IMPLEMENTATION OF FBMC USING VIVADO

A Project report submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

Submitted by

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PRAGNANAM BRAHMA

ANITS

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES (UGC AUTONOMOUS) (*Permanently Affiliated to AU, Approved by AICTE and Accredited by NBA &NAAC with 'A' Grade*) Sangivalasa, Bheemili mandal, Visakhapatnam. (A.P) 2020-2021

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CERTIFICATE

This is to certify that the project report entitled "**IMPLEMENTATION OF FBMC USING VIVADO**" submitted by **N.Naveen (319126512102), Eswar Teja (319126512111), B.Keerthi (319126512068), CH.Pranay Babu (320126512L16)** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Electronics & Communication Engineering of Andhra University, Visakhapatnam is a record of Bonafede work carried out under my guidance and supervision.

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ABSTRACT

Filter bank multicarrier (FBMC) is one of the effective candidates for the fifth generation of wireless communication networks. 5G (5th-generation wireless systems) is accepted as the next major stage of mobile telecommunication technology. The extent of 5G will be expanded mobile broadband services to next-generation automobiles and connected machines. Researchers have established that FBMC/OQAM, a filter bank multicarrier with offset quadrature amplitude modulation, will be the air interface for the next-generation 5G network. One of the alternate multicarrier modulation technologies is acknowledged to be filter bank multicarrier (FBMC). FBMC provides better spectrum shape than orthogonal frequency-division multiplexing (OFDM) and facilitates mobility. Therefore, researchers are quite interested in efficient hardware implementations. For orthogonal frequency-division multiplexing (OFDM), cyclic prefix (CP) and guard band are utilized, which results in spectral efficiency loss; however, FBMC applications do not require CP and guard band. The requirement for CP and guard band is abolished by FBMC's offset QAM (OQAM) and band-limited filtering features on each subcarrier. In this project, a brand-new pipelined hardware architecture for the FBMC/OQAM modulator's filter design has been proposed.

Keywords: FBMC, OQAM, OFDM, Cyclic prefix (CP), 5G.

CONTENTS

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LIST OF ABBREVIATIONS

1.	FBMC	Filter Bank Multi Carrier
2.	OFDM	Orthogonal Frequency Division Multiplexing
3.	ISI	Inter Symbol Interference
4.	ICI	Inter Carrier Interference
5.	FFT	Fast Fourier Transform
6.	MUX	Multiplexer
7.	DEMUX	Demultiplexer
8.	PSD	Power Spectral Density
9.	5G	Fifth Generations
10.	LTE	Long Term Evolution
11.	CP-OFDM	Cyclic Prefix - Orthogonal Frequency Division Multiplexing
12.	BER	Bit Error Rate
13.	SNR	Signal to Noise Ratio
14.	PAPR	Peak to Average Power Ratio
15.	OQAM	Offset Quadrature Amplitude Modulation
16.	ACE	Active Constellation Extension
17.	MIMO	Multiple Input Multiple Output
18.	POCS	Projection onto Convex Sets
19.	SGP	Smart Gradient Projection
20.	IP	Internet Protocol
21.	Wi-Fi	Wireless Fidelity
22.	IFFT	Inverse Fast Fourier Transform
23.	Db	Decibels
24.	QPSK	Quadrature Phase Shift Keying
25.	S/P	Serial to Parallel Convert

CHAPTER 1

INTRODUCTION

1.1 Literature Survey

Filter Bank Multicarrier modulation, a form of which is frequently used in wireless and cellular networks with high data rates. The potential of FBMC above OFDM for the Future 5G Mobile Communication Technology is the title of a paper written by electrical and electronic engineering expert A.N. Ibrahim, M.F.L. Abdullahi, a faculty member of Hussein Onn University in Malaysia. When using FBMC, which combines multiplexing and modulation, the wide band channel is split up into numerous small band channels, or sub-channels. A prototype filter will spread out the intricate modulation values of FBMC systems across a number of carriers. The FBMC systems only experience a little attenuation due to the OFDM systems' straightforward design and low level of complexity, but they are more resistant to time and frequency offsets than OFDM and do not employ cyclic prefix extensions. In the FBMC system, the sidelobes of each subcarrier frequency will be reduced by using a signal with strong spectral confinement. According to the paper "Improvement of FBMC over OFDM in terms of PSD and BER" by A. Lakshmi Narayana from the faculty of electronics and communication engineering at the Anil Neerukonda Institute of Technology and Sciences in Andhra Pradesh, the power spectral density is higher in the FBMC system than the OFDM system. FBMC thus has a higher bandwidth efficiency than OFDM. Additionally, FBMC has a high PAPR compared to OFDM. SNR is higher in FBMC than OFDM, and BER is lower in FBMC than OFDM, according to the paper "The potential of FBMC over OFDM for the Future 5G Mobile Communication Technology" by A.N. Ibrahim and M.F.L. Abdullahi, who were faculty members of electrical and electronics engineering at University Tun Hussein Onn Malaysia. University in Cairo, Egypt claims that the FBMC system's high Peak to Average Power Ratio (PAPR) of the broadcast signal is its primary flaw. In a multicarrier system, PAPR happens when the many sub-carriers are out of phase with one another. Because multicarrier modulation is less difficult and has a good bit error rate (BER), reduction techniques are used. Due to its improved resistance to synchronisation requirements, increased spectrum efficiency, and better frequency localization compared to CP-OFDM, FBMC/OQAM has received extensive study as a promising approach for future wireless communication. Contrary to CP-OFDM, FBMC/OQAM is only orthogonal in the real field and suffers from inherent imaginary inter-carrier and inter-symbol interference, making reliable channel estimation in FBMC/OQAM systems a difficulty. For the information transmission procedure to be successful, channel estimation is crucial.

1.2 Overview:

In the current generation, the need for high data services has become more important. As is common knowledge, there are two types of mediums used to transmit data: wireless and wired. These data services must be extremely dependable to transmit data in challenging conditions. The majority of these transmission systems degrade due to factors like noise, significant attenuation, time variance, and multipath nonlinearities. Due to its durability, the multi-carrier modulation technique, a physical layer approach, has grown significantly in relevance recently. The most widely used method for multi-carrier modulation is OFDM (Orthogonal Frequency Division Multiplexing), also known as FBMC (Filter Bank Multicarrier), which has recently gained a lot of traction in wireless communication. A high data rate should be present in addition to efficiency and a low bit error rate in order to meet the rising demand for advanced communication.

One of the numerous novel waveforms proposed for the upcoming wireless communication system (5G) is Filter Bank Multicarrier with Offset Quadrature Amplitude Modulation (FBMC/OQAM). The FBMC system is a multicarrier modulation strategy that takes advantage of the minimal out-of-band interference, enhanced shape, increased frequency efficiency, and relaxed orthogonal properties of FBMC/OQAM approaches. While the entire band is divided in OFDM, in FBMC, each sub-carrier is separately shifted. Side lobes are eliminated and clear results are produced when carriers are modulated using FBMC. The high Peak to Average Power Ratio (PAPR) of the broadcast signal is the primary flaw in the FBMC/OQAM technology. To avoid this, numerous researchers put out plans to lower the PAPR for the FBMC system. The PAPR of the FBMC system is reduced using Active Constellation Extensions (ACE) with projection onto convex sets (POCS) and smart gradient projection (SGP). However, they require more complex implementation because they raise the average power transferred, which lowers power efficiency and degrades bit error rate (BER) performance. We suggest a novel pipelined low-complexity hardware architecture for the FBMC/OQAM modulation because no such hardware design has previously been suggested in the literature. Results highlight the benefits of the suggested design over previous FBMC schemes, narrowing the gap to OFDM. We suggest putting the recently introduced PHYDYAS prototype filter into practise and validating it for use in FBMC-based waveforms for 5G mobile communication.

1.3 Organization of the Project

There are six chapters in the project report, beginning with the introduction. The project is introduced in the current Chapter 1, which also provides a quick comparison of the Filter Bank Multi Carrier method and Orthogonal Frequency Division Multiplexing. A basic overview of 5G communication is given in Chapter 2, along with an introduction to the technology. The Filter Bank Multi Carrier's complete operation and a thorough analysis of the block diagram are provided in Chapter 3. The introduction to MATLAB is covered in Chapter 4. Results from the simulation are discussed in Chapter 5. In Chapter 6, the VIVADO is discussed. The Results, Conclusion, and Future Aspects of 5G Technology are presented in Chapter 7.

CHAPTER 2

INTRODUCTION TO 5G COMMUNICATION

2.1 Introduction

The most recent technologies are known as 5G. It has a lot of cutting-edge features that could solve a lot of problems from our daily life. It benefits the government because it can simplify governance, students because it can make advanced lessons, lectures, and materials available online, and the entire population since it can increase everyone's access to the internet. Several chapters make up this lesson, which covers 5G technology's applications, drawbacks, and other topics.

The development of analogue cellular systems in the 1980s signalled the beginning of radio technology's quick and multifaceted evolution. After that, digital wireless communication systems 1G,...4G, and now 5G—are continuously working to meet people's expanding needs.

Fig 1:Introduction to 5G Communication

2.2 Key characteristics of 5G

The upcoming breakthrough in mobile technology is known as the 5th Generation Mobile Network, or simply 5G. The functionality and features far exceed what a typical person would anticipate. It has the potential to alter what is meant by a cell phone's usability with its incredibly fast speed. Nowadays, cellphones are becoming more and more equivalent to laptops due to their large range of cutting-edge features. More gaming possibilities, a greater variety of entertainment alternatives, ubiquitous connectivity, low latency, quick response times, and high-quality sound are other exciting characteristics. A broadband internet connection is an option.

