A PHYSICAL LAYER TECHNIQUE (FBMC) FOR 5G AND BEYOND

[1]Radhika Y T, [2]Dr. Prabhavathi S
[1] M.Tech Student, [2]Professor
[1]Department of Electronics and Communication Engineering,
[1]RYMEC, Ballari, INDIA.

Abstract:

The upcoming wireless communication systems require optimal usage of the bandwidth provided. As the technology is getting advanced, the data traffic is going to increase so there is difficulty in utilizing the spectrum provided if the conventional physical layer technique called as Orthogonal Frequency Division Multiplex (OFDM) is used, because it needs cyclic prefix. There is also difficulty while Multiple- input and Multiple-output (MIMO) is to be used. This paper develops a method prior to the OFDM which provides more spectral efficiency and characterized for the well-localized spectrum, this technique is called as Filter Bank Multi-Carrier (FBMC).To show that FBMC is an well-organized modulation scheme than the OFDM, this paper compares the responses and density estimates of FBMC and OFDM through the results simulated using MATLAB.

***Index terms* -** Wireless communication systems, bandwidth efficiency, OFDM, FBMC, MATLAB, Filter banks, Multi-carrier modulation.

I. INTRODUCTION:

The major phase in the mobile telecommunications standard is the upcoming generation of wireless system that is 5G and beyond. As the technology advances the number of users to accommodate the available spectrum increases, this will automatically increase the data traffic (*R. Nissel et al.*). When there was a concept to develop new generations for the wireless systems, then a modulation scheme called as FBMC became the front runner to get the attention of engineers who were participating in the designing of future wireless systems and this technique does not use the Cyclic Prefix (CP) as used by the OFDM process (*B. Farhang-Boroujeny*).

In the OFDM technique the cyclic prefix is used, which will reduce the inter symbol interference. The cyclic prefix is added to each period of a symbol. It is generated by copying the fraction of end bits of the symbol at the starting. Generally 25% of the total number of bits is added as a CP. For example if a symbol is having 32-bits the 25% of it is 8-bits is added as CP. Due to the presence of cyclic prefix there will be reduction in the available bandwidth which causes less accumulation of the information bits. FBMC provides a solution for this problem (*B. Farhang-Boroujeny*).

In FBMC there are mainly three types they are cosine multi tone, filtered multi tone and offset QAM or staggered multi tone. In this paper Offset Quadrature Amplitude Modulation (OQAM) is proposed. In the OQAM technique the orthogonality between the sub-carriers is maintained and also there will be separation of real and imaginary components that is the in-phase and quadrature components are out of phase by 90 degree (*M. Bellanger, et al.*). The FFT block is required at the modulator and demodulator. Analysis and Synthesis filter banks are used at the receiver and transmitter side respectively.

At first a prototype filter which was introduced by the Physical Layer for Dynamic Access and cognitive radio (PHYDYAS) project is designed and then the different carriers are created by shifting the response of filter at zero carrier frequency in the frequency domain. The simulations in MATLAB show that the FBMC technique is a well organized method than OFDM (*A. N. Ibrahim, et al.*).

II. MULTICARRIER MODULATION:

The principle of multicarrier modulation scheme is as shown in the figure 1. Where the large data is divided and then sent over the transmitter. There are different types of multicarrier schemes in this paper OFDM and FBMC processes are discussed.

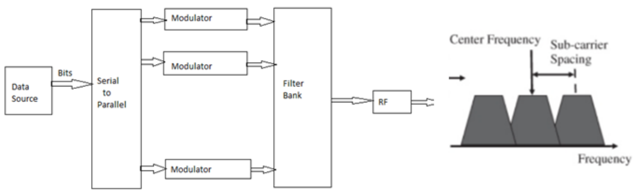


Figure 1: Principle of Multi carriers

III. STRUCTURE OF OFDM AND FBMC:

ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM):

