International Journal of Innovative Research in Science and Engineering
Volume 08, Issue 06, 2022
www.ijirse.com
ISSN: 2454-9665

Analysis of Filter Bank Multicarrier Modulation SchemesFor Future Wireless Systems

ModugulaDevi VenkataSucharitha[1], Katru Ramya[2], RamaduguSyam Sudheer[3], KatariAshok[4] ,[5]Mrs.T.AnjiReddy M.Tech., [6]Ms R.Lakshmi Kavya M.Tech

[1,2,3,4]UG Students in Tirumala Engineering College, Narasaraopet, Andhra Pradesh, Guntur District -522601

[5]Assoc.Professor in Tirumala Engineering College, Narasaraopet, Andhra Pradesh, Guntur District -522601

[6]Assoc.Professor in Tirumala Engineering College, Narasaraopet, Andhra Pradesh, Guntur District -522601

Abstract: Potential wireless network systems require higher information rates wireless communication. Current physical layer techniques of wireless connectivity, such as conventional OFDM-based multi-carrier communications, are very hard to support traditional applications in huge connection and the sensory Internet. The major reason is that conventional OFDM devices use rectangular time- domain windows with very poor frequency localization. Furthermore, to safeguard strict orthogonality, flexible adjustment of system parameters such as subcarrier frequency and spacing is quite hard, which indicates that conventional OFDM systems are very hard to use in future wireless technology with diverse equipment in a massivelylinked environment. CP OFDM has poor OOBemissions. The existing techniques in OFDM, like filtering and windowing, reduce the Out of band emissions (OOB), but these will be effective and efficient only when the number of subcarriers is large. Usage of a large number of subcarriers in future wireless systems, in every case is not possible. So FBMC is chosen and considered as the solution for future wireless systems, due to its better spectral properties. I offer a good cohesive structure, rational discussion and success assessment of FBMC in this article and contrast it with systems based on OFDM. **Index**

Terms: 5G, OFDM, FBMC, QAM, OQAM,
CP-OFDM, OOB Emissions.

INTRODUCTION:

Future mobile devices will be extremely diverse and will feature a wide variety of feasible applications. We have to have a versatile distribution of the available time-frequency resources to effectively sustain such varied use applications. Ultimately, for 5G OFDM was selected with changes. By Considering alternative models over OFDM we don't except huge amounts of efficiency and gain. We do it to know about the pro's and con's of existing modulation schemes by employing a fair comparison. We make a comparison of OFDM with Filter Bank Multicarrier (FBMC), which produces much better spatial properties. Various versions of Filter bank Multi Carrier systems exit but w e will concentrate primarily on Offset QAM (OQM) as it offer s the greatest spatial properties. The two findingsdue to which FBMC is considered as the feasible option are: First, FBMC can be made to provide excellent localization in frequency and as well as in time, which results in efficient time-frequency resource allocation. It possesses small delay spread which will ensure that easy one-tap equalizers will be adequate to obtain optimal performance. We demonstrate that FBMC enables effective coexistence within the same band between distinct usage instances and that it can be used effectively in small-latency transmissions.

1 MULTICARRIER MODULATION (MCM)

Information is transferred over pulses in multi- carrier schemes that generally overlap in time and frequency. Tiny bandwidths are allotted to these pulses, thus transforming frequency selective channels into various sub-channels (sub-carriers) with negligible interference, nearly frequency flat. According to the Balian-Low theorem, multi-carrier systems have to fulfill some constraints, which are mathematically difficult to be achieved at the sametime. Table I illustrates the following.TABLE I

COMPARISON OF DIFFERENT MULTICARRIER SCHEMES (FOR AWGN)

	Maximum Symbol Density	Time-Localization	Frequency-Localization	(Bi)-Orthogonal	Independent Transmit Symbols
OFDM (noCP)	Yes	yes	No	Yes	Yes
Windowed Filtered OFDM	No	yes	yes	Yes	Yes
FBMC-QAM[1]	No	yes	Yes	Yes	Yes
FBMC-OQAM	Yes	yes	Yes	real only	Yes
Coded FBMC-OQAM	Yes	Yes	yes	yes, after de-spreading	No

Anmulticarrier system should have maximum symbol density $TF=1$,time localization $\sigma t<\infty$,frequency localization $\sigma f<\infty$ and also satisfy strict orthogonality condition $(gl1,k1(t),gl2,k2(t))=\delta(l2-l1),(k2-k1)$,($\delta$ denotesthe Kronecker delta function).