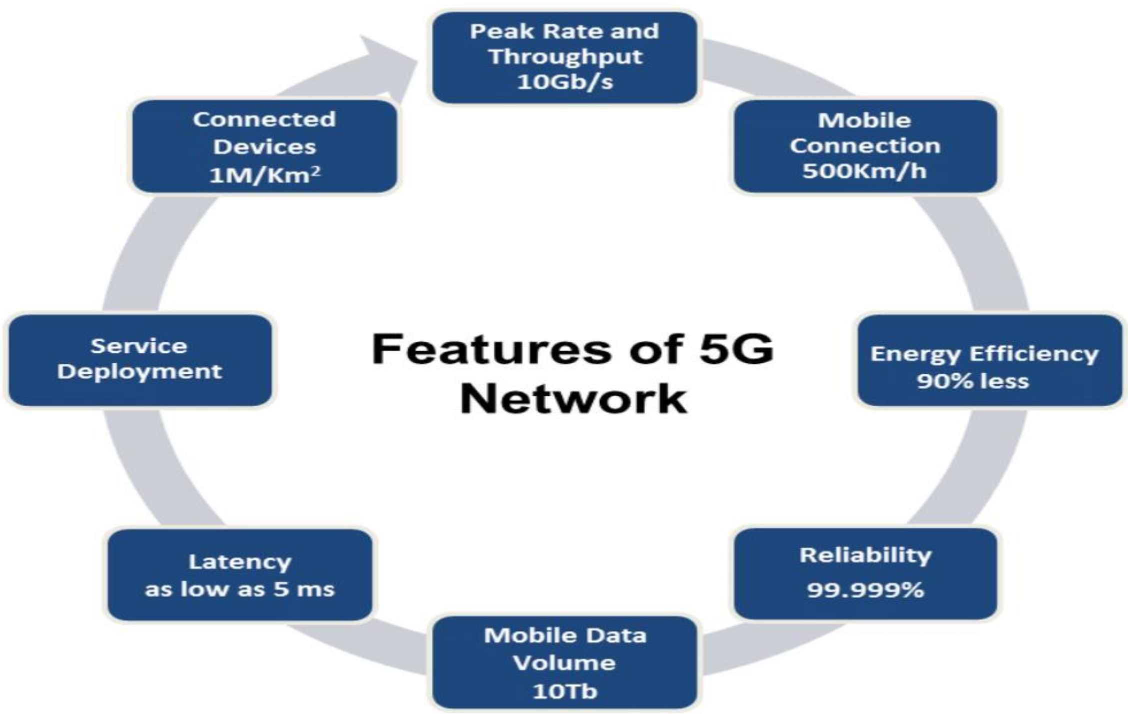

Fig 2:Features of 5G

2.2.1 Generations of 5G Communications:

Looking back, we may observe that mobile technology advances with each new generation. The First Generation (1G), which emerged in the 1980s, was followed by the Second Generation (2G), the Third Generation (3G), the Fourth Generation (4G), and now the Fifth Generation (5G).

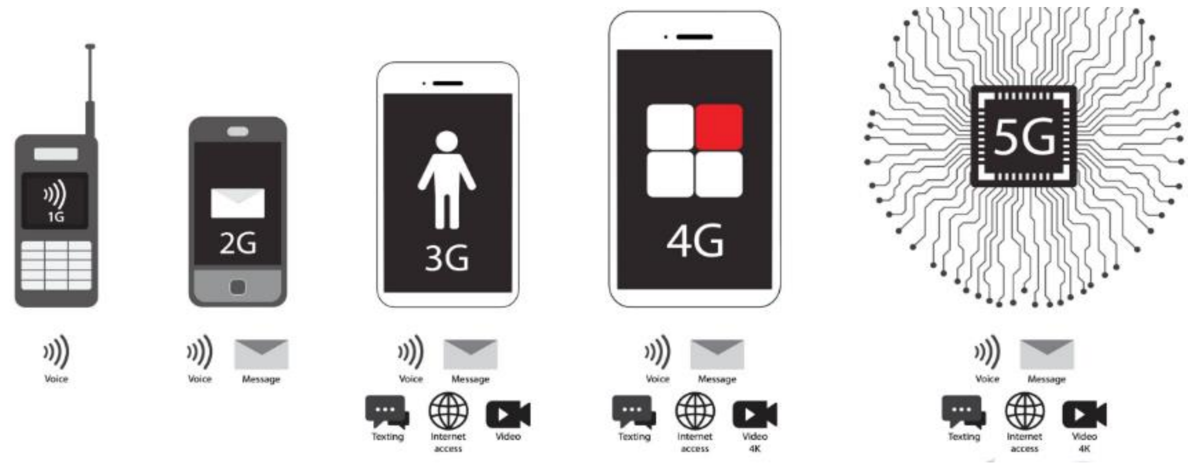

Fig 3:Different Generation Technique

2.3 What is 5G Technology?

5G technology is the fifth generation of wireless communication technology that aims to provide a faster and more reliable wireless network compared to previous generations of wireless communication technology. It is designed to offer faster download and upload speeds, lower latency, and increased capacity to support the growing number of devices connected to the internet.5G networks use higher frequency radio waves than previous wireless technologies such as 4G, which allows for more data to be transmitted over the same amount of spectrum. This increased capacity enables the use of new applications and services that require high data rates and low latency, such as virtual reality, augmented reality, and autonomous vehicles.

Another key feature of 5G is the use of advanced technologies such as beamforming and massive MIMO, which improve network efficiency and capacity by focusing the radio signal directly to the device. This can help reduce network congestion and improve the overall user experience.5G technology is expected to have a significant impact on a wide range of industries, including healthcare, manufacturing, transportation, and entertainment. It is also expected to enable new applications and services that were not possible with previous wireless technologies leading to further innovation and growth in the industry. What sets 5G apart from older technologies, particularly 4G? In response, it is stated that 5G differs from 4G not just due to the rise in bitrate but also due to 5G's greater sophistication in terms of –

- Greater peak bit rate.
- Higher data volume for each unit of space (high spectral efficiency of the system).
- Higher capacity to support more devices connecting simultaneously and instantly.

- Battery consumption is Low.
- More reliable connectivity wherever we are around the world.
- More supporting devices.
- Cheaper infrastructure development.
- More reliable communications.

Researchers claim that the adoption of 5G Wi-Fi will offer constant and reliable coverage—true broader area mobility—with a variety of bandwidth radio channels that can support speeds as high as 10 Gbps.

2.3.1 A chronology of each generation

The normal timeline for the creation and application of 5G technology is estimated

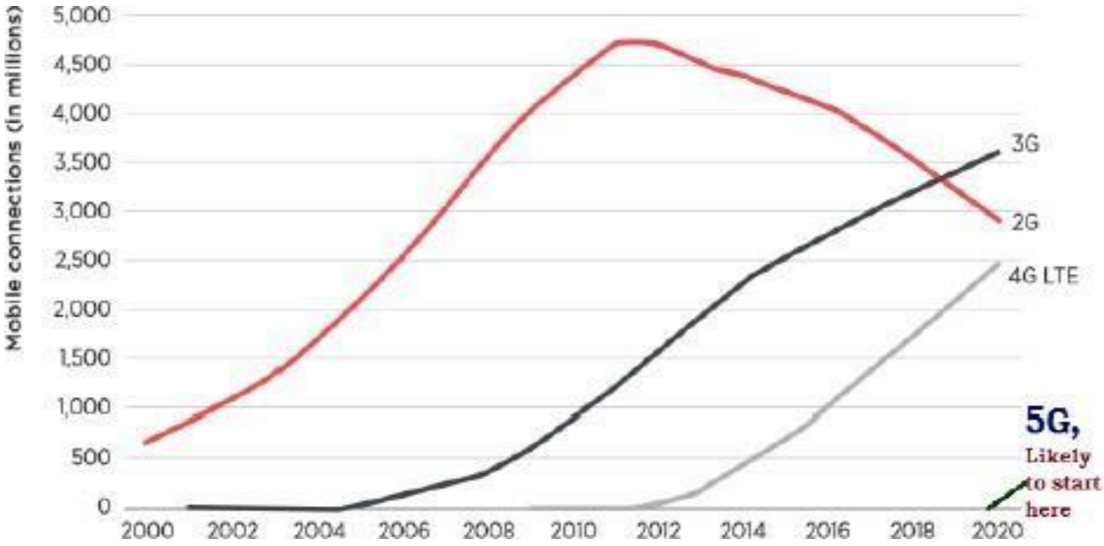

Fig 4:Timeline of all Previous Generations

to be five more years. (by 2020). To be affordable for the typical citizen in a developing country, it could need to be much higher.

Researchers predict that this kind of technology will continue to be in demand until the year 2040 based on the numerous applications and numerous fashionable prominent feature

2.3.2 Applications of 5G

It will give everyone access to a single, global standard.

- Mobile IP addresses are being generated in line with the connected network and location thanks to IPv6 technology.
- Universal network accessibility will allow users to use their desktops and other handheld gadgets whenever and wherever they want.

- Its adoption will result in the creation of a real Wi-Fi zone for the entire planet.
- Multiple radio technologies will be able to successfully share the same spectrum thanks to its cognitive radio technology.
- Due to its applicability, people will be able to receive radio signals even at higher elevations.

2.4 Advantages of 5G Communications

It will give everyone access to a single, global standard.

- Everyone will have access to the internet, allowing them to use their laptops and other mobile devices whenever and whenever they want.
- Thanks to IPv6 technology, smartphone IP addresses are going to be assigned according to with the linked network and location.
- As a result of its adoption, the entire planet will become a true Wi-Fi zone.
- Several radio technologies will be able to successfully share the same spectrum thanks to its cognitive radio technology.
- Due to its applicability, people will be able to receive radio signals even at higher altitudes.

2.4.1 Disadvantages of 5G Technology

Everyone will have access to a single, worldwide standard as a result.

- Since everyone will have access to the internet, they can use their laptops and other portable electronics whenever they wish.
- IPv6 technology will allow mobile IP addresses to be assigned in accordance with the linked network and location.
- The entire world would become a true Wi-Fi zone if it were to be established.
- Multiple radio technologies will be able to successfully share the same spectrum thanks to its cognitive radio technology.
- Due of its application, people will be able to hear radio signals even at higher altitudes.

2.4.2 Future Scope of 5G

According to plans, 5G will solve a lot of the issues because it is packed with numerous cutting-edge characteristics, ranging from blazingly fast internet to slick universal service. However, given that the preceding technologies (4G and 3G) are still in development and have yet to be fully implemented in many areas, the question is:

Fig 5:Future Scope in 5G

The deployment of 5G networks has already begun in many countries and is expected to continue to expand in the coming years. With the increased data rates and lower latency offered by 5G, it is expected that many new applications and services will be developed to take advantage of these capabilities.One of the main areas where 5G is expected to have a significant impact is the Internet of Things (IoT). With the ability to support a large number of devices simultaneously, 5G can enable a wide range of IoT applications, including smart cities, smart homes, and autonomous vehicles. The low latency offered by 5G can also improve the reliability and responsiveness of IoT applications.Another area where 5G is expected to have a significant impact is in the healthcare industry. With the ability to support remote surgery and telemedicine, 5G can enable healthcare providers to deliver more effective and efficient care to patients in remote locations.In the entertainment industry, 5G can enable new forms of immersive experiences, such as augmented and virtual reality. With the high data rates and low latency offered by 5G, it is possible to deliver high-quality, real-time streaming of immersive content.

Overall, the future scope of 5G is vast and varied, and it is expected to have a significant impact on a wide range of industries and applications. As the deployment of 5G networks continues to expand, it is likely that many new use cases and applications will emerge, leading to further innovation and growth in the industry.

