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PSD ANALYSIS OF FBMC SYSTEM USING PHYDYAS FILTER

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***Abstract*— Orthogonal Frequency Division Multiplexing (OFDM) technique has its own dominant effect on broadband transmission systems. It has been an excellent waveform choice for next generation wireless communication system such as LTE/LTE-A system. However, the frequency spectrum behavior of subcarrier signals in OFDM is not good enough, which is the main source of problems for future development as the spectrum allotted is limited. Filter Bank Multi-Carrier (FBMC) technique, on the other hand, as a candidate waveform for 5G mobile communications, is an elegant method that solves most of these problems by pulse shaping the individual subcarrier by using a filter bank. This paper, investigates the PHYDYAS prototype filter response for both OFDM and FBMC systems.**

***Index Terms*— FBMC System, PHYDYAS Filter, PSD Analysis.**

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a Multi-Carrier Modulation (MCM) techniue which is successfully used in WiMAX, LTE, LTE-Advanced. MCM technique have been extensively used over the last decade for broadband wireless communications. Among many other multicarrier techniques, Orthogonal frequency division multiplexing dominates the current broadband wireless communication systems. OFDM has been an excellent waveform choice for WiFi, WiMAX, 4G-LTE/LTE-A. It is widely adopted because of a number of advantages that it offers, such as orthogonality of subcarrier signals and flexibility towards Multiple-Input Multiple-Output (MIMO) channels. Also it is highly immune to Inter Symbol Interference (ISI)[1]. However, there are also some disadvantages that are not suitable for 5G communications, such as, OFDM requires the use of a Cyclic Prefix (CP) which doesn't have any useful information, and large side-lobes is present between adjacent subcarriers. Large side lobes in OFDM creates challenging problem in practical systems. These side lobes result in reduced spectral efficiency of OFDM. To meet the 5G waveform requirements like high spectral efficiency, ultra-high rate and low latency some new candidate waveforms such as, Filter Bank Multi-Carrier (FBMC), Universal Filtered Multi-Carrier (UFMC) and Generalized Frequency Division Multiplexing (GFDM), have been proposed [2, 3].

FBMC is a multicarrier transmission technique that introduces a filter-bank to efficiently pulse shape the signal that is conveyed on each individual subcarrier. It is a family of MCM techniques in which a prototype filter is designed to achieve a certain goal, such as minimizing inter symbol interference, Inter-Carrier Interference (ICI) and stop band energy. At the transmitter, Inverse Fast Fourier Transformation (IFFT) operation is followed by CP insertion in OFDM (to overcome ISI), while it is followed by a Poly Phase Network (PPN) in FBMC. The modulation used in FBMC is Offset Quadrature Amplitude Modulation which helps in achieving the orthogonality in real domain. The use of filter banks such as Hermite, PHYDYAS or RRC in FBMC helps in improving the Power Spectral Density (PSD) as compared to OFDM along with achieving other benefits of OFDM. In this study spectrum of FBMC system using PHYDYAS filter is analysed. This paper, investigates the PHYDYAS filter response for both OFDM and FBMC systems.

The rest of the paper is organized as follows: Section II describes of the transmitter and receiver model for OFDM and FBMC techniques. Prototype filter design is given in section III, simulation results are shown in section IV and paper is concluded in section V.

II. TRANSCEIVER MODEL FOR OFDM AND FBMC SYSTEM

In section A and B transceiver model for OFDM and FBMC system are described respectively. The FBMC as a new waveform candidate for 5G mobile communications is an OFDM-like modulation format, while the FBMC subcarriers are different from OFDM because it does not contain CP, and signals are passed through filters that can suppress the side lobes of the signals.

A. OFDM Block Diagram:

In OFDM system, at the transmitter, the input data sequence is baseband modulated using a digital modulation scheme. Various modulation schemes could be used such as BPSK, QPSK (also with their differential form) and QAM with several different signal constellations. Then, the mapped symbols are converted to parallel signal by serial-to-parallel conversion, and then sent to the IFFT module to transform it into time domain signals, after that CP is added. The cyclic prefix is inserted so that each OFDM symbol is preceded by a copy of the end part of that same symbol. It acts as a buffer region where delayed information from the previous symbols can get saved. At the receiver side, first CP is removed from the received signal then perform FFT operation to transform it into frequency domain signals and then resultant signal is converted to parallel to serial conversion and then demodulate the signal, as shown in Fig.1 [4].

