-band leakage, which prevents OFDM from coexisting with other communication networks.

Multicarrier are proposed for channel sensing and coexistence of primary and secondary users[5], and good separation or filtering for different subcarriers such as FBMC is needed to avoid interference among them. FBMC aims to address the disadvantages of OFDM by improving spectral properties and channel utilization, as well as higher data rates, which are possible within such a specified wireless communications bandwidth [15]. Figure1.shows that the OFDM system with all subcarriers has a single band whereas in FBMC system each subcarrier has its own single band.

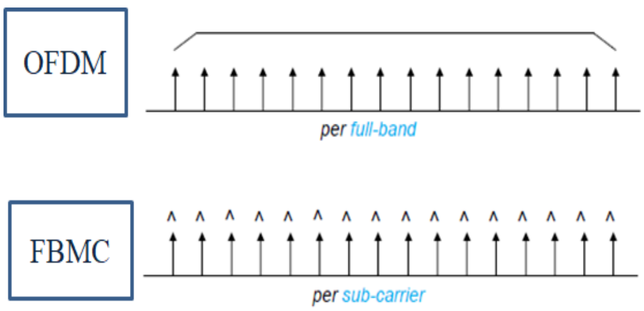

Figure1: Subcarriers in OFDM and FBMC systems

2. OFDM SYSTEM

OFDM is a digital signal modulation technique for reducing distortion and crosstalk by splitting a single data stream into many narrowband channels at different frequencies.

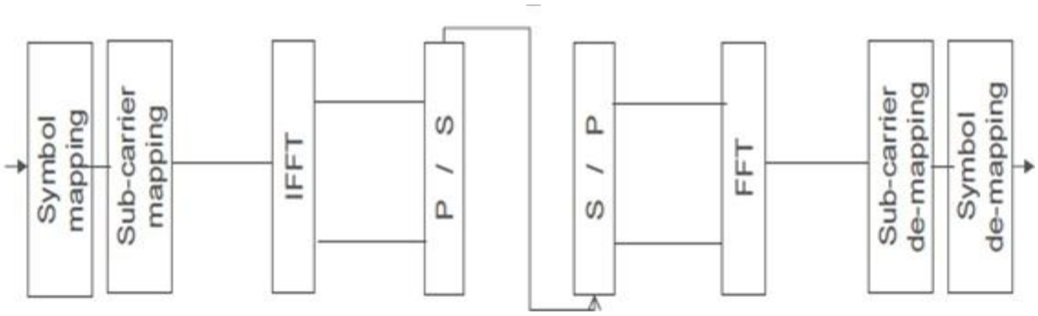

Figure 2: OFDM Block Diagram

Subcarrier orthogonality provides robustness towards multipath effects and allows for a quick and easy implementation an FFT block is used in Figure2. and the ability to use adaptive modulation and strategies of bit-loading, and on the other hand, the traditional OFDM system has a range of flaws as it results, in a low-cost solution for accommodating the complex and demands of 5G wireless networks [2]. OFDM uses a repetitive timeframe called cyclic prefix (CP) among two symbols to solve time distortion and facilitate per sub-carrier equalization.

The presence of a cyclic prefix in the OFDM system causes inefficient use of available transmission time, causing the optimal latency condition to be violated, leading to poor spectral fidelity and reduced throughput [2]. In OFDM, the transmitting and receiving filters are time-limited rectangular pulses with very high-frequency side-lobes, which causes spectral leakage to neighboring sub-carriers. Inter-Carrier Interference (ICI) is caused by these out-of-band emissions [1].

In time-varying cell networks, its orthogonality among many of the sub-carriers is distorted, which results in ICI. Inter Symbol Interference (ISI) and Inter Carrier Interference (ICI) affect OFDM, and stringent synchronization procedures and increasing power usage is required. The OFDM scheme has a high PAPR (Peak-to-average power ratio), some spectral efficiency loss due to Cyclic Prefix incorporation, and imperfect synchronization induces orthogonality loss [3]. The current development work would concentrate on the application of FBMC to address these shortcomings.

