# Universal Filtered Multi Carrier (UFMC) Technique in 5G

**DISSERTATION-II**

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**IN**

**Electronics and Communication Engineering**

**By**

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## CERTIFICATE

This is certify that Kamurthi Ravi Teja bearing Registration no. 11614099 have completed objective formulation/Base paper implementation of the thesis titled **"Universal Filtered Multi carrier (UFMC) technique in 5G"** under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of thesis has ever been submitted for any degree at any university.

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First and foremost, I would like to express my sincere gratitude and appreciation to my guide Shakti Raj Chopra, for his whole-hearted and invaluable guidance, inspiring discussions, encouragement, and support throughout my work. I found him always sincere in helping me even during his busiest hours of the day. His ardour and earnestness for studies are respected and will never be forgotten. Without his sustained and sincere effort, this report would not have taken this shape.

We are also indebted to all authors of the research papers and books referred to, which have helped us in carrying out the research work.

Kamurthi Ravi Teja

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## DECLARATION

I, Kamurthi Ravi Teja, student of M. Tech under Department of Electronics and Communication of Lovely Professional University, Punjab, hereby declare that all the information furnished in this Dissertation-II report is based on my own intensive research and is genuine.

This report does not, to the best of our knowledge, contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

Kamurthi Ravi Teja

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# CONTENTS

# Abstract

This article describes the merits of Universal Filtered Multi Carrier (UFMC). It is a multi-carrier modulation technique in fifth generation network (5G). Orthogonal Frequency division Multiplexing (OFDM), a modulation technique in 4G, have some drawbacks like side band leakages and high Peak to Average Power ratio (PAPR) issues. With the advent of Internet of Things (IOT) and the move towards user-centric processing makes the OFDM technique more unfeasible. Filter Bank Multi carrier (FBMC) is another multi carrier technique, which is more better than OFDM, have some issues in practical aspects. So, a move to another multi carrier technique Universal Filtered Multi Carrier (UFMC).

This paper also gives the clear knowledge on PAPR and Bit Error rate (BER) of UFMC system. The simulations results in MATLAB shows that the BER values are increasing with increase in number of bits per sub carrier. The PAPR value of UFMC is 8.2379 and the PAPR value of OFDM is 8.8843 when 16 QAM mapping technique is used. And for 4QAM mapping technique the BER value is less than other mapping techniques. UFMC is more robust like FBMC to multi-carrier interference.

# Abbreviations

| | |
|---|---|
| 5G PPP | 5G Infrastructure Public Private Partnership |
| BER | Bit Error Rate |
| CDMA | Code Division Multiple Access |
| CP | Cyclic Prefix |
| DAC | Digital- to-Analog Converter |
| FA | Firefli Algorithm |
| FBMC | Filter Bank Multi Carrier |
| FDD | Frequency Division Duplex |
| FDMA | Frequency Division Multiple Access |
| FFT | Fast Fourier Transform |
| HPA | High Power Amplifiers |
| IFFT | Inverse Fast Fourier Transform |
| IOT | Internet of Things |
| ISI | Inter Symbol Interference |
| LTE | Long Term Evolution |
| M2X | Machine to Any Communication |
| MAMMOET | Massive MIMO for Efficient Transmission |
| MBB | Mobile Broadband Networks |
| MIMO | Multiple Input Multiple Output |
| MU-MIMO | Multi User- Multiple Input Multiple Output |
| OFDM | Orthogonal Frequency Division Multiplexing |
| OFDMA | Orthogonal Frequency Division Multiple Access |
| PAPR | Peak to Average Power Ratio |
| PSD | Power Spectrum Density |
| QAM | Quadrature Amplitude Modulation |
| QOE | Quality Of User Experience |
| QOS | Quality Of Service |
| RAN | Radio-Access-Network |

| | |
|---|---|
| RB | Resource Block |
| SE | Spectrum Efficiency |
| STBC | Space-Time Block Coding |
| TCO | Total Cost of Ownership |
| TDD | Time Division Duplex |
| TDMA | Time-Division Multiple Access |
| UFMC | Universal Filtered Multi Carrier |
| V2V | Vehicle to Vehicle Communication |

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# CHAPTER 1

# INTRODUCTION

## 1.1 INTRODUCTION TO 5G

5G is the fifth generation mobile communication network. Now we are in 4G i.e. Fourth generation mobile communication network .This 4G is introduced in the year 2000, but it came into existence in the year 2009.The location first commercialized in South Korea. Similarly 5G was introduced in the year 2010, but we might expect this 5G in 2020 [1].The technology used in 5G is 4G+wwww. It is having the bandwidth of greater than 1 Gbps. Researchers are saying that it can support the data speed up to 10 Gbps. This gives contiguous consistent coverage using 5G Wi-Fi technology. If we see our past mobile generations for every 10 years the technology is deploying or upgrading or taking a new place in the mobile communication network, starting from First Generation to Fifth Generation. One of the most important thing in fifth generation technology was Low battery consumption. As we are seeing in our 3G/4G devices almost every device is facing the battery draining problem .So here in 5G this problem is overcoming in this 5G technology. We can convert our normal world into real Wi-Fi zone. For every technology researchers are facing some issues, even in this fifth generation technology mobile communication. We discussed about this issues in the below paragraph. With this we can get high spectrum efficiency. There are some major challenges which the 5G technology is being facing in the research of development. It is having good future scope in the coming years. So, because of this we can say clearly that 5G technology is an Incredible, Intelligent and creative technology. It is really going to change the living world of every people through its performance, speed and its dynamic characteristics.

## 1.2 5G SPECTRUM

5G spectrum for United Kingdom Public Candidate is described below. It consists of WI-FI, Mobile Broadband, PSME audio. This is for Telecom TV service.

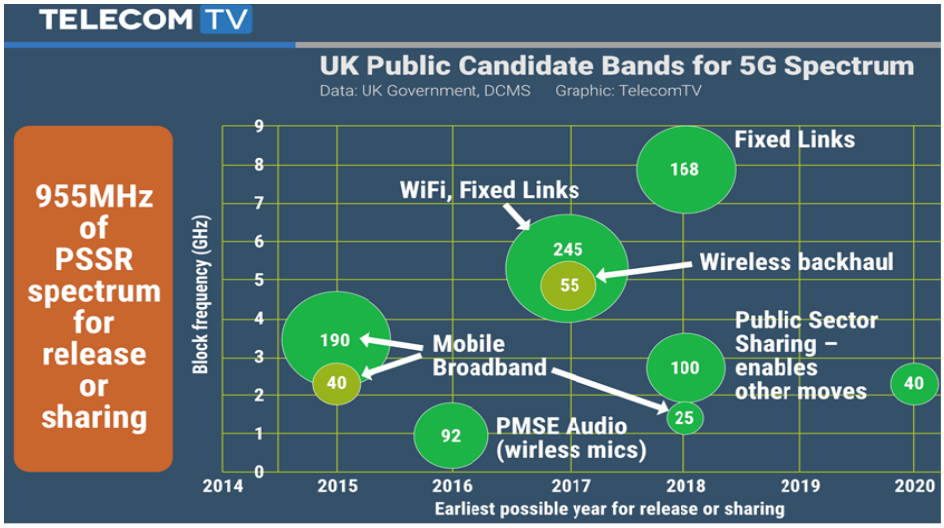


Fig 1: UK's 5G spectrum

For a 5G physical and Mac layer building blocks, the spectrum is greater than 6 GHz and the Waveform used in this a 5G physical and Mac layer building blocks are based on OFDM, GFDM and UFMC. Here Full duplex, TDD, FDD Duplex modes are used. BPSK and QPSK modulation techniques are used [2].

5G will make or create a beautiful and wonderful real Wi-Fi zone. Bases on the network availability, we can do anything by sitting and connecting to Internet. We can book train, bus, flight tickets etc. through online in seconds. We can download large size files in a very less time.5G's cognitive radio technology will facilitate different version of radio technologies to share the same spectrum efficiency. 5G will make the integrated global standard for all. It means the 5G applications is just like a accomplishment of dream.

## 1.3 ADVANCED FEATURES

5G will cover large area (worldwide coverage).It has a good feature that it has a capability to connect 10 to 100 number of devices.

The battery consumption of this technology will be very low when compared with the previous technologies.

Above all, almost 90% of reduction in network usage of energy.

5G is going to create wonders in the coming 2020.Everyone teachers, doctors, engineers, government officials, all administrations and even a common man can use this technology.

## 1.4 ADVANTAGES

We can detect the earthquakes, weather and climatic changes in advance with the help of this 5th Gen. advanced technology.

In space we can send and retrieve the data easily and that too with high speed. With the help of 5G, we can easily manage all the previous technologies. Because of large network coverage and high bandwidth, there is a possibility to connect up to 60000 connections. That's the great feature in 5G.When coming to the education, the coming future in that era is through online mode i.e. Online classes, online exams, online assignments, online attendance, online payments everything under online. For this 5G network will helps a lot.

While coming to the treatment, a doctor can check or give treatment though some advancements in technology. We can take control our laptops, pc's or devices. We can easily detect the person or object in any place he or it will be. Our government can easily govern the people by interacting with the people through online portals. So that every common can post their problems in that portal to probe the issue.

The most routine bad problem is crime rate. By installing some security devices, security alarm systems we can easily reduce the crime rate. We can see the universe, planets, and galaxies i.e. about space information through this good forthcoming 5th generation.

## 1.5 DISADVANTAGES

There are some issues in the 5th generation technology.

They are

a) Infrastructure

b) security issues

c) still Researching

d) High cost

- **Why 5G faces security issues?**

Everything now a day's things get hack easily by attackers through online. They easily decrypt the encrypted data with some software techniques.

In order to protect from this, many precautions should be taken. So, the researchers are working on that area.

- **Why 5G faces Infrastructure issue?**

Another issue in 5G is Infrastructure problem. In order to install this many techniques, methods are involving in this. So, it is pretty high expensive. Infrastructure for 5G really needs a lot of place to work or to do research on that particular area.

- **Why Research work issue?**

In order to compete the existed technology, many researches are still doing researches to compete the previous technologies.

So many companies like Nokia, Huawei, kept a lot of efforts in this 5G technology in order to maintain their stability in the market.


Fig 1.2 The possible components for a new 5G air interface.

For a 5G physical and Mac layer building blocks, the spectrum is greater than 6 GHz and the Waveform used in this a 5G physical and Mac layer building blocks are based on OFDM, GFDM and UFMC. Here Full duplex, TDD, FDD Duplex modes are used. BPSK and QPSK modulation techniques are used.

## 1.6 INTRODUCTION TO MODULATION TECHNIQUES IN 5G

At present the main data transmission technology in wireless communication system is Orthogonal Frequency Division Multiplexing (OFDM). OFDM is using in LTE/LTE advanced (4G) and IEEE 802.11 (WI-FI) networks. OFDM is a modulation technique with strongly efficient in bandwidth usage. It is immune to multipath fading and Inter Symbol Interference (ISI). The recent advancements in Digital signal processing make the OFDM very popular. Above all advantages, OFDM is having some disadvantages like high PAPR (Peak to Average Power Ratio) and high Bit error rate (BER) [13]. The sensitivity of devices used in the OFDM transmitter side such as Digital- to-Analog Converter (DAC) and High Power Amplifiers (HPA) are very harsh to the signal processing loop which affects the performance of the system. When we operate with high power Amplifiers, it produces signal excursions into the non-linear region [4]. The spectrum utilization of OFDM is not better when compare to other modulation techniques like UFMC. Spectrum efficiency plays a main role in rapid Mobile Broadband Networks (MBB). The most valuable resources to the telecom field is Spectrum resources. Spectrum resources represent one of the largest investments in terms of Total cost of Ownership (TCO). However, Limited spectrum resources hinder MBB development.

But in order to meet the higher requirements in 5G, this OFDM technology is not sufficient. This is because of poor spectral containment, power inefficiency, Bandwidth inefficiency and sensitive to severe dispersions. So, evolution of new technologies like Filter Bank Multi Carrier (FBMC) and Universal Filtered Multi Carrier (UFMC) emerged. However, FBMC is the not right one because large filter length affects the symbol decoding time and having complex receiver structure in MIMO [28]. Also FBMC is not suitable for burst transmissions or delay sensitive applications. So, the good right candidate in 5G is UFMC [1], [3]. In UFMC filtering is applied to a group of sub carriers. UFMC system not only enables QAM transmission and MIMO schemes but also provides lower out of band radiation with short frame length. UFMC is best suited for

uplink with multiple number of users [2]. The forthcoming 5G mobile communications aims on providing higher performance than LTE-Advanced and more concentrated on higher transmission data rate of 20 GB/sec. The major applications in 5G are Internet of Things (IOT), Cognitive Radios, Vehicle to Vehicle Communication (V2V) and Machine to Any (M2X) Communication. This article gives an implicit knowledge on Orthogonal Frequency Division Multiplexing, Filter Bank Multi Carrier and UFMC.

