Performance Analysis of Several Modulation Schemes Used in 5G Communicators, Such as FBMC, UFMC, and OFDM

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***Abstract*—**In recent years, Filter Bank Multi-Carrier (FBMC) has garnered significant attention as a compelling alternative to Orthogonal Frequency Division Multiplexing (OFDM). FBMC is lauded for its superior frequency efficiency, surpassing that of OFDM, while also exhibiting a reduced occurrence of out-of-band (OOB) emissions. However, FBMC does grapple with the challenge of a high peak-to-average power ratio (PAPR), a concern that has persisted from OFDM systems. To address this, FBMC has incorporated PAPR reduction techniques based on OFDM principles. Our project aimed to delve into an analysis of various modulation schemes, including FBMC, UFM, and OFDM, which are pivotal in the realm of 5G communications. We assessed critical aspects like PAPR, Bit Error Rate (BER), Spectral Density, and Spectrum Efficiency to gauge the efficacy of these modulation techniques. Furthermore, we explored the adaptability of these schemes to diverse wireless communication channels, thereby augmenting their utility. To assess the system's capacity for accommodating multiple users, we considered the potential integration of Multiple Input Multiple Output (MIMO) technology.
Keywords—OFDM, wireless Communication, FBMC, UFM

1. INTRODUCTION

Faster data rates, lower latency, and improved connection are just a few of the ways in which the introduction of 5G technology has revolutionized the telecoms industry. Multiple modulation techniques, each optimized for a distinct aspect of data transmission, form the backbone of 5G communication networks. Filter Bank Multi-Carrier (FBMC), Universal Filtered Multi-Carrier (UFMC), and Orthogonal Frequency Division Multiplexing (OFDM) are three modulation techniques that have emerged as frontrunners in 5G communication. These frameworks are essential to the functioning of 5G communicators because they provide novel solutions to the problems presented by the dynamic nature of the digital world. Explored here are the ideas underlying various modulation schemes, as well as their practical uses and potential impact on the future of wireless communication. Crucial modulation methods in the field of 5G communication systems include Filter Bank Multi-Carrier (FBMC), Universal Filtered Multi-Carrier (UFMC), and Orthogonal Frequency Division Multiplexing (OFDM).

FBMC is a promising modulation system that efficiently utilizes spectrum resources by using advanced filtering techniques to individual subcarriers, decreasing interference between them. This makes FBMC an excellent choice for applications where spectrum efficiency is paramount, such as in highly dense networks, IoT gadgets, and mission-critical communications. Low-latency communication and adaptability to varying channel conditions make it a desirable option for 5G networks.

In order to fulfill the requirements of 5G communication, UFMC is yet another novel modulation method. It supports dynamic frequency allocations and has adaptable filtering that makes it suitable for non-contiguous spectrum allocation. Because of its enhanced spectrum efficiency and increased interference protection, UFMC is well-suited to situations with erratic and shifting channel circumstances.

However, OFDM has been around for a while and is frequently used today. It has been an essential part of 4G networks and will continue to be so in 5G. The data stream is split up into several subcarriers and sent all at once using OFDM's multicarrier method. Although it uses more bandwidth than FBMC and UFMC, OFDM can adapt to a broad variety of channel circumstances and is hence very reliable. Since it strikes a good compromise between spectral efficiency and resilience, it excels in mobile broadband applications and situations. Modulation methods like FBMC, UFMC, and OFDM must be carefully selected and implemented for 5G communication systems to succeed. With the help of these various approaches, the 5G network will be able to handle a wide range of applications and usher in a new age of high-speed, always-on, and low-latency wireless communication. The strategic use of these modulation schemes will continue to play a pivotal role in determining the course of global communications as technology advances.

The distinctive characteristics and optimal application domains of various modulation methods become clear upon closer inspection.

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When spectrum efficiency is critical, FBMC's sophisticated filtering mechanisms shine. This makes it an attractive option for Internet-of-Things (IoT) devices, which often function in low-bandwidth settings and necessitate low-power connectivity. Because of the need of real-time data transmission in fields such as driverless cars and industrial automation, FBMC's ability to enable low-latency communications is also critical.

In diverse and dynamic networks, UFMC's spectrum management flexibility in handling non-contiguous spectrum allocations is invaluable. For instance, UFMC can change by intelligently distributing subcarriers, making the most of available bandwidth in urban areas where network operators may need to efficiently deploy spectrum resources in response to fluctuating traffic needs. It's also compatible with several services, so it can handle both high-volume data transfers and time-sensitive conversations without a hitch. Since OFDM has been tried and tested, it is employed in many different 5G implementations. It is particularly well-suited for mobile broadband communications, where the ability to deal with complex channel circumstances, such as high mobility and urban settings, is essential. Network operators that want to develop their networks with little disturbance and cost might use OFDM because of the technology's maturity and widespread acceptance.

