Performance Measures of Filter Bank Multi-Carrier Waveform for 5G Communication

Mr.J.Dinesh Kumar[#1], Mr.C.Balamurugan[*2]

[#1]*Assistant Professor, Department of ECE, National Engineering College, Kovilpatti, Tamil Nadu, India*

[*2]*Assistant Professor Senior Grade, Department of ECE, National Engineering College, Kovilpatti, Tamil Nadu, India*

Abstract

In this paper, a novel technique based on filter bank multicarrier modulation (FBMC) is proposed to generate a new waveforms in future wireless communication for efficient spectrum utilization. FBMC is an alternate technique to orthogonal frequency division multiplexing (OFDM) and it reduces inter symbol interference (ISI) and inter carrier interference (ICI) which is present in orthogonal frequency division multiplexing. Orthogonal frequency division multiplexing needs CP for processing which makes the network inefficient. In our proposed work, data bits are symbol mapped, frequency spreading and inverse fast fourier transform (FFT) operation is performed in the transmitter side to generate FBMC modulated data for transmission. The modulated data is transmitted over the channel. In the receiver side, fast fourier transform operation, frequency de-spreading and signal de-mapping is performed. The proposed method results are compared in terms of bit error rate (BER) and mean square error (MSE) with the OFDM techniques, FBMC outperforms OFDM.

Keywords— *FBMC, OFDM, ISI, ICI, Bit Error Rate, Mean Square Error, FFT*

I. INTRODUCTION

Dramatic growth in mobile data communication necessitates the development of wireless networks to address the new challenges in spectrum use scenarios such as cognitive radio and opportunistic dynamic radio access in an efficient and flexible way. Toward this end, it is desirable to aggregate multiple non-contiguous chunks of spectrum to achieve high data rates. Thus, highly flexible waveforms are required to effectively allocate the demanding spectrum to the users, providing rapidly decaying transition bands and high out-of band (OoB) attenuation for synchronization immunity and avoiding interference between users.

Multicarrier modulation (MCM) with its appealing characteristics such as simpler equalization and adaptive modulation techniques, presents the key element in efficient spectrum usage by activating the subcarriers in the available frequency slots. Multicarrier modulation is proposed instead of single carrier modulation which reduces ISI. In single carrier modulation, the entire bandwidth is allotted to single symbol and bandwidth of signal exceeds coherence bandwidth. But in Multicarrier modulation the spectrum is allotted to different users called sub-carrier whose bandwidth smaller than coherence bandwidth.

In multi carrier modulation, OFDM uses traditional modulator and demodulator techniques. However, IFFT and FFT operation is performed in FBMC for trans-receiving purpose and it is new way to transmit the symbol. OFDM is advanced modulation techniques used in 4G communication systems like LTE (Long Term Evolution). High peak average power ratio and cyclic prefix (CP) results the OFDM system inefficient for future 5G communication.

FBMC is a multi carrier advance technique generates filter coefficient at the transmitter and receiver side to nullify the effect of ISI without using CP results efficient bandwidth utilization and it leads to have better performance in FBMC as compared to OFDM techniques. In implementing the FBMC system, the orthogonal between sub-carrier is not present is a huge problem. Spatial multiplexing, Equalization and Interference cancellation schemes are used to address the issue. FBMC technique is used in future 5G communication and IOT. Section II discusses the review of various papers related to OFDM. Section III tells the mathematical description and the implementation of OFDM and FBMC with necessary equation and block diagrams. Section IV analyse the values of OFDM and FBMC and the performance of both can be plotted using tool such as MATLAB.

Section V concludes the performance of OFDM and FBMC based on the simulation results. The performance of OFDM and FBMC is evaluated and output results FBMC better than OFDM. Degradation of orthogonality occurs for OFDM due to imperfect synchronization between subcarrier but in FBMC orthogonality is maintained automatically between subcarrier.

