Performance Analysis of Next Generation Waveform In Fading Environment

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Abstract- *In order to provide a higher data rate in future radio communication systems, multicarrier techniques are receiving increased attention. The PAPR problem in OFDM and other issues, such as intersymbol interference, are all addressed by the modulation method known as filter bank multicarrier (FBMC). A derivative of OFDM is FBMC. In essence, the FBMC is a modulation and multiplexing multicarrier scheme that is used to increase bandwidth efficiency by using filter banks to remove interference from subcarriers rather than using guard intervals between two or more subcarriers, which is the primary issue in wireless networks. Inter-channel interference is a major issue in LTE and is reduced using this method. New modulation techniques, like FBMC, are needed to handle 5G systems. In this study, we examine the FBMC's performance assessment and compare it with an OFDM-based system. Using MATLAB, we additionally examine the throughput of the FBMC in a Rayleigh fading scenario.*

Keywords- FBMC, OQAM, OFDM, Channel Estimation, Time-Frequency Analysis, Measurements

I. INTRODUCTION

Wireless communication is the process of exchanging the data or information over the distance without using wires, cables or any other form of electrical conductors. Wireless is a big term today which allows using the RF or electromagnetic waves as a medium. [1]-[5]Radio frequency waves are used to carry information or data as a medium for that data. Wireless means there is no need of physical connection such as wires or cables between transmitter and the receiver to transfer any information or to exchange data over the distance.

In these days, the mobile devices or wireless devices connecting to the internet are increasing very fast. To provide the better services to these devices is very important task for the incoming technology. There are many waveforms available for 5G. [6]Out of them, one is OFDM (Orthogonal Frequency Division Multiplexing). OFDM divides the total available bandwidth into different subcarriers. To reduce the interference and to increase the spectral efficiency, ODM use the Cyclic Prefix (CP).OFDM have various problems like high PAPR (Peak to average Power Ratio). To overcome this problem FBMC comes into existence. FBMC (Filter Bank Multicarrier) with OQAM (Offset Quadrature Amplitude Modulation) which is the extension or type of the recent OFDM (Orthogonal Frequency Division Multiplexing) increases the spectral efficiency and reduce the PAPR. The FBMC/OQAM provides the better spectral efficiency as compare to OFDM and also useful to gives the high data rates. However, FBMC/OQAM reduces the adjacent channel interference using filter banks and the number of users can use or share the spectrum simultaneously. Next generation wireless systems should support a large range of possible use cases, such as machine to-machine communications and low-latency [7]-[13] transmissions. This requires a flexible assignment of the available time frequency resources, not possible in conventional Orthogonal Frequency Division Multiplexing (OFDM) due to its poor spectral behaviour. For such diverse applications, (FBMC) [1] becomes an efficient alternative to OFDM due to much better spectral properties. In this paper we will study the performance analysis of FBMC and compare it with OFDM .

II. SYSTEM MODEL

(i) OFDM SYSTEM MODEL

The OFDM is consists of by adding the modulated subcarriers signals transmitted in parallel to IFFT.[13]-[20] In general we have transmitted signal $S_n(t)$ for OFDM symbol

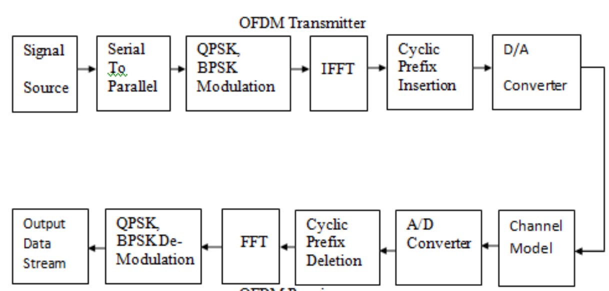

Fig. 1 OFDM Transmitter and Receiver

Mathematically, each carrier can be described as a complex wave:

$$S_C(t)=A_C(t)e^{j[\omega c(t)+\Phi c(t)]}(1)$$

Where $S_c(t)$ = the real part of original signal
$A_c(t)$ = the Amplitude of the carrier