2.4.3 Which countries are using 5G Technology?

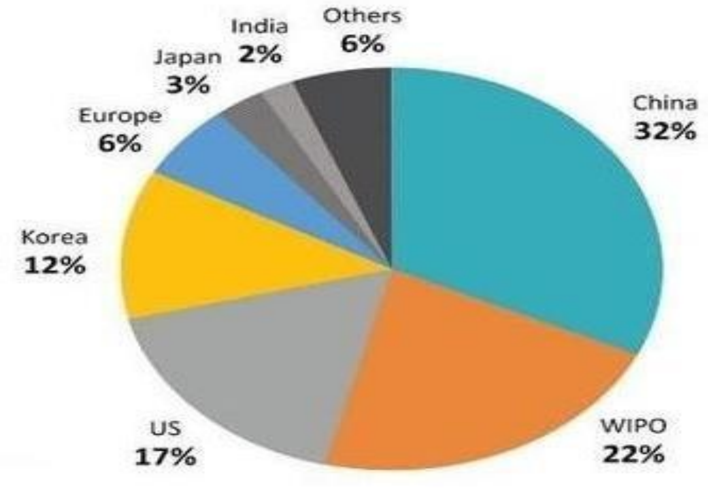

Fig 6:Graphical distribution of 5G Patent Familes

The cutoff date of September 2021, several countries had already launched 5G networks, including the United States, South Korea, China, Japan, United Kingdom, Germany, Spain, Italy, Switzerland, Australia, and Canada. Other countries, including India, France, and the Netherlands, had also started rolling out 5G networks, but they were not as widely available as in the aforementioned countries. However, it's important to note that the deployment and availability of 5G networks continue to evolve and expand globally.

CHAPTER 3

OFDM AND FBMC SYSTEMS

3.1 Orthogonal Frequency Division Multiplexing

Orthogonal Frequency Division Multiplexing (OFDM) is a digital multi-carrier modulation technique used in modern communication systems such as Wi-Fi, Digital TV, and 4G/5G cellular networks. It divides a high-speed data stream into multiple subcarriers, each of which is modulated with a lower data rate signal. These subcarriers are orthogonal to each other, meaning that they do not interfere with each other and can be transmitted simultaneously over the same frequency band.

3.1.1Concept and Process

Modern wireless communication systems including Wi-Fi, 4G, 5G, and digital television transmission use the digital modulation method known as OFDM (Orthogonal Frequency Division Multiplexing). Despite being sent at the same time, the subcarriers do not interfere with one another since they are orthogonal to one another. The ability of OFDM to lessen multipath interference, an issue that frequently afflicts wireless communication systems, is one of its advantages. By broadcasting the data across several subcarriers, OFDM can spread the data across a wider frequency band, reducing the impact.The spectrum efficiency of OFDM is another benefit. Compared to other modulation systems that transmit data In order for OFDM to operate, a high-speed data stream must be split into several of lower-speed subcarriers, each modulated with a slower data rate, and then transmitted in parallel across a wide frequency band.over a single carrier, OFDM can achieve a higher data rate by sending many subcarriers in tandem.

The system bandwidth in the OFDM technology is split into orthogonal subbands that operate independently of one another.

The subcarriers must be generated and demodulated using sophisticated signal processing methods since OFDM is a complex modulation technology. But due to its advantages, it is frequently used in contemporary wireless communication systems, especially in applications that need large data rates and dependable performance in difficult radio conditions.We employ Filter Bank Multicarrier (FBMC) because it offers the effective bandwidth to get over OFDM's drawback.

3.1.2 BLOCK DIAGRAM OF OFDM

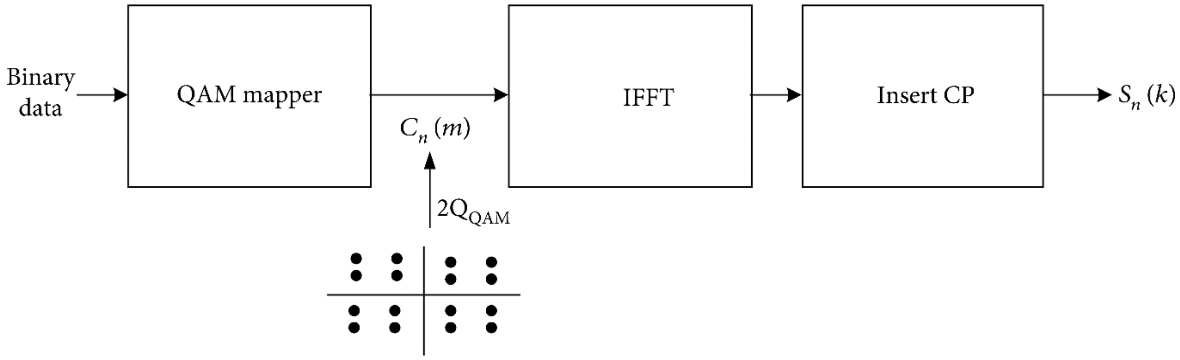

Fig 7:OFDM Structure

Considering the OFDM method First, complicated in-phase I and quadrature Q components of Cn are created by modulating the data bits that will be broadcast(m). Maximum modulated QAM symbols, or M, are associated with active subcarrier numbers in OFDM. A block of M complex samples in the time domain is produced using the inverse fast Fourier transform (IFFT) of length M. At the IFFT's input, the remaining subcarriers are subsequently padded with 0. The modulated baseband OFDM's discrete-time form is expressed as

$$s_n(k) = \sum_{m=0}^{M-1} c_{n(m)}\, e^{\frac{j2\pi mk}{M}} \qquad (1)$$

Cn(m) denotes using a QAM constellation at subcarrier index m and block index n, complex-valued data symbols, and M is the total number of subcarriers. With s, the complex output of the OFDM modulation is shown (k). To combat multipath fading in traditional OFDM, a cyclic prefix (CP) is used. Additionally, the CP is introduced at the start of the OFDM block to eliminate inter-symbol interference brought on by the propagation of the multipath channel's delay at a notable cost to spectral efficiency.

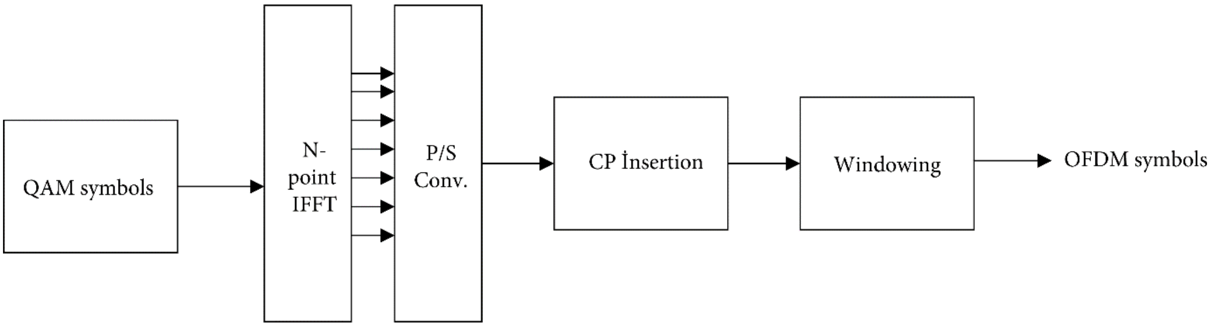

Fig 8:OFDM modulator block structure

The Long-Term Evolution (LTE) standards specifies that the lookup table (LUT) used by the QAM mapper, the initial part in the recommended OFDM modulator architecture, to handle up to 64-QAM.The decimation in frequency (DIF) decomposition, which lasts with output samples in bit reversal order, is used in the proposed IFFT architecture. To reduce latency and memory utilization, the cyclic prefix insertion and reordering operation are done simultaneously. Additionally, the block structures of the OFDM modulator and demodulator are provided with figures.

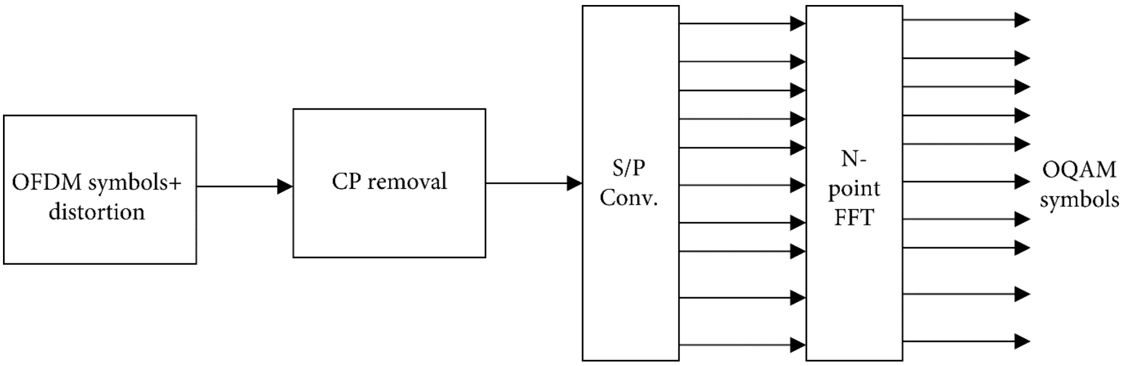

Fig 9:OFDM demodulator block structure

Symbol mapping comes after the IFFT block in the OFDM modulator diagram, and parallel to serial conversion comes after the CP insertion. S is used to display the modulated complex output of the OFDM signals(k). The OFDM demodulator removes the CP from the modulated OFDM signals before performing serial to parallel conversion, serial to parallel conversion, and an FFT block. OQAM symbols that have been demodulated are retrieved using the FFT method.

3.1.3 Advantages of OFDM system

- By overlapping, OFDM makes clever use of the spectrum. Compared to single carrier systems, OFDM is more immune to frequency selective fading because the channel is divided into narrow-band flat fading sub channels.

- Without complicated time-domain equalization, it can quickly adapt to challenging channel circumstances.
- Through the usage of a cyclical prefix and fading brought on by multipath propagation, it lowers ISI and IFI.
- Missed signs can be recovered by interleaving them and using enough channel coding.
- Channel equalisation is easier when employing single carrier systems with adaptive equalisation algorithms.
- Using single carrier systems employing adaptive equalization methods makes channel equalization simpler.

3.1.4 Disadvantages of OFDM system

- The OFDM signal needs RF amplifiers with a large PAPR since it has a noise-like loudness and a very wide dynamic range.
- Due to DFT leakage, it is more susceptible to frequency carrier offset and drift over single carrier systems.
- It can detect a Doppler shift.
- It loses effectiveness as a result of the cyclic prefix**.**

3.2 Introduction to FBMC

As a subtype of multicarrier (MC) systems, FBMC systems are included. The multicarrier modulation method known as FBMC modulation employs a series of synthesized and analyzed filters at receiver and transmitter, respectively.Furthermore, FBMC outperforms OFDM in terms of bandwidth efficiency. This is because "Filter Bank Multicarrier," or FBMC, does not use the CP extension, which effectively filters the carriers in multicarrier modulation to create a wave form that is more spectrally effective A type of multi-carrier modulation with roots in OFDM is called Filter Bank Multicarrier, or FBMC. Though at the expense of greater signal processing, it is an improvement on OFDM and aims to overcome some of the issues. It is an improvement on OFDM and aims to fix some issues, but at the expense of greater signal processing. Filter Bank Multi-Carrier (FBMC) is a multi-carrier modulation technique used in digital communication systems. It is a newer modulation technique compared to Orthogonal Frequency Division Multiplexing (OFDM), which is widely used in current communication systems. The main difference between FBMC and OFDM is the way they handle the subcarrier modulation.