# CHAPTER 2

## LITERARATURE REVIEW

**1. Title:** Implementation and study of Universal Filtered Multi Carrier Frequency Offset for 5G
**Author's Name:** Sathipriya N.S and P.Rani

UFMC, a generalization of Filtered OFDM and FBMC multi-carrier modulation technique. Generally in filtered OFDM, entire band is filtered where as in FBMC individual sub carriers are filtered. But in UFMC group of sub carriers are filtered. This is the main difference in Filtered OFDM, FBMC and UFMC multi-carrier. Grouping of sub carriers helps in reducing the filter length in UFMC. IN UFMC, to retain the complex orthogonality, QAM is used which works with existing MIMO. Here the full band of 'N' sub carriers is partitioned into several sub bands. Each sub band has a fixed number of sub carriers. In transmitter section no need of employing all sub bands for a transmission. To get rid of from the sub band carrier interfere, Inverse Fast Fourier Transform (IFFT) is used. At each N-point IFFT, sub bands are computed and zeros are allocated for unallocated carriers

**2. Title:** Resource Block management for uplink UFMC systems.

**Author's Name:** Hyunsoo Kim, Jonghyun Bang, Sooyong Choi and Daesik Hong.

In UFMC filtering is applied to a group of sub carriers. UFMC system not only enables QAM transmission and MIMO schemes but also provides lower out of band radiation with short frame length. UFMC is best suited for uplink with multiple numbers of users. UFMC, a generalization of Filtered OFDM and FBMC multi-carrier modulation technique. Generally in filtered OFDM, entire band is filtered where as in FBMC individual sub carriers are filtered. But in UFMC group of sub carriers are filtered. This is the main difference in Filtered OFDM, FBMC and UFMC multi-carrier. Grouping of sub carriers helps in reducing the filter length in UFMC. IN UFMC, to retain the complex orthogonality, QAM is used which works with existing MIMO. Here the full band of 'N' sub carriers is partitioned into several sub bands. Each sub band has a fixed number of sub carriers. In transmitter section no need of employing all sub bands for a transmission. To get rid of from the sub band carrier interfere, Inverse Fast Fourier Transform (IFFT) is used. At each N-point IFFT, sub bands are computed and zeros are allocated for unallocated carriers.

**3. Title:** UFMC : The 5G Modulation Technique

**Authors Names:** N.Rani and Shanti Rani

UFMC, a generalization of Filtered OFDM and FBMC multi-carrier modulation technique. Generally in filtered OFDM, entire band is filtered where as in FBMC individual sub carriers are filtered. But in UFMC group of sub carriers are filtered [6]. This is the main difference in Filtered OFDM, FBMC and UFMC multi-carrier. Grouping of sub carriers helps in reducing the filter length in UFMC. IN UFMC, to retain the complex orthogonality, QAM is used which works with existing MIMO. The whole UFMC transmitter section in shown in figure 1. Here the full band of 'N' sub carriers is partitioned into several sub bands. Each sub band has a fixed number of sub carriers. In transmitter section no need of employing all sub bands for a transmission. To get rid of from the sub band carrier interfere, Inverse Fast Fourier Transform (IFFT) is used. At each N-point IFFT, sub bands are computed and zeros are allocated for unallocated carriers. IFFT converts frequency domain ($X_i$) to time domain ($x_i$). Now the time domain signals comes from the IFFT goes to Band filter of length 'L' block. Each sub band output is filtered by band filter of Length 'L' Actually band filters uses Chebyshev window/filtering operation. Here parameterized side lobes attenuation is used to filter the IFFT outputs. Now all the outputs from the band filters are summed at the end and passes through the channel.

From the channel the data bits are transmitted to UFMC receiver. UFMC receiver do's 2N-point Fast Fourier Transform (FFT). FFT converts the data of time domain to frequency domain. To prevent Inter Symbol Interference (ISI), guard intervals of zeros are added between successive IFFT symbols. ISI is due to transmitter filter delay. To receive N length frequency domain signal 'Y', even sub carriers are discarded. Now the data goes for equalization process and the original data bits are retrieved by symbol demapping.

**4. Title:** Waveform contenders for 5G-suitability for short packet and Low latency transmissions **Author's Name:** Frank Schaich, Thorsten Wild and Yejian chen.

But in order to meet the higher requirements in 5G, this OFDM technology is not sufficient. So, the evolution of new technologies like Filter Bank Multi Carrier (FBMC) and Universal Filtered

Multi Carrier (UFMC) emerged. However, FBMC is the not right one because large filter length affects the symbol decoding time and having complex receiver structure in MIMO. Also FBMC is not suitable for burst transmissions or delay sensitive applications. So, the good right candidate in 5G is UFMC. In UFMC filtering is applied to a group of sub carriers. UFMC system not only enables QAM transmission and MIMO schemes but also provides lower out of band radiation with short frame length. UFMC is best suited for uplink with multiple number of users.

**5. Title:** On MIMO-UFMC in the presence of Phase Noise and Antenna Mutual Coupling.

**Author's Name:** Xiaoming Chen, Shuai Zhang and Anxue Zhang,

With a specific end goal to concentrate on the impacts of shared coupling and stage commotion on MIMO-UFMC frameworks, we expect culminate time synchronization and perfect channel estimation. For effortlessness and without loss of sweeping statement, we accept spatial multiplexing with zero-compelling MIMO decoder (Schenk et al., 2005) in this paper.

In this area, we direct recreations to explore the impacts of stage commotions of both free-running and PLL-based oscillators. For the two cases, we accept 1,024 subcarriers, out of which, 832 are information subcarriers, 32 are scattered pilots, and 160 are monitor band subcarriers. The dynamic subcarriers are stacked with 64 quadrature plentifulness balance (64-QAM) images. q = 7 obscure (cf. area 3) are decided for stage commotion alleviation. The Dolph-Chebyshev filter with 64 taps and 40 dB stop band concealment is picked as the model filter for the UFMC modulation. A three-tap Rayleigh fading channel with equal average tap gain of 1/3 is accepted. We accept the channel remain consistent inside 20 UFMC images after which an autonomous channel acknowledgment is drawn. Altogether, 100 channel acknowledge are produced. With a specific end goal to concentrate on the impacts mutual coupling and phase noise, we assume a 3-D uniform multipath environment, a pair of parallel lossless half-wavelength ($\lambda/2$) dipole reception apparatuses at the transmitter, and four perfect radio wires (i.e., no connection or common coupling) at the collector. The explanatory articulation of the impedance framework of the parallel dipoles as a component of dipole detachment can be found in Balanis (2005). The correlation magnitudes and total embedded radiation efficiencies (including the antenna crisscross) of the parallel dipoles with/without common coupling as elements of dipole detachment in wavelength ($\lambda$). The relationships with/without common coupling can be ascertained with the diagnostic articulations of self-

impedance and shared impedances of parallel dipoles in Balanis (2005), while the aggregate implanted radiation efficiency with shared coupling can be computed as 1|S11|2|S21|2, where the S parameters can be promptly changed over from the self-impedance and shared impedances of parallel dipoles (Pozar, 2005). Note that without shared coupling the aggregate inserted radiation efficiency winds up plainly 1|S11|2. As can be seen, for little dipole detachment (< 0.37 λ), the relationship when taking (electromagnetic) common coupling into account is littler than that when the shared coupling impact is precluded. However the shared coupling debases the aggregate inserted radiation efficiency when the dipole partition is littler than 0.5 λ. For the free-running oscillator case, we expect the 3 dB transmission capacity of the stage commotion is β = 100 Hz. The inspecting recurrence is thought to be 20 MHz. The channel taps are at the zeroth, fourth, and eighth time tests. Each channel tap coefficient takes after complex Gaussian appropriation (whose sufficiency is Rayleigh disseminated in non-observable pathway situation) with measure up to difference (i.e., normal tap control) of 1/3. For image mistake rate (SER) recreations, we first numerically produce the MIMO channel and the content underneath). We expect the channel remain consistent amid 50 UFMC images, after which a free channel is produced. Altogether, 100 MIMO channel acknowledge are produced (each compares to 50 UFMC images). The time signal is acquired by convolving the transmit (time area) motion with the channel motivation reaction (i.e., the channel taps). Within the sight of stage commotion and AWGN, the got flag is first duplicated by the transporter stage clamor and after that additional by an AWGN. At each channel acknowledgment, the (prompt) SER is figured by contrasting the transmitted images and the distinguished ones more than 50 UFMC images (each with 832 64-QAM images). The SER in the multipath blurring channel is acquired by averaging over the 100 channel acknowledge. A similar method is rehashed for each SNR, every dipole partition, and each stage commotion case. Figure 3 demonstrates the SER execution of a 4 × 2 MIMO-UFMC system in the multipath blurring channel under various dipole partitions (i.e., 0.1, 0.2, and 0.3 λ). For every dipole division, the SERs of the MIMO UFMC system without stage commotion (PN) remedy, with CPE revision, with PN alleviation are plotted, individually.

**6. Title:** Universal Filtered Multi Carrier for 5G

**Author's Names:** Mohammad Zafar, Irsad Hussain and Waleed Shahjehan.

UFMC has bring down out-of-band outflow and is likewise perfect with the various info different yield (MIMO) procedure. Be that as it may, as other multicarrier waveforms, it suffers from phase noise of imperfect oscillator. In contrast to the rich literature on phase noise impact on MIMO-OFDM (where the radio wire shared coupling impact is generally overlooked however), there is little work investigating the phase noise effect on MIMO-UFMC. In this paper, we study the MIMO-UFMC systems in the nearness of stage commotion and with/without common coupling impact. A stage clamor moderation conspire for MIMO-UFMC frameworks is displayed. The plan does not require itemized information of the stage clamor statistics and can effectively mitigate the phase noise within each UFMC symbol. Moreover,it is shown that at little receiving wire partitions, the execution of the MIMO-UFMC framework producing the shared coupling results into account is superior to that when the common coupling impact is neglected.

**7.Title:** Comparative Analysis of UFMC technology in 5Gnetworks.

**Author's Name:** Grigory Bochechka, Valery Tikhvinskiy and Bolat Nurgozhin.

At present the main data transmission technology in wireless communication system is Orthogonal Frequency Division Multiplexing (OFDM). OFDM is using in LTE/LTE advanced (4G) and IEEE 802.11 (WI-FI) networks. OFDM is a modulation technique with strongly efficient in bandwidth usage. It is immune to multipath fading and Inter Symbol Interference (ISI). The recent advancements in Digital signal processing make the OFDM very popular. Above all advantages, OFDM is having some disadvantages like high PAPR (Peak to Average Power Ratio) and high Bit error rate (BER). The sensitivity of devices used in the OFDM transmitter side such as Digital- to-Analog Converter (DAC) and High Power Amplifiers (HPA) are very harsh to the signal processing loop which affects the performance of the system [14]. When we operate with high power Amplifiers, it produces signal excursions into the non-linear region [4]. The spectrum utilization of OFDM is not better when compare to other modulation techniques like UFMC. Spectrum efficiency plays a main role in rapid Mobile Broadband Networks (MBB). The most valuable resources to the telecom field is Spectrum resources. Spectrum resources represent one of the largest investments in terms of TCO. However, Limited spectrum resources hinder MBB development.

But in order to meet the higher requirements in 5G, this OFDM technology is not sufficient.This is because of poor spectral containment, power inefficiency, Bandwidth inefficiency and sensitive to severe dispersions. So, evolution of new technologies like Filter Bank Multi Carrier (FBMC) and Universal Filtered Multi Carrier (UFMC) emerged. However, FBMC is the not right one because large filter length affects the symbol decoding time and having complex receiver structure in MIMO. Also FBMC is not suitable for burst transmissions or delay sensitive applications. So, the good right candidate in 5G is UFMC [1], [3]. In UFMC filtering is applied to a group of sub carriers. UFMC system not only enables QAM transmission and MIMO schemes but also provides lower out of band radiation with short frame length. UFMC is best suited for uplink with multiple number of users [2]. The forthcoming 5G mobile communications aims on providing higher performance than LTE-Advanced and more concentrated on higher transmission data rate of 20 GB/sec. The major applications in 5G are Internet of Things (IOT), Cognitive Radios, Vehicle to Vehicle Communication (V2V) and Machine to Any (M2X) Communication.