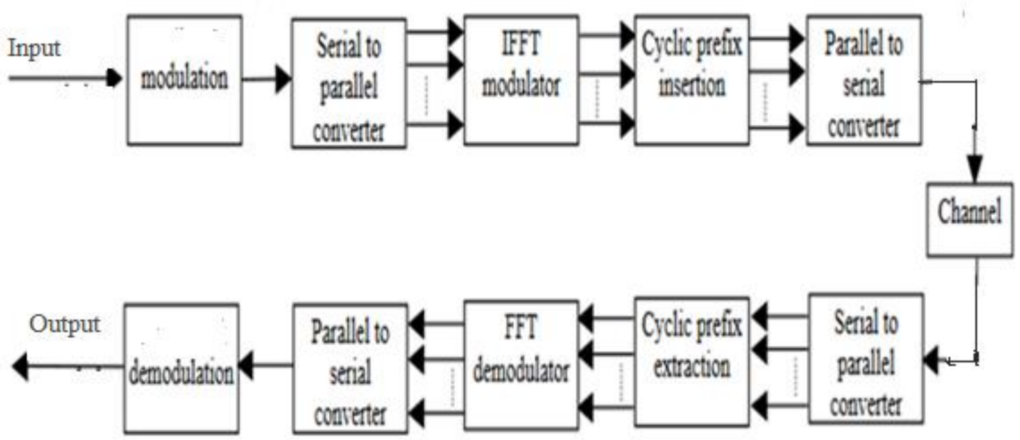

Fig.1 OFDM Block Diagram

B. FBMC Block Diagram:

FBMC is an evolved version of OFDM. The Filter Bank Multi Carrier (FBMC) transmission technique leads to an enhanced physical layer for conventional communication networks and it is an enabling technology for the new concepts like cognitive radio etc. This shows the direct application of the FFT to multicarrier communications, pointing out the limitations of the spectrum leakage. Then, these FFT approach can evolve to a filter bank approach which is straightforward to design and implement. For each block of data, the time window is extended beyond the multicarrier symbol period and the symbols overlap in the time domain. This time overlapping is on the basis of conventional efficient single carrier modems where interference between the symbols is avoided if the channel filter satisfies the Nyquist criterion. This fundamental principle is readily applicable to multicarrier transmission. Regarding implementation, the filter bank approach is just an extension of the direct FFT approach and it can be realized with an extended FFT. The other way which requires less computations, is the so-called Poly Phase Network (PPN)-FFT technique, which keeps the size of the FFT but adds a set of digital filters.

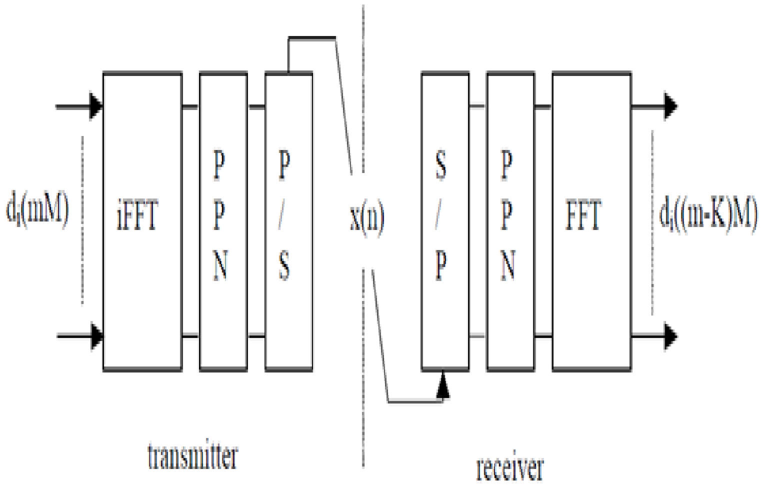

Fig. 2 FBMC Block Diagram

FBMC systems are a subclass of multicarrier systems based on principle i.e. dividing frequency spectrum into many narrow sub-channels. The main feature of filter banks in sub-band system configuration, in which the analysis filter banks divide the original signal into its sub-bands and the subsequent synthesis filter banks reconstruct the original signal in a properly processed form. FBMC improves the spectral property using prototype filter i.e., Prototype filter spans multiple symbol periods T and Adjacent symbols are overlapped & added in time with offset T. The Inverse Fast Fourier Transform (IFFT) can serve as a multicarrier modulator and the Fast Fourier Transform (FFT) can serve as a multicarrier demodulator. The block of data at the input of the IFFT in the transmitter is recovered at the output of the FFT in the receiver, since the FFT and the IFFT are cascaded. The size of the IFFT and the FFT is M and a set of M data samples, d (mM) with $0 \leqslant i \leqslant M - 1$, is fed to the IFFT input [5].

