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DESIGN AND PERFORMANCE ANALYSIS OF OFDM AND FBMC MODULATION TECHNIQUES

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Abstract. ***Researchers have already proved that data consumption in coming years will increase by leaps and bounds, so the present technologies like 3G, OFDM (Orthogonal Frequency Division Multiplexing) cannot hold the addition of huge capacitance, data use and demand of high data-rate. Hence, on that point is a necessity of fifth generation mobile communication system (5G). Presently the rollout for 5G is going virtually everywhere in the world and among several issues; selection of better modulation techniques is seen as unitary of the significant issues in the implementation of the 5G. In this work, we designed and analyse the performance of OFDM and FBMC (Filter Band Multi Carrier) multicarrier modulation schemes on the basis of Bit Error rate (BER) and Signal to Noise Ratio (SNR). Simulation results and mathematical analysis have confirmed that the performance and spectrum utilization of FBMC is better or equivalent as compared to OFDM, which can be very useful in next generation mobile communication and Internet of Things (IOT).***

Keywords: FBMC OFDM, BER

1. INTRODUCTION

In a single modulation carrier technique, the entire bandwidth is allocated to a single carrier that transmit a symbol and the bandwidth of the signal is greater than the coherence bandwidth which results in Inter-Symbol-Interference (ISI). Now, consider a system having a multi-carrier at the spacing B/N, where B is bandwidth and N is the number of Sub-carriers [1]. In multi-carrier techniques, the cannel spectrum is allotted to the numbers of different carrier also called as sub-carriers whose bandwidth are smaller than the coherence bandwidth which results no ISI i.e. converting wide band channel into a narrow band. In the year 1971, Weinstein and Ebert introduced a new way of transmitting the symbols in multicarrier techniques known as Discrete Fourier Transform which replaced the traditional method of using a set of modulators and demodulators for trans-receiving purpose which was complex to implement which was employed in OFDM. OFDM is a multicarrier technique where all sub-carriers are orthogonal to each other, resulting no interference with each other. Overall, OFDM is one of the most advance modulation technique used in a 4G mobile communication system like LTE (Long Term evolution), Wi-Max (Wide Interoperability Microwave Access Architecture), LAN 802.11/a/g/n standard which supports the data-rate up-to 100 – 200 Mbps. OFDM possess certain disadvantages like high PAPR (Peak Average Power Ratio), Cyclic Prefix (CP) which makes OFDM less efficient. Due to several disadvantages of OFDM, it may not consider for the 5G, Hence the new modulation technique has to be explored [2-4]. FBMC is multi-carrier advance technique of OFDM where instead of CP a set of array of filters is used at the transmitter and receiver which nullified the effect of ISI without the use of CP which make it efficient in-terms of bandwidth and performance as compared to OFDM. FBMC is considered to be one of the useful candidates for 5G mobile communication and IOT due to their low out of band (OOB) radiation. Due to the internal interference, use of no Cyclic-prefix between the symbols, FBMC loses the orthogonally between the sub-carriers which is the major issue in the implementation of FBMC. However, techniques like Equalization, Interference cancellation schemes and spatial multiplexing techniques may be used to overcome this issue [5-6]. In [7], performance of OFDM and FBMC is evaluated and output result reveals that FBMC is better than OFDM and OFDB performance can be improved by using high coding rate. In [8], the throughput of OFDM and FBMC is analysed by determining the BER under doubly selective channel. Simulation results show that FBMC outperforms OFDM. In [9], OFDM and FBMC are designed for multiple access uplinks. Experimental result reveals that the efficiency of OFDM degrades due to loss of orthogonality due to imperfect synchronization between subcarriers whereas in FBMC, orthogonality is maintained automatically between the subcarriers. In this paper, we introduced a new FBMC-OFDM transmission scheme which employs a PHYDAS filter for a block of subcarriers unlike FBMC where filtration is applied to all subcarriers. OFDM-FBMC reduces the internal interference and Out of Band (OOB) radiation which can be very useful in IOT and next generation mobile communication.

2. PROPOSED METHODOLOGY

In this section, a complete mathematical model of OFDM and FBMC is discussed.