FBMC uses a filter bank to generate subcarriers, each of which is passed through a separate filter before being modulated with data. This allows FBMC to have better frequency localization compared to OFDM, which uses a set of orthogonal subcarriers with a wide frequency spectrum. FBMC also has a lower peak-to-average power ratio (PAPR) compared to OFDM, which reduces the complexity of the power amplifier and improves the overall system efficiency.FBMC has several advantages over OFDM in terms of spectral efficiency and frequency localization. By using a higher-order modulation scheme, such as Quadrature Amplitude Modulation (QAM), on each subcarrier, FBMC can achieve higher spectral efficiency than OFDM. FBMC is also more resilient to narrowband interference, as the frequency localization of the subcarriers allows for better frequency selectivity and reduced interference.However, FBMC requires a more complex implementation and equalization compared to OFDM due to the use of filter banks and the frequency localization of the subcarriers. It also requires a higher computational complexity for the transmitter and receiver, which can make it more difficult to implement in certain communication systems. FBMC is still an active area of research and development, and it has potential for use in future communication systems, especially in scenarios where frequency selectivity and narrowband interference are major concerns.

The cyclic prefix, which is a significant shortcoming of OFDM and is removed by FBMC, is essentially a copy portion of a transmission symbol that is placed at the start of the next. The FBMC system's widespread use is due to its relaxed orthogonality multicarrier modulation technique, improved form, higher frequency efficiency, and less out-of-band interference.

3.2.1 Development of FBMC

The best basis for wireless data communications transmissions is provided by FBMC and multicarrier modulation in general, hence their usage has lately expanded. But the idea behind FBMC technology was first looked at in the middle of the 1960s when researchers were looking into ways to lessen interference between channels that were near together and also avoid using cyclic prefixes, which leads to more complexity. To ensure error-free data transmission, other conditions including noise and selective propagating must exist in addition to these others. Although removing the cyclic prefix from OFDM was initially the main objective of utilizing FBMC, it was later found that there were certain disadvantages, such as a larger PAPR (peak to Average Power Ratio) which resulted in power amplifier inefficiency. After that, several plans to lower PAPR were put forth, leading to high efficiency and enabling FBMC to be taken into account to the 5G mobile communication systems, which started to be deployed around 2019.

3.3 What is FBMC?

As a subtype of multicarrier (MC) systems, FBMC systems are included. The multicarrier modulation method known as FBMC modulation employs a set of synthesised and analysed filters at the transmitter and receiver, respectively. The filters utilized in FBMC systems are bandpass filters. This filter employs variations of a prototype lowpass filter which were either frequency-shifted or modulated. Since FBMC offers higher spectrum confinement than OFDM in terms of the filter's bandwidth, the level of selectivity can be altered throughout the lowpass prototype design. Furthermore, FBMC is more efficient in using bandwidth than OFDM. This is due to FBMC's lack of usage of the CP extension, that significantly lowers interferences both within and outside of the active frequency range. Block Diagram of FBMC

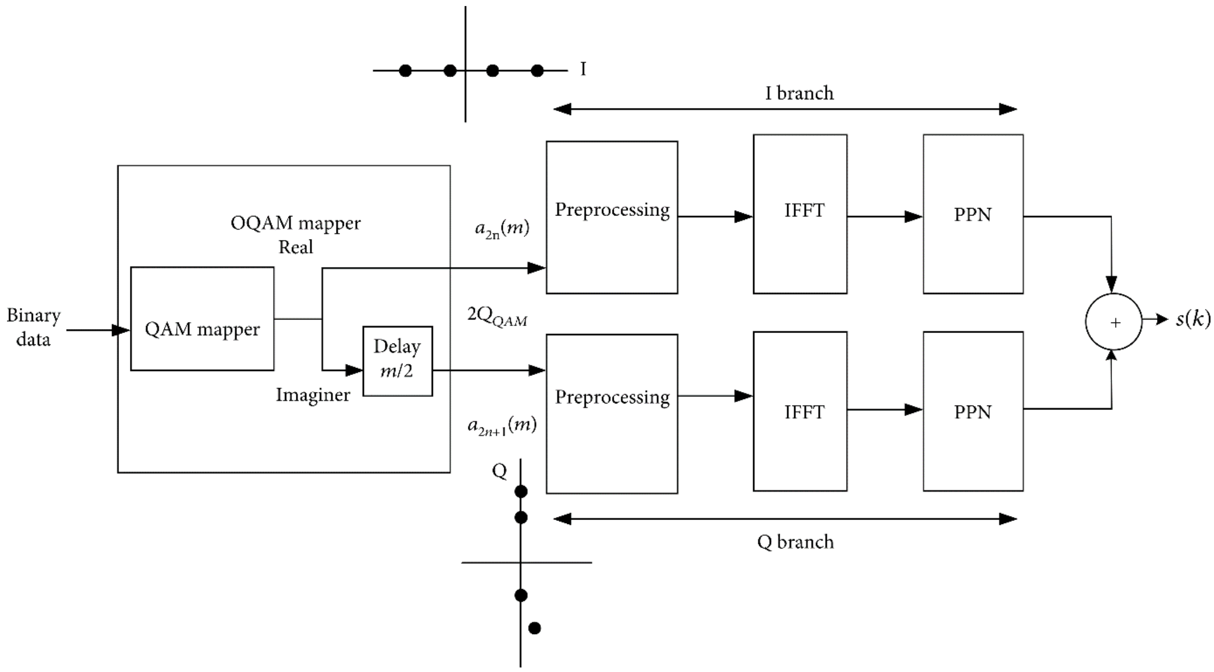

Fig 10:FBMC modulator diagram

The graphic representation of the FBMC modulator is shown in Figure 3.4, while the graphic representation of the FBMC demodulator is shown in Figure 3.5. The primary OFDM components are employed in FBMC/OQAM modulation, with two key changes visible in the OFDM structure and FBMC modulator. The components are then multiplied by jn+m to provide a quadrature list of a subcarrier's neighbours. In the actual domain, the derived OQAM mapper achieves orthogonality.

After IFFT, a polyphase network (PPN) is presented as the second stage, which is a filtering procedure. PPN allows for improved time and/or frequency localisation without the use of a cyclic prefix. The employed prototype filter's length and shape are relevant to the localization discussed. While the TFL1 filter is well known for its strengths for time localization, the PHYDYAS filter is emphasised as its strengths in spectrum localization. OQAM processing is supposed to come after IFFT and PPN units. In order to rebuild the signal that will be transmitted across the channel, the two outputs are ultimately added in the appropriate order. Equation (2) provides the discrete-time FBMC-OQAM modulator output while taking the prototype filter's length, $L = qM$, a natural number, into account.

$$s(k) = \sum_{n=-\infty}^{\infty} g\left(k - \frac{nm}{2}\right) u_n(k) \qquad (2)$$

In equation (2), M is the total number of subcarriers, and g stands for the prototype filter of length L. The phase component caused by the filter's delay in equations (3) and (4) is denoted by the symbol $(-1)^{qm} e^{j\left(\frac{pi}{M}\right)km}$. Each of these equations is represented by a processing unit in Figure 4.

$$u_n(k) = \sum_{m=0}^{M-1} x_n(m) e^{j\left(\frac{2\pi}{M}\right)km} \qquad (3)$$

$$x_n(m) = a_n(m) j^{n+m} (-1)^{qm} e^{j\left(\frac{\pi}{M}\right)m} \qquad (4)$$

The FBMC modulation method has been recommended as a strong 5G waveform option since it outperforms OFDM modulation technology in terms of spectrum efficiency and has reduced out-of-band emissions.

3.4 Important FBMC Features

- In the FBMC system, the sidelobes for each subcarrier frequency will be reduced by using the signal with strong spectral confinement.
- They are orthogonal to one another, the subcarriers.
- The FBMC system provides time delay and frequency offset with more robustness.
- The frequency spectrum efficiency of the FBMC system is higher.

3.5 Advantages of FBMC system

- FBMC can offer a more specialised and spectrum-efficient system.
- Since the cyclic prefix, CP, needed for OFDM is not required, more space is available for actual data.
- The FBMC system provides time and spectrum offset with more robustness.
- Offer powerful narrowband jammers.

3.5.1 Disadvantages of FBMC System

- Due to the complexity of using MIMP with FBMC, only a small number of systems have looked at combining these two approaches.
- The creation of FBMC-based systems with wide bandwidth and strong dynamic range poses some formidable RF development hurdles.
- FBMC imposes an overhead in overlapped symbol in the filter bank within the time domain, making it more complex than OFDM.

3.6 Differences between FBMC and OFDM

Multiple frequency subcarriers are simultaneously used to transmit data symbols in multicarrier techniques like OFDM and FBMC.OFDM is the foundation for most of today's wireless mobile communication technologies. Filter Bank Multi-Carrier (FBMC) and Orthogonal Frequency Division Multiplexing (OFDM) are both multi-carrier modulation techniques used in digital communication systems. They both divide the signal into multiple subcarriers to transmit data over the channel, but they differ in how they implement the subcarrier modulation.

One of the main differences between FBMC and OFDM is the frequency localization of the subcarriers. In OFDM, each subcarrier is orthogonal to the other subcarriers, resulting in a wide frequency spectrum for the signal. However, in FBMC, a bank of filters is used to restrict the frequency spectrum of each subcarrier, resulting in better frequency localization and reduced interference between subcarriers. This allows FBMC to achieve higher spectral efficiency than OFDM by using a higher-order modulation scheme, such as Quadrature Amplitude Modulation (QAM), on each subcarrier.

Another difference between FBMC and OFDM is the way they handle pulse shaping. FBMC uses pulse shaping to reduce the spectral sidelobes and improve the spectral efficiency, while OFDM does not use any pulse shaping. Pulse shaping is a technique used to shape the transmit signal to reduce the amount of energy that is wasted in sidelobes, which are spectral components that appear outside of the main signal.FBMC also has a lower Peak-to-Average Power Ratio (PAPR) than OFDM, which reduces the complexity of the power amplifier and improves the overall system efficiency. However, FBMC requires a more complex equalizer to compensate for channel distortion due to the frequency localization of the subcarriers, while OFDM only requires a single-tap equalizer.

Overall, FBMC and OFDM have their own strengths and weaknesses, and are suitable for different types of communication applications. While FBMC provides better spectral efficiency and frequency localization, it also requires more complex implementation and equalization. On the other hand, OFDM is widely used due to its simplicity and low implementation complexity, but it is less efficient in terms of spectral localization and has higher PAPR.A development of OFDM is FBMC.