CP-OFDM

Applied in WLAN and 4G communication systems, CP-OFDM is the most prominent multi-carrier system. CP-OFDM uses rectangular transmission and receives pulses that significantly decrease the complexity of the computation.The presence of CP implies that the pulse transmitted is mildly larger than the received pulse, maintaining orthogonality in selective frequency transmissions.

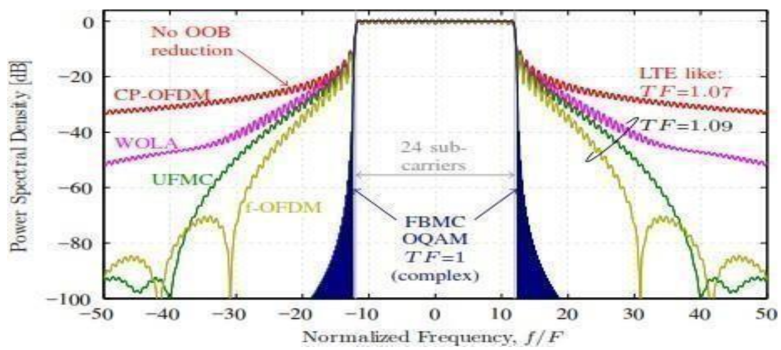


Fig. 1.*The figure shows the simulation resultscomparing*

CP OFDM,FBMC,UFMC,WOLA and FBMC

OQAM. and depicts that FBMC will have better spectral properties compared to OFDM techniques and also maintains the maximum symbol density TF

= 1(complex). (In this simulation we have considered the PHYDAS prototype filter in FBMC).In CP OFDM (Bi)-Orthogonality condition will be:

T = T0 + TCP; F = 1/T0 with localization σt = T0 + TCP ; σf = ∞, 2√3, Where T0 is the time- scaling parameter which depends on the time spacing of the desired subcarrier. Unfortunately, in the frequency domain, the rectangular pulse is not located, resulting in elevated OOB emissions as in Figure 1. This becomes the greatest drawback ofCP-OFDM. Furthermore, in frequency-selective channels, the addition of CP (Cyclic prefix)simplifies equalization but decreases spectral efficiency. No CP is required in an AWGN channel. We are presently discussing filtering and windowingto decrease the OOB emissions.

Windowed OFDM(WOLA)

We consider the windowing technique in OFDM called _Weighted Over-Lap and Add‘ (WOLA- OFDM). The

International Journal of Innovative Research in Science and Engineering
Volume 08, Issue 06, 2022
www.ijirse.com
ISSN: 2454-9665

rectangular pulse edges are windowed (replaced) at the transmitter by a smoother function(windowing) and then WOLA symbols of the neighborhood are overlapped in time. Windowing is applied even at the receiver, and the add, overlap operations are performed within the same WOLA symbol, which results in reduced inter-band interference. Cyclic Prefix should be considered long enough for both the transmitter window and the receiver to account for.

FILTER BASED OFDM TECHNIQUES: Two

techniques are suggested for the OFDM system with filtering concept. First, Universal Filtered Multi-Carrier(UFMC) in which the Dolph-Chebyshev window is applied for every subband. The receiving filter is just as essential as the transmission filter.

Filtering of subbands has to be applied even at the receiver side. Orthogonality is ensured by giving time-frequency spacing of TF= 1.14. Spectral efficiency is enhanced by reducing the time- frequency spacing to TF= 1.09 and enable tiny self- interference. Considered another OFDM based on filtering technique is f-OFDM. In this scheme, the we consider large number of subcarriers per a subband which will be usually much higher than that of UFMC. This scheme considers a filter which is based on a sinc pulse i.e ideal rectangular filter which ismultiplied by a Hann window; it is also feasible to use other filters. Usually the filters are longer in f- OFDM compared to those which are considered in Universal Filtered Multi carrier systems. From simulation results shown in Fig 1 we can see that filtering and windowing schemes used in OFDM will decrease the elevated Out Of Band emissions in CP- OFDM, but comprises the spectral efficiency

.Filtering and windowing techniques try to reduce the Out Of Band emissions but can‘t achieve as low as in FBMC, which even provides maximum symbol density(TF) = 1.