**8. Title:** Improving Spectral Efficiency of FBMC-OQAm though Virtual symbol.

**Authors Names:** saltberg and Chang

Chang and saltzberg introduced the multi carrier methods twenty years back. Both OFDM and FBMC supports MIMO technology, but OFDM has some drawbacks. So, the main aim of FBMC is to overcome some of the short comings of OFDM. In OFDM ‘Cyclic Prefix’ is must and should to avoid Inter Symbol Interference (ISI) and to convert the channel to a number of sub-carrier channels. But in FBMC, Cyclic Prefix is not used, but it has the capability to convert the channel to a set of sub-carrier channels and to remove ISI. The sub-carriers spectral localization in OFDM are weak which might results in spectral leakages and also interference issues with unsynchronized signals. These problems can be rectified using FBMC technique. When the carriers were modulated in OFDM, the side lobes might spread out at either side. Even this problem can also be rectified by using FBMC which gives very good clear results. So, FBMC is the derivative of OFDM. Signal Overlapping, extreme fading and ISI damages or deteriorates the communication system. So, in FBMC Fast Fourier Transform (FFT) and Inverse Fast Fourier Transform (IFFT) is used to avoid ISI and signal overlapping’s.

Both Orthogonal Frequency Division Multiplexing (OFDM) and Filter Bank Multi carrier (FBMC) supports MIMO system. The primary reason of using OFDM in MIMO system is to remove interference and the main aim of FBMC is to overcome some of the shortcomings in OFDM. Actually FBMC is the betterment of OFDM. So, FBMC is equals to the derivative of OFDM. Both plays a prominent role in the area of wireless communication modulation techniques. But by using filter banks it has possible to get our desired results than OFDM. In Massive MIMO FBMC concept, the complexity of the system and delay can be reduced by reducing the sub-carriers. Actually in Massive MIMO FBMC system, Analysis can be done at Receiver side and Synthesis at Transceiver side [15].

**9. Title:** Review of Massive MIMO, FBMC and OFDM

**Author's Names:** Kamurthi Ravi Teja and Shakti Raj Chopra

OFDM is required to accomplish high limit and Robustness (fights with Interference). Fading, multipath delay are influencing the correspondence framework to harm. Be that as it may, the outrageous blurring and Inter Symbol Interference (ISI) happens at the collector side. Thus, in view of these we are getting mistakes and furthermore diminishes the framework execution. Despite the fact that we are having Adaptive leveling, because of its high cost and postponement in the coding make it's troublesome[29], [30]. At that point comes Orthogonal Frequency Division Multiplexing (OFDM) strategy. In OFDM, it comprises of a few sub transporters piece to transmit the information. Quick Fourier Transform and Inverse Fast Fourier Transform are utilizing to dispose of from the ISI and flag covering. ISI will come the transmitted flag is mutilated by other transmitted signs. In this procedure, the aggregate flag recurrence band is partitioned into N sub channel recurrence. We are isolating this flag band in light of the fact that to abstain from covering. In OFDM the principle imperative capacity is looking after orthogonality. It's is clarified scientifically utilizing numerical articulations. Contrast amongst OFDM and FBMC are: OFDM underpins MIMO to expel interference yet it has high PAPR and it needs High power. This is fairly uproarious and low density spectrum. Yet, FBMC is a method to beat every one of the weaknesses that were experienced with OFDM. OFDM require the utilization of "Cyclic Prefix" to stay away from Inter Symbol Interference (ISI) and change over the channel to sub channel transporters. Spectral localization of the subcarrier brings about Spectral edge and impedance issues with

unsynchronized issues. Side lobes may spread out either side, But with filter Banks we can dispose of from that spread out.

**10. Title:** Massive MIMO spectral efficiency

**Authors Names:** H. Caire and Ram Prasad

since MIMO-UFMC systems should work in multipat [16]h blurring situations, we have to assess the stage clamor impact on MIMO-UFMC system likewise in a multipath blurring channel, despite the fact that the oscillator stage clamor is autonomous of the multipath blurring channel.) Stage commotion pay for OFDM frameworks have been considered seriously in the writing. For instance, Zhangetal. (2004) proposed an ICI self cancellation scheme by modulating one symbol to two adjacent subcarriers with opposite weights. The scheme can effectively cancel the stage noise effect; however, it reduces the ghastly efficiency considerably. Petrovic et al. (2007) proposed a recurrence space ICI adjustment technique which dispenses with the stage clamor impact by evaluating discrete phantom parts of the stage commotion. The technique was additionally upgraded in Tchamov et al. (2013) by direct introducing between contiguous OFDM images, bringing about upgraded framework execution (at the cost of marginally expanded intricacy and one additional OFDM image delay). In any case, these ICI revision strategies require iterative preparing with expanded many-sided quality and idleness. Another recurrence space stage commotion relief technique in view of non iterative most extreme probability estimation was proposed by Rabiei et al. (2010). Geometry-based stage clamor estimation was proposed by Mathecken et al. (2016). The previously mentioned stage clamor moderation plans are for single-antenna OFDM frameworks, while stage clamor impacts on MIMO-OFDM system have been contemplated in Bittner et al. (2008), Corvaja and Armada (2010), Hamila et al. (2016), Liu et al. (2006), and Schenk et al. (2005). With the exception of Bittner et al. (2008) that utilization iterative preparing to make up for the stage commotion, most MIMO-OFDM work turned to basic CPE redress and left the ICI uncompensated. The previously mentioned take a shot at stage commotion moderation is only restricted to customary OFDM frameworks.

**11. Title:** PAPR analysis of OFDM

**Author's Names:** Mohsin Khan, Samima Iqbal and Waseem Asghar.

In OFDM the entire bandwidth is divided into number of sub-carriers and these sub carriers are transmitted in parallel to increase symbol duration to achieve high data rates and to reduce ISI. An OFDM signal is the sum of all sub carriers signal which are modulated at the cub channels of equal bandwidth.

High PAPR value and high BER are the major disadvantages in OFDM. The sensitivity of devices used in the OFDM transmitter side like DAC and HPA are very harsh to the signal processing loop which affects the performance of the system

# CHAPTER 3

# OBJECTIVES

## 3.1 UFMC MUST SUPPORTS MIMO TECHNOLOGY

We know that there is a huge good demand for higher data rate, so all the telecommunication companies had started the research work on 5G. MIMO system technology primarily concentrates on higher spectral efficiency and focuses on high coverage area for all cell edge users. In a communication system, fading and multi path delays are creating problems which results in errors and also affects the performance of the system. So, In order to overcome these problems there are some techniques called Filter Bank Multi carrier (FBMC), Universal Filtered Multi-Carrier(UFMC) and Orthogonal Frequency Division Multiplexing (OFDM) which overcomes the above said problems in communication system. Both FBMC and OFDM technologies supports MIMO, but there are some cons in OFDM. In fact, FBMC is considered as the development of OFDM. The important principle in MIMO system is Spatial Multiplexing. Between transmitter and receiver, the multiple information is shared in streams parallely which is known as Spatial Multiplexing. Here the multiple information is transferred through space [23].

By MIMO and UFMC being clarified, indicate distinctive tests directed with various UFMC MIMO designs. By changing the quantity of reception antennas at the recipient and transmitter and utilizing various advanced modulation schemes, the execution of the UFMC MIMO system can be assessed. Massive MIMO is the key technology in 3G/4G and 5G wireless communication network system. MIMO technology is preferred because of high data rate transmission. The parameters like high Capacity and Robustness plays a very prominent role in Massive MIMO communication system. And even antenna gain improves the Signal-to-Noise Ratio (SNR) in Massive MIMO system. This technology is used in broadband standards like Long Term Evolution (LTE) and WI-FI systems because of less complexity and good quality of service (QOS).

## 3.2 SYSTEM RELIABILITY

The likelihood that a system, including all equipment, software, and programming, will tastefully play out the errand for which it was outlined or expected, for a predetermined time and in a predefined situation. So, system reliability is also the objective.

## 3.3 SPECTRUM UTILIZATION

Spectrum efficiency plays the main role in rapid Mobile Broadband Networks (MBB). Now a day's data services have a good demand due to online videos, online payments, personal clouds, O2O and HTML5 etc. A good quality of user experience (QoE) needs wider network coverage, larger network capacities and fast network access. To support 3G/4G /5G network technologies additional large spectrum resources and new developed technologies for spectrum efficiency are required. The most valuable resources to the telecom field is Spectrum resources. Spectrum resources represent one of the largest investments in terms of TCO. And Limited spectrum resources hinder MBB development.

## 3.4 VANISHING THE DRAWBACKS OF PREVIOUS TECHNIQUES

OFDM, a modulation technique in 4G, have some drawbacks like side band leakages, high Peak to Average Power ratio (PAPR) and spectrum utilization issues. So, a move to another technique called Universal Filtered Multi Carrier (UFMC).

# CHAPTER 4

# OFDM SYSTEM

In OFDM the entire bandwidth is divided into number of sub-carriers and these sub carriers are transmitted in parallel to increase symbol duration, to achieve high data rates and to reduce ISI. An OFDM signal is the sum of all sub carriers signal which are modulated at the cub channels of equal bandwidth.

Typically PSK or QAM modulation schemes are used in OFDM transmission. Serial to Parallel stage is a process of adding all sub carriers and combining them into a single signal. After that the signal is fed to the Inverse Fast Fourier Transform (IFFT).

Here IFFT takes 'N' symbols at a time where N is the number of sub carriers. The summing of all N sinusoids is the output of IFFT. The number of computations are reduced by IFFT. Complexity of OFDM system is also determined by using IFFT points. It is very important that more IFFT points demands more power but enhances resolution. IFFT performs the transformation efficiently and ensures orthogonality of the sub carriers.

Output of IFFT is

$$X_n = (1/N) \sum_{p=0}^{N-1} X[p] . e^{j2\pi.p.n/N} \quad , 0 \leq n \leq N-1 \ldots. (4.1)$$

Cyclic prefix (CP) is added in order to preserve orthogonality and CP helps in increasing required transmission bandwidth and then it lowers the spectral efficiency. CP provides multipath immunity and synchronization tolerance. A number of independently modulated sub carriers result in High PAPR causing performance degradation of the system. High PAPR also increases complexity of ADC and DAC.

At the receiver FFT is used to bring the signal in frequency domain. It is used to process the signal. Actually FFT output is the symbols that were sent to the IFFT.

Output of FFT is

$$X_p = \sum_{n=0}^{N-1} Xn . e^{-j2\pi/Nnp} \quad , 0 \leq p \leq N-1 \ldots\ldots..(4.2)$$

The process of reverse modulation is known as Demodulation and is done in the frequency domain at the receiver side.