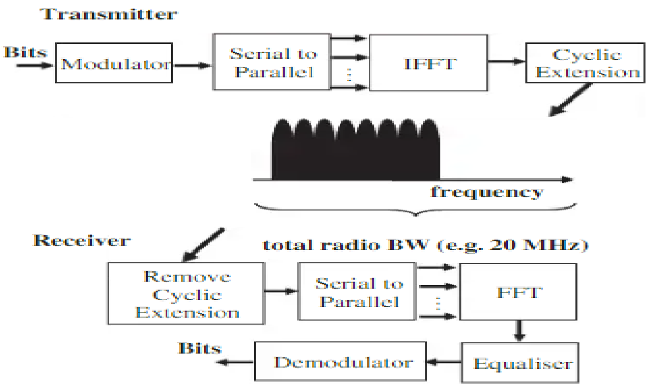


Figure 2: OFDM Structure

The OFDM is a multicarrier modulation scheme that is used for 4G systems. The carriers are separated by 15KHz. The high data stream is divided into lower rate data streams and then transmitted over the channel. The bits are modulated and then fed to the serial to parallel converter block and then the divided data is carried by different subcarriers generated by the IFFT section. To each subcarrier cyclic prefix is added at the header. At the receiver side the cyclic extension is removed and then FFT is used so that low rate data bits from different subcarriers are recovered. A Minimum Mean Square Error (MMSE) equalizer is used to perfectly reconstruct the signal and then the signal is demodulated as shown in the figure 2..

FILTER BANK MULTICARRIER (FBMC):

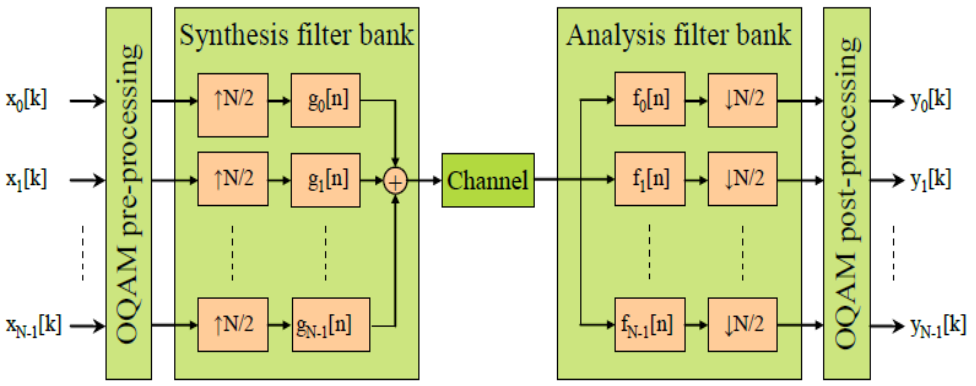


Figure 3: Structure of FBMC

FBMC is a multicarrier modulation scheme which provides better spectrum efficiency than OFDM. The general structure of FBMC is shown in the figure 3. The first step is to design the prototype filter, this is done according to the Nyquists criterion which is specified by the PHYDYAS project. The impulse response of the prototype filter is given by

$$h(t) = 1 + 2\sum_{k=1}^{K-1} H_k \cos(2\pi \frac{kt}{KT})$$

Where K is the factor of overlapping, T is the symbol duration and H_k is the coefficients of the filter in frequency domain and it is given in the table 1.

Table 1: Coefficients of the filter

K	H_0	H_1	H_2	H_3
2	1	$\sqrt{2}/2$	-	-
3	1	0.911438	0.411438	-
4	1	0.971960	$\sqrt{2}/2$	0.235147

The filter banks are formed by using the extended IFFT and FFT. In order to reduce the complexity in the computations polyphase structure is used as shown in figure 4.