III. Prototype Filter Design

Digital transmission is based on the Nyquist theory, the impulse response of the transmission filter must cross the zero axis at all the integer multiples of the symbol period. The condition translates in the frequency domain by the symmetry condition about the cut-off frequency, which is half the symbol rate. Then, a straightforward method to design a Nyquist filter is to consider the frequency coefficients and impose the symmetry condition. In transmission systems, the global Nyquist filter is generally split into two parts, a half- Nyquist filter in the transmitter and a half-Nyquist filter in the receiver. Then, the symmetry condition is satisfied by the squares of the frequency coefficients. The frequency coefficients of the half-Nyquist filter obtained for K = 2, 3 and 4 are given in Table 1.

The subcarrier filters are very narrow in frequency, and thus require rather long filter lengths (typically up to 4 times the basic multicarrier symbol length, indicated by the overlapping factor K, which is a key design parameter of FBMC, and thus the single symbols are overlapping in time accordingly. For achieving orthogonality, Offset-Quadrature Amplitude Modulation (OQAM) is to be applied. So, FBMC is not orthogonal with respect to the complex domain, it is orthogonal in real domain only [6].

Table.1 Prototype Filter Coefficients

K	H_0	H_1	H_2	H_3	σ^2 (dB)
2	1	$\sqrt{2}/2$	-	-	-35
3	1	0.911438	0.411438	-	-44
4	1	0.971960	$\sqrt{2}/2$	0.235147	-65

The FBMC used a prototype filter which is designed by using the Nyquist pulse shaping principal to filter each sub-carrier individually without CP, whereas OFDM symbol is multiplied by a window before transmission in order to reduce the power of out-of-band subcarriers quickly. As FBMC has the capability to greatly reduce the spectral leakage problem which exists in OFDM, hence it results in negligible Inter-Symbol Interference (ISI) and Inter-Carrier Interference (ICI) with reduced side lobe performances of Physical layer for Dynamic Access and cognitive radio (PHYDYAS) prototype filter [5].

IV. Simulation and Result

The PHYDYAS prototype filter response of both OFDM and FBMC is shown in Fig.1. this figure shows the magnitude response (dB) with respect to normalized frequency for overlapping factor k = 4 and number of sub-carriers m = 64

