FBMC-New Multicarrier Modulation Technique

B. Sujitha Gowri
PG Student, Department of ECE
JNTUACEA
Ananthapuramu, India

Dr. P. Ramana Reddy
Professor, Department of ECE
JNTUACEA
Ananthapuramu, India

***Abstract*—OFDM is the basic multi carrier modulation technique for both wireless and cellular communications. OFDM is a perfect choice for point-to-point communication, which offers minimum complexity and achieves very high bandwidth. However, it has several challenges such as, limited spectral efficiency and large out of band emissions. In order to overcome these challenges, there are several modulation techniques being developed in these days, among these Filter Bank Multi Carrier (FBMC) is one of the techniques. This paper describes about Power Spectral Density (PSD) and Bit Error Rate (BER) of the FBMC and conventional Cyclic Prefix (CP) based Orthogonal Frequency Division Multiplexing (OFDM) systems under Additive White Gaussian Noise (AWGN) channel. FBMC technique has less out of band emissions as a result of less number of side lobes. Meanwhile, the omission of CP improves the bandwidth efficiency of the system.**

Keywords—OFDM; FBMC; OQAM

I. INTRODUCTION

By the year 2020, density of users increases to use massive Internet of things and they require high data rates with high spectral efficiency. By integrating new waveforms, multi antennas, multiple radio technologies, multiple access techniques, millimetre wave bands, high spectral efficiency and low latency can be achieved.

Multi Carrier Modulation (MCM) is a method of sending data by splitting it into several parallel sub-streams and sends each sub stream on a different frequency known as a subcarrier. The Inverse Fast Fourier Transform itself acts as a multi carrier modulator and the Fast Fourier Transform serves as a multi carrier demodulator.

The receiver (FFT) is to be perfectly aligned in time with the transmitter (IFFT) for the proper functioning of the system. In multi path propagation, due to the channel impulse response, the multi carrier symbols overlap at the receiver input and it is no more possible to demodulate with just Fast Fourier transform, because Inter Symbol Interference has been introduced and the orthogonally property of the carriers has been lost. There are two options to maintain this orthogonality:

1. Extending the symbol duration by a cyclic prefix known as OFDM.
2. Keep the timing and the symbol duration as it is, but add some processing to the FFT, this scheme is FBMC.

FBMC may be considered as the flexible waveform configuration for fifth generation wireless communications because of its negligible out of band emissions. Unlike OFDM, Cyclic Prefix is not used in FBMC. It will improve the bandwidth efficiency. FBMC uses prototype filters with Offset QAM (OQAM) modulation technique. Advantages of FBMC waveform are higher throughput, good BER and gain in PSD.

II. OFDM TECHNIQUE

Orthogonal Frequency Division Multiplexing is a powerful way to solve the problem of Inter Symbol Interference (ISI). In the transmitter of OFDM, a bit stream is usually mapped to quadrature amplitude modulation symbols.

The serial-to-parallel converter then takes a block of symbols as a function of frequency and mixes each symbol with one of the sub-carriers by adjusting the amplitude and phase. After the addition stage the data that represent the in-phase and quadrature components as a function of time. The mixing and addition steps are simply converted the data from a function of frequency to a function of time. This can be performed by the Inverse Fast Fourier Transform (IFFT) and pick up the time-domain signal from the output. This can then be digitized, filtered and mixed with radio frequencies for transmission.

Receiver takes multiple copies of the transmitted signal with different arrival times in a multi path environment. These are added together, giving a sine wave with the same frequency but a different amplitude and phase. In order to reduce this symbol interference, the last part of the each symbol is added to the front end of that symbol known as cyclic prefix. The OFDM transceiver block diagram is as shown in Figure 1.

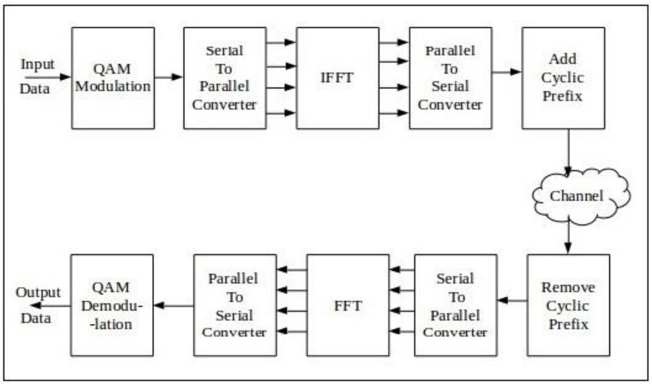

Figure 1: Block Diagram of OFDM Transceiver

OFDM receiver starts by sampling the incoming signal, filtering it and converting it into baseband. It then passes the data through Fast Fourier Transform to recover amplitude and phase of each sub carrier.

OFDM has been adopted in the DSL and wireless standards such as IEEE 802.11, 802.16, 3GPP-LTE and LTE-Advanced.