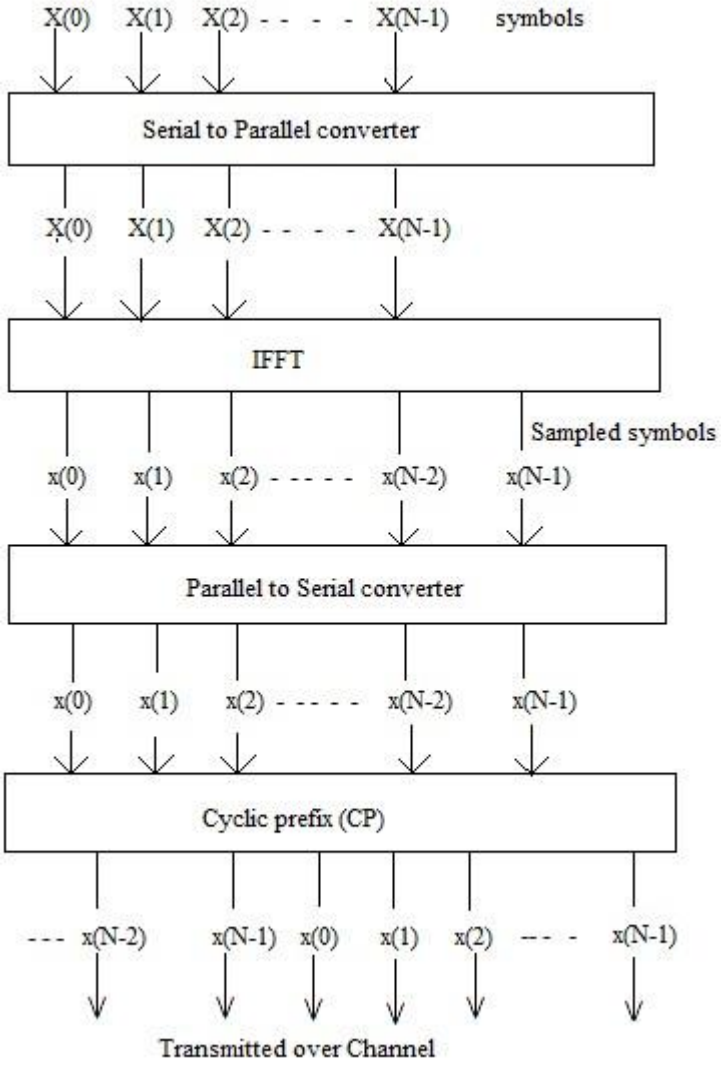


Fig 4.1: OFDM Transmitter Section

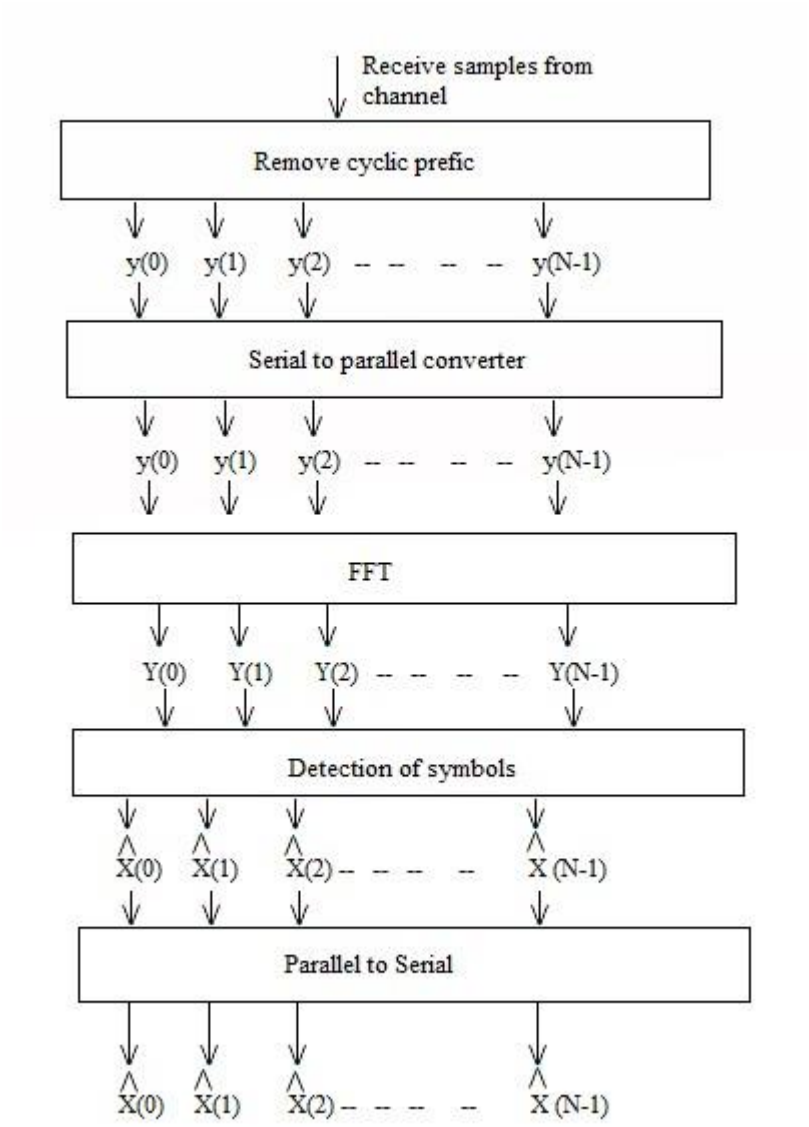


Fig 4.2: OFDM Receiver Section

When the 200 subcarries are used in power spectral density of OFDM and dividing the overall band into 10 sub bands, each sub band having 20 sub carriers, the spectral utilization is not good in OFDM. So, that's why high energy consumption and spectral crisis are sill the major problems in 4G. The spectral efficiency of OFDM is shown in the figure using Matlab simulation.But in order to meet the higher requirements in 5G, this OFDM technology is not sufficient. So, evolution of new technologies like Filter Bank Multi Carrier (FBMC) and Universal Filtered Multi Carrier (UFMC) emerged. However, FBMC is the not right one because large filter length affects the symbol decoding time and having complex receiver structure in MIMO. Also FBMC is not

suitable for burst transmissions or delay sensitive applications. So, the good right candidate in 5G is UFMC.

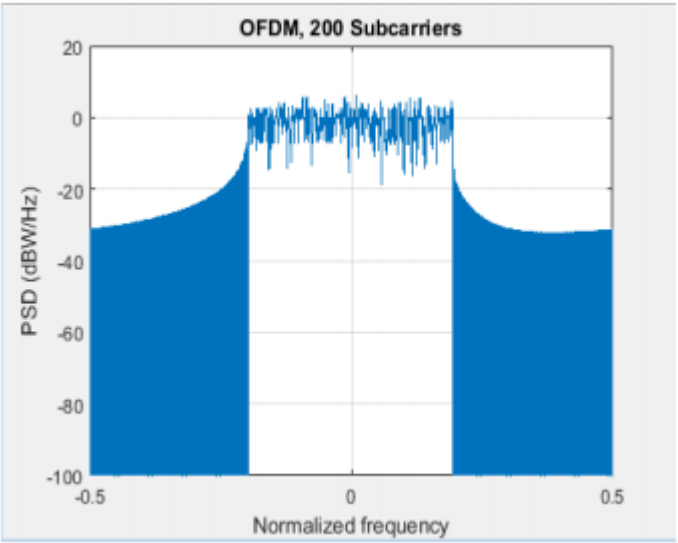


Fig 4.3: PSD of OFDM

# CHAPTER 5

# SPECTRUM EFFICIENCY

## 5.1 Spectrum Efficiency

Spectrum efficiency plays the main role in rapid Mobile Broadband Networks (MBB). Now a day's data services have a good demand due to online videos, online payments, personal clouds, O2O and HTML5 etc. A good quality of user experience (QoE) needs wider network coverage, larger network capacities and fast network access. To support 3G/4G /5G network technologies additional large spectrum resources and new developed technologies for spectrum efficiency are required.

The most valuable resources to the telecom field is Spectrum resources. Spectrum resources represent one of the largest investments in terms of TCO. And Limited spectrum resources hinder MBB development.

## 5.2 Maximizing spectrum utilization through unified network planning.

Spectrum efficiency improvement proposed by HUAWEI has given three solutions to improve the spectrum efficiency. Refarming, TDD/FDD co-ordination and Macro small cell co-carrier design. Refarming solution helps operators dramatically increase spectrum efficiency and network coverage at low cost. TDD/FDD coordination maximizes the utilization of fragments through optimization and global network simulation centre. HUAWEI deployed this in over 70 LTE networks. The macro cell co carrier design saves rollout costs of site and also maximizes spectrum efficiency [4].

The 5G cell correspondences have drawn heaps of considerations from both scholastic and mechanical fields. Among all the basic prerequisites, for example, high pinnacle throughput, ultra-low inertness and substantial gadget thickness, and so on., a prevalent spectrum efficiency (SE) is additionally accentuated. Clearly, the radio range asset is of basic significance for remote correspondences, particularly while considering the way that the vast majority of the accessible range has been dispensed to existing remote correspondence frameworks. Acquiring the necessities from the entire 5G framework, the empowering advances for 5G should contemplate SE change. Leaps forward in baseband and RF engineering, propelled RF area preparing and organize design

are important for the advancement of 5G. Plus, new physical layer advances are additionally called for, where various access conspire, channel coding plan and waveform are three key viewpoints. Various access plans are turning points for various age remote frameworks from 1G to 4G. Frequency Division Multiple Access (FDMA) for 1G, time-division multiple access (TDMA) for 2G, Code Division Multiple Access (CDMA) for 3G and orthogonal frequency division multiple access (OFDMA) for 4G are altogether orthogonal various access.

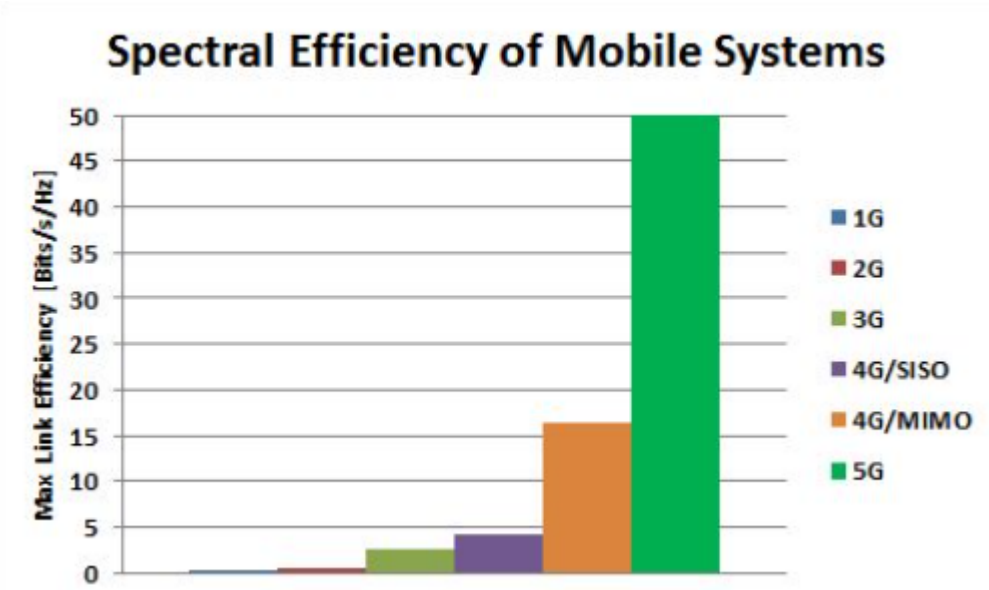


Fig 5.1: Spectral Efficiency Of Mobile System [otenga.com, spectrum efficiency]

The spectral utilization is not good in OFDM. So, that's why high energy consumption and spectral crisis are sill the major problems in 4G. The spectral efficiency of OFDM is shown in the figure using Matlab simulation. But in order to meet the higher requirements in 5G, this OFDM technology is not sufficient. So, evolution of new technologies like Filter Bank Multi Carrier (FBMC) and Universal Filtered Multi Carrier (UFMC) emerged. However, FBMC is the not right one because large filter length affects the symbol decoding time and having complex receiver structure in MIMO. Also FBMC is not suitable for burst transmissions or delay sensitive applications. So, the good right candidate in 5G is UFMC.

# CHAPTER 6

# COMPARISON OF OFDM, FBMC AND UFMC

There are many multi carrier techniques in mobile communications. They are

1. OFDM
2. FBMC
3. UFMC

## 6.1 Orthogonal Frequency Division Multiplexing (OFDM)

At present the main data transmission technology in wireless communication system is Orthogonal Frequency Division Multiplexing (OFDM). OFDM is using in LTE/LTE advanced (4G) and IEEE 802.11 (WI-FI) networks. OFDM is a modulation technique with strongly efficient in bandwidth usage. It is immune to multipath fading and Inter Symbol Interference (ISI). The recent advancements in Digital signal processing make the OFDM very popular. Above all advantages, OFDM is having some disadvantages like high PAPR (Peak to Average Power Ratio) and high Bit error rate (BER) [5]. The sensitivity of devices used in the OFDM transmitter side such as Digital- to-Analog Converter (DAC) and High Power Amplifiers (HPA) are very harsh to the signal processing loop which affects the performance of the system. When we operate with high power Amplifiers, it produces signal excursions into the non-linear region [4]. The spectrum utilization of OFDM is not better when compare to other modulation techniques like UFMC. Spectrum efficiency plays a main role in rapid Mobile Broadband Networks (MBB). The most valuable resources to the telecom field is Spectrum resources. Spectrum resources represent one of the largest investments in terms of TCO. However, Limited spectrum resources hinder MBB development.

But in order to meet the higher requirements in 5G, this OFDM technology is not sufficient.This is because of poor spectral containment, power inefficiency, Bandwidth inefficiency and sensitive to severe dispersions. So, evolution of new technologies like Filter Bank Multi Carrier (FBMC) and Universal Filtered Multi Carrier (UFMC) emerged. However, FBMC is the not right one because large filter length affects the symbol decoding time and having complex receiver structure in MIMO. Also FBMC is not suitable for burst transmissions or delay sensitive applications. So, the good right candidate in 5G is UFMC [1], [3]. In UFMC filtering is applied to

a group of sub carriers. UFMC system not only enables QAM transmission and MIMO schemes but also provides lower out of band radiation with short frame length. UFMC is best suited for uplink with multiple number of users [2]. The forthcoming 5G mobile communications aims on providing higher performance than LTE-Advanced and more concentrated on higher transmission data rate of 20 GB/sec. The major applications in 5G are Internet of Things (IOT), Cognitive Radios, Vehicle to Vehicle Communication (V2V) and Machine to Any (M2X) Communication.
This article gives an implicit knowledge on Orthogonal Frequency Division Multiplexing, Filter Bank Multi Carrier and UFMC.