The real signal is the real part of $S_c(t)$. Both $A_c(t)$and $f_c(t)$,the amplitude and phase of the carrier, can vary on a symbol by symbol basis. The values of the parameters are constant over the symbol duration period t.
As we know OFDM consists of many carriers. Thus the complex signals $S_s(t)$is represented by:

$$S_S(t)=1/N\sum_{n=0}^{N=1} An\ e^{j[(\omega n(t)+\Phi n]} \quad (2)$$

Where, $\omega_n=\omega_0+n\Delta\omega$

This is in form of continuous signal. If we calculate the waveform of each part or component of signal over a single symbol duration, then the variables $A_c(t)$ and $f_c(t)$ reaction to the not changeable values, which depend upon the frequency of that particular carrier, and so can be writtenas:

$$\Phi_n(t)=\phi_n \quad (3)$$
$$A_n(t)=A_n$$

If the input data is sampled with the use of a sampling frequency 1/T, then the output data is presented as following:

$$S_S(KT)=1/N\sum_{n=0}^{N-1} An\ e^{j[(\omega o+n\Delta\omega)KT+\Phi n]} \quad (4)$$

Here, we are bound to the time by which we analyses the signal to N samples. This is suitable than the period of a single data symbol. So, we have a relationship:

$$t=NT$$

By simplifying the equation (3.3) without any loss of quality by assuming ω_0 =0, then we have signal as:

$$S_S(KT)=1/N\sum_{n=0}^{N-1} An\ e^{j[(n\Delta\omega)KT+\Phi n]} \quad (5)$$

In equation (4), the term $A_n e^{j\phi n}$ is not larger than a explanation of the signal in sampled frequency realm, also $S_s(kT)$ is the time domain image.OFDM is a multicarrier modulation technique. When multiple of carriers placed near to each other, then it generates the OFDM signal. The sidebands expand out one side, when the modulation of any data or information take place and applied to the carrier. It is the mandatory for the receiver that it should be capable to get the full signal to get original signal back effectively. When signals are sent near to each other they should be situated as that the receiver can differentiate those using filter and there should be guard band among them. But in case of OFDM subcarrier sidebands overlap with each other and they can be received without any interference, because of the orthogonality property. It can be obtained by getting the carrier difference equal to the inverse of symbol duration.

There is a mandatory that the transmitting and receiving system in OFDM should be linear. Because non linearity cause of interference among multiple carriers due to which the inter modulation distortion occurs. And this will also produce unwanted signals which can cause of interference and affects the orthogonality of transmission carriers

(ii) FBMC System Model

FBMC is derivative of OFDM. Cyclic Prefix Orthogonal Frequency Division Multiplexing (CP- OFDM) have some drawbacks so that we use the filter bank based multi-carrier (FBMC), which provides the improved spectral and bandwidth efficiency. FBMC is the extension to the OFDM. [18]. As we know that the wireless devices connecting to internet increasing day by day with very fast rate. And this will further increase in future, so that to handle this situation new modulation techniques are needed. One of them is FBMC which provide the higher data rate than OFDM. This is the modulation technique which transmits the data by splitting it into various sub-channels and sends each sub-carrier over separate carrier signals.

a.FBMC Transmitter

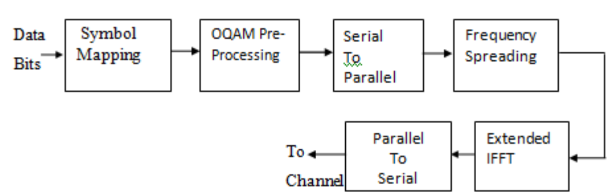

Fig.2 FBMC Transmitter

The FBMC transmitter consists of blocks as: OQAM (offset quadrature amplitude multiplexing), serial to parallel and parallel to serial data conversion block, frequency spreading and extended IFFT. Firstly we are giving the data bits to the mapping unit of FBMC. The functioning of each block of FBMC transmitter is given as shown in fig. 2

Symbol mapping

In the FBMC transmitter the data bits are given to symbol mapping block. The mapping of the symbols takes place to reduce the overlapping between two or more symbols. To reduce the overlapping there is need to map the symbols perfectly. After that the OQAM is used to increase the data rate. In remote systems, the physical layer incorporates the remote medium, so the physical layer utilizes simple analog data to convey the bits. In other way, sinusoidal waveforms are utilized to transmit coded bits (1s) over the air. In a computerized systems, the sinusoidal waveforms are "discrete time" in nature in that a one sinusoidal waveform has a constant with an all pre characterized begin time and end time.