3. FBMC SYSTEM

The majority of today's wireless mobile networking technology is built on an extension of the OFDM scheme called OFDM with FBMC system [2]. Multicarrier processes, such as OFDM and FBMC, are multicarrier approaches in which data symbols are sent over several frequency subcarriers at the same time. According to the multicarrier nature of both signals, they have built-in support for frequency selective reference adoption, and the main difference across OFDM and FBMC systems is the pulse shaping introduced on every subcarrier [4]. The most significant improvement in the FBMC system is the replacement of the CP in OFDM with a multicarrier system that uses a filter bank as shown in Figure3. at both transmitter and receiver sections.

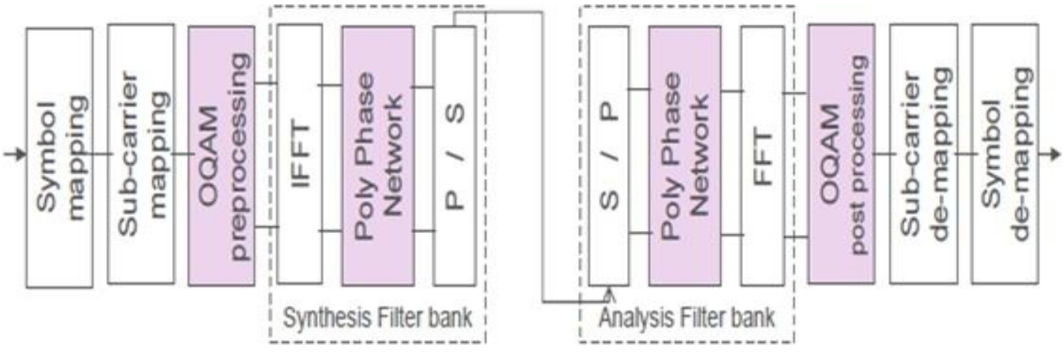

Figure 3: Reconstruction of modulators for FBMC by using different prototype filters and OQAM processing.

Symbol Mapping: This block's main function is to translate binary data into symbols and then map such symbols as frames to subcarrier mapping as input.

Subcarrier Mapping: It's important for making FBMC frames. Every frame of framed data has a preamble configuration that is used for fast carrier frequency tuning and timing synchronization and the frequency of each subcarrier is chosen from an orthogonal signal range, and those frequencies are known at the receiver to recover the signal.

IFFT: It transforms a region or signals to the frequency domain and is also known as the backward Fourier transform.

FFT: It represents the frequency domain by converting a signal from its original domain.

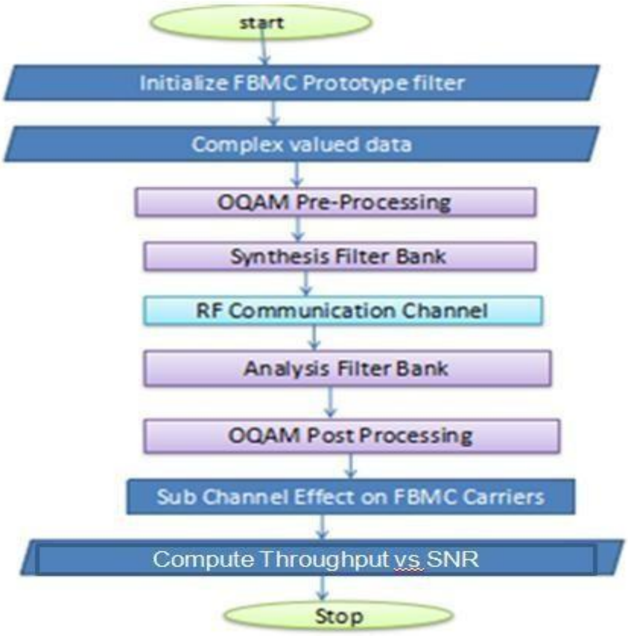

Figure 4: Flowchart of FBMC-OQAM

The prototype filter is the first filter throughout the filter bank attached to the zero frequency carriers that can deliver excellent functionality [5], and it uses the Offset Construction Quadrature Amplitude Modulation (OQAM) technique.

OQAM Pre-Processing: It has two operations

- Complex –to-real conversion
- Multiplication by sequence

OQAM Post-Processing: It also has the twooperations

- Multiplication by sequence
- Real-to-complex conversion

FBMC Methodology

The prototype filter for the zero frequency carriers is the FBMC solution, and it serves as the foundation for the other subcarrier filters. Filter banks will split a signal into sub-bands of different frequencies, allowing the spectrum to be partitioned equally [5]. Filters are defined using several multicarrier symbols which coincide within the time domain is known as the overlapping factor K. The order of the prototype filters can be modified as the length of the filter is P = $M*K-1$ where K = 2, 3, or 4.