FBMC-QAM.

Some researchers sacrifice frequency localization in order to define FBMC QAM, which in terms of OOB emissions makes the FBMC-QAM scheme even worse than OFDM. Others compromise orthogonality to achieve time-frequency localization and time-frequency spacing (TF) equal to one. In our analysis of FBMC-QAM, we consider a time- frequency spacing (TF) equal to two, i.e compromising spectral efficiency to achieve all the other required properties as listed in Table I. The elevated time-frequency spacing in a dual selective channel improves the general robustness. The primary motive for selecting TF= 2 is for the direct

implementation in Filter bank multi-carrier scheme employing-Offset QAM. A Hermite pulse is the most prominent prototype filter for FBMC-QAM.In FBMC-QAM using hermite pulse we have Orthogonality condition as T =
T0; F = 2/T0 →TF = 2 with Localization:σt = 0.2015 T0; σf =0.403 $T0^{-1}$. In frequency and time, such Hermite pulses possess the same shape, permitting us to utilize symmetries. It focuses on Gaussian pulse and consequently has a decent joint time- frequency localization $\sigma t\sigma f$ = 1.021/4, nearly as excellent as the bound of $\sigma t\sigma f \geq 1/4\sim$ 0.08 (achieved by the Gaussian pulse), which makes it comparatively resistant to double- selective circuit. We then consider another important filter, which is the PHYDYAS prototype filter built with Orthogonal condition as :T = T0; F = 2/T0 → TF = 2 and Localization :σt = 0.2745 T0; σf = 0.328 T0−1.Usage of PHYDAS filter will give stronger frequency- localization but worse time- localization compared to the Hermite prototype filter. Even worseis the joint time- frequency localization.

2 FILTER BANK MULTI-CARRIER SYSTEMWITH OFFSET-QAM

Offset QAM(FBMC OQAM) is FBMC-QAM

related, whereas it will have the same density of symbols as in OFDM without CP. The complex condition of orthogonality

$\langle gl1,k1(t),gl2,k2(t)\rangle=\delta(l2-l1),(k2-k1)$ is swappedwith the less stringent condition of orthogonality

$R\{\langle gl1,k1(t),gl2,k2(t)\rangle\}=\delta(l2-l1),(k2-k1)$.In FBMC-OQAM we first

- Design a p(t)= p(−t) prototype filter which will be orthogonal for a time spacing of T= T0 and a frequency spacing of F= 2/T0,resulting in TF= 2.
- Then we reduce the time-frequency spacing (orthogonal) by a factor of 2, i.e. T= T0/2 andF= 1/T0.
- The induced interference is shifted to the purely imaginary domain by the phase shift $\theta l,k=\underline{\Pi}(l + k)$.

We have achieved the density equal to TF= 0.5, but we must note that this is only for real-valued information symbols and we require another cycle so that complex information symbols are also transmitted, resulting in a time frequency spacing (TF) equivalent to one for complex symbols. Generally, a complex symbol's real-part is mapped in the first time-slot and then the imaginary-part is mapped in the second time-slot, so it is called offset-QAMIn the OQAM process, we introduce a half symbol delay between I and Q components of QAM symbols. We introduce this delay to achieve baud- rate spacing between subsequent subcarriers, removing the requirement of CP to remove the inter- symbol and inter-carrier interference. Thereby Offset QAM will have more bandwidth efficiency than OFDM. In OQAM N parallel data streams are first fed to N filters and then I and Q components are altered in time by half symbol duration, T/2. Outputs from these filters have to be modulated with N subcarriers, whose frequencies are separated by 1/T.