OQAM Processing

In FBMC, any type of modulation can be utilized at whatever point the sub-channels are isolated. For instance, if just the sub-channels with even (odd) list are abused, there is no overlapping and QAM modulation scheme can be utilized. In any case, if high speed is needed, all the sub-channels must be misused and a particular modulation is expected to adapt to the recurrence space covering of the neighboring sub-channels. on the off chance that greatest information rate is the target, the neighboring sub-channels must be abused and the covering signs are isolated by the counterbalanced QAM method. In the plan, at time "n", the genuine contribution of sub- channel "i" is utilized, while it is the nonexistent contribution of sub-channels "i±1" which is encouraged by information. At time "n+1", it is the inverse. All the while, the image rate ends up plainly 2δf the time unit is 1/2δf. Truth be told, concerning QAM, a period balance of a large portion of the backwards of the sub-channel dividing is presented. OQAM (Offset quadrature amplitude multiplexing) have two different methods: first is the complex to real i.e. preprocessing and second is the real to complex conversion i.e. post processing.

Serial to Parallel (S/P) Conversion

Change of a flood of information components got in same time succession, i.e., each one in turn, into an information stream comprising of numerous quantities of information components transmitted at the same time. Appear differently in relation to parallel-to-serial change.

Frequency Spreading

Spread range is a sort of remote trades in which the repeat of the transmitted banner is deliberately changed. This results in a significantly more unmistakable information exchange limit than the banner would have if its repeat were not changed. Frequency spreading allow us obtain more accurate equalization. So, large number of bits per symbol can be sent and the bandwidth of each subcarrier can be increased. Increasing the bandwidth of each subcarrier tends to greater bandwidth capability; lower complication; small senstive to carrier frequency offset (CFO); mitigated peak- to-average power ratio (PAPR).

P/S, Overlap & Sum

Parallel to serial conversion is inverse of serial to parallel. In which each stream of data received in distinct time sequence, that's not at a one time, in to a data building of single data elements transmitted once time. It is called parallel to serial conversion. The overlap defined as when two signals are mixed with each other is called overlap, but in FBMC signals are not overlap with each other.

Extended IFFT

A data symbols are applied to one input of the IFFT and it modulates one carrier. In a filter bank with interfering factor K, a data symbol modulates 2K-1 carriers. Therefore, the filter bank in the transmitter can be employed as : - an IFFT of length KM is utilized, to create all the mandatory carriers, - a particular data symbol di (mM), after multiplying by the filter frequency parameters, is given to the 2K-1 inputs of the IFFT. In real, the data symbol is stretched over various IFFT inputs and the procedure can be known as "weighted frequency spreading". For every input, the output of the IFFT is a combination of KM samples and, the symbol rate is 1/M, K consecutive IFFT outputs overlap in the time domain. Therefore, the filter bank output is given by an overlap and sum operation.

b. FBMC Receiver

Filter Bank Multicarrier receiver work the opposite from transmitter to obtain the actual information back. It contains the FFT, symbol de – mapper and frequency de-spreading etc blocks.

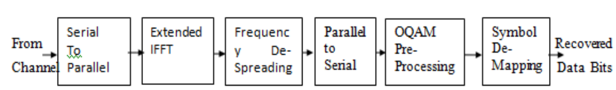

Fig.3 FBMC Reciver

For the better performance of the receiver the transmitter should align in time domain properly with transmitter. Now the channel has multipath propagation, which is due to impulse response of channel. So that the multicarrier overlap with each other, and it is not possible to demodulate the symbol with FFT at the receiver. Because inter-symbol interference has been developed and due to that orthogonality has been lost. So we have two options for this, one is the increase the symbol time and guard time, called

OFDM. Another option is the add some processing to FFT and keep time and guard interval as they are previously. This is called FBMC, because the additional processing and FFT combined together which construct the filter bank

Frequency de-spreading

It acts inverse of frequency spreading. It is used to regain the transmitted signal at the receiver side. Received baseband waveform is the combination of the transmitted waveform and noise in the channel.

Symbol De-mapping

The de-mapper modulation type matches the mapper's modulation types, where the original transmitted signal should be recovered. It perform the operation opposite from the mapper at the receiver side. At the receiver end data bits are recovered.

FBMC is also a multicarrier scheme as OFDM, but there are some difference between FBMC and OFDM. FBMC has better spectral efficiency than OFDM. The main drawback of OFDM is use of CP (Cyclic Prefix) as shown in Fig.3.15 Cyclic prefix is basically a replica of conveyed symbol, due to this the throughput of transmission reduces. And using cyclic prefix the power wastage take place and it also requires the more bandwidth to transmit the signal.