M = symbol size, K= $values\ of\ P_0P_1P_2\ldots$, P= length of prototype filter and the transmitted signal s(t) of Throughout the time domain, a multicarrier device is specified as :

$$S(t)=\sum_{k=0}^{k-1}\sum_{k=0}^{k-1} g_{l,k}\ (t)\ X_{l,k} \qquad (1)$$

Where in (1) the s(t) is a transmitted signal of a multicarrier system $x_{l,k}$ denotes the transmitted symbol at subcarrier position l, and time position k. The transmitted basis pulse in (2), $g_{l,k}$(t) in s(t) is defined as:

$$g_{l,k}(t) = p(t-kT)e^{j2\pi lF\,(t-kT)}e^{j\theta l\,.k} \qquad (2)$$

Thus p(t) is a time and frequency shifting variant of prototype filter, including T denoting time sampling and F symbolizing frequency spacing, whereas $g_{l,k}$(t) is pulse basis (basis pulse and orthogonal) (subcarrier spacing), $\theta_{l,k}$ is phase shift which becomes relevant in FBMC-OQAM [5]. The FBMC provides good side lobe attenuation while using this prototype filter, but enhances spectral performance, and perhaps a superior prototype filter is constructed only with overlapping factor K, and indeed the FBMC gives excellent side lobe attenuation while using this prototype filter, therefore boosts spectral efficiency.

A synthesis analysis configuration is called Transmultiplexer, and a digital filter bank is a series of filters with a standard input or output (TMUX).

Synthesis filter bank: Synthesis filter bank works as MISO (multi inputs and single output). It consists of M upsamplers and M synthesis filters accommodate the synthesis filter bank shown at the transmitter side in Figure3. M/2 upsamples its input signals, which can then be filtered using synthesis filters

Analysis filter bank: The analysis filter bank is used to analyze the spectrum and works as SIMO (single input and multi outputs). It has an M analysis filter & M downsamplers compensate the analytical filter bank used at the receiver side as shown in Figure3. To generate the output signal, each input signal will be first filtered with only an analytical filter upon being downsampled by the factor of M/2.

A theory with basis pulses in (3), $g_{l,k}$(t) is based upon this received signal r(t).

$$Y_{l,k} =< r(t), g_{l,k}(t) >= \int_{-\infty}^{\infty} r(t) g_{l*k(t)dt} \qquad (3)$$

the received signal r(t), $y_{l,k}$ is a noisy received signal, $g_{l*,k}$ conjugative which is an inverse function of basis pulse and with the filter frequency samples l,k denotes the length of subcarriers and no of samples.

Hermite polynomials in (4), Hn(•) are used to build a prototype filter with FBMC-QAM.

$$P(t)=\frac{1}{\sqrt{T_0}} e^{-2\pi(\frac{t}{T_0})^2} \sum_{\substack{i=\{0.4.8.\\12.16.20\}}}^{\infty} a_i H_i(2\sqrt{\pi} = \frac{t}{T_0}) \qquad (4)$$

Whereas the time and frequency shifted version of the prototype filter is p(t) and with T denotes the orthogonal, i={0,4,8..} coefficients and TF=2 of time-frequency spacing. The complex-orthogonality status is balanced by the real-orthogonality property when R is added for FBMC-QAM, and it has the same symbol density as the OFDM without CP.

For one time-frequency location, in (5) the ergodic potential is given as

$$C=E_{\hbar}\{log_2(1+|\hbar|^2 SNR)\} \qquad (5)$$

$E_{\hbar}$ denotes an ergodic indicator, which is the maximum reciprocal knowledge between the input and output of channel power C, and h denotes the channel's impulse response with signal to noise ratio SNR. In certain circumstances, in (6) a data symbols being chosen from the fixed signal constellation which is used the BICM capacity:

$$C_B = E_{\hbar}\left\{max_{x\epsilon\{A_1A_2..\}}(M-\sum_{i=1}^{m} E_{b,\frac{y}{\hbar}}\left[log_2\frac{\sum_{x\epsilon X} pdf_{\hbar}\left(\frac{y}{x}\right)}{\sum_{x\epsilon X_b^i}\left(\frac{y}{x}\right)}\right])\right\} \qquad (6)$$

Where C_B is the BICM capacity, which also includes the adaptive symbol alphabets $\{A_1A_2\ldots.\}$ and at once the subcarrier spacing (pulse shape) matches the channel statistics, a one-tap equalizer is sufficient for the FBMC receiver [6], Assuming that each subcarrier has a limited bandwidth subcarrier band, an equalization strategy is applied at the output of the analysis filter banks [9]. The primary aim of FBMC is to equalize the segment prior to taking the actual portion in order to prevent unreal (imaginary) interference. As a consequence, channel estimation should be performed in the dynamic domain, which takes into account imaginary interference and complicates the estimation process.