2.1. Implementation of OFDM:

Let us consider a composite signal given by:

$$Y(t) = \sum_i Xi\, h\, e^{\frac{j2\pi itb}{n}} + n \qquad (1)$$

The equation (1) implies that an OFDM system transmit N symbols using a N sub-carriers in a time period of N/B with sampling time Ts = 1/B. (where N= no of sub-carriers, B =bandwidth) and h is fading coefficient. Hence, for the V^{th} sample, the time instant of transmitting symbols at VTs is given by the following equation:

$$Y\,(v) = Y(Vts) = Y\left(\frac{v}{B}\right) = \sum_i Xi\,h\,e^{\frac{j2\pi iBV}{NB}} + n \quad (2)$$

Hence the above equation becomes:

$$Y\,(v) = Y(Vts) = Y\left(\frac{v}{B}\right) = \sum_i Xi\,e^{\frac{j2\pi iV}{N}} + n \quad (2.1)$$

where n is noise, the equation (2.1) states, composite signal can be generated and transmitted by using a discrete Fourier/inverse Fourier transform having a much lower complexity than using a set of modulators and demodulators. At the receiver the signals can be detected by using a coherent demodulator (using FFT) given by:

$$Y(r) = Y(t) * e^{-j2\pi lB/N} \quad (3)$$

Hence, putting the value of equation (1) in equation in (3):

$$Y(r) = \frac{B}{N}\int_0^{N/B}\left(\sum_i Xi\,h\,e^{j2\pi iVt/N}\right)e^{-j2\pi lB/N} + \text{n} \quad (4)$$

$$Y(r) = \frac{B}{N}\int_0^{N/B}\left(\sum_i Xi\,h\,e^{\frac{j2\pi(i-l)Bt}{N}}\right)dt + \text{n}e^{-j2\pi lB/N} \quad (5)$$

Let us consider$(i - l = K), B/N = Fc$, hence the equation (5) can be written as:

$$Y(r) = \frac{B}{N}\sum_K \int_0^{\frac{N}{B}}(h\,Xi\,e^{j2\pi KFct} \quad + ne^{-\frac{j2\pi lB}{N}}) \quad (6)$$

Now, let us consider special case such that, when I ≠ l and I =1 then equation (6) can be written as:

$$\int_0^{N/B} e^{\frac{j2\pi(i-l)Bt}{N}} = 0 \quad \text{for I} \neq 1 \quad (6.1)$$

$$\int_0^{N/B} e^{\frac{j2\pi(i-l)Bt}{N}} = 1, ne^{-\left(\frac{j2\pi lB}{N}\right)} = \boldsymbol{\sigma n^2} \text{ for I=1.} \quad (6.2)$$

Hence the equation (6) reduces to:

$$Y(r) = h\frac{N}{B} * \frac{B}{N}Xi + \boldsymbol{\sigma n^2} \quad (7)$$

Hence equation (7) reduces to:

$$Y(r) = hXi + \boldsymbol{\sigma n^2} \quad (7.1)$$

The equation (7) is system model of for wireless communication and detection of symbol. BER of the system is given by:

$$BER = Error\ in\frac{Y(r)}{y(r)} \quad (8)$$

Let us consider symbols generated by Xi:

$$X(i) = X(L + N - 1) \ldots\ldots X(N-3), X(N-2), X(N-1), (X(0), X(1) \ldots\ldots X(n) \quad (9)$$

Where $(X(0), X(1) \ldots\ldots X(n)$ are the present symbols and $Xp(L + N - 1) \ldots\ldots X(N-3), X(N-2), X(N-1)$ are the past symbols present during transmission.