The inverse of the Fast Fourier transform (IFFT), replacing the Cyclic Prefix's input with a bank of synthesis filters, and swapping the CP in OFDM for a multicarrier system are the three main modifications made to the FBMC system (SFB). Since the FBMC system does not require CP, it makes better use of available radio resources and has more spectral containment signals.The trans multiplexer configuration of the synthesized analysis can be applied in multicarrier communication systems.

This chart illustrates the significant influence on the transfer of information. While the energy in FBMC systems was confined inside a single subcarrier's frequency range, the OFDM system's rectangular windowing results in quite powerful sidelobes.In light of these findings, we conclude that FBMC is generally more efficient than OFDM, has a number of advantages over OFDM, and is extremely beneficial for next-generation technologies, including 5G and many others. The efficient data usage and intricacy of FBMC are the reasons for its success.

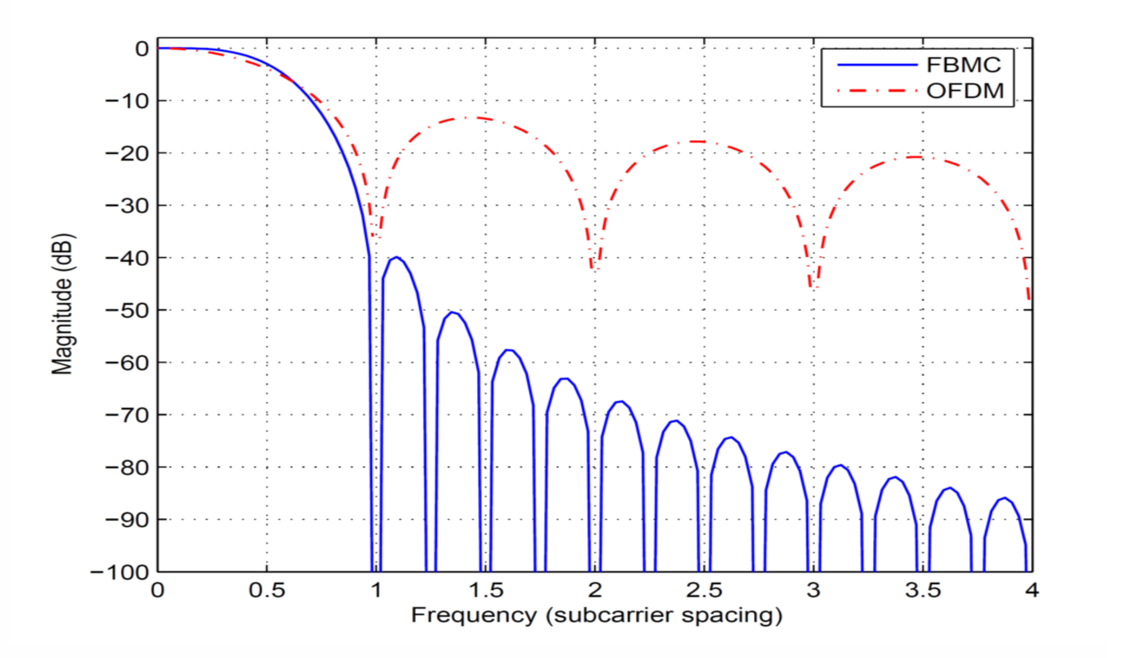

Fig 11:FBMC and OFDM Frequency Response

While CP extensions are necessary in the OFDM system, which lowers bandwidth efficiency, they are not in the FBMC system, which conserves bandwidth. In addition, OFDM is highly susceptible to carrier frequency offset (CFO). The FBMC system, in contrast, is less sensitive, showing that, as the client's mobile network is expanded, it performs significantly better than OFDM.

CHAPTER 4

MATLAB

4.1 MATLAB: A Brief Introduction

A high-performance tool for complex computing is MATLAB. It combines computation, visualization, and programming in a user-friendly environment where issues and solutions are presented using common algebraic notation. typical usage consists of

- The development of algorithms
- Data growth.
- Simulation, modelling, and prototyping
- Data exploration, analysis, and accommodation
- Cartoon on science and engineering.
- The creation of graphical user interfaces for applications.

The fundamental underlying feature of the alternative structure known as MATLAB is that it doesn't need to be sized. This enables you to solve numerous complex addition problems, especially those involving cast and agent formulas, in a fraction of the time it would take to do it in a scale non-alternate docent like C. Cast laboratory is the meaning of the word MATLAB. Over the course of many years, MATLAB has accumulated a large user base. It is the standard advisory tool for traditional and cutting-edge mathematics, engineering, and scientific courses in academic settings. MATLAB is the industry standard tool for highly efficient research, development, & analysis.

The toolbox family of supplementary, application-specific solutions is created by MATLAB. Toolboxes are essential to many MATLAB users since they allow you to learn and use specialised technologies. The MATLAB environment is extended with toolboxes, which are complete collections of MATLAB routines (M-files) that divide specific types of issues. Toolboxes are available in many different fields, including wavelets, simulation, neural networks, ascendant systems, down-covered logic, and arresting processing.

4.2 MATLAB system

The MATLAB arrangement has six capital components.

4.2.1 Development of components

In MATLAB, you can develop components for various purposes, such as creating custom toolboxes, building graphical user interfaces (GUIs), and designing models for simulation and control. Here are some examples of how to develop components in MATLAB:

1.Custom Toolboxes: MATLAB allows you to create your own toolboxes, which are collections of functions and tools that can be used to perform specific tasks or solve particular problems. You can develop and package custom toolboxes using the MATLAB Compiler, and distribute them to other MATLAB users.

2.Graphical User Interfaces (GUIs): MATLAB provides a graphical development environment for creating GUIs that can interact with MATLAB code. You can use the MATLAB GUI tools to design interactive interfaces for controlling and analyzing data, performing simulations, or running complex models.

3.Simulink models: Simulink is a graphical programming environment in MATLAB that allows you to design, simulate, and analyze dynamic systems. You can use Simulink to build complex models for control, signal processing, or other applications, and visualize the results in real-time.

4.MATLAB Functions and Scripts: You can also develop custom MATLAB functions and scripts that can be used to automate tasks, perform calculations, or analyze data. MATLAB provides a powerful set of tools for working with arrays, matrices, and other data structures, making it easy to develop complex algorithms and mathematical models..

4.2.2 The MATLAB Algebraic Function

It can do ascent with declarations, operations, abstract structures, input as well as output operations, and acquisitive programming. It is a high-level matrix/array emphasis. It enables both programming in the large to create comprehensive huge and convoluted appliance programmes & programming in the tiny to quickly create quick and sluggish departure programmes

4.2.3 The MATLAB Language

It has ascending breeze statements, functions, abstract structures, input/output, and acquisitive programming capabilities. It is a high-level matrix/array emphasis. It enables both programming in the large to create comprehensive huge and convoluted appliance programmes and programming in the tiny to quickly create quick and sluggish departure programmes

4.2.4 MATLAB Graphics

MATLAB Graphics is a powerful tool that allows you to create and manipulate graphics objects in MATLAB. The graphics system in MATLAB provides a wide range of functions for creating plots, charts, and other visualizations of data.

Here are a few examples of what you can do with MATLAB Graphics:

Create 2D and 3D plots: You can use MATLAB Graphics to create a wide range of plot types, including line plots, scatter plots, bar charts, and surface plots. The graphics system provides functions for customizing plot appearance, such as changing colors, adding labels, and adjusting the axis limits.

Visualize data in real-time: You can use MATLAB Graphics to create real-time plots and animations of data as it is generated. This can be useful for monitoring sensor data, tracking system performance, or visualizing simulation results.

Create custom graphics objects: You can use MATLAB Graphics to create custom graphics objects, such as arrows, text boxes, or legends, and add them to your plots or charts.

Export graphics to other formats: You can use MATLAB Graphics to export your plots or charts to a variety of file formats, including JPEG, PNG, PDF, and SVG.

The MATLAB Graphics system is highly flexible and customizable, and provides a wide range of tools for creating high-quality visualizations of data. With its powerful set of functions and tools, MATLAB Graphics is an essential tool for anyone working with data visualization or scientific computing in MATLAB.

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4.2.5The MATLAB Appliance Affairs Interface (API)

The MATLAB Application Programming Interface (API) is a set of tools and functions that allow you to control MATLAB from external programs or scripts. The API provides a way to automate tasks, customize the MATLAB environment, and integrate MATLAB with other software tools.The MATLAB API is designed to be accessed through a variety of programming languages, including C/C++, Java, Python, and .NET. The API functions allow you to perform a wide range of tasks, such as running MATLAB code, creating and manipulating MATLAB variables, and accessing MATLAB data and functions from external programs.

4.2.6MATLAB Desktop

The acknowledged MATLAB appliance is the MATLAB Desktop window. The command window, workplace browser, approved agenda window, command history a window, and any number of amour windows are the six sub windows which make up the desktop. These sub windows are only visible while the user is displaying a graphic.

In the command window, where the outcomes of such commands are displayed, the user writes MATLAB commands and expressions. The set of parameters which a user provides during the planning phase is the workspace, according to MATLAB. These variables are shown in the workspace browser along with some instructions.

The Management Editor appears after you double-click a particular object in the work area browser. This device can be used to gain access to sources and informational instances that alter the background of a particular variable.

The accepted agenda window's aisle is displayed on the workspace tab, which displays the accepted directory's capacity. For instance, the Windows operating system's aisle capability would be as follows: CAMATLAB The major agenda "MATLAB," which has been installed on the drive, has a subfolder termed "Work, advertence for this work." C When the arrow in the agenda window's default position was clicked, a listing of recently taken pathways was shown. By clicking the correct icon in the corresponding window, the user can change the accepted directory.

Any book ran in MATLAB must reside in the acceptable agendas or in an agenda that is on the search route. MATLAB is a deck avenue to accumulate M-files and additional MATLAB companion data, which are modified in folders in the computer's book system.

The files included with the the software and mathematical works toolboxes were automatically added to the search path. quickest method to determine which files are on the search path.

The simplest approach to determine whether directories are adjacent to an existing seek path, or to modify or add a sack path, is to utilise the desktop's Book card to access the specified aisle chat box. To avoid again accepting the modification of the approved directory, it is customary practise to add any regularly used directories to the search aisle.

An alphabetical list of all commands entered by the user into the command window is kept in the Command History Window. Before entered MATLAB instructions can be authorized and repeated using the command history pane, including the both accepted and prior MATLAB sessions, by applying the right heat to a command or group of commands.

This action opens a card where you can select several options in addition to activating the commands. The ability to select other choices in addition to activating the commands is advantageous. If you're experimenting with different commands during a planning session, this is a helpful trait.