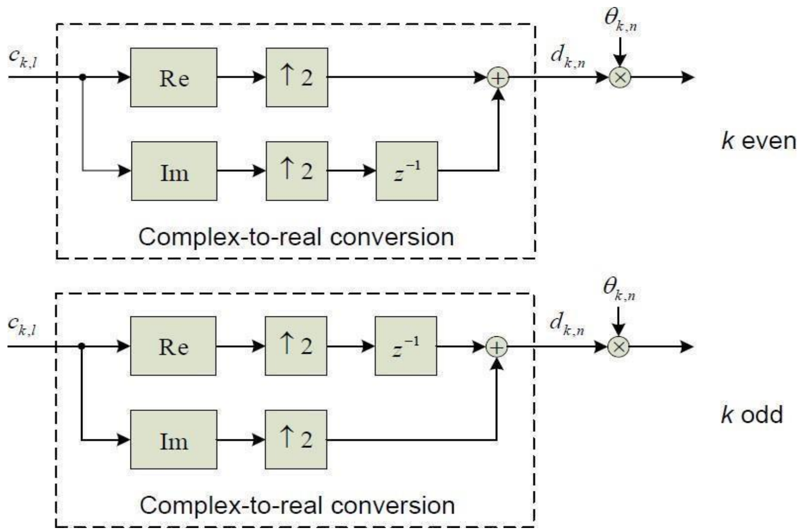


Fig3. *Structure of FBMC OQAM*

For a complex symbol

$$x(t)=\sum_{m=0}^{N-1}\sum_{l=-\infty}^{\infty}s_m[l]h(t-nT)e^{j\frac{\pi}{2T}(t-lT)}e^{jm(\frac{2\pi t}{T}+\frac{\pi}{2})}$$

(1)

$s^I[n]$is in-phase component and $s^Q[n]$ is quadrature the transformation is distinct. The sample rate is raised by 2 in complex to real transformation followed by the multiplication of these symbols by the sequence of θk,n.

k component of the kth Subcarrier and nth symbol. OQAM Pre-Processing:

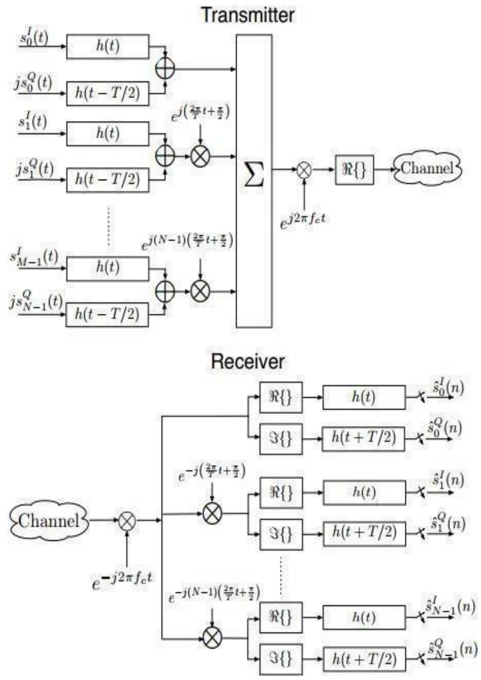


Fig 4 QAM to Offset QAM conversion process

OQAM Post Processing

Now we have to reconvert the Offset QAM signal back to the QAM signal. There are two steps in this conversion process as shown. The input is multiplied by a sequence of θk,n and then the real part of this signal is taken. Then it is fed to real-complex- conversion block, in which the sampling rate is decreased by 2 and then two successive complex- valued symbols (with one multiplied by j) gives a real symbol ˆc kn.FBMC-OQA compro mises strict orthogonality to real orthogonality, thereby losing complex orthogonality. This is the main disadvantage of the Offset QAM based FBMC technique. So we have tried to recover complex orthogonality by using a new technique called as_Coded FBMC- OQAM‘

The FBMC Offset QAM technique requires prior- processing and end-processing sections to generate FBMC signals. Figure 4 shows the pre-processing block that converts the signal from QAM to OffsetQAM. Given complex input signal ck,l, is converted into the real domain by separating real and complex parts into two new symbols dk,2l and dk,2l+1. For odd number and even number of subchannel,