In essence, FBMC, UFMC, and OFDM reflect several aspects of 5G communication, each of which caters to a unique set of requirements and concerns. Strategically deploying these modulation schemes is crucial to the success of 5G because it ensures the technology can deliver on its promises across a wide range of applications, from ultra-reliable low-latency communications to huge machine-type connectivity. The careful selection and implementation of these modulation schemes will remain important to the continuous development of next-generation wireless networks, even as the 5G environment continues to change and diversify.

2. LITERATURE SURVEY

Robin Gerzaguet et. All (2017) Future 5G systems will need to be able to adapt to a wide variety of mobile network deployment circumstances, which will need the efficient and adaptable utilization of non-contiguous unused spectrum. To achieve the highest levels of SE, 5G air interface technology will need to be adaptable and capable of mapping different services to the most optimal frequency and radio resource configurations. Alternatives to standard CP-OFDM have so been widely investigated in the past several years. Multiple alternatives for the 5G multicarrier waveform (OFDM, UFMC, FBMC, GFDM) have been compared fairly in this study by using a standardized framework. The computational complexity, computational complexities, power spectral density, and SE of the various waveforms have been evaluated. Different parametrization and configurations of the waveforms' resistance to interference in an asynchronous multi-user uplink situation have also been explored [1]

Ali J. Ramadhan (2022) The purpose of this research was to determine which waveforms are appropriate for 5G by comparing their performance to that of OFDM and analyzing the results. The comparison was based on factors such as spectrum efficiency, tail problem, spectral confinement, mobility, latency, complexity, and compatibility with 4G (LTE). Despite F-OFDM's low spectral efficiency due to the absence of CP, simulation findings demonstrate that it obtained ideal results, showing that it can be readily implemented in 5G. Since F-OFDM demonstrated excellent adaptability, asynchronous transmission, a straightforward transceiver, reduced interference with adjacent subcarriers, and minimal OOB emissions, it is well-suited for use in any mMTC setting. The FBMC's low OOB emissions, low BER, and best-possible spectral efficiency were all attributable to OQAM modulation, despite the high transceiver complexity caused by the long filter length. This makes it the best option for eMBB and URLLC uses. In addition, UFMC's brief data burst capability and non-orthogonality deemed it a good fit for mMTC applications. [2]

Pooja Rani et. All (2017) Universal filter multi carrier (UFMC) is one of the potential multi carrier modulation approaches for future generation wireless communication systems. Since UFMC offers superior sub carrier separation similar to FBMC (Filer Bank Multi Carrier) and less complexity than OFDM (Orthogonal Frequency Division Multiplexing), it appears to be the most appealing option. However, a greater PAPR (Peak to Average Power Ratio) is a drawback of this method. In this work, we offer SC- UFMC, a hybrid PAPR reduction method that combines Selective Localization and Mapping (SLM) with Clipping. Filter length, FFT size, and Bits per sub carrier are only some of the design factors tested to determine how well the suggested method performs. Based on the simulation findings, the hybrid approach is superior than SLM and clipping in terms of PAPR reduction. In order to lessen the PAPR of UFMC signals, this research proposes a unique hybrid technique called SC-UFMC. Analysis and simulations demonstrate that the Hybrid scheme is superior to the more traditional SLM and Clipping methods for reducing PAPR in UFMC systems. In addition, the impact of several design parameters on

PAPR reduction in SC-UFMC has been studied, leading researchers to conclude that the suggested method is superior to more established approaches in this regard. [3]

Nilofer Shaik et. All (2022) The physical layer has to be rethought in light of the many new features of 5G MMIMO communications. While OFDM is an improvement over previous methods, it is far from perfect due to the presence of a number of problems when applied to realistic system characteristics. There is a cost, even if there are suggestions for alleviating difficulties by treating their symptoms rather than their causes. As a result, we rethought the filtered multicarrier paradigm and invented UFMC. Authors may be able to acquire the advantages of OFDM without any of its drawbacks if we use UFMC. UFMC is similar to OFDM in that it can handle fragmented bandwidth and has improved performance in coordinated multipoint transmission and greater SE. UFMC performs better than OFDM in low-latency, high-burst transmission scenarios, and it has the potential to provide complex orthogonality. In addition, this study covers the MELS CE method for the OFDM and UFMC system. When comparing UFMC with OFDM 5G systems, the suggested CE technique performs better for the former. In this study, authors focus on the BER and MSE metrics. In contrast to MMIO-OFDM systems, MMIO-UFMC systems' BER and MSE improve with increasing SNR. [4]

A.N. Ibrahim et. All (2017) The biggest thing that will happen in the mobile communication business is the debut of 5G mobile communication technology which is on schedule for deployment in 2020 in conjunction with the Olympic Games in Tokyo. The next evolution in communication technology is 5G mobile communications. In order to provide connection for a wide variety of applications, 5G mobile communication will need to vastly expand upon the capabilities of previous generations. These features allow for extremely fast data transfer rates, near-perfect uptime, and little lag