The polyphase decomposition is given by

$$B_1(Z) = \sum_{p=0}^{M-1} e^{\frac{j2\pi p}{M}} Z^{-p} H_p(Z^p)$$

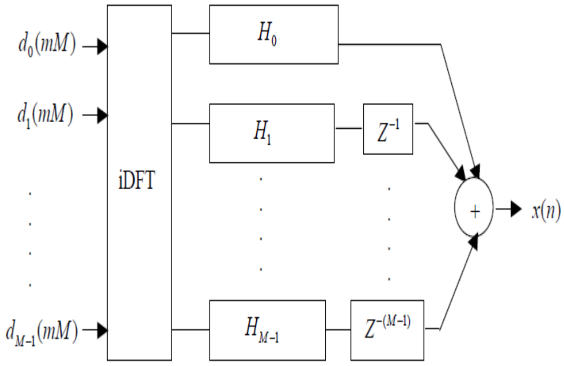


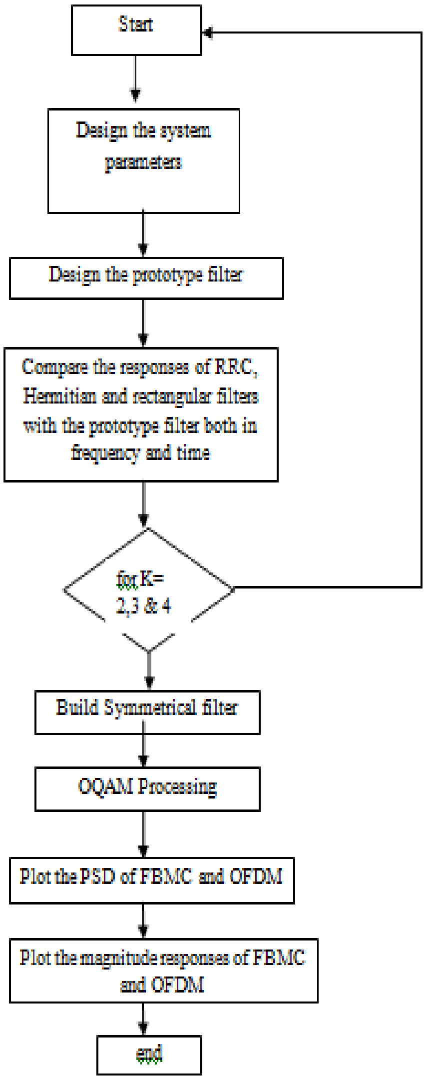
Figure 4: Polyphase structure

The real and imaginary parts are separated with the help of OQAM processing; this doubles the symbol rate which causes gap between imaginary and real parts. In order to compensate this problem interpolation and decimation is done by a factor of 2.

The polyphase matrix for the structure in figure 4 is given by

$$\begin{bmatrix} B_0(Z) \\ B_1(Z) \\ . \\ . \\ B_{M-1}(Z) \end{bmatrix} = \begin{bmatrix} 1 & 1 & . & . & 1 \\ 1 & W^{-1} & . & . & W^{-M+1} \\ . & . & . & . & . \\ . & . & . & . & . \\ 1 & W^{-M+1} & . & . & W^{-(M-1)^2} \end{bmatrix} \begin{bmatrix} H_0(Z^M) \\ Z^{-1}H_1(Z^M) \\ . \\ . \\ Z^{-(M-1)}H_{M-1}(Z^M) \end{bmatrix}$$

IV. FLOW CHART TO COMPARE OFDM AND FBMC IN MATLAB:



From the flow chart it is observed that the OFDM and FBMC are compared by considering different parameters by using MATLAB.

V. SIMULATION RESULTS:

The techniques OFDM and FBMC are compared based on different aspects. The different types of prototype filters are compared. The system parameters considered for the simulation purpose are shown in the table 2.

Table 2: System parameters

System Parameters:

Number of points of FFT	1024
Number of Guard Bands	212 on either sides
Bits per sub-carrier	8 for 256 QAM
Overlapping factor for FBMC	K=4
Signal to Noise Ratio	12 dB
Number of Sub-carriers	256

At first the prototype filter is designed and the simulated output is shown in the figure 5.

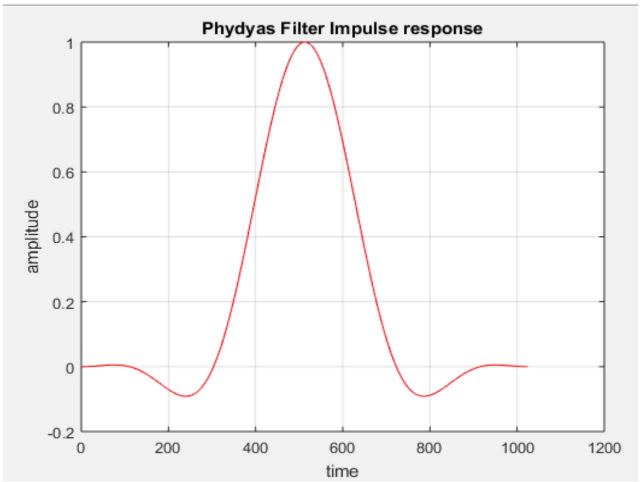


Figure 5: Phydyas Filter's Impulse Response.