From equation (9), we can conclude that, channel can be modelled as selective multi-tap channel is given by. considering a first symbols given by:

$$y(0) = h(0)X(o) + h(1)X(N-1) + h(2)X(N-2) + \cdots .. + h(L-1)X(N+L-1) \quad (9.1)$$

From equation (9), we conclude that, there is interference in $X(0)$ due to the previous symbols that result in ISI. Hence, taking some transmitted symbols and prefixing before the desire symbol, the ISI can be reduced which is also called CP. Hence, using adding CP, the received symbols can be defined by the following equation:

$$Y(N-1) = h(0)x(N-1) + h(1)\,x(N-2) \ldots + h(L-1)x(N-L) \quad (9.2)$$

Now, equation (9.2) states, all samples belong to the current OFDM symbols. Overall with CP, the system model reduces to:

$$Y(k) = h(k) * x(k) + n \quad (10)$$

Y(k) is N point DFT of Y and h(k) is coefficient fading after zero padding and X(k) is DFT of IFFT (modulated information). Hence received signal is a circular convolution of coefficient fading and symbols transmitted which is possible due to the addition of CP, which is a flat fading channel. Hence, by using a CP, frequency selective channel is converted into a flat fading channel. The addition of CP also indicates that the same information is repeated twice, which means bandwidth loss due to the repetition is of symbols which is one of the disadvantages of CP.

2.2. Calculation of Cyclic Prefix (CP)

Let us consider the effect of CP for 4G system based on OFDM where N = 256 sub-carriers, Bandwidth = 4MHz. The bandwidth assigned to sub-carriers is $\frac{B}{N} = \frac{4MHz}{256} = 15.625\ KHz$. BW of channel is greater than coherence bandwidth (200 to 300 KHz), therefore it practice a Flat fading. OFDM transmission deprived of CP is N/B= 64µsec. CP is given by (12.5/100)*64µsec=8µsec. Hence loss of bandwidth: 8/72=11.12%. Hence, 11% of bandwidth is lost.

2.3. Implementation of FBMC

FBMC is advance technique of OFDM. In FBMC everything is similar to OFDM; only instead of CP we use arrays of filters at transmitter and receiver. The transmitter side the baseband equivalent of a discrete time FBMC signal as follows [1], [10].

$$X(n) = filters(\sum_{k=0}^{N-1}\sum_{m\in Z} a_{k,n}g\left[n - \frac{mN}{2}\right]e^{\frac{2\pi}{N}}\,k\left(n - \frac{D}{2}\right)m) \quad (11)$$

Where N= no. of subcarriers, D= Delay, ϕk,n = phase term, $a_{k,n}$= real transmitted symbols. The above equation implies that after IFFT, instead of adding CP, a set of filters can be used which take care of ISI and similarly at the receiver, the signal is demodulated given by:

$$Y(r) = filters\ (X(n)) \qquad (12)$$

Here, Y(r) is the received signal.

2.4. Implementation of FBMC OFDM

In the proposed work, a new method FBMC-OFDM is implemented by using a filter at the transmitter and receiver. The implication of the proposed work is that, FBMC-OFDM subcarriers are divided into even and odd blocks and filtration are applied on it, which is still not viewed in any former study. It enhances the throughput of the system by scaling down the parameters reason for the internal interference of the system.

At transmitter side the discrete time FBMC signal is given as follows:

$$X(n) = \sum_{k=0}^{N-1} \sum_{m\in Z}^{l} a_{k,m} g\left[n - \frac{mN}{2}\right] e^{\frac{2\pi}{N}} \qquad (13)$$

Where N - no.of subcarriers, D - Delay, $a_{k,m}$ – real transmitted symbols, $\varphi_{k,m}$ – phase term.

The real and imaginary parts are driven by the phase term $\varphi_{k,m}$ given by:

$$\varphi_{k,m} = \varphi_0 + \frac{\pi}{2}(m+k) - \pi mk \qquad (14)$$

Here φ_0 =0, we can write the equation (14)

$$Xz = \sum_{k=0}^{N-1} \sum_{m\in Z} a_{k,m} g_{k,m}[n] \qquad (15)$$

Where $g_{k,m}$ [n] = shifted version of g[n] in time and frequency domain. The demodulated symbol over the k^{th} sub-carrier and the n^{th} instant is determined using the inner product of t (m) and $g_{k,m}$[n]:

$$r_{k',m'} = \langle s, g_{k'm'} \rangle = \sum_{n=-\infty}^{+\infty} s[n]\, g^*{}_{k'm'}[n] \qquad (16)$$

$$r_{k',m'} = \sum_{n=-\infty}^{+\infty} \sum_{k=0}^{N-1} \sum_{m\in Z} a_{k,m} g_{k,m}[n] g^*{}_{k'm'}[n] \qquad (17)$$