In OFDM the entire bandwidth is divided into number of sub-carriers and these sub carriers are transmitted in parallel to increase symbol duration, to achieve high data rates and to reduce ISI. An OFDM signal is the sum of all sub carriers signal which are modulated at the cub channels of equal bandwidth. Typically PSK or QAM modulation schemes are used in OFDM transmission. Serial to Parallel stage is a process of adding all sub carriers and combining them into a single signal. After that the signal is fed to the Inverse Fast Fourier Transform (IFFT).

Here IFFT takes 'N' symbols at a time where N is the number of sub carriers. The summing of all N sinusoids is the output of IFFT. The number of computations are reduced by IFFT. Complexity of OFDM system is also determined by using IFFT points. It is very important that more IFFT points demands more power but enhances resolution. IFFT performs the transformation efficiently and ensures orthogonality of the sub carriers.

Output of IFFT is

$$X_n = (1/N) \sum_{p=0}^{N-1} X[p] . e^{j2\pi.p.n/N} \quad , 0 \leq n \leq N-1 \ldots\ldots\ldots\ldots (6.1)$$

Cyclic prefix (CP) is added in order to preserve orthogonality and CP helps in increasing required transmission bandwidth and then it lowers the spectral efficiency. CP provides multipath immunity and synchronization tolerance. A number of independently modulated sub carriers result in High PAPR causing performance degradation of the system. High PAPR also increases complexity of ADC and DAC.

At the receiver FFT is used to bring the signal in frequency domain. It is used to process the signal. Actually FFT output is the symbols that were sent to the IFFT.

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The process of reverse modulation is known as Demodulation and is done in the frequency domain at the receiver side. When the 200 subcarries are used in power spectral density of OFDM and dividing the overall band into 10 sub bands, each sub band having 20 sub carriers, the spectral utilization is not good in OFDM. So, that's why high energy consumption and spectral crisis are sill the major problems in 4G. The spectral efficiency of OFDM is shown in the figure using Matlab simulation.But in order to meet the higher requirements in 5G, this OFDM technology is not sufficient. So, evolution of new technologies like Filter Bank Multi Carrier (FBMC) and Universal Filtered Multi Carrier (UFMC) emerged. However, FBMC is the not right one because large filter length affects the symbol decoding time and having complex receiver structure in MIMO. Also FBMC is not suitable for burst transmissions or delay sensitive applications. So, the good right candidate in 5G is UFMC.

Fading and Multipath delay are the important parameters which effects and damages the communication system. Extreme fading and ISI occurs at the receiver side when the transmitted signal is distorted by other transmitted symbols. So, because of these, the performance of the system degrades and gives errors. Even channel coding and Adaptive equalization techniques are also not using much because of cost effective and inherent delay in the coding.

Then comes OFDM modulation technique. OFDM supports MIMO. Capacity and Robustness are the two special properties that OFDM have. OFDM always fights and removes the interference and helps in removing the distortions [3].

Orthogonal Frequency Division Multiplexing (OFDM) is the modulation technique which are used for high data rate and high spectral efficiency. OFDM has a multiple number of sub carrier blocks to transmit data. To get rid of from Inter Symbol Interference (ISI) and to avoid signal overlapping, Fast Fourier Transform (FFT) and Inverse Fast Fourier Transform (IFFT) are used in OFDM modulation technique. Inter Symbol Interference (ISI) is the interference comes when the transmitted signal is distorted by other signals. With the help of 'Cyclic Prefix', Inter Symbol Interference (ISI) can be removed easily and also converts the channel to sub channel carriers. But OFDM have negative shades that I discussed below.

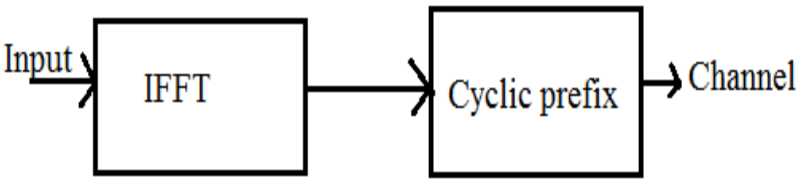


Fig.6.1: Orthogonal Frequency Division Multiplexing.

When the sub carriers are modulated in OFDM, side lobes spreads out at the either side. But with the help of Filter Banks (FB), we can rectify that. And the spectral localization of the sub carrier is weak in OFDM and results in spectral leakage. OFDM system has some interference issues with unsynchronised signals [3]. So, in order to overcome these we have developed OFDM called Filter Bank Multi Carrier (FBMC). It would have discussed in the next section. In fact, FBMC is the betterment of OFDM.

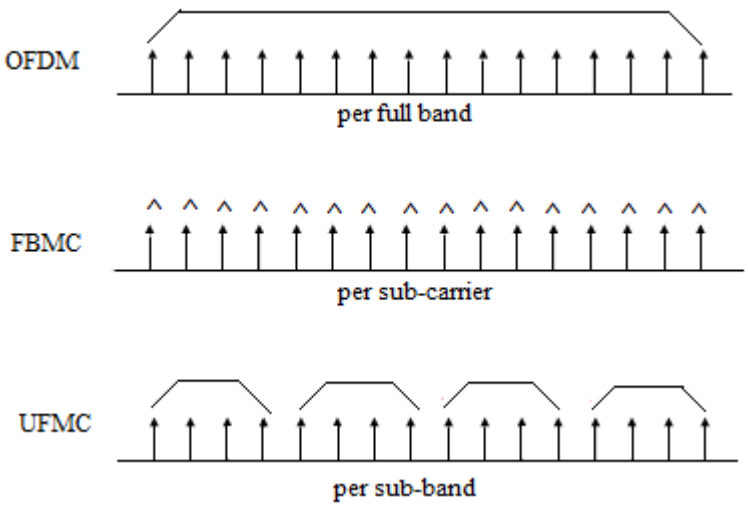


Fig 6.2: Filtering methods of OFDM, FBMC and UFMC.

Chang and saltzberg introduced the multi carrier methods twenty years back. Both OFDM and FBMC supports MIMO technology, but OFDM has some drawbacks. So, the main aim of FBMC is to overcome some of the short comings of OFDM. In OFDM 'Cyclic Prefix' is must and should to avoid Inter Symbol Interference (ISI) and to convert the channel to a number of sub-carrier channels. But in FBMC, Cyclic Prefix is not used, but it has the capability to convert the channel to a set of sub-carrier channels and to remove ISI. The sub-carriers spectral localization in OFDM are weak which might results in spectral leakages and also interference issues with unsynchronized

signals. These problems can be rectified using FBMC technique. When the carriers were modulated in OFDM, the side lobes might spread out at either side. Even this problem can also be rectified by using FBMC which gives very good clear results. So, FBMC is the derivative of OFDM. Signal Overlapping, extreme fading and ISI damages or deteriorates the communication system. So, in FBMC Fast Fourier Transform (FFT) and Inverse Fast Fourier Transform (IFFT) is used to avoid ISI and signal overlapping's.

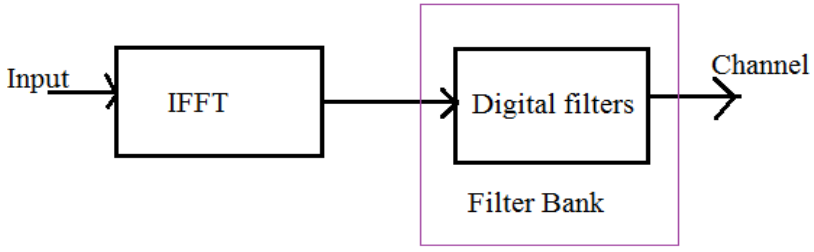


Fig.6.3: Filter Bank Multi Carrier

Both Orthogonal Frequency Division Multiplexing (OFDM) and Filter Bank Multi carrier (FBMC) supports MIMO system. The primary reason of using OFDM in MIMO system is to remove interference and the main aim of FBMC is to overcome some of the shortcomings in OFDM. Actually FBMC is the betterment of OFDM. So, FBMC is equals to the derivative of OFDM. Both plays a prominent role in the area of wireless communication modulation techniques. But by using filter banks it has possible to get our desired results than OFDM. In Massive MIMO FBMC concept, the complexity of the system and delay can be reduced by reducing the sub-carriers. Actually in Massive MIMO FBMC system, Analysis can be done at Receiver side and Synthesis at Transceiver side. Now let's see UFMC.

## 6.2 Universal Filtered Multi- Carrier (UFMC)

Generally in filtered OFDM, entire band is filtered where as in FBMC individual sub carriers are filtered. But in UFMC group of sub carriers are filtered. This is the main difference in Filtered OFDM, FBMC and UFMC multi-carrier. Grouping of sub carriers helps in reducing the filter length in UFMC. IN UFMC, to retain the complex orthogonality, QAM is used which works with existing MIMO. The whole UFMC transmitter section in shown in figure 1. Here the full band of 'N' sub carriers is partitioned into several sub bands. Each sub band has a fixed number of sub

carriers. In transmitter section no need of employing all sub bands for a transmission. To get rid of from the sub band carrier interfere, Inverse Fast Fourier Transform (IFFT) is used. At each N-point IFFT, sub bands are computed and zeros are allocated for unallocated carriers. IFFT converts frequency domain ($X_i$) to time domain ($x_i$).

Now the time domain signals comes from the IFFT goes to Band filter of length 'L' block. Each sub band output is filtered by band filter of Length 'L'. Actually band filters uses Chebyshev window/filtering operation. Here parameterized side lobes attenuation is used to filter the IFFT outputs. Now all the outputs from the band filters are summed at the end and passes through the channel.

From the channel the data bits are transmitted to UFMC receiver. UFMC receiver do's 2N-point Fast Fourier Transform (FFT) [6]. FFT converts the data of time domain to frequency domain. To prevent Inter Symbol Interference (ISI), guard intervals of zeros are added between successive IFFT symbols. ISI is due to transmitter filter delay. To receive N length frequency domain signal 'Y', even sub carriers are discarded. Now the data goes for equalization process and the original data bits are retrieved by symbol demapping.

TABLE 6.1

OFDM V/S FBMC V/S UFMC

| **Sl. No** | **Orthogonal Frequency Division Multiplexing (OFDM)** | **Filter Bank Multi carrier (FBMC)** | **Universal Filtered Multi-Carrier (UFMC)** |
|---|---|---|---|
| 1 | OFDM, requires the use of "Cyclic Prefix". | No need of "Cyclic Prefix" | No need of "Cyclic Prefix" |
| 2 | It has some spectral leakage issue. | No spectral leakage in FBMC | No spectral leakage in UFMC |
| 3 | Interference issues with unsynchronized signals. | No interference issues with unsynchronized signals. | No interference issues with unsynchronized signals |

| | | | |
|---|---|---|---|
| 4 | Helps in removing extreme fading and ISI. | Also helps in removing fading and ISI problems. | Also helps in removing fading and ISI problems. |
| 5 | Overlapping of signals can be avoided by using OFDM. | FBMC helps to avoid signal overlapping. | UFMC helps to avoid signal overlapping |
| 6 | When carriers were modulated, side lobes might spread out at either side. | No spread outs of side lobes in FBMC | No spread outs of side lobes in UFMC |
| 7 | OFDM reduces Peal to Average Power Ratio (PAPR) which causes signal distortion at the output of the power Amplifier. | FBMC also reduces PAPR by using the reduction techniques. | UFMC also reduces PAPR by using the reduction techniques. |

## 6.3 PAPR EFFECT

The disadvantage with Multi carrier system in FBMC or in OFDM, produces signal excursions into the non-linear region (when operates with power Amplifiers). Because of signal excursions, distortions might comes. Some distortions causing spectral leakage cannot be modify or correct at the receiver side and can be compensated by using Pre-Distortion Algorithm technique at the Transmitter side [10]. So to avoid these power peaks, Peak to Average Power Ratio (PAPR) reduction techniques are available [7].

The relationship between the maximum sample power in a transmitted OFDM symbol and its average power is known as PAPR. PAPR effects the system, when large number of sub-carriers are out of phase. Here the distortions occurs at the output of the power amplifier. High PAPR definitely degrades the transmit signal quality [3]. Block coding, Tone Injection, partial Transmit Sequence and Selected Mapping are the techniques which are used to reduce the PAPR effect.