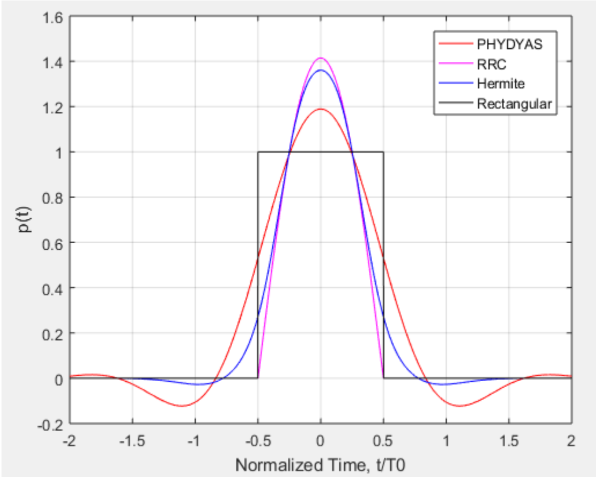


Figure 6: Responses of different filters in the time domain.

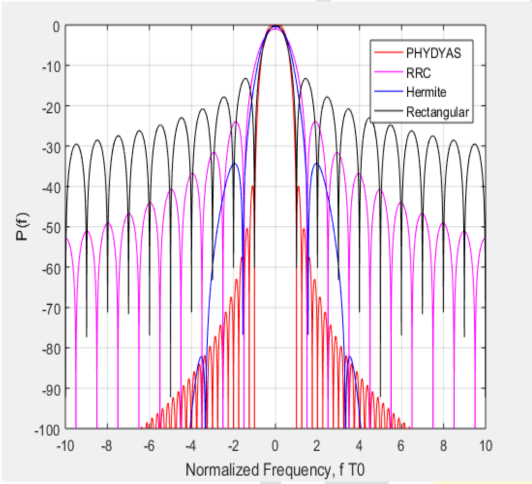


Figure 7: Responses of different filters in the frequency Domain

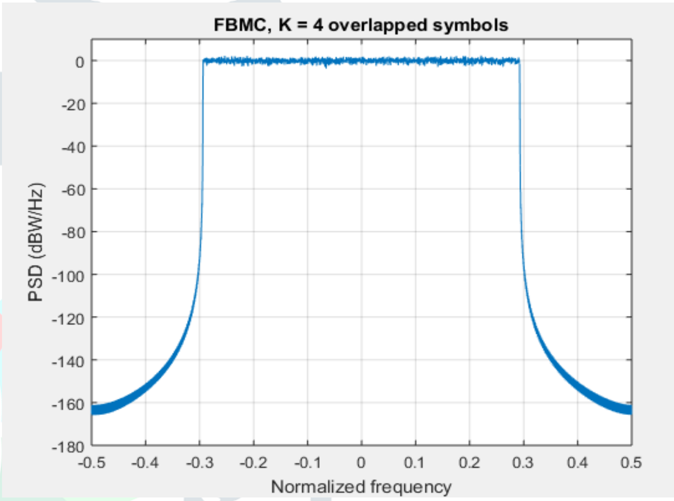


Figure 8: Power spectrum estimation of FBMC

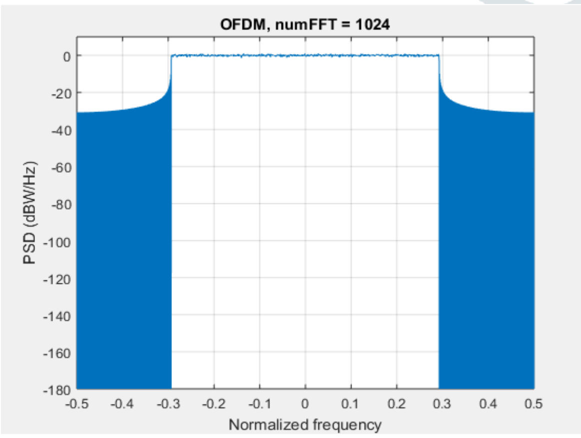


Figure 9: Power spectrum estimation of FBMC

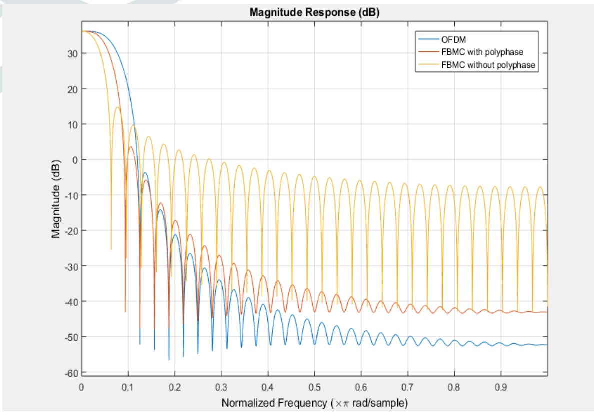


Figure 10: Magnitude responses of OFDM and FBMC.

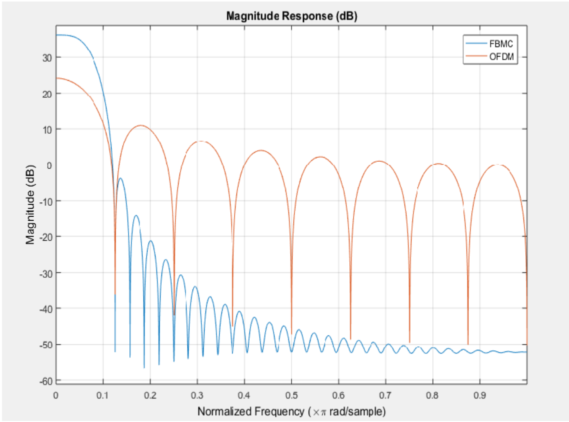


Figure 11: Magnitude responses of phydyas and prototype filter of FBMC and OFDM.

The number of subcarriers are considered to be less than or equal to half of the size of FFT. The different filter responses such as Hermitian, Root Raised cosine and the response of the rectangular filters are compared with the response of the phydyas filter. These are compared in both time domain and the frequency domain as shown in the figures 6 and 7.

The estimates of the power spectrum using periodogram function are shown in the figures 8 and 9. In the power density estimates there is leakage in the bandwidth in case of OFDM. But in FBMC there is no leakage. Since there are large number of users, it is difficult to provide service within the specified bandwidth with the presence of cyclic prefix hence there is leakage. The FBMC developed using the filter banks and the polyphase structures to block the inter symbol interference instead of using the cyclic prefix at the header part so spectrum can be efficiently used.