II. RELATED WORKS

In this paper [1], ISI caused by the OFDM techniques due to the delay spread of wireless channel. The overall performance of OFDM system improved by channel estimation and detection, time and frequency offset estimation and correction, peak to average power ratio reduction, inter carrier interference. The work also tells application of OFDM in current system and standards. The basic principle of OFDM and its techniques deal with problems in wireless systems, which include channel estimation, timing and frequency-offset estimation, ICI mitigation, and PAPR reduction.

In this [2], OFDM is modulation techniques achieves higher data rate. The OFDM utilizes bandwidth applications like video conferencing. OFDM techniques proposed to be used in 4th generation cellular system. The bit error rate of QAM is very high in multipath surroundings along with the ISI. It is best suited to multi-path channel than single carrier transmission such as QAM. The desire for high data rate wireless communication was increased drastically.

In this [6], multicarrier transmission, transmit a data stream over a number of lower data subcarrier. OFDM splits the total transmission bandwidth into non overlapping subcarrier and transmit the symbol using these subcarriers. The carrier frequency offset estimation that improves the performance of OFDM in wireless communication. The demand for high data rate wireless communication has been increasing dramatically in recent decade. OFDM is the emerging multi-carrier modulation technology of can solve this problem.

In this [8], survey of OFDM behaviours, principles and analysed different techniques like Peak to Average Power Ratio (PAPR) reduction and frequency offset estimation that improve performance of OFDM for wireless communications. But the OFDM has a strong anti-multi path interference capability in a high-speed data transfer conditions and also have high spectral efficiency.

In [3], the number of person using communication devices increased drastically results large amount of data transmitted with higher data rate over the channel. For proper frequency selectivity of the transmission channel, OFDM provides higher data rate without ISI. This technique is used in future generation wireless communication. OFDM solves the problem of ISI use of cyclic prefix at high data rate. It has low complexity, high spectral efficiency. The carrier frequency offset and high peak to average power ratio are some of the imitations of OFDM.

In this [4], OFDM is a popular wireless network of IEEE standard and 4G communications. The benefit of OFDM over single carrier without equalization filters. The main drawbacks of OFDM are its high peak to average power ratio and its sensitivity to phase noise and frequency offset.

In this [8], a survey of FBMC modulation technique to combat ISI and ICI was carried out. OFDM uses cyclic prefix results increase in bandwidth leads to inefficient utilisation of spectral efficiency. The performance of the system based on bit error rate and ISI can be reduced by implementing various modulation techniques.

In this [5], increase in demand of usage of communication equipment and faster development of broad band technologies in pace with high speed data transfer. The next generation mobile system integrated with service like data transfer, video call, audio call and internet access without buffering. OFDM techniques along with MIMO used in multicarrier modulation techniques used in LTE wireless network system. It reduces the receiver complexity. Cyclic prefix used to solve the ISI and ICI problem in OFDM system. The modulation techniques such as BPSK, QPSK, 16-QPSK are implemented in the system. BER depends on sub-carrier and symbol time. The result shows that the system has low bit error rate, high SNR, high data rate which improve the system performance. However the addition of CP results excessive utilisation of bandwidth.

III. PROPOSED METHODOLOGY

A. Implementation of OFDM:

1) OFDM Transmitter

Each carrier can expressed as,

$$S_c(t) = A_c(t) e^{j(2\Pi f_c t + \Phi_c(t))} \tag{1.1}$$

The total complex signal $S_s(t)$ can be represented by,

$$S_s(t) = \frac{1}{N}\sum_{n=0}^{N-1} A_n(t) e^{j(2\Pi f_n t + \Phi_c(t))} \tag{1.2}$$

where $A_n(t)$, $\Phi c(t)$, f_n and N amplitude, phase, carrier frequency and carrier respectively.

$$f_n = f_0 + n/T \text{ , T=N}\Delta t \text{ , } \Delta f = 1/N\Delta t \tag{1.3}$$

N - Number of carriers.