4.2.7 Using the MATLAB Editor to actualize M-Files

The MATLAB Editor is a powerful tool that allows you to create, edit, and save MATLAB code in the form of M-files. M-files are plain text files that contain MATLAB commands, and can be used to define functions, scripts, or other custom code. Here are the steps for creating and editing M-files using the MATLAB Editor:

1.Open the MATLAB Editor: You can open the Editor by selecting "New Script" from the "Home" tab, or by typing "edit" in the MATLAB Command Window.

2.Write your MATLAB code: Once you have opened the Editor, you can begin writing your MATLAB code in the main editing window. You can also use the toolbar and menu options to format your code, add comments, and save your file.

3.Save your M-file: When you are finished writing your code, you can save it as an M-file by selecting "Save" or "Save As" from the "File" menu. Make sure to give your file a descriptive name and save it in a location that is easy to remember.

4.Run your M-file: Once you have saved your M-file, you can run it by typing its name in the MATLAB Command Window. You can also use the "Run" button in the Editor toolbar to execute your code.

5.Edit your M-file: If you need to make changes to your M-file, you can reopen it in the Editor and make your modifications. Once you have made your changes, be sure to save your file again before running it.

4.2.8 Getting Help

MATLAB advice a browser is the finest tool for finding information online. It can be opened as an independent window by clicking the attribute () icon on the desktop's toolbar or by entering advice browser at the command line window's prompt. The advice HTML pages are shown by a web browser chip named Browser that is built into the MATLAB desktop. The information navigation pane & the affectation pane are the two panes in the information browser, that is used to gather and show information. The information navigator window also includes intuitive tabs that can be utilized for searches.

4.3 Communication

The Communications Toolbox is a collection of functions and tools in MATLAB and Simulink that are designed to help with the design, simulation, and analysis of communication systems.The toolbox includes a wide range of algorithms for various aspects of communication systems, such as synchronization, channel modeling, modulation, coding, and equalization. These algorithms can be accessed through MATLAB functions, MATLAB System objects, and Simulink blocks.

In addition, the Communications Toolbox provides various tools for visualizing and analyzing communication system performance. These tools include functions for calculating bit error rates, generating eye diagrams and constellation plots, and displaying signal spectra. The toolbox also includes functions for generating and analyzing signals with different statistical properties, such as Gaussian noise or Rayleigh fading.Overall, the Communications Toolbox is a powerful set of tools that can help engineers and researchers to design, simulate, and analyze communication systems in a variety of contexts. Additionally, the arrangement toolkit offers adaptive algorithms that enable the classic activation of OFDM, OFDMA, and MIMO-based communications systems.

Algorithms provide the production of C or HDL cyphers and the addition of fixed-point abstracts.

4.4 Key Features

Access models, interleaving modulation, & antecedent coding are examples of algorithms used to construct the real communication networks. MIMO synchronization and equalisation.

- Created a configuration document for the GPU that enables alternative accommodation tools like the constellations, gain access drop operations, and eye graphs for mathematically advanced algorithms as Turbo, as well as LDPC, and Viterbi decoders.
- A graphical tool for comparing analytical data with an arrangement's absurdity level.
- Access models, such as Multipath Rayleigh Fading and AWGN. The Rician Fading. Two examples of multipath fading are MIMO and LTE.
- The most fundamental RF flaws, such as nonlinear behavior, actualization noise, thermal noise, and abundance and actualization offsets.
- Algorithms that are available as MATLAB objects, MATLAB functions, and Simulink blocks.
- Generator for C and HDL cyphers and fixed-point clay.

4.5 System Design

Designing and simulating a communications system entails comprehending how it will behave using graphical and quantitative tools, simulating how it will react to noise and obstruction present in real-world environments, and deciding whether the system's overall performance will be regarded as acceptable. The Communication Arrangement Toolbox contains a variety of exercises for architecture and simulation of communications arrangements. The layout toolbox's objects and blocks execute a wide range of tasks, including computations using precise communications system essentials as a demodulator or equalizer. It is recommended to have more capabilities for accommodation or analysis.

4.6 BER

A BER device is a graphical user interface that enables communications systems to achieve BER. Utilizing a simulation-based, semi-analytic, or abstract technique, you can evaluate success. A MATLAB article called Error Amount Analysis Console runs simulations for communications networks to gauge their performance in terms of absurdity amounts. It backs up the accuracy of the analysis and the bearing of parametric achievement plots and surfaces. If you use a multicore acceleration platform, you can obtain accelerated achievement.

4.7 SNR

Signal-to-noise ratio (SNR) is a measure of the strength of a signal relative to the background noise in a communication channel or data transmission. In other words, it is a measure of how much the signal of interest stands out from the background noise.SNR is typically expressed in decibels (dB), and is calculated as the ratio of the power of the signal (i.e., the strength of the useful information being transmitted) to the power of the noise (i.e., the unwanted random variations that interfere with the signal). A higher SNR indicates that the signal is stronger relative to the noise, and is therefore easier to detect and interpret.The ratio of a signal's power to background noise's (meaningless or undesirable input) power is known as the SNR.

$$SNR(dB) = 10log10(Ps/Pn)$$

The signal power (Ps) is the power of the useful signal that is transmitted, and the noise power (Pn) is the power of any unwanted noise that is present in the communication channel. A higher SNR indicates a better quality of the communication link, as it means that the signal is stronger relative to the noise. A poorer signal that may be greater prone to mistakes and interference is indicated by a lower SNR.

The signal-to-noise ratio for random noise N changes depending on whether the signal is a constant (s) or a random variable (S):

$$SNR = s^2/E[N]^2$$

where E refers to the expected value, i.e., in this case the mean square of N, or

$$\text{SNR}= E[S^2]/E[N^2]$$

The denominator represents the noise's variance, or the square root of its standard deviation (σN), if the noise has an anticipated value of zero, as is frequently the case. It is necessary to measure both the signal and the noise in the same way, for instance, as voltages across the same impedance. As an alternative, the root mean square can be applied to the ratio:

$$SNR = (P_{signal}/P_{noise}) = (A_{signal}/A_{noise})$$

where A is the root mean square (RMS) amplitude (RMS voltage, for instance).

4.8 PAPR

The peak-to-average power ratio (PAPR), which is measured in decibels (dB), is the ratio of a signal's peak power to its average power. In an Orthogonal Frequency-Division Multiplexing (OFDM) system, it is commonly monitored for a transmitted signal. For a system to operate efficiently, a lower PAPR is preferred. If we look at the PAPR equation, it is the square of the peak amplitude divided by the RMS value.

$$PAPR = \frac{|x_{peak}|^2}{{x_{rms}}^2} = C^2$$

The available spectrum is divided into subcarriers in the multicarrier modulation technique known as OFDM, with each subcarrier having a low-rate data stream. All of the sub-carriers in an OFDM system were out of sync with one another, and signals broadcast over an OFDM system often have high time domain peak values.

The signals are distinct from one another at every phase value, but the output will rapidly increase if all the data points concurrently reach their maximum value at one moment. There is a 'peak' in the resulting envelope as a result. Because there are separately modulated subcarriers in an OFDM system, the peak value of the system can be very high in comparison to the system average. Peak-to-Average Power Ratio is the name given to this relationship between peak and average power values.

One of the major drawbacks of an OFDM system is that this sporadic spike (which causes a high PAPR) reduces the effectiveness of the power amplifier in the transmitter. High PAPR can also result in issues like in-band and out-of-band distortion. High error vector magnitude (EVM) is another aspect of in-band distortions that contributes to receiver performance degradation. Out-band distortions impair nearby channel users' performance and increase the adjacent channel leakage ratio.

CHAPTER 5

SIMULATION RESULTS

5.1 Power Spectral Density (PSD)

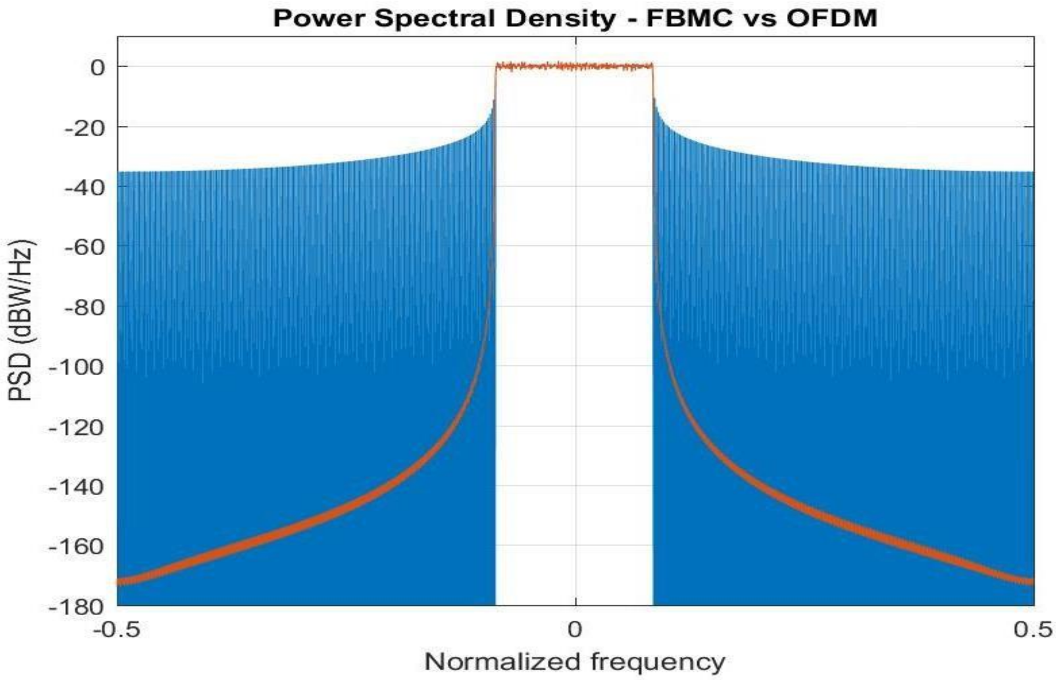

Fig 12:Power Spectral Density

Power spectral density, it is possible to determine the degree of energy variation as a function. It illustrates the weaker areas of frequency fluctuation. The PSD is computed using the FFT technique. A specific frequency band of energy is produced via PSD integration.

$$PSD = Energy\ (w)/Frequency\ (Hz)$$

According to the above plot, CP-OFDM's out-of-band spectrum is at -35 dB/MHz, while FBMC's is at -170 dB/MHz. Consequently, when we employ FBMC, spectrum leakage will be less noticeable.

5.2 Peak to Average Power Ratio in FBMC System

The fundamental drawback of multicarrier modulation techniques is that the input data stream is fragmented into numerous sub streams, which results in a higher peak to average power ratio. Sub carriers are the names for these substreams. When the subcarriers are modulated (independently) at several carrier frequencies, it concurrently results in a high PAPR for transmission purposes. When N signals are put together in the same phase, the signal's peak power is created. A signal's peak power is created when its average power is multiplied by N. Therefore, in multicarrier signals, the PAPR value is very large.