Based on Block-Type Pilot Arrangement Channel Estimation

If indeed the channel is stable mostly during block when the pilots are sent to each carrier and now all the data subcarriers are transmitted via the channel, there may be no frequency calculation error, but there will also be random errors to noise sources [8]. A (Least Square) LS estimator is used to achieve perfect channel estimation. The channel estimate at pilot sub-carriers confirmed the LS estimation is given by:

$$\text{Hp (k)} = \frac{Yp(k)}{Xp(k)} \qquad (7)$$

Where $Y_p(k)$ and $X_p(k)$ are errors output and received output in (7), at the Kth pilot sub-carriers respectively. Cognitive radios, Digital subscriber lines, power line communications, and doubly dispersive networks, among other applications, can benefit from FBMC. The key advantage of FBMC is that it can provide spectrum performance, and the cyclic prefix, CP, necessary for OFDM is not required, freeing up more space for real data [8].

4. RESULTS

Simulation Results of FBMC-OQAM and OFDM

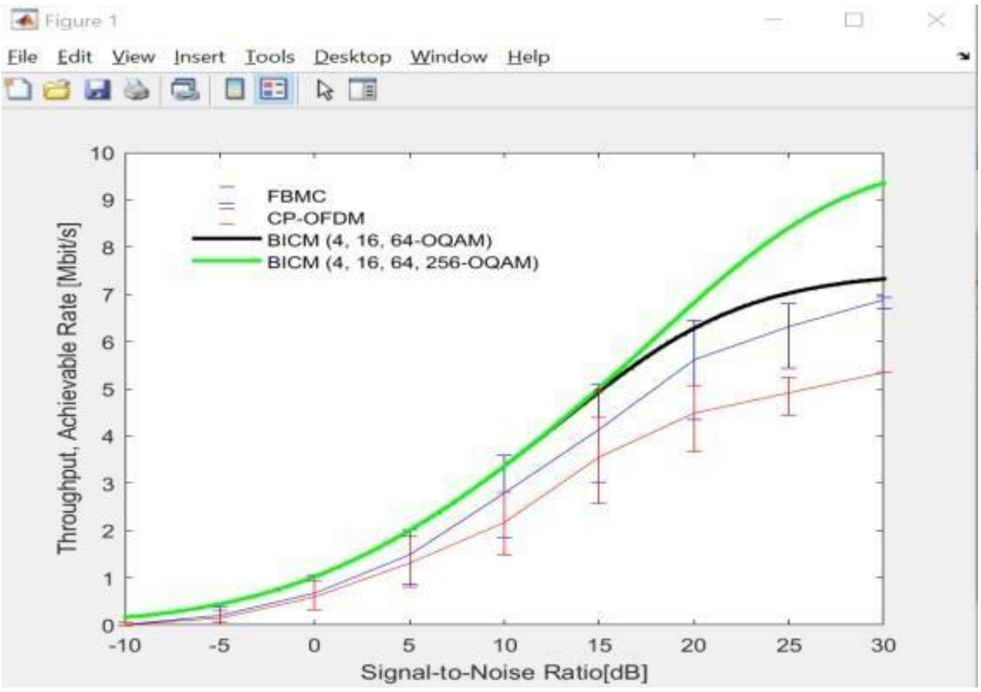

Figure5. Simulation outcome of throughput vs. SNR bythe measurements of various techniques like FBMC, CP-OFDM, and BICM with OQAM.