$N\Delta t$ - Symbol duration in each sub-channel

Δf - Sub-channel spacing.

The Inverse Discrete Fourier Transform (IDFT) is defined as,

$$f(k\Delta t) = \frac{1}{N}\sum_{n=0}^{N-1} F(n\Delta f) e^{j(2\Pi nk/N)} \tag{1.4}$$

An OFDM signal based on orthogonal signal set written as,

$$x(t) = \sum_{K=-\infty}^{\infty} \sum_{n=0}^{N-1} d_{k,n} \Psi_n (t - kT) \qquad (1.5)$$

where, $d_{k,n} = a_{k,n} + jb_{k,n}$

$\Psi_n(t)$ = orthogonal signal set. n=0,1,..,N-1 0<t<T

$d_{k,n}$ - Transmitted data on the nth carrier of the kth symbol.

$a_{k,n}$ - In-phase component

$b_{k,n}$ - Quadrature component,

The transmitted waveform $D(t)$ can be expressed as,

$$f(K\Delta t) = a(n)\cos(2\Pi f_n t) + b(n)\cos(2\Pi f_n t) \qquad (1.6)$$

2) *Cyclic Prefix*

In multi-path channel, delayed replicas of previous OFDM signal lead to ISI between successive OFDM signals. Insert a guard interval between successive OFDM signals. Guard interval leads to inter carrier interference (ICI) in OFDM demodulation A copy of the last part of OFDM signal is attached to the front of itself.

3) *OFDM Receiver*

The demodulation process performed on the sampled signals with proper window size. The CP are removed (which now contains ISI), and fed to the FFT block for further operation. Each symbol modulated on different subcarrier is now multiplied by complex channel gain results the FFT of CP removed data. Finally, QPSK demodulation is done based on the channel information. Fig 1.0 below shows the block diagram of OFDM modulation.

The Discrete Fourier Transform (DFT) of the transmitted signal is defined as,

$$F(n\Delta f) = \frac{1}{N}\sum_{n=0}^{N-1} f(k\Delta t)e^{-j2\Pi kt/N)} \qquad (1.7)$$

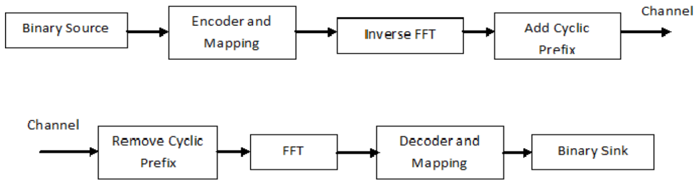

Fig. 1.0 Orthogoal Frequency Division Multiplexing Transceiver

B. *Implementation of FBMC:*

In FBMC based system, the subcarriers are filtered by dedicated filter pair $g(t)$ in the receiver and $\gamma(t)$ at the transmitter. These filters structure is termed as analysis filter at the transmitter and synthesis filter at the receiver. Fig 2.0 below shows the block diagram of FBMC modulation.

The mathematical formula is expressed as,

$$s(t) = \sum_{n=0}^{N-1}\sum_{m=0}^{M-1} d_{n,m} g_{n,m}(t) \qquad (1.8)$$

$$s(t) = \sum_{n=0}^{N-1}\sum_{m=0}^{M-1} d_{n,m} g(t - mT)e^{j2\Pi nF(t-mT)} \qquad (1.9)$$

where,

$d_{n,m}$ - Transmitted data on the mth carrier of the nth symbol.