The Peak to Average Power Ratio is expressed as

$$PAPR_{dB} = 10\log(\frac{\max[x(t)x*(t)]}{E[x(t)x*(t)]})$$

Here, E is the signal expectation, and |X(t)| is the magnitude of the X(t). where max represents the maximum value over time, E[.] represents the expected value or average over time, and | | represents the magnitude of a complex quantity

An essential consideration in the layout of multicarrier communication systems is the PAPR, which is a measurement of the distortion brought on by non-linearities in the transmitter and receiver. A high PAPR can cause inter-symbol interference (ISI) and signal distortion, which can impair the system's performance. As a result, lowering the PAPR is frequently an objective while designing multicarrier communication systems, and many methods are employed to do so.

5.3 SNR vs BER IN FBMC

In FBMC, the SNR can affect the overall system performance, as it directly impacts the quality of the received signal. A higher SNR generally results in a better quality of the received signal and lower BER.

BER refers to the probability that a bit is incorrectly received. It is affected by various factors, including channel noise, interference, and distortion. In FBMC, a lower BER indicates a better performance of the communication system.

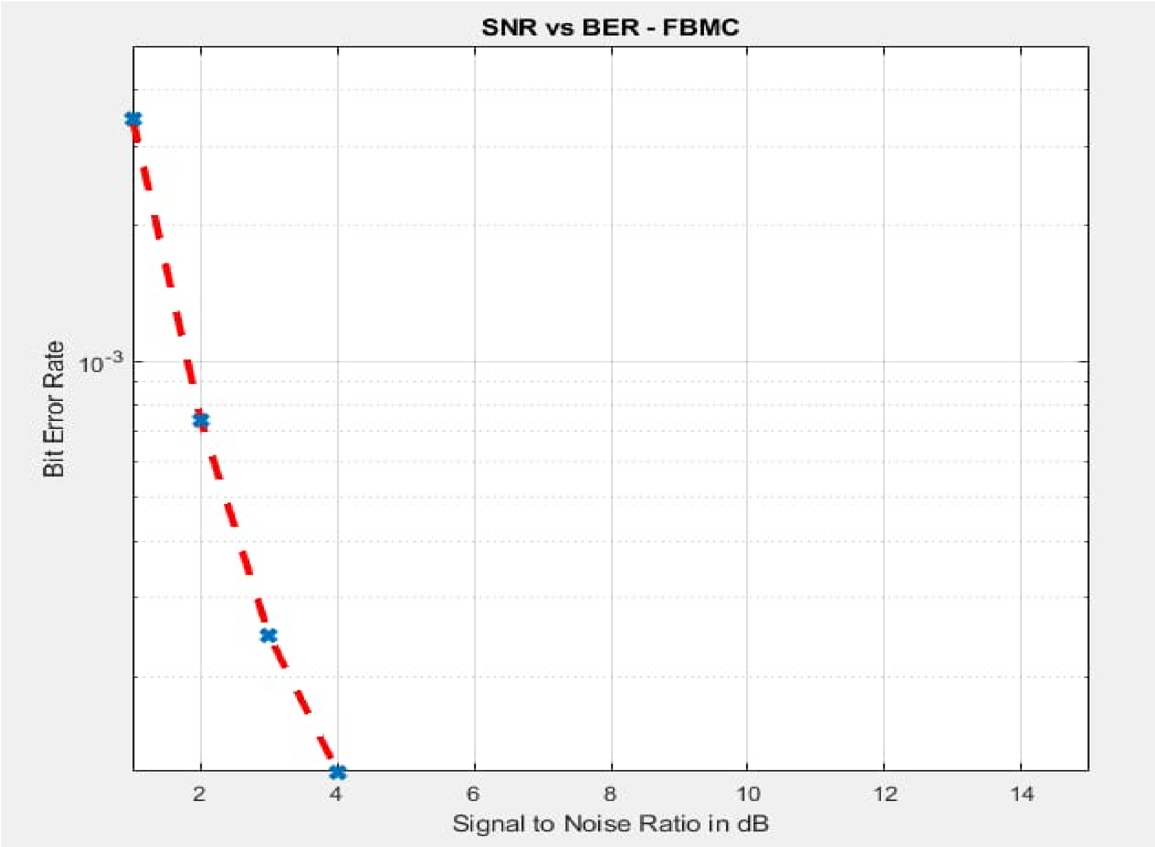

Fig 13:SNR vs BER

This ratio is closely related to the Signal-to-Noise-Ratio (SNR), that is measured in decibels (dB). A high SNR is necessary for a low BER. The BER will be higher if the SNR is weak. Simply put, a strong signal is better to a weaker one since it is less likely to include false information.

In an FBMC system, the BER can be affected by various factors, such as the filter bank used, the modulation scheme, the coding scheme, and the channel characteristics. The filter bank used in an FBMC system can affect the BER performance because Inter-carrier interference (ICI) and inter-symbol interference (ISI) can be introduced, which can reduce the signal quality and raise the BER.The modulation scheme used can also affect the BER because it establishes the symbol's bit rate, and a higher number of bits per symbol can lead to a higher BER.

CHAPTER 6

VIVADO

6.1 Introduction to Vivado

Xilinx created the full software package Vivado for designing, implementing, and verifying digital circuits. It is a potent tool for building complicated systems on PLDs like FPGAs and SoCs, which are programmable logic devices.Using Vivado, designers can use a variety of design tools and approaches to build and improve complex digital circuits. It offers a hardware-description language (HDL) designer for individuals who prefer to use code-based designs along with a GUI (graphical user interface) for creating and revising hardware designs.

Vivado also offers a wide range of simulation tools, including behavioral, functional, and timing simulation. This enables designers to test and verify their designs before implementation, reducing the risk of errors and improving the efficiency of the design process. One of the key features of Vivado is its high-level synthesis (HLS) capability, which allows designers to use C, C++, and SystemC code to create digital circuits. This feature is particularly useful for designers who are not familiar with traditional HDLs such as Verilog and VHDL.

Vivado includes a synthesizer, place-and-route engine, and bitstream generator, which enables designers to create optimized and efficient FPGA designs. Vivado also supports a range of development boards and platforms, making it easy to prototype and test designs on real hardware.

6.2 Key components of the Vivado system

1.Vivado Design Suite:

This is the main software tool for designing and implementing digital circuits on FPGA and SoC devices. For developing & verifying circuits using Verilog or VHDL are two examples of hardware description languages (HDLs) it offers a graphical user interface.

2.Vivado High-Level Synthesis:

This is a tool that allows designers to specify their designs in C, C++, or SystemC and automatically generates optimized RTL code.

3.IP Catalog:

This is a library of pre-designed functional blocks that can be used in a design. The IP catalog includes blocks for memory controllers, communication interfaces, video and image processing, and other common functions.

4.Vivado Simulator:

This is a comprehensive verification environment that allows designers to simulate their designs, perform functional and timing analysis, and debug issues in the design.

5.Vivado Implementation:

This is a tool for implementing the design on the target FPGA or SoC device. It includes features for placement, routing, and timing analysis.

6.Vivado Debugging and Profiling:

This includes advanced debugging and profiling tools that allow designers to analyze the performance and behavior of their designs, identify bottlenecks, and optimize the design for performance and power.

6.3 VIVADO SYSTEM DESIGN

Vivado provides a complete system design solution for FPGA and SoC devices.

1.Design Entry:

Vivado supports several methods for entering the design, including graphical design entry, HDL design entry, and IP integrator. Designers can use these methods to create the system architecture and specify the functionality of each component.

2.IP Integration:

Vivado includes an IP integrator tool that allows designers to integrate IP cores into their system design. The tool provides a graphical interface for connecting and configuring IP cores and simplifies the process of integrating complex IP blocks.

3.Hierarchical Design:

Vivado supports hierarchical design, which allows designers to break a large design into smaller, more manageable blocks. Hierarchical design makes it easier to understand and modify complex systems and enables teams to work on different parts of the design simultaneously.

4.System Validation:

Vivado provides a comprehensive system-level validation environment that allows designers to test and validate their system design. The environment includes simulation, debugging, and verification tools that enable designers to ensure that the system meets its requirements and specifications.

5.Embedded System Design:

Vivado supports embedded system design by allowing designers to create and integrate software with their FPGA or SoC design. The tool provides a complete solution for creating and debugging embedded software, including support for debugging and profiling.

6.Vivado Desktop:

The Vivado desktop is the graphical user interface (GUI) of the Vivado software tool suite. It provides a user-friendly environment for designing and verifying complex hardware systems using FPGAs and SoCs.The Vivado desktop consists of several windows, menus, and toolbars that allow designers to create, edit, and simulate their hardware designs. The main window is the Project Manager, which provides a hierarchical view of the design and its associated files. This window allows designers to add and remove design files, create new files, and organize their design into a logical hierarchy.

The Vivado desktop also includes a source code editor that allows designers to create and edit hardware description language (HDL) code, such as VHDL and Verilog. The editor provides syntax highlighting, code folding, and other features to make writing and editing code easier and more efficient.

Another key feature of the Vivado desktop is its simulation capabilities. The software includes a built-in simulator that allows designers to test and verify the functionality of their designs before implementation. The simulator can be used to test the design using test benches, waveform viewers, and other tools to ensure that the design is working as intended.

The Vivado desktop also includes a range of design automation tools that can help designers to optimize their designs, reduce design time, and improve design quality. These tools can automate many of the design tasks, such as placement and routing, timing analysis, and power optimization.

7. Getting Vivado help:

Xilinx Documentation: Xilinx provides extensive documentation for Vivado, including user guides, tutorials, and reference manuals. You can access the documentation from the Xilinx website.

Xilinx Community Forums: The Xilinx community forums are a great resource for getting help with Vivado. You can ask questions and get answers from other users and Xilinx experts.

Xilinx Technical Support: If you have a specific technical issue or question, you can contact Xilinx technical support. You can submit a support case through the Xilinx website or contact them by phone.

Online Training: Xilinx offers online training courses that cover various aspects of Vivado, from basic design flow to advanced optimization techniques. These courses are available for free or for a fee, depending on the level of access you require.

Third-Party Training: There are also third-party training providers that offer Vivado training courses. These courses may be more specialized or tailored to specific industries or applications.

6.4 KEY FEATURES OF VIVADO SYSTEM

Vivado is a comprehensive tool suite for designing and implementing programmable logic devices such as FPGAs and SoCs. It offers a range of features that make it a powerful tool for designing complex hardware systems. Some of the key features of Vivado are:

1.High-Level Synthesis (HLS):

One of the key features of Vivado is its HLS capability. HLS allows designers to create hardware designs using high-level programming languages like C, C++, and SystemC. This feature can significantly reduce design time and improve productivity by allowing designers to focus on the functionality of the design rather than the implementation details.