So, eventually, the improvement in the point-to-point MIMO to Multi User-MIMO (MU-MIMO) serves the multiple numbers of users simultaneously which is the biggest achievement in the

wireless communication 3G/4G/5G networks. Massive MIMO is the key technology in the wireless communication system which provides high data rate transmission. The parameters like high system capacity, high spectral efficiency and low power consumption are the important characteristics of Massive MIMO system. Moreover it reduces the complexity of the system. Pilot contamination effect [24], [25] is the most adverse situation in the communication system which gives channel estimation errors and cause Interference. It can be removed by using some techniques which I discussed in the Pilot contamination Para. Fading, multipath delay and some errors can be minimized and rectified using OFDM and FBMC modulation techniques. Among these two filter banks are the most preferable one which overcomes the drawbacks in OFDM. Because FBMC is the development of OFDM. So, I would like to name FBMC as the derivative of OFDM.

## 6.4 PAPR REDUCTION

In UFMC the symbols are isolated and applying exclusively to blocks of N point IFFT , resource blocks and filter independently and consolidated to frame a UFMC symbol. So we propose a technique that applies the stage rotation to the every resouce block to shape a low PAPR mix of 'B' resouce block and phase vector 'P' of length 'B'. One enhancer needs to configuration to choose an ideal arrangement of asset square and stage vector mix as appeared in [Figure 6]. The resultant UFMC as depicted in beneath equation.

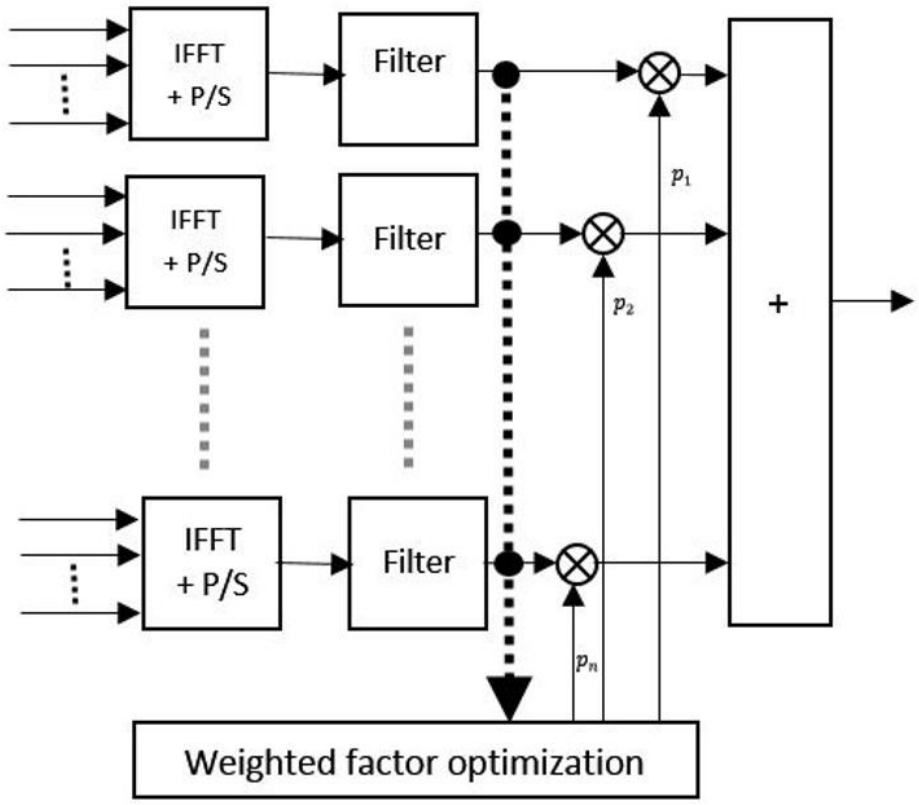


Fig 6.4: Signal Scrambling Technique for UFMC

$$x_k = \sum_{i=1}^{B} (F_{i,k} \,.\, V_{i,k} \,.\, X_{i,k} \,.\, P_B') \ldots\ldots\ldots\ldots\ldots\ldots (6.3)$$

$P_B$' is low PAPR best phase vector. This ideal phase vector $P_B$' need to send as side information to beneficiary to recover the first UFMC symbol. The streamlining agent needs to choose the stage factor by catch the information from the yield from the channel and inquiry the vector of measurements 'B'. On the off chance that conceivable stage factors are 'an' at that point size of a vector space is . Here for reproduction, we are taking 20 resource blocks and 4 conceivable stage factors, so there will be estimate vector space. So we require a heuristic inquiry strategy to locate an ideal arrangement from a huge pursuit space. There are a considerable measure of heuristic pursuit strategies which are propelled by normal development strategy. In this paper we are utilizing GA7, PSO8, ABC9 and FA10 which are meta-heuristic calculations as enhancers.

FA has two noteworthy advantages over different calculations

- Automatically subdivision
- Ability of overseeing multimodality

FA relies upon fascination in the light so appeal diminishing with remove. This prompts the entire individuals can ordinarily part into littler gatherings, and each social affair can swarm around neighborhood best. Among all these area courses of action, the best worldwide optima can be found. This subdivision enables the fireflies to be able to discover all optima in the meantime if the populace measure is tastefully higher than the measure of modes which lead parallel registering naturally for speedier meeting to ideal arrangement [8].

## 6.5 FA(FIREFLI ALGORITHM)

Firefly calculation was first created by Xin-She Yang in late 2007 at Cambridge University, which depended on upon the glinting outlines and conduct of fireflies. For the most part, Firefly figuring three respected rules that

1. Fireflies are unisex

2. The likelihood of data sharing between fireflies is relying on the shine

3. The brilliance of a firefly is corresponding to the cost work.

Each firefly has its appeal β delineated by the monotonically lessening limit of the partition (r) between two any fireflies:

$$\beta(r) = \beta_0 e^{-\gamma r^m} \quad m \geq 1 \ldots\ldots\ldots\ldots(6.4)$$

$\beta_0$ = Attraction coeefiecient value

$\gamma$ = light absorption coefficient

The fireflies distance from position $x_i$ to $x_j$ is defined as

$$r_{ij} = \left| |x_i - x_j| \right| = \sqrt{\sum_{k=1}^{d}(x_{i,k} - x_{j,k})^2} \ldots\ldots\ldots..(6.5)$$

$x_{i,k}$ = $k^{th}$ component of spatial cordinate

The calculation of firefly movement is in the form

$$X_i = x_i + \beta_0 e^{-\gamma r^2_{i,j}} \quad (x_j - x_i) + \acute{\alpha} (rand - 1/2) \ldots..(6.6)$$

The initila fireflies population is written as

$$X_i = LB + rand\ .\ (UB- LB)\ldots\ldots\ldots\ldots(6.7)$$

LB = Lower bound

UB = Upper bound

## 6.6 PROBLEM FORMULATION

F(p) = PAPR(p)

$$PAPR(P) = \frac{\text{peak power } [x(p)]}{\text{Average } Power\ [x(p)]} \qquad \ldots\ldots(6.8)$$

$$P = (p_1, p_2, p_3, \ldots\ldots\ldots, p_B)$$

Starting populace of fireflies "pi (i=1,2,… ,B) ". Light power of every firefly is figured by target work which is equivalent to PAPR at pi. For all fireflies that implies for all pi. The best cost capacity will be considered as advanced an incentive in the wake of performing most extreme emphasess. The comparing firefly position is taken as best arrangement which is considered as the best stage vector

# RESEARCH METHODOLOGY

# CHAPTER 7

# Universal Filtered Multi- Carrier (UFMC)

## 7.1 UFMC

UFMC, a generalization of Filtered OFDM and FBMC multi-carrier modulation technique. Generally in filtered OFDM, entire band is filtered where as in FBMC individual sub carriers are filtered. But in UFMC group of sub carriers are filtered [6]. This is the main difference in Filtered OFDM, FBMC and UFMC multi-carrier. Grouping of sub carriers helps in reducing the filter length in UFMC. IN UFMC, to retain the complex orthogonality, QAM is used which works with existing MIMO. The whole UFMC transmitter section in shown in figure 7.1. Here the full band of 'N' sub carriers is partitioned into several sub bands. Each sub band has a fixed number of sub carriers. In transmitter section no need of employing all sub bands for a transmission. To get rid of from the sub band carrier interfere, Inverse Fast Fourier Transform (IFFT) is used. At each N-point IFFT, sub bands are computed and zeros are allocated for unallocated carriers [9]. IFFT converts frequency domain ($X_i$) to time domain ($x_i$). After the N-point IFFT, the output can be written as

$$Y_i = \text{IFFT}\ \{x_i\} \qquad (7.1)$$

Now the time domain signals comes from the IFFT goes to Band filter of length 'L' block. Each sub band output is filtered by band filter of Length 'L' It is expressed as

$$y = H. \sim Q.\ y_i \qquad (7.2)$$

Where H is called toeplitz matrix having dimensions (N+L-1) and '~Q' is called as Inverse Fourier matrix.Actually band filters uses Chebyshev window/filtering operation. Here parameterized side lobes attenuation is used to filter the IFFT outputs. Now all the outputs from the band filters are summed at the end and passes through the channel.From the channel the data bits are transmitted to UFMC receiver. UFMC receiver do's 2N-point Fast Fourier Transform (FFT). FFT converts the data of time domain to frequency domain. It is shown in the form of equation

$$\sim Y = \text{FFT}\ \{\ [y^T, 0, 0, \ldots\ldots\ldots, 0]\ \} \qquad (7.3)$$

To prevent Inter Symbol Interference (ISI), guard intervals of zeros are added between successive IFFT symbols. ISI is due to transmitter filter delay. To receive N length frequency domain signal 'Y', even sub carriers are discarded. Now the data goes for equalization process and the original data bits are retrieved by symbol demapping. It is shown in the UFMC receiver section figure 7.2.

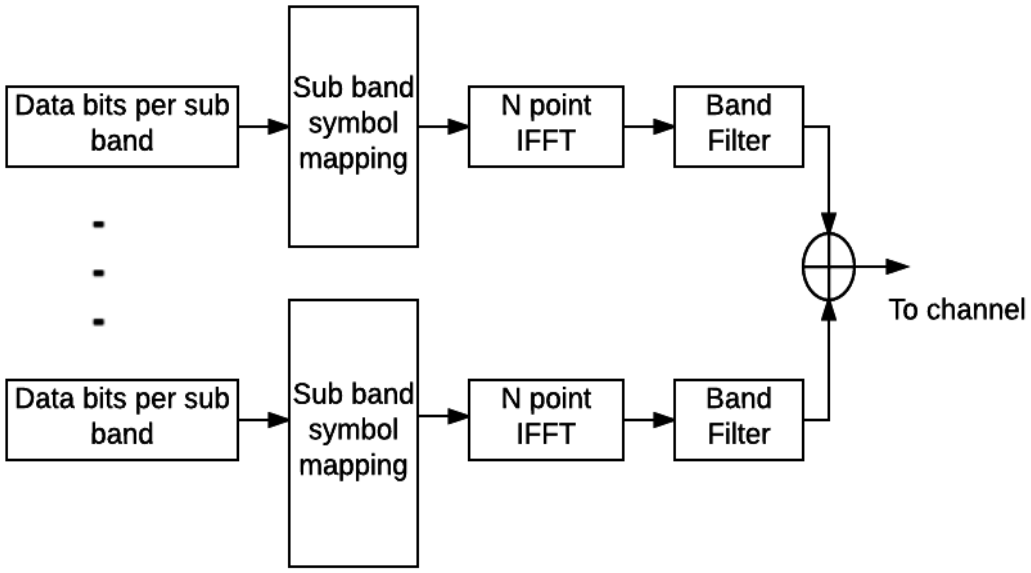


Fig 7.1: UFMC Transmitter section

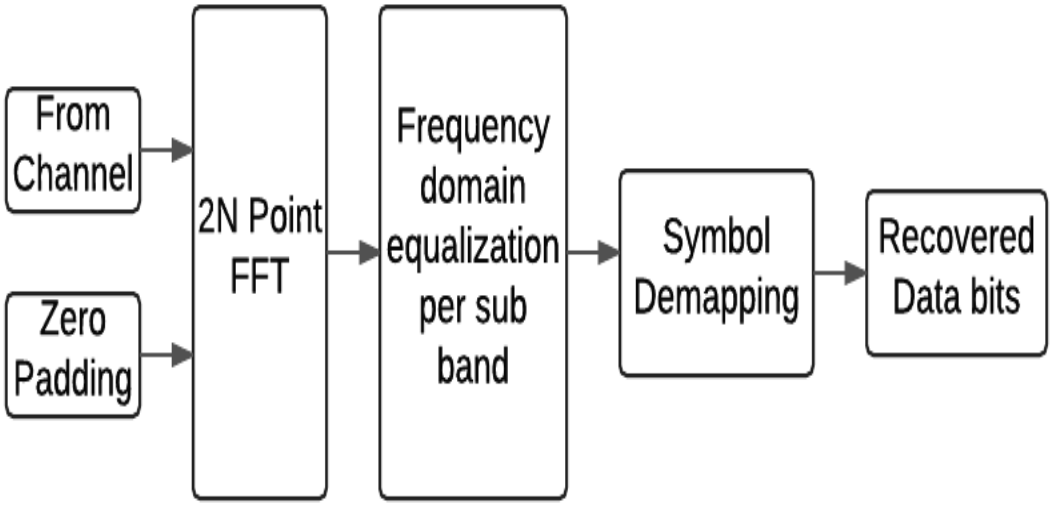


Fig 7.2: UFMC Receiver section

## 7.2 UFMC MIMO

This section would have been discussed the importance and need of Massive MIMO technology. In 5G mobile communication system, Massive MIMO plays very significant role. High energy consumption and spectral crisis are still the major challenges in 4G (the fourth generation mobile communication). We know that there is a huge good demand for higher data rate, so all the telecommunication companies had started the research work on 5G. MIMO system technology primarily concentrates on higher spectral efficiency and focuses on high coverage area for all cell edge users. In a communication system, fading and multi path delays are creating problems which results in errors and also affects the performance of the system. So, In order to overcome these problems there are some techniques called Filter Bank Multi carrier (FBMC), Universal Filtered Multi-Carrier(UFMC) and Orthogonal Frequency Division Multiplexing (OFDM) which overcomes the above said problems in communication system. Both FBMC and OFDM technologies supports MIMO, but there are some cons in OFDM. In fact, FBMC is considered as the development of OFDM.