By looking at the magnitude response of OFDM and FBMC as shown in the figures 10 and 11 it is clear that there is more leakage in OFDM.

IV.CONCLUSION

In this paper it is proved that there are more spectral emissions that are out of the given bandwidth in the OFDM system hence the information sent may get lost. The FBMC is shown to be the better approach to provide more efficient bandwidth. The simulation results showed that the proposed technique is well convenient method to be used for the upcoming generations of wireless systems.

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]. B. Farhang-Boroujeny, "Filter bank multicarrier modulation: A waveform candidate for 5G and beyond," *Advances in Electrical Engineering*, vol. 2014, December 2014.

[3]. 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

[4]. M. Bellanger, D. Le Ruyet, D. Roviras, M. Terré, J. Nossek, L. Baltar, Q. Bai, D. Waldhauser, M. Renfors, T. Ihalainen, *et al.*, "FBMC physical layer: a primer," *PHYDYAS, January*, 2010.

[5]. A. N. Ibrahim, and M. F. L. Abdullah The potential of FBMC over OFDM for the future 5G mobile communication technology, AIP Conference Proceedings **1883**, 020001 (2017); https://doi.org/10.1063/1.5002019 **,** Published Online: 14 September 2017.

[6]. B. Farhang-Boroujeny, "OFDM Versus Filter Bank Multicarrier," IEEE Signal Processing Magazine, vol. 23, pp. 92-112, May 2011.