2.IP Cores:

Vivado includes a suite of pre-designed Intellectual Property (IP) cores that designers can use to accelerate the development process. These IP cores are pre-verified, reusable blocks of code that can be integrated into a design to provide additional functionality without the need to create the code from scratch.

3.Design Flow Automation:

Vivado provides a highly automated design flow that can help designers to reduce design time and improve design quality. The software includes a range of design automation tools that can optimize the design process and improve the quality of the design.

4.Debugging and Verification:

Vivado includes a range of debugging and verification tools that can help designers to identify and fix design issues. The software includes a built-in simulator that allows designers to simulate their designs and verify their functionality before implementation. It also includes a range of debug tools that can help designers to identify and fix issues in their designs.

5.Implementation:

Vivado provides a range of implementation tools that can help designers to implement their designs on FPGA and SoC platforms. The software includes a place and route tool that can optimize the placement and routing of the design to improve performance and reduce power consumption. It also includes a timing analyzer that can help designers to identify and fix timing issues in the design.

6.5 Disadvantages of Vivado

Vivado is a widely used software suite for designing and programming FPGAs and SoCs. While it offers many benefits and advantages, there are also some potential disadvantages to using Vivado:

Steep Learning Curve:

Vivado is a complex software suite with a steep learning curve. Beginners may find it difficult to use, and even experienced users may need time to master all of its features.

High System Requirements:

Vivado requires a high-performance computer with a significant amount of RAM and processing power. This can be a significant investment for some users, especially hobbyists or small businesses.

Expensive License:

Vivado requires a license to use, and the cost can be high, especially for the full-featured version. While there is a free version available, it has some limitations and may not be sufficient for more complex designs.

Limited Compatibility:

Vivado only supports a limited number of FPGA families, and not all devices from those families are supported. This can be a limitation for designers who need to work with specific hardware.

Proprietary Software: Vivado is a proprietary software suite, which means that users are dependent on the vendor for updates, bug fixes, and new features. This can be a disadvantage for users who prefer open-source software or who want more control over their tools.

CHAPTER 7

VIVADO RESULTS

7.1 Implementation of Filter Bank Multi-Carrier (FBMC) modulation in Vivado

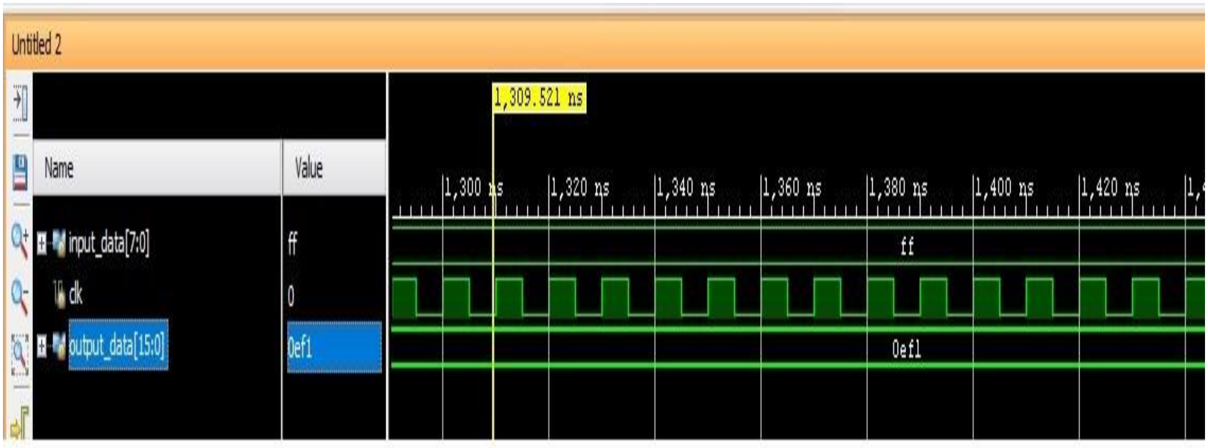

Fig 14: FBMC modulation in Vivado

To implement the prototype filter of FBMC in hardware, the filter designed in MATLAB needs to be realized using a hardware description language (HDL) such as Verilog or VHDL. Vivado is an integrated development environment (IDE) provided by Xilinx that allows designers to develop and simulate digital circuits using HDLs.

Figure 14 shows the analog input, output, and clock signal of the filter of FBMC with the adjusted analog signal format in Vivado. The analog input is the signal that needs to be filtered. The analog output is the filtered signal. The clock signal is a periodic signal that controls the timing of the filter's operation.In Vivado, the analog signal is represented as a digital signal by quantizing the analog values to discrete levels. The number of bits used for quantization determines the resolution of the digital representation. The analog signal is then fed into the filter, which performs the filtering operation on the digital representation of the signal. The filtered digital signal is then converted back to analog form to obtain the analog output signal.

The clock signal is used to synchronize the operation of the filter with the other components of the system. The clock signal determines the rate at which the filter processes the input signal. In Vivado, the clock signal is a digital signal with a constant frequency.The adjusted analog signal format in Vivado refers to the specific way in which the analog signal is represented as a digital signal. This includes the number of bits used for quantization, the sampling rate, and the encoding scheme used to represent the analog values as digital values.

In summary, Figure 14 illustrates the analog input, output, and clock signal of the filter of FBMC with the adjusted analog signal format in Vivado. This format refers to the specific way in which the analog signal is represented as a digital signal, and it determines the resolution, sampling rate, and encoding scheme used for the digital representation. The clock signal is used to synchronize the operation of the filter with the rest of the system.

7.2 Schematic obtained from Vivado for FBMC

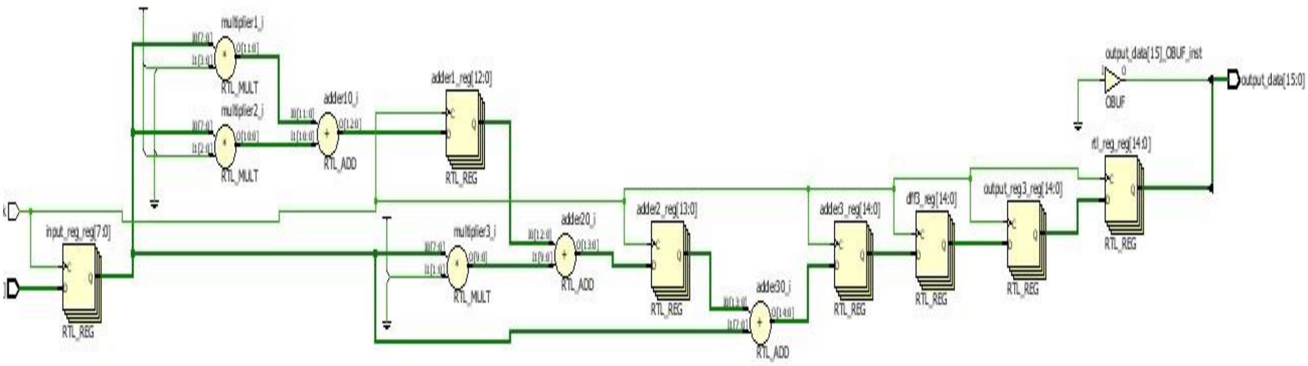

Fig 15: Schematic obtained from Vivado for FBMC

The prototype filter of FBMC is a complex digital signal processing filter that uses a filter bank to modulate and demodulate data on each sub-band. To implement the filter in hardware, a digital circuit design is required that consists of various hardware components such as D-type flip flops, RTL multipliers, RTL adders, and RTL registers.

Figure 15 shows a representation of the PHYDYAS prototype filter of FBMC designed with hardware fittings. The fittings include a complex structure with 45 cells, 25 I/O ports, and 75 nets.

The cells represent the individual hardware components that make up the filter circuit. The number of cells in the circuit depends on the complexity of the filter and the number of sub-bands used in the FBMC system. The cells may include various types of logic gates, flip flops, multiplexers, and other digital circuits. The I/O ports represent the input and output connections of the filter. The number of I/O ports depends on the number of sub-bands and the input and output data format used in the FBMC system. The I/O ports may include clock signals, data signals, and control signals.

The nets represent the interconnections between the cells and the I/O ports. The number of nets depends on the complexity of the filter and the number of connections required between the cells and the I/O ports. The D-type flip flops are used to store and synchronize digital data signals in the circuit. The RTL multipliers and RTL adders are used to perform digital signal processing operations such as multiplication and addition. The RTL registers are used to store intermediate results and synchronize the data flow through the filter.

In summary, Figure 15 shows a representation of the prototype filter of FBMC designed with fittings. The fittings include a complex structure with cells, I/O ports, and nets. The cells represent the individual hardware components such as D-type flip flops, RTL multipliers, RTL adders, and RTL registers. The I/O ports represent the input and output connections of the filter, while the nets represent the interconnections between the cells and the I/O ports.

CHAPTER 8

CONCLUSION

8.1 Conclusion:

Future wireless communication systems might profit from the modulation technique known as Filter Bank Multicarrier/Offset Quadrature Amplitude Modulation (FBMC/OQAM). The design of FBMC/OQAM modulation involves several important considerations. The choice of prototype filter is critical for achieving good performance in relation to spectral containment, bandwidth efficiency, robustness to channel impairments. Root Raised Cosine (RRC) filters are commonly used in FBMC/OQAM systems because they can achieve a good trade-off between the bandwidth efficiency and inter-carrier interference (ICI) reduction. Gaussian filters and Nyquist filters are also popular choices, depending on the specific requirements of the application.

OQAM method application is essential for achieving great spectrum efficiency and low ICI. The OQAM technique involves splitting the subcarriers into real and imaginary parts and applying separate filters to each part. This technique ensures orthogonality between the subcarriers and eliminates the need for a guard interval to prevent inter-symbol interference. The choice of modulation scheme affects the manifestation of the system in relation to spectral efficiency, power efficiency, robustness to noise and interference. Phase Shift Keying (PSK) and QAM, or quadrature amplitude modulation, are frequently utilised in FBMC/OQAM systems because they provide good performance and low complexity.

The design of FBMC/OQAM modulation involves careful consideration of several factors, including the choice of prototype filter, implementation of the OQAM technique, and choice of modulation scheme. These factors should be optimized to achieve the desired performance metrics, such as bandwidth efficiency, spectral containment, and robustness to channel impairments. In order to achieve high-performance wireless communication, it is essential to design and implement the FBMC/OQAM modulation scheme, which is a potential modulation method for future wireless communication systems.

The prototyping and modeling of a prototype filter for FBMC involves several stages, including the layout of the filter in software, the implementation of the fbmc in vivado, and the testing and evaluation of the filter's performance.The modeling process can be done using simulation tools such as MATLAB/Simulink or specialized design software. The filter's performance can be evaluated using various metrics include the power spectral density, error vector magnitude, and bit error rate.

The implementation and of a prototype filter for FBMC is essential for ensuring the filter's functionality and its ability to meet the system's requirements. It can also provide insights into potential optimization and improvements that can be made to the filter's design.

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