III. FBMC TECHNIQUE

The core of the FBMC system is the TMUX (Trans-multiplexer) configuration. The channel equalization problem is handled separately so the transmission channel is typically omitted when analyzing and designing TMUX systems. QAM and OQAM constellation diagrams are as shown in below Figure 2.

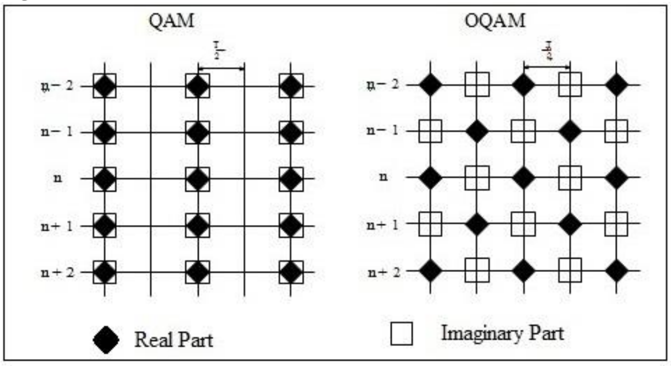

Figure 2: Constellation Diagram for QAM and OQAM

The FBMC transmitter accepts a stream of bits and converts them to symbols using QAM modulation technique. The complex valued symbols passes through OQAM processing block. FBMC has four stages:

1) OQAM Pre-Processing
2) Synthesis Filter Bank
3) Analysis Filter Bank
4) OQAM Post-Processing

FBMC Transmitter block diagram is as shown in below Figure 3.

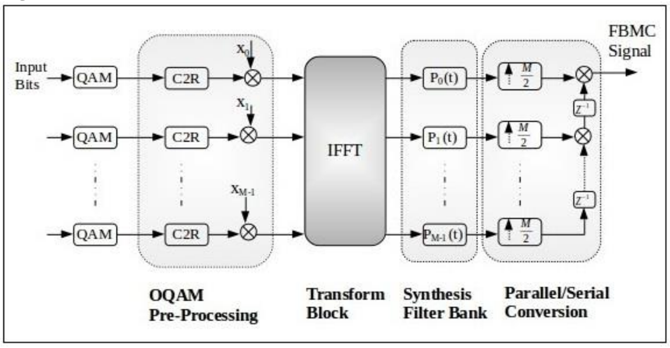

Figure 3: Block Diagram of FBMC Transmitter

A. OQAM Pre-Processing

It has two operations, first operation is complex-to-real conversion, where the real and imaginary parts of complex-valued symbols are separated to form two new symbols and this is known is staggering. It increases the sample rate by a factor of 2. The second operation is the multiplication by sequence. The input signals to the IFFT are purely real or imaginary after OQAM processing.

B. Synthesis Filter Bank

Synthesis Filter Bank is used at the transmitter side. It consists of M up samplers and M synthesis filters. The input signals are first up sampled by M /2 and then filtered with synthesis filters.

FBMC receiver block diagram is as shown in figure 4 below. It includes Analysis Filter Bank and OQAM post processing stages.

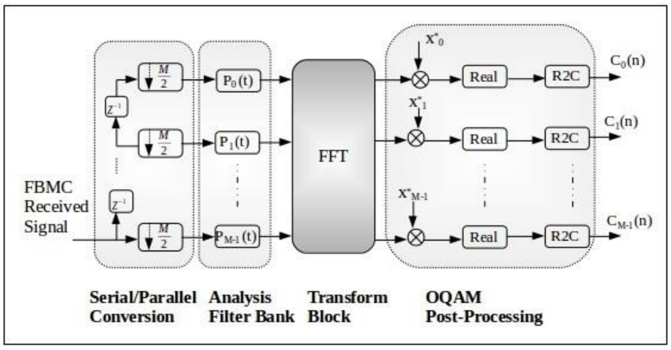

Figure 4: Block Diagram of FBMC Receiver

C. Analysis Filter Bank

Analysis Filter Bank used at the receiver side. It is constructed by M analysis filters M down samplers. The input signal is first filtered by analysis filter and these are down sampled by a factor of M /2 to form output signal.

D. OQAM Post-Processing

Post processing also has two operations.

1) Multiplication by sequence
2) Real-to-complex conversion

In Real-to-Complex conversion two successive real-valued symbols form a complex-valued symbol (De-staggering). It decreases the sampling rate by a factor 2.

E. Prototype Filter Design

The first filter in the filter bank associated with the zero frequency carrier is called prototype filter because the other filters are deduced from it through frequency shifts. In this work, the better prototype filter is designed with the overlapping factor K=4. The frequency domain coefficients of filter are shown below:

P0=1; P1=0.971960; P2=0.707; P3=0.235147

FBMC provides good side lobe attenuation by using this prototype filter, which improves spectral efficiency and they satisfy the below equation,

$$\frac{1}{K}\sum_{k=-K+1}^{K-1}\left|p_k{}^2\right| = 1$$

Base on these coefficients, the frequency response of the filter with M sub carriers is obtained through the equation,

$$p(f) = \sum_{k=-(K-1)}^{K-1} p_k \frac{\sin\left(\pi\left(f-\frac{k}{MK}\right)MK\right)}{MK\sin\left(f-\frac{k}{MK}\right)}$$

The impulse response p[m] of the prototype filter is given by applying the IFFT to the frequency responses

$$p[m] = 1 + 2\sum_{k=1}^{K-1}(-1)^k p_k \cos\left(\frac{2\pi k}{MK}m\right); m = 1 to L_P - 1$$

Where,
k = Subcarrier index
K= Overlapping factor
M= Number of subcarriers

Impulse response of prototype filter with overlapping factor K=4 is as shown in Figure 5 below.