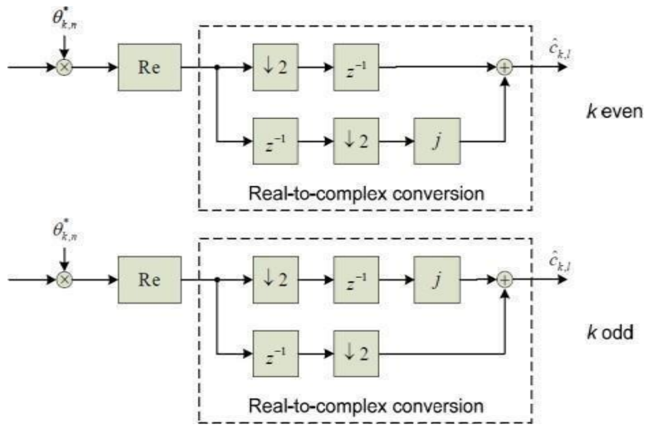


Fig 5. *OQAM to QAM reconversion process.*

4. CODED FBMC-OQAM:

We have seen that in FBMC OQAM we havesubstituted strictly complicated orthogonality withless real orthogonality. This will requiresynchronous phase transmissions(difficult in the up-link). Complex orthogonality will have to berecovered in OQAM if we want to use all MIMOmethods and channel estimation techniques as inOFDM. To accomplish this we go for coded FBMC OQAM in which symbols are spread in frequency or time.We use easy one-tapequalizers that can be used until the channel is either flat in time (if we spread over time) or frequency (if we distribute in frequency). On the other side, the primary disadvantagewill be the enhancedsensitivity to doubly-selective channels.

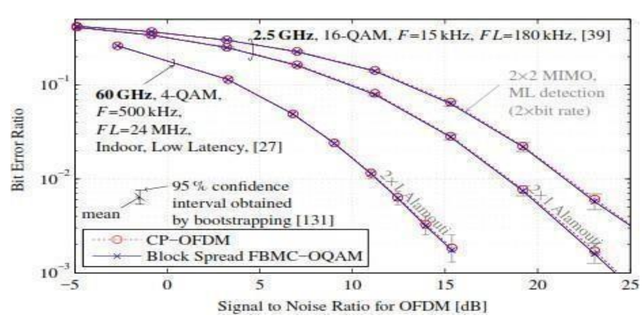


Fig.6.*Simulation results which show that Coded*

International Journal of Innovative Research in Science and Engineering
Volume 08, Issue 06, 2022
www.ijirse.com
ISSN: 2454-9665

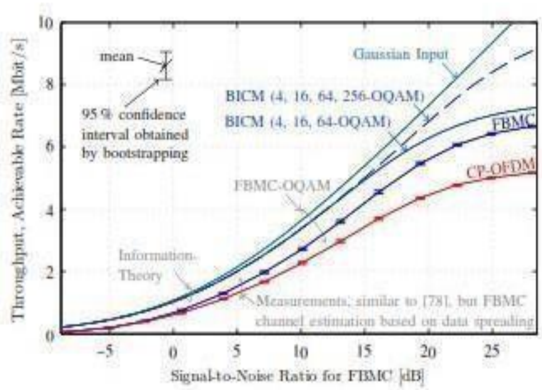
FBMC OQAM and OFDM have the same BER

5 PERFORMANCE EVALUATION

We have compared the various OFDM schemes with FBMC schemes in terms of SIR, BER, and throughput to find the best modulation scheme for5G systems

THROUGHPUT

The efficient utilization of bandwidth and removal of cyclic prefix, makes FBMC have greater throughput compared to the Orthogonal frequency division multiplexing technique. The channel estimate in Fig.7 is focused on the data propagation strategy in conjunction with an average moving block interpolation, i.e. all pilot measurements within a time frequency scope of 15 (complex-valued) time signs and 12 subcarriers are averaged to achieve an information location estimate. Such a technique of interpolation is feasible because in moment and frequency the channel is extremely linked. OFDM and FBMC have the same transmitting energy that results in a 0.82 dB lower FBMC SNR relative to OFDM as the energy is distributed over a bigger bandwidth. A significant remark here is the saturation of the throughput. If one raises the SNR from 0dB to 10dB, i.e. a factor of 10 increase in SNR results in a 300% increase in throughput. But after a certain level i.e Now if the SNR is expanded from 20dB to 30dB, which is also mathematically a factor of 10, We find that output will only increase by 20%. Even if a sign alphabet up to 256- OQAM is considered, the reachable level only rises by 40%. Thus, a large SNR offers only a tiny increase in throughput but needs considerably greater energy and



hardware expenses.