The major research areas on MIMO technology is discussed below with a neat table. In a conventional Massive MIMO system, Ultra-linear 50 watt amplifiers are utilized. In any case, now specialists are utilizing minimal effort speakers with yield controls in mille-watt. Chang and Saltzberg are the two writers and researchers which were at that point talked about Multi Carrier procedure twenty years back. When the system is operated with power Amplifiers, the multi-carrier systems such as OFDM and FBMC produces signal excursions into the non-linear region which leads to distortions [12]. The spectral leakage cannot be modified or corrected but compensated by using prediction algorithm technique at the transmitter side [10]. The FBMC technique is not only using in 4G/5G, but it is also using in Aeronautical communication system. Here they used L-band for air to ground communication. In this they introduced a new concept called spectrally shaped Filter Bank Multi Carrier (SS-FBMC) to obtain the error flow free BER results. International Civil Aviation Organization (ICAO) is doing improvements or developments in Aeronautical communication system based on spectrally shaped FBMC (SS-FBMC).

Multiple Input and Multiple output (MIMO) is a marvellous wireless technology that can provide very good performance when compared to single-input and single-output. MIMO means installing

multiple transmitting antennas at the transmitter side and multiple receiving antennas at the receiver side and together called as MIMO. Generally the short technical term for Multiple Input and Multiple output is MIMO. In general massive means very large. So, installing very large antenna array at each base station to serve many number of users simultaneously is known as Massive MIMO [17].

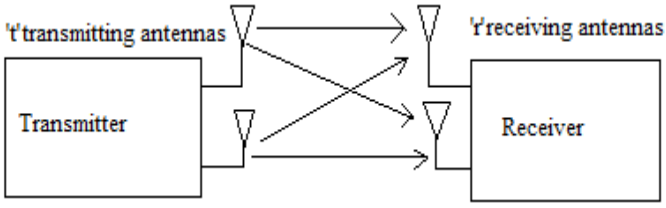


Fig 7.3: Multiple Input and Multiple output (MIMO)

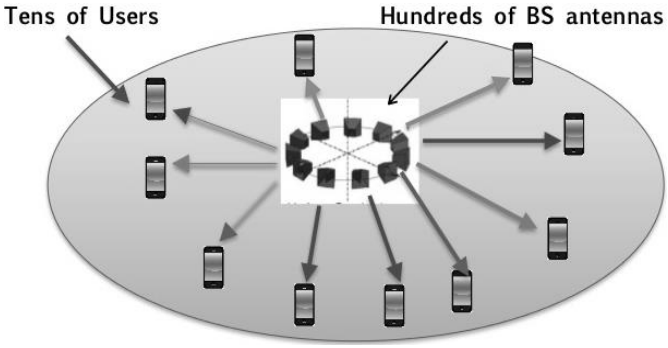


Fig 7.4: Massive MIMO technology.

Let's develop the model for MIMO system. At the transmitter section, x1, x2…. $X_t$ are the 't' transmitting antennas which is shown in the figure 3. When stacking in vectors, $\begin{bmatrix} x1 \\ x2 \\ . \\ xt \end{bmatrix}$ and it isthe 't' dimensional transmitting vector.

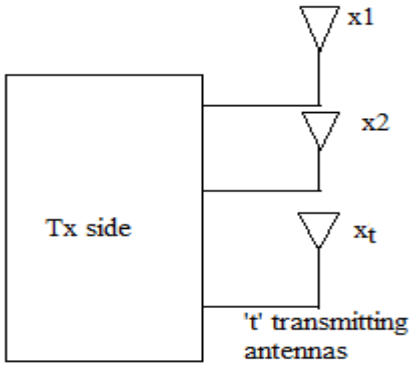


Fig 7.5: MIMO transmitting section.

Similarly at the receiving section, y1, y2 … $y_r$ are 'r' receiving antennas as shown in figure 4.

When stacking in vector $\begin{bmatrix} y1 \\ y2 \\ . \\ yr \end{bmatrix}$ and it is the 'r' dimensional receiving vector [12].And both the transmitting and receiving sections are together called as system.

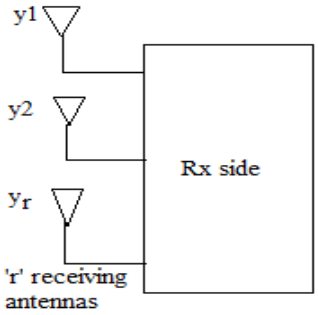


Fig 7.6: MIMO Receiving Section

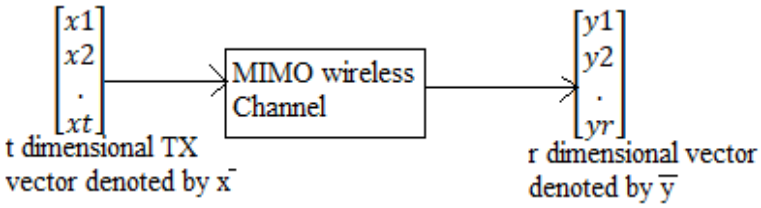


Fig 7.7: MIMO System

Here the wireless MIMO channel transforms the 't' dimensional transmitter vector into 'r' dimensional. Such a transformation is called Matrix Transformation. At the MIMO channel, the whole vector equation is written as in the form of

$$\overline{Y}r\times_1 = H\ \overline{X}_{t\times 1} + \overline{W}_{r\times 1} \qquad (7.4)$$

Where $\overline{Y}r\times_1$is the r dimensional vector

H is r×t matrix

$\overline{W}$ is the Noise in 'r' dimensional vector

The important principle in MIMO system is Spatial Multiplexing. Between transmitter and receiver, the multiple information is shared in streams parallely which is known as Spatial Multiplexing. Here the multiple information is transferred through space [18].

Massive MIMO is the key technology in 3G/4G and 5G wireless communication network system. MIMO technology is preferred because of high data rate transmission. The parameters like high Capacity and Robustness plays a very prominent role in Massive MIMO communication system. And even antenna gain improves the Signal-to-Noise Ratio (SNR) in Massive MIMO system. This technology is used in broadband standards like Long Term Evolution (LTE) and WI-FI systems because of less complexity and good quality of service (QOS).

It has become very important technology in Power Line Communication (PLC) which is a best example of home networking standard ITU_T G.9963. Actually MIMO technology, differs fundamentally from Smart Antenna technology. The recent advancement in MIMO is point-to-point MIMO to Multiple user-MIMO (MU-MIMO). Here the base station with multiple antennas serves simultaneously to the multiple users. It is shown in the figure 2.

High energy consumption and spectral crisis are still the challenges in 3G and 4G networks. So, in order to overcome these drawbacks, Massive MIMO technology emerged in 5G which you can expect this 5G by 2020. Companies Huawei, Motorola and HMD Nokia are on this 5G research work.

MIMO system for 5G primarily focuses on advanced techniques to achieve high spectral efficiency and high data rate transmission [19]. Previously in Massive MIMO technology, Ultra-linear 50 watt amplifiers are used. But now mille-watt range low cost amplifiers are using.

Specifically in Massive MIMO system, the three important pros are:

1. It increases the system capacity and spectral energy efficiency.
2. And it consumes very low power (in mille-watts).
3. MIMO technology reduces the complexity of the system.

Antenna Mutual Coupling, Spatial correlation and Hardware impairments leads to Channel Estimation Errors [26]. Basically hardware impairments are more at user side than Base station side. So, the work on this error was started. Organizations like Rusk Lund Test beds at Lund University and Commonwealth Scientific and Industrial Research Organization (Australia) are working on different types of Antenna array Configurations [27]. The information related to Research areas and projects are tabulated and shown in the table 7.1.

TABLE 7.1
RESEARCH AREAS AND PROJECTS

| **S L. no** | **Research Project/Research groups** | **HTTP location** | **Research field** |
|---|---|---|---|
| 1 | MOST (Ministry of science and Technology 863-5G project) | http://www.most.gov.cn/eng/programm | Massive MIMO and Radio-Access-Network (RAN) architecture |
| 2 | MAMMOET (Massive MIMO for Efficient Transmission) | http://www.mammoet.project.eu | Massive MIMO |
| 3 | 5G PPP (5G Infrastructure Public Private Partnership) | http://5g-ppp.eu | Next generation of communication networks and ubiquitous super-fast connectivity |
| 4 | METIS (Mobile and wireless communication Enablers for Twenty-Twenty) | http://www.metis2020.com | Providing holistic system to 5G technology system. |

In [20], the author explains about the pilot contamination effect and pilot reuse. Actually the limiting factor in Massive MIMO system is Pilot Contamination. It comes due to the reuse of same pilot set among interfering cells. Due to the Pilot contamination effect, Chanel estimation errors arises.So, because of this Massive MIMO system's rate would decrease. Even if the base station antennas increases, pilot contamination effects the Massive MIMO system.

In [21] researchers clearly explains how to eradicate the pilot contamination effect. They used pilot transmission protocol which is used to cancel the pilot contamination effect. Here the author has introduced time shifting pilot transmission. Over lapping of non-orthogonal pilot signals can be eradicated by using this pilot transmission protocol. In pilot allocation there are some rules :

1. Co-ordination based pilot allocation rule is suggested in , to achieve free interference channel estimation and cancels or reduces the pilot contamination effect [22].
2. Another Co-ordination based pilot allocation in , utilizes slow fading coefficient information.

The above said rules are used for removing pilot contamination effect. Pilot Reuse is the intra-cell interference within a cell which gives errors. In order to mitigate this, base antennas must be increased. As specified before that, there are a few confinements in OFDM waveform, which makes it not appropriate for future 5G. For 5G application situations, UFMC alone would not have the capacity to cover them up altogether. For ultra-speed, anyplace whenever availability, high unearthly productivity and different gadget similarity the MIMO system joined with UFMC is relied upon to demonstrate the coveted outcomes. The advanced balance plans and number of transmit and get receiving wires and their setup would influence the execution of the system.

A 2x2 MIMO system appeared in Figure 3 is utilized to clarify the idea of UFMC MIMO. The transmission strategy is the same as 2x1 Alamouti encoder with the exception of two get reception antennas rather than one. In 2x2 MIMO space-time block coding (STBC) for UFMC, two signs are transmitted on two flag times and are gotten however two recipient receiving antennas utilizing the four fading channels [8].