Filter bank modulation systems are more complicated than OFDM. This happens due to the swap of FFT/IFFT modules by the filter banks. Main contrast factor in these two schemes is quantity of multiplications (real) per symbol (complex). In OFDM realization, Split radix algorithm will have

$$CFFT/IFFT = M (\log(M) - 3)+4 \quad (3.7)$$

In FBMC, no. of real mltiplications per complex symbol is calculated as follows

$CSFB = \log_2(M/2) - 3 + 4*K$

$CAFB = 2 (\log_2(M) - 3) + 4*K$

Where, SFB is synthesis filter bank and AFB is analysis filter bank.OFDM suffers from poor spectral selectivity compare to FMBC

III. RESULT

OFDM is one of the most important candidate waveform for 5G. FBMC performance of transmitter and receiver is present in the PSD graph as depicted in figure 4 . In FBMC arrangement filtering is given on per sub carrier basis which gives good sub carrier distinction and it is not necessary to add cyclic prefix as OFDM and hence the FBMC is having more spectral efficiency than that of OFDM. FBMC gives good sub carrier distinction because it filters the signal on per sub carrier basis but higher FFT size and the filtering scheme used in signal creation makes the system much more complex than that of OFDM. SNR increases with the BER reduction.

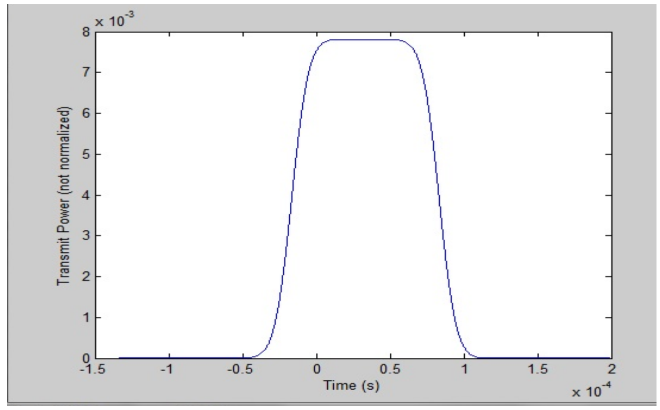

Fig 4. Transmission Power

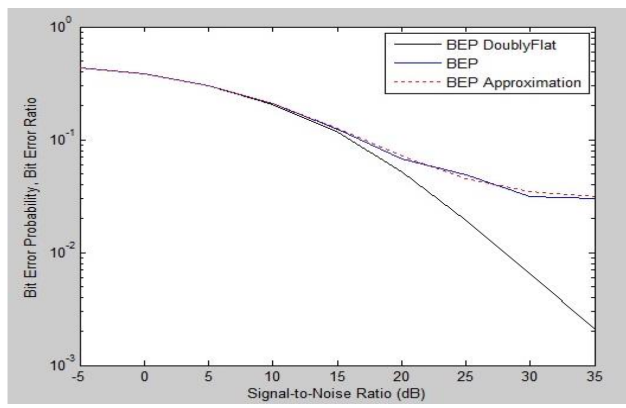

Fig 4.1 SNR vs BEP

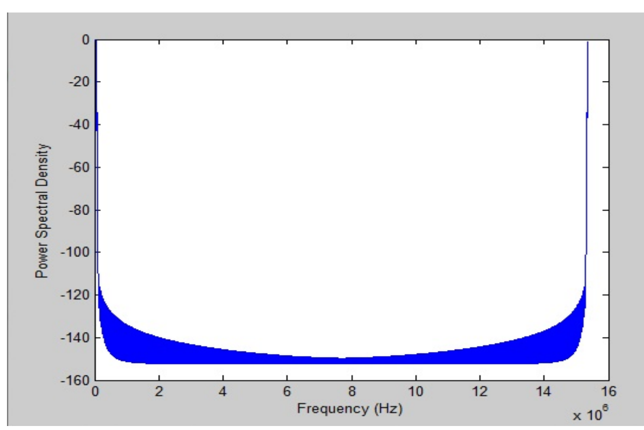

Fig 5 Power spectral density

we investigate the influence of time-variant multipath propagation on OFDM without CP, CP-OFDM and FBMC

(Hermite prototype filter [6]). Furthermore, our theoretical derivations of Section III are validated by Monte Carlo simulations and we show the approximation error for the assumption of Gaussian distributed interference. Figure 4.1 shows the BEP over SNR for the special case of doubly flat fading. The performance is independent of a specific modulation scheme but we should keep in mind that FBMC has a lower out-of-band emission than OFDM. Further more, for the same bandwidth FL, FBMC and OFDM without CP have the same bit rate while the bit rate for CP-OFDM is lower by a factor of (1+TCPF). Nonetheless, all modulation schemes use the same transmit power PS, allowing a fair comparison.