The transmitted-received antenna impulse response can be derived assuming null data except one frequency position (k_0, n_0) where a unit impulse is applied. The equation (17) becomes:

$$r_{k'm'} = \sum_{n=-\infty}^{+\infty} g_{k0,n0}[n] g *_{k'm'}[n] \qquad (18)$$

$$r_{k'm'} = \sum_{n=-\infty}^{+\infty} g\left[n - \frac{m_0 N}{2}\right] g\left[n - \frac{mN}{2}\right]. e^{i2\pi/N}(k_0 - k')\left(n - \frac{D}{2}\right) e^{i(\varphi_{k_0,m_0} - \varphi_{k'm'})} \qquad (19)$$

By using the substitution of m by n $+ m_0$N/2 and denoting $\Delta m = m' - m_0, \Delta k = k' - k_0$, we obtain:

$$r_{k'm'} = \sum_{n=-\infty}^{+\infty} g[n] g\left[n - \frac{\Delta n N}{2}\right] e^{i\frac{2\pi}{N}\Delta k}\left(\frac{D}{2} - n\right). e^{i\pi(\Delta k + k0)\Delta m}\, e^{-i\pi(\Delta k + \Delta m)} \qquad (20)$$

3. SIMULATION RESULTS

The simulated results are obtained and analysed by using a MAT-LAB simulation discussed below. The simulation parameters are given in Table.1.

Table 1. Parameters of Simulation

OFDM	FBMC	FBMC OFDM
FFT Size=64 Subcarriers = 64 CP = 11% loss insertion. Filter= No used	FFT Size=64 Subcarriers= 64 CP = No CP Filter = PHYDAS Overlapping Factor K=2 Length of Filter = K*M-1	FFT Size = 64 Subcarriers = 64 CP = 11% loss Filter= PHYDAS Overlapping Factor K=2 Length of Filter = K*M-1

The Figure 1 shows the subcarriers of OFDM, FBMC and FBMC OFDM with overlapping factor (k= 1 and 2).

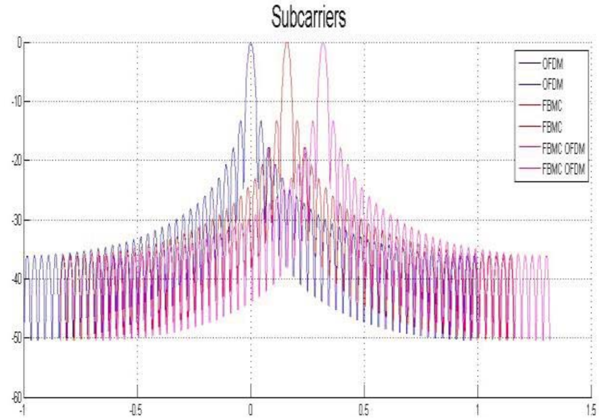

Figure 1. Subcarriers of OFDM, FBMC and FBMC OFDM

The effect of Carrier Frequency Offset (CFO) is shown by Figure 2. The above figure states that for smaller CFO, the performance of BER is good as compared to higher value of CFO.As shown above, For CFO=0.1, the performance is better as compared to CFO = 0.2 and 0.3.

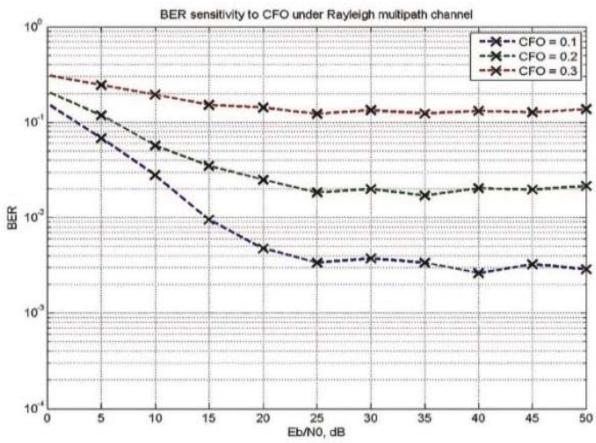

Figure 2. OFDM of BER vs Eb/No with CFO

The Figure 3, implies the BER vs SNR performance for FBMC. As shown above the BER is more for a low SNR and gradually decrease when SNR is increased. The above figure also states that, the BER can be zero for high SNR but practically it is not possible to use high power because it reduces the performance of the system. Hence, quality of transmission can be achieved by controlling the power in an efficient way.