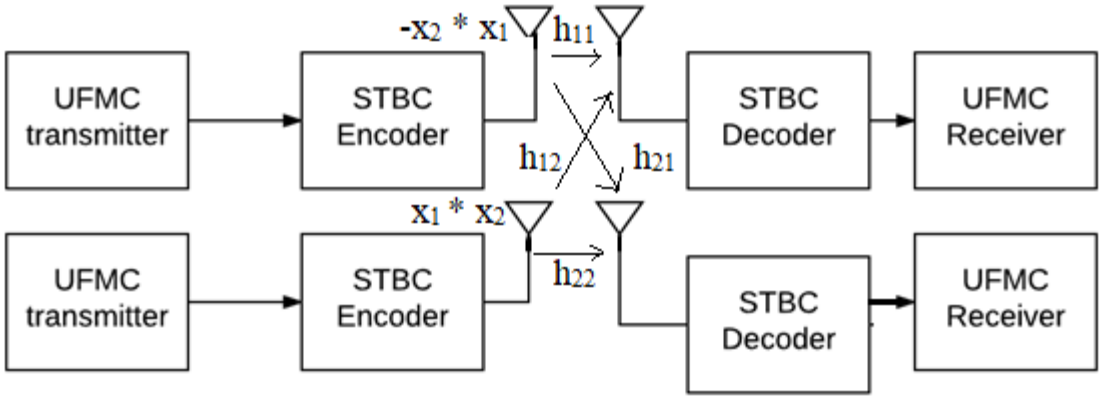


Fig 7.8: UFMC MIMO STBC

On the off chance that the channel gains are spoken to by $H_{qp}$ among the $p^{th}$ transmitter and $q^{th}$ receiver. In this manner the numerical type of the received signal over signal time can be given by

$$y_1(t) = h_1 x_1 + h_2 x_2 + w(1)$$

$$y_2(t) = h_1 x^*_2 + h_2 x^*_1 + w(2)$$

The second time signal of the received signal is written as

$$y_1(t) = h_3 x_1 + h_4 x_2 + w(3)$$

$$y_2(t) = - h_3 x^*_2 + h_4 x^*_1 + w(4)$$

The final signal received is represented by

$$Y=Hx + W \qquad (7.5)$$

By MIMO and UFMC being clarified, indicate distinctive tests directed with various UFMC MIMO designs. By changing the quantity of reception antennas at the recipient and transmitter and utilizing various advanced modulation schemes, the execution of the UFMC MIMO system can be assessed.

## 7.3 UFMC MIMO WITH DIFFERENT MODULATIONS

For nitty gritty system execution assessment, in this area, the quantity of transmitting and accepting antennas are kept consistent while balance plans are changed. This test empowers the

determination of best modulation with a particular reception antenna game plan that can utilized for particular applications.

A. 1x1 Antenna Configuration

- PDSCH with 10MHz transfer speed
- BER for QPSK < 16QAM < 64QAM
- Less BER are in QPSK
- More bit errors are in 64QAM
- If the bit errors expands more bits will be gone.
- Single transmitting antenna
- Single accepting recieving antenna
- Same antenna design for all the modulation plans.
- Different modulation conspires that are QPSK, 16QAM, 64QAM

**B. 2x2 Antenna Configuration**

- Less errors (bit)are in QPSK
- More error bits are in 64QAM
- Bit error in 16QAM are in the middle of QPSK and 64QAM
- Two transmitting antenna
- Different modulation that are QPSK, 16QAM, 64QAM
- PDSCH with 10MHz data transmission
- BER for QPSK < 16QAM < 64QAM

**C. 4x4 Antenna Configuration**

- Two receiving antenna
- Two transmitting antenna
- Less error bits are in QPSK
- More error bits are in 64QAM
- Error bits in 16QAM are in the middle of QPSK and 64QAM

- Same reception apparatus setup for all the modulations.
- Different modulation plans that are QPSK, 16QAM, 64QAM
- PDSCH with 10MHz data transmission
- BER for QPSK < 16QAM < 64QAM

# CHAPTER 8

# RESULTS AND DISCUSSION

200 sub carriers are used in power spectral density of OFDM and FBMC. And divided the overall band into 10 sub bands, each sub band have 20 sub carriers. Efficient power utilization is the major criteria in wireless communication system. From the figures 8.1 and 8.2, the spectrum utilization is very good in UFMC system than OFDM system [9]. Average power ratio of UFMC for different mapping techniques is listed in Table 8.2.

PAPR values in UFMC are high except for 16QAM. PAPR for UFMC is better for 256 QAM. From the table we can say the PAPR 16 QAM mapping scheme is better for UFMC system.

From the figures 8.1 and 8.2, it is proved that the spectrum utilization in OFDM is not good and the spectrum utilization in UFMC technique is good. And the PAPR values for both UFMC and OFDM are 8.2848 dB and 7.5653 dB. So, the PAPR of UFMC is better compared to OFDM (4G technique) using 16 QAM mapping method. Orthogonal Frequency division Multiplexing (OFDM), in 4G have some drawbacks like side band leakages and high Peak to Average Power ratio (PAPR) issues. With the advent of Internet of Things (IOT) and the move towards user-centric processing makes the OFDM technique more unfeasible. So, UFMC is a right candidate for 5G.

Table 8.1: System parameters

| **Parameter** | **Value** |
|---|---|
| Total number of FFT points | 512 |
| Sub band size | 20 |
| Sub band Offset | 156 |
| Bits per sub carrier | 2, 4, 6, 8 |
| Number of sub bands | 10 |
| Filter Length | 43 |
| Side lobe attenuation | 40 |
| SNR (dB) | 15 |

Table 8.2: PAPR values for UFMC and OFDM for different mapping techniques at 5dB SNR.

| **Mapping technique** | **PAPR of UFMC** | **PAPR of OFDM** |
|---|---|---|
| 4 QAM | 9.04 | 8.4377 |
| 16 QAM | 8.2379 | 8.8843 |
| 64QAM | 8.6229 | 9.9269 |
| 256 QAM | 8.0416 | 7.2553 |

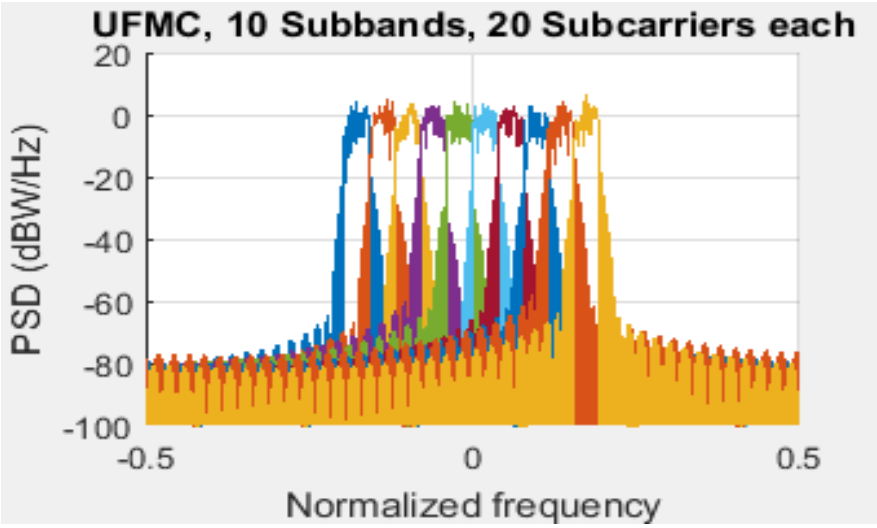


Fig 8.1: PSD of UFMC

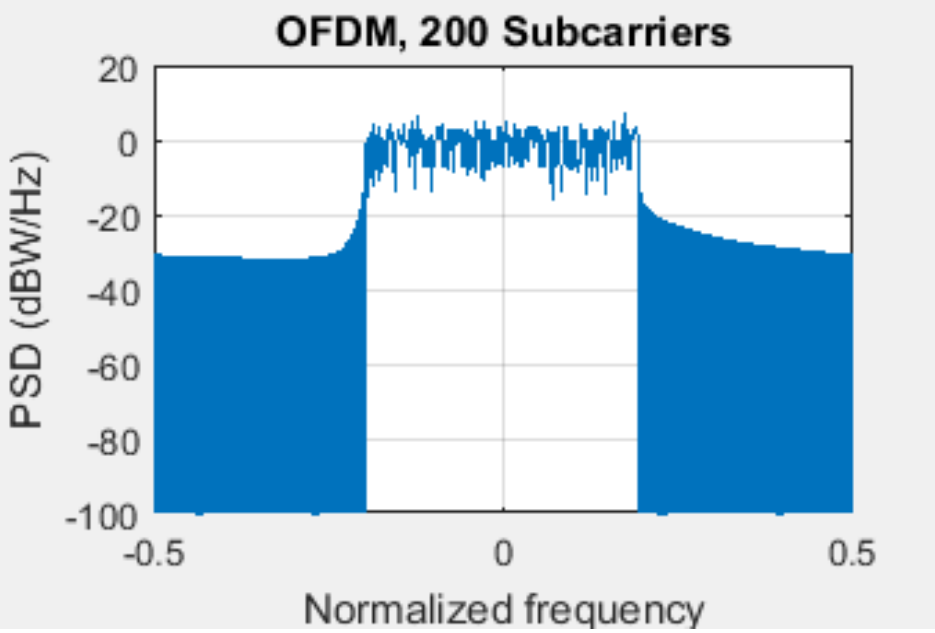


Fig 8.2: PSD of OFDM

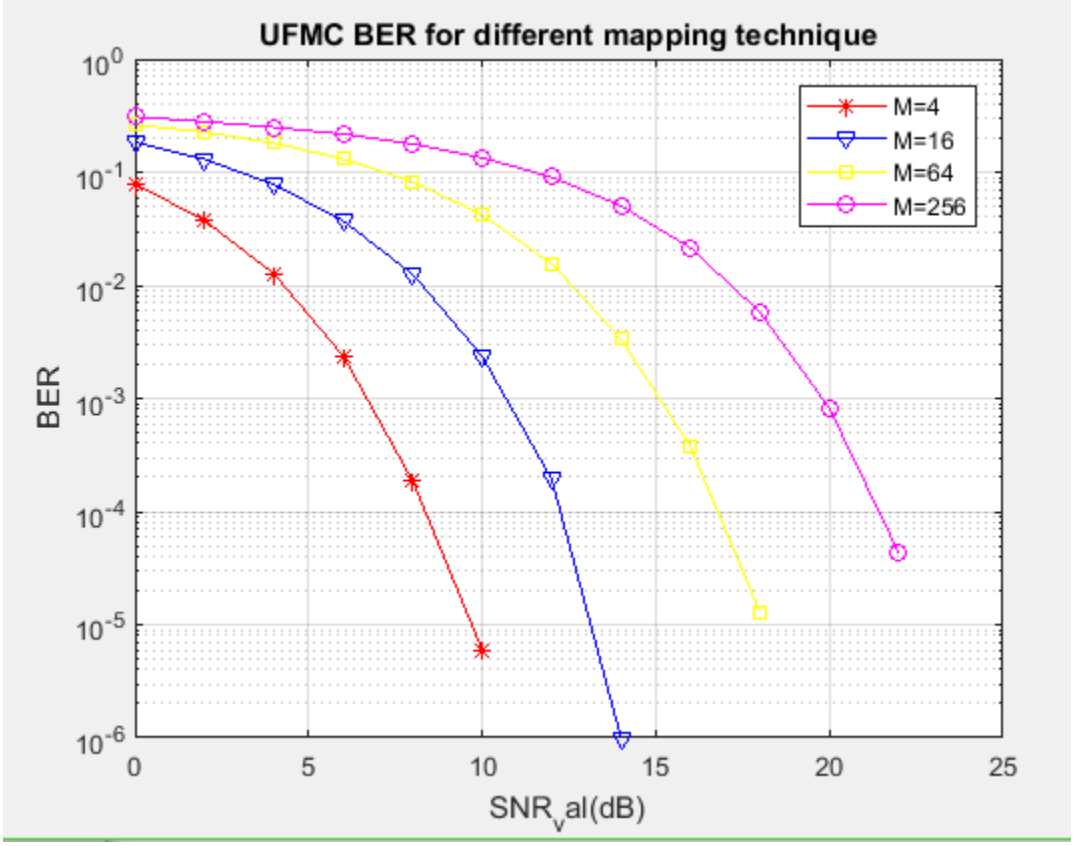


Fig 8.3: BER of different mapping techniques

# CHAPTER 9

# CONCLUSION AND FUTURE SCOPE

## CONCLUSION

From the figures 8.1 and 8.2, it is proved that the spectrum utilization in OFDM is not good and the spectrum utilization in UFMC technique is good. And the PAPR values for both UFMC and OFDM are 8.2848 dB and 7.5653 dB. So, the PAPR of UFMC is better compared to OFDM (4G technique) using 16 QAM mapping method. Orthogonal Frequency division Multiplexing (OFDM), in 4G have some drawbacks like side band leakages and high Peak to Average Power ratio (PAPR) issues. With the advent of Internet of Things (IOT) and the move towards user-centric processing makes the OFDM technique more unfeasible. So, UFMC is a right candidate for 5G.

## FUTURE WORK

- Optimizing the UFMC filters, Security are the future works deals with it.
- Consequently, up to best of our insight our proposed arrangement gives most little difficult answer for UFMC as far as calculations required and in addition equipment rules to accomplish easiest usage.
- Besides, we will update the RB administration system together considering traffic requests and channel conditions [11].

At long last the choice of the 5G safety efforts in tight interworking with the plan of the general 5G organizes design. With this paper, we go one stage toward this path and would like to advance the general work towards a sound 5G security engineering.

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