For a Pedestrian A channel model at low velocities, one tap equalizers are sufficient for CPOFDM and FBMC, but not necessarily for OFDM without CP. The interference in case of a Vehicular A channel at 500 km/h is mainly dominated by the Doppler spread, so that FBMC (with a Hermite prototype filter) performs better than OFDM. For a time-invariant channel, the BEP of CP-OFDM becomes the same as for doubly-flat fading. FBMC, on the other hand, is effected by a relatively high delay spread in a Vehicular A channel, so that it deviates from doubly-flat fading at high SNR values (not shown in the Figure). However,for practical relevant SNR ranges smaller than 20 dB this is no issue.

OFDM suffers from poor spectral selectivity compare to FMBC. The same is shown in the figure 6:

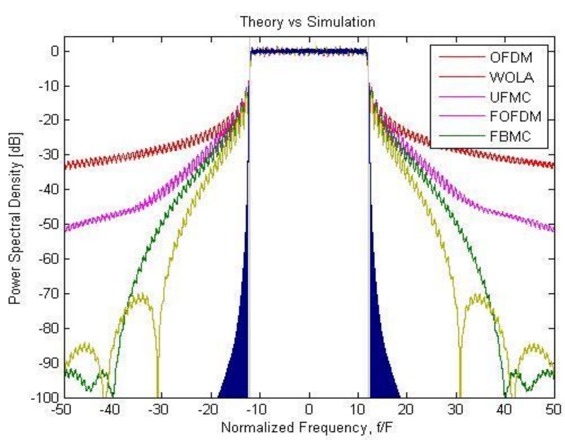

Fig.6. Comparison

Windowing (WOLA) and filtering (UFMC, f-OFDM) can improve the spectral properties of CP-OFDM. However, FBMC still performs much better and has the additional advantage of maximum symbol density, TF = 1 (complex). For FBMC we consider the PHYDYAS prototype filter with O = 4.

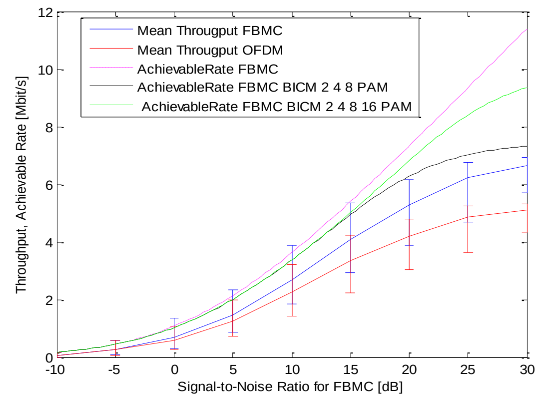

Fig.7. Throughput vs SNR

Fig. 7 shows the measured throughput as well as the theoretical bounds discussed so far (for Rayleigh fading). FBMC has a higher throughput than OFDM due to a higher usable bandwidth and because no CP is used. We now employ the data spreading approach and not auxiliary symbols. This further improves the throughput. OFDM and FBMC have the same transmit power which leads to a smaller SNR for FBMC compared to OFDM because the power is spread over a larger bandwidth . The measured throughput is only 2 dB worse than the theoretical BICM bound. An important observation here is that the throughput saturates. If we increase the SNR from 0 dB to 10 dB, that is, by a factor of 10, then the throughput increases by approximately 300%. On the other hand, if we increase the SNR from 20 dB to 30 dB, also a factor of 10, the throughput only increases by 20%. Even if we consider a symbol alphabet of up to 256-OQAM (BICM), the achievable rate only increases by 40%. Thus, a high SNR provides only a small throughput gain while power and hardware costs are significantly higher

IV. CONCLUSION

Here, we intended the FBMC transmitter and recipient side and more it is projected in 5G wireless communication arrangement. At the transmitter side we have used the OQAM processing and the synthesis filter bank. In recipient side we have used the polyphase structure and the OQAM post processing. To mitigate the computational complication we have utilized multiple stage filter banks. Our concentration is on scheming of FBMC and accomplishment as the suitable waveform for the 5G communication arrangement. In simulation outcome we can obviously find that the limitations of OFDM are recovered by the filter bank multicarrier. FBMC perform filtering on a per-subcarrier basis to give out of band spectrum characteristics. The baseband filtering is completed using either a poly phase network or an extended IFFT. Filtering can use distinct interfering factors to give changeable levels of out-of-band rejection. FBMC has a higher throughput than OFDM due to a higher usable bandwidth and because no CP is used. So, QAM-FBMC can be a suitable waveform result for 5G mobile communications.

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