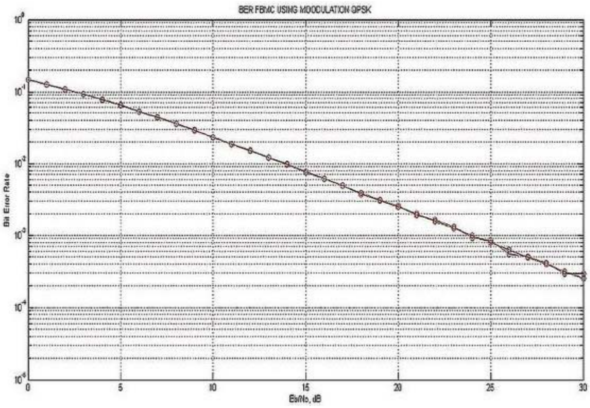

Figure 3. FBMC BER vs SNR

The Figure 4, implies the BER vs SNR performance for FBMC OFDM. BER is more for a low SNR and gradually decrease when SNR is increased. The BER performance is not so effective for 0 to 5 dB due to the complexity of the system.

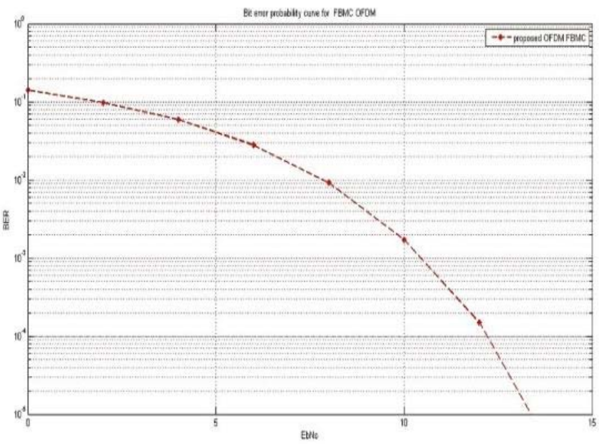

Figure 4. BER Vs SNR for Proposed OFDM FBMC

The Figure 5, gives the performance of OFDM and FBMC. Here in above figure, 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.

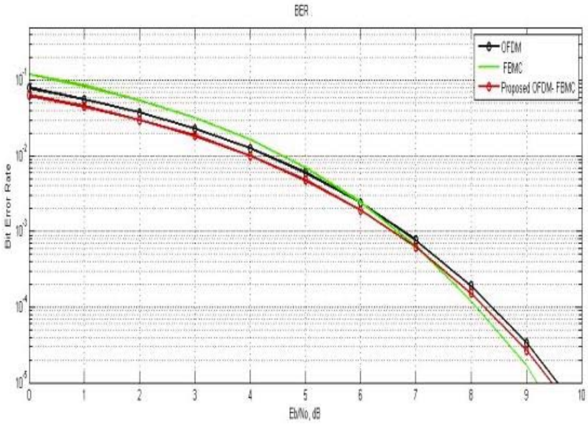

Figure 5. Proposed BER vs Eb/No for OFDM and FBMC

4. CONCLUSION

In the proposed work, OFDM, FBMC and FBMC-OFDM is implemented and studied. The accuracy of proposed work is verified thoroughly by analysing the mathematical models and simulated results. As verified in this work, FBMC-OFDM achieved the better BER for low SNR. But for high SNR, FBMC performance is better as compared to OFDM and equivalent to FBMC-OFDM without the addition of Cyclic Prefix between the symbols. Hence, it is concluded that the performance of FBMC and FBMC-OFDM can be further improved by using advance error correction techniques. Overall, one can say, FBMC and FBMC-OFDM is a strong candidate for next generation mobile communication as compared to OFDM.

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