The results obtained were compared to information theory and measurements of CP-OFDM, BICM with FBMC-OQAM, and Matlab software was used to incorporate OFDM and FBMC systems. Since FBMC has a higher outturn than the OFDM system due to the higher available information measures and lack of CP overhead, channel calculation in FBMC system uses the information spreading process, while in BICM, Using such a symbol alphabet up to 256-OQAM increases the achievable rate, where 64 and 256 OQAM are modulation index stages. The calculated throughput is similar to the feasible values when the SNR is large, but the throughput benefit is lower, and the power and hardware costs are far higher. As a result, SNR often operates in the middle of the spectrum.

5. CONCLUSION

The FBMC system is the physical layer version. For a group of sub-carriers, an FBMC system employs a single filter which is a unique modulation method known as multicarrier modulation. Multicarrier modulation is a signal waveform in which several carriers are closely spaced in an extremely large block to carry data. The calculated throughput is similar to the feasible values when the SNR is high, but with a limited throughput gain and the power and hardware costs are higher. As a consequence, SNR often operates in the middle of the spectrum. Owing to more available bandwidth and no CP overhead, FBMC has a higher throughput than the OFDM system.

REFERENCES

[1]. R. Nissel, S. Schwarz, and M. Rupp, “Filter bank multicarrier modulation schemes for future mobile communications,” IEEE Journal on Selected Areas in Communications, vol. 35, no. 8, pp. 1768–1782, 2017.

[2]. R. Nissel, “Filter bank multicarrier modulation for future wireless systems,” Dissertation, TU Wien, 2017. [Online]. Available: https: //publik.tuwien.ac.at/files/publik 265168.pdf

[3]. R. Nissel and M. Rupp, “Enabling low-complexity MIMO in FBMCOQAM,” in IEEE Globecom Workshops (GC Wkshps), Dec 2016.

[4]. R. Nissel, J. Blumenstein, and M. Rupp, “Block frequency spreading: A method for low-complexity MIMO in FBMC-OQAM,” in IEEE SPAWC, July 2017.

[5]. Taewon Hwang, Chenyang Yang, Gang Wu, Shaoqian Li.(2009) ‘OFDM and Its Wireless Applications: A Survey’; *IEEE Transactions on Vehicular Technology*

[6]. R. Nissel, E. Zochmann, M. Lerch, S. Caban, and M. Rupp, “Low- ¨ latency MISO FBMC-OQAM: It works for millimeter waves!” in IEEE International Microwave Symposium, June 2017.

[7]. R. Nissel and M. Rupp, “Pruned DFT spread FBMC: Low PAPR,low latency, high spectral efficiency,” IEEE Trans. Commun., 2018, to appear.

[8]. R. Nissel and M. Rupp, “OFDM and FBMC-OQAM in doubly-selective channels: Calculating the bit error probability,” IEEE Communications Letters, vol. 21, no. 6, pp. 1297–1300, 2017.

[9]. Behrouz Farhang and Boroujeny (2011), “OFDM Versus Filter Bank Multicarrier”, *IEEE Transactions on Signal Processing Magazine*, Volume: 28, Issue: 3,pp 92-112.

[10]. Behrouz Farhang and Boroujeny, “Filter Bank Multicarrier Modulation: A Waveform Candidate for 5G and Beyond”, *Hindawi Publishing Corporation Advances in Electrical Engineering* ,Volume 2014

[11]. B.M.Popovic (2010), “Efficient DFT of Zadoff-Chu sequences”, *IEEE Transactions on Electronics Letters*,Volume: 46, Issue: 7, pp.502-503.\

[12]. Juho Lee, Younsun Kim, Yongjun Kwak and Yingyang Li (2016), “LTE-Advanced in 3GPP Rel - 13/14: An Evolution Towards 5G”, *IEEE Transactions on Communications Magazine Communications Standards Supplement*, pp.36-42.

[13]. Stijn Van Caekenberghe, André Bourdoux, and Jérôme Louveaux (2014), “Preamble-based frequency-domain joint CFO and STO estimation for OQAM- based filter bank multicarrier , *EURASIP Journal on Advances in Signal Processing*.

[14]. M. Tanda, T. Fusco, and A. Petrella “Joint symbol timing and CFO estimation for OFDM/OQAM systems in multipath channels*,” Eurasip Journal on Advances in Signal Processing*, vol. 2010, Article ID 897607.

[15]. A. Naveena, K. pranathi, “A Survey on Channel Estimation in Multicarrier Modulation Schemes” Dept of ETE G. Narayanamma Institute of Technology and Science (for women) Hyderabad ISSN : 0950-0707 Volume X Issue III march 2021.