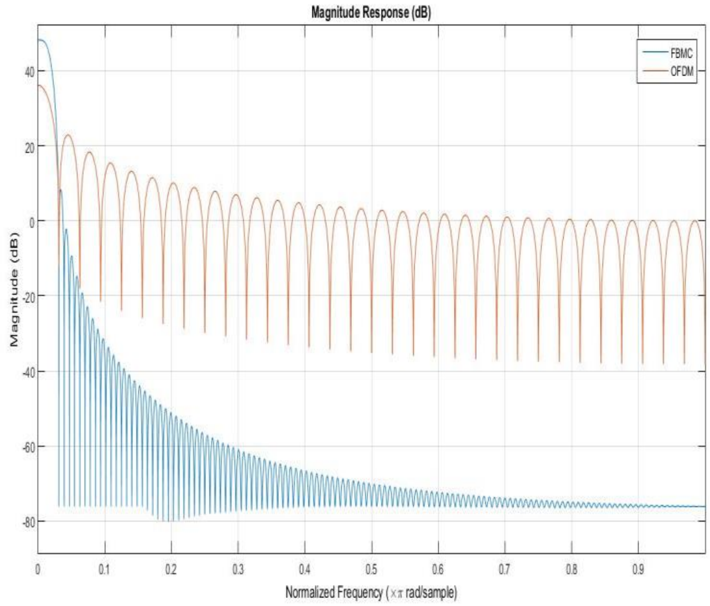

Fig.1 PHYDYAS response of OFDM and FBMC

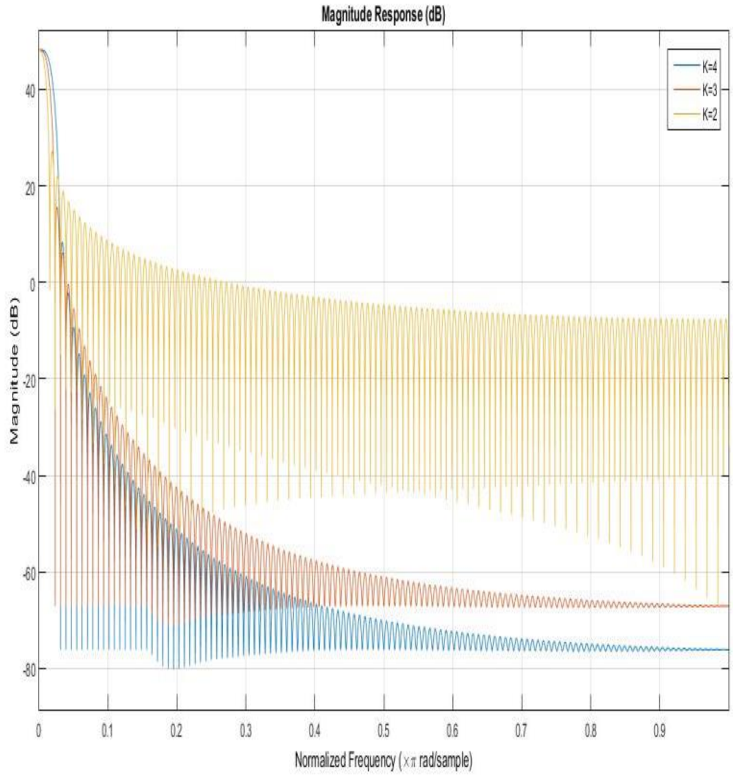

Fig.2 PHYDYAS response for K=2, 3, 4

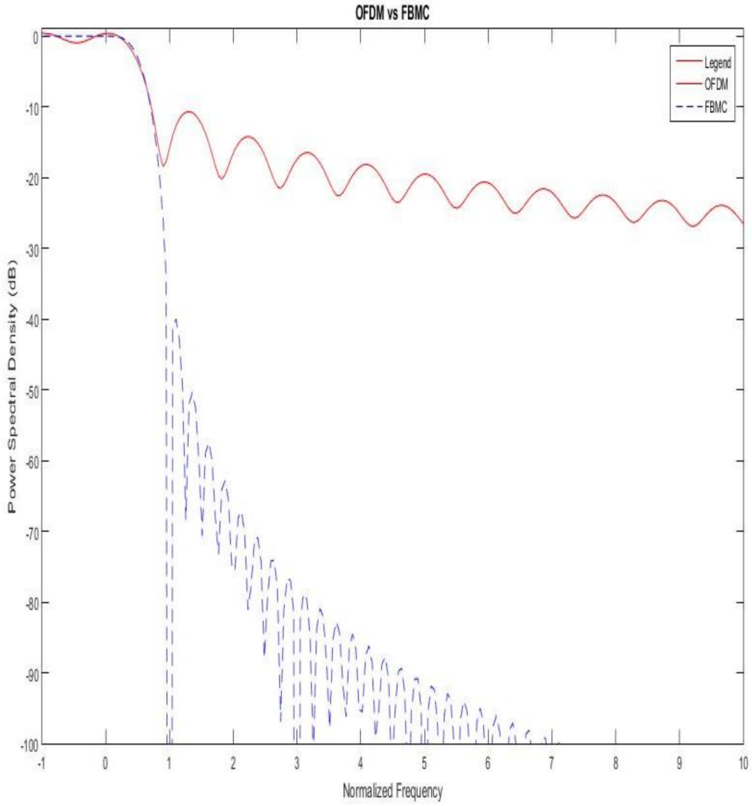

Fig.3 PSD of OFDM and FBMC for K=4

The response of PHYDYAS filter of FBMC is shown in Fig.2 which is magnitude response (dB) v/s normalized frequency for different overlapping factors. Prototype filters are characterized by the overlapping factor K, which is the ratio of the filter impulse response duration to the multicarrier symbol period T. The factor K is also the number of multicarrier symbols which overlap in the time domain. The Power Spectral Density (PSD) of OFDM and FBMC is shown in Fig.3 in dB with respect to normalized frequency for overlapping factor K= 4. The signal is transmitted at a carrier frequency of fc=2.4955GHz with L=128 subcarriers and a subcarrier spacing of F = 15KHz. leads to a transmission bandwidth of F*L = 1.92 MHz with the modulation using 16-QAM.

V. CONCLUSION

In this paper, we review the spectrum behavior of FBMC by using the prototype filter called PHYDYAS filter with different overlapping factors and then comparing it with the OFDM. Therefore, FBMC performs well in the aspects of power spectral density as its spectrum leakage is lower when compared to OFDM. This paper tells us the designing of FBMC and expectations towards an efficient waveform for the 5G communication system. From the simulation results we can clearly say that the drawbacks of OFDM are solved by the filter bank multicarrier. FBMC applies filtering on a per-subcarrier basis to provide out of band spectrum characteristics. The baseband filtering is done using either a poly phase network or an extended IFFT. Filtering can use different overlap factors (i.e., K factor) to provide varying levels of out-of-band rejection.

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