Fig.7 *shows that FBMC will have larger throughput compared to OFDM due to higher available bandwidth and removal of Cyclic Prefix.*

International Journal of Innovative Research in Science and Engineering
Volume 08, Issue 06, 2022
www.ijirse.com
ISSN: 2454-9665

SIGNAL-TO-INTERFERENCE RATIO: SIR is the measurement factor which will give us the information regarding where noise is dominated by interference. Calculation of SIR in Offset QAM is not as easywhen compared to QAM. This is because OQAM uses phase compensation in conjunction with the actual portion. Figure 11 demonstrates how the standardized guard band relies on the SIR. The greater the group of guards, the less we notice interference. As demonstrated in Fig. 8, it is of utmost significance to obtain windowing and filtering. Without it, standard Cyclic Prefix-OFDM, WOLA, Universally filtered multicarrier systems, filtered-OFDM and do not differ much. Windowing and filtering has to be applied at the receiver also. Cyclic Prefix-OFDM, WOLA, Universally filtered multicarrier systems, filtered-OFDM will possess good SIR as shown in Fig. 8, but not as good as compared to SIR in FBMC. Let's suppose that we need a 45dB SIR. Then fOFDM requires a F= 0.24FL guard band. FBMC, on the other hand, will possess a greater efficiency of ρ= 0.97. Information speed in FBMC is therefore about 50% greater than in fOFDM. Elevated subcarrier spacing (F= 120kHz)will allow signals of low latency.

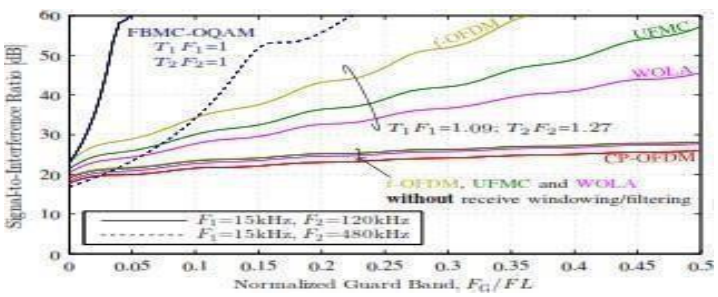


Fig.8. *The figure shows that FBMC will have higher SIR than OFDM, which means that we can employ much smaller guard bands.. Windowed (WOLA) and filtered(UFMC, FOFDM) OFDM will show efficient results only when windowing and filtering operationsare applied at the receiver also.*

This implies that we need to further increase the spacing of the subcarrier by a factor of four (O= 4) in FBMC to obtain fair comparison in terms of latency, resulting in F= 480 kHz which implies that it will have the same latency as of Orthogonal frequency- division Multiplexing. Then the amount of subcarriers in FBMC reduces from L= 12 to 3. From Fig.8 we find that a greater spacing between subcarriers i.e F= 480kHz needs a bigger guard band, but the time- frequency efficiency is still about 40% greater than in f-OFDM. Thus, it is not generally accurate to state that the Filter Bank Multi-Carrier system is not suitable for low- latency transmissions.

6 CONCLUSION

Once the amount of subcarriers is elevated, OFDM (Orthogonal frequency division multiplexing) based systems (filtered- OFDM, WOLA, Universally filtered multicarrier systems) will have a comparatively elevated spectral efficiency. Not all feasible cases for potential wireless devices will utilize such a large amount of subcarriers. FBMC becomes much more efficient than OFDM for atiny amount of subcarriers, especially when the transmission band is split among distinct use cases.

REFERENCES

[1] Society in motion: Challenges for LTE and beyond mobile communication, IEEE Commun.Mag., FeatureTopic: LTE Evolution,vol.54,no5.,2016.

[2] TSG RAN; study on scenaries and requirements fornextgeneration access technologies; release 143GPP, OCT.2016.

[3] Filtered-OFDM-enable for flexible wave form in the 5Thgeneration Cellular networks, by X. Zhang, M .Jia, l, Chen, J. Ma, and J.Qin, in IEEE GlobalCommunicationsConference 2015,pp.1-6.

[4] Subcarrier spacing-how to make use of thisdegree of freedom, F. Schaich, T.Wild, and R.Ahmed.