$g_{n,m}(t)$ - Analysis Filtered coefficients

T - Time Period

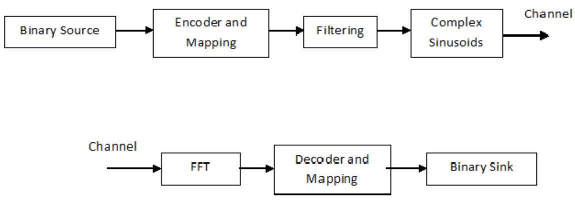

Fig. 2.0 Filter Bank Multicarrier Transceiver

IV. SIMULATION RESULT

The simulated result are obtained and analyzed by using MATLAB simulation tool discussed below. The Fig 3.0, shows the BER versus SNR performance for OFDM. As shown in Fig 3.0 below the SNR is low results larger BER and gradually SNR increased then BER is going to decrease. The plot also infers that, the bit error rate can be very low for high SNR.

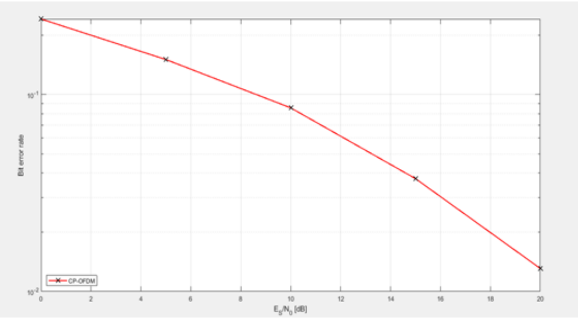

Fig. 3.0 Bit Error Rate versus Signal-to-Noise ratio for OFDM

The Fig 4.0, shows the BER versus SNR performance for FBMC. As shown in Fig 4.0 below the BER is more for a low SNR and BER gradually decrease when SNR is increased.

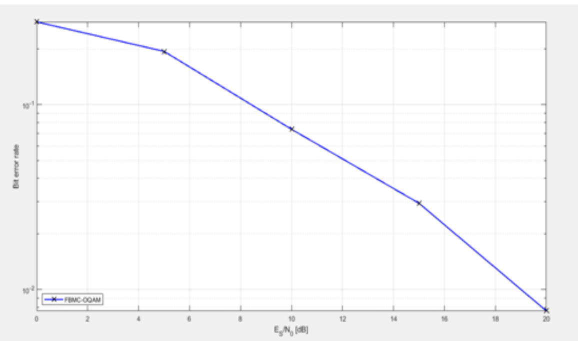

Fig. 4.0 Bit Error Rate versus Signal-to-Noise ratio for FBMC

The Fig. 5.0 below gives the performance of OFDM and FBMC. Here in below Figure 5, we can see that the performance of OFDM and FBMC is equivalent. The only difference in the performance of OFDM is achieved by using a CP whereas the same performance in FBMC is achieved without the addition of CP. The SNR is low for FBMC as compared to OFDM. The SNR reaches the intermediate value the BER of FBMC overcomes the OFDM. Finally, the BER of FBMC large at high SNR when compared to the BER of OFDM.

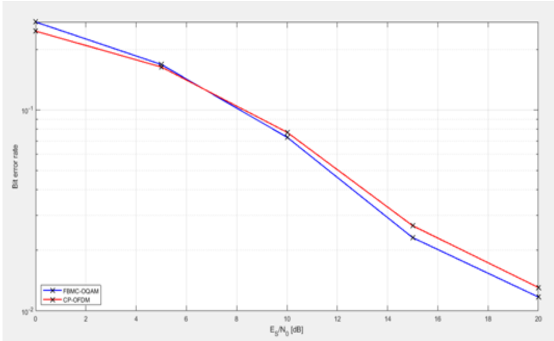

Fig. 5.0 Comparison of Bit Error Rate versus Signal-to-Noise ratio for FBMC and OFDM

V. CONCLUSIONS

In our proposed work, OFDM and FBMC system can be implemented and studied. The accuracy of the work verified thoroughly by studying the mathematical model and simulated results. For high SNR, FBMC performance is better compared to OFDM and another feature of FBMC is that without the addition of cyclic prefix. To further improve the efficiency of FBMC system by using advanced error correction techniques. The FBMC system is best suited for future generation mobile communication as compared to OFDM.

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