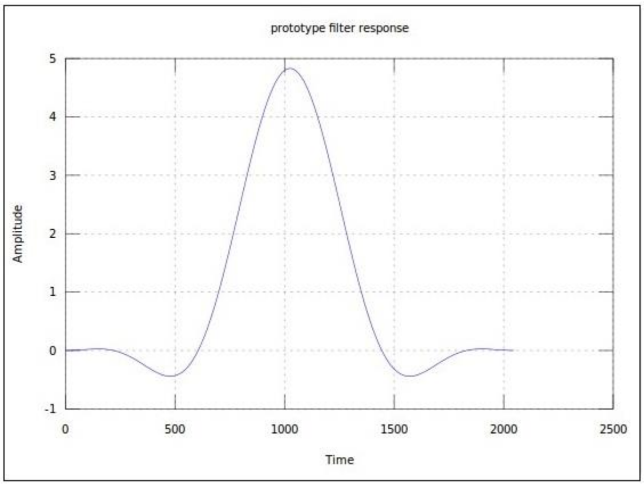

Figure 5: Impulse Response of Prototype Filter for K=4

IV. PERFORMANCE METRICS

Performance metrics of this project are Power Spectral Density (PSD) and Bit Error Rate (BER).

A. Power Spectral density (PSD)

Power Spectral Density (PSD) shows the strength of the energy of a signal as a function of frequency and it can be measured in dB/Hz. Energy can be obtained within a particular frequency range by integrating PSD within that frequency range.

Steps to calculate PSD are as follows:

1) *Consider the transmitted signal 'x'*
2) *Calculate FFT of transmitted signal which is 'y'*
3) *Calculate magnitude of 'y' and the resultant signal is 'z'*
4) *Square of 'z' is the required PSD of signal*

PSD depends on modulation level and it increases with increase in modulation level.

B. Bit error Rate (BER)

BER is the number of bit errors per unit time. It is unit less and often expressed as percentage. BER curves are used to measure the performance of a digital communication system. Bit errors are caused by:

- Damaged connections
- Incorrect signal levels
- Adjacent channel interference
- Noise in the channel

Theoretical probability of bit error expression is same for both OFDM and FBMC under AWGN channel, which is given by the following equation:

$$p_b \approx \frac{\sqrt{M}-1}{\sqrt{M}\log\left(\sqrt{M}\right)} erfc\left(\sqrt{\frac{3\log(M)E_b}{2(M-1)N_0}}\right)$$

Where,
M=Modulation Level

V. ADVANTAGES

- FBMC uses OQAM modulation technique and it allows pulse shaping filters
- FBMC has higher side lobe decay compare to OFDM
- It has high bandwidth efficiency
- Suitable for fragmented spectrum for Co Ordinated Multipoint
- FBMC is suitable for environments with high mobility than OFDM

VI. CONCLUSION

In this paper, new multicarrier modulation technique Filter Bank Multi Carrier is introduced to improve the bandwidth efficiency of existing Orthogonal Frequency Division Multiplexing. FBMC gives overall better performance compared to OFDM, proving FBMC as an ideal candidate for fifth generation cellular networks.

REFERENCES

[1] "Comparison and evaluation between OFDM and FBMC systems". http://www.redes.unb.br/lasp/files/events/WSA2015/WSA_2015_Paper/07_He.pdf
[2] M. Bellanger, "FBMC physical layer: a primer, PHYDYAS", Jan 2010
[3] "Waveform Candidate Selection-5G NOW", [Online]. Available: http://www.5gnow.eu/wpcontent/uploads/2015/04/5GNOW_D3.1_v1.1_1.pdf
[4] "Prototype Filter and Structure Optimization", Available: www.ict-phydyas.org
[5] "Estimation of FBMC/OQAM Fading Channels using Dual Kalman Filters", http://dx.doi.org/10.1155/2014/586403
[6] "Comparative Analysis of FBMC and OFDM Multicarrier Techniques for Wireless Communication Networks", International Journal of Computer Applications (0975-8887) Volume 100- No.19, August 2014
[7] "Application of the FBMC Physical Layer in Cognitive Radio Scenario"
[8] A. Sahin, I. Guvenc, and H. Arslan, "A survey on multicarrier communications: Prototype filters, lattice structures, and implementation aspects," Communications Surveys Tutorials, IEEE, vol. 16,no.3,pp. 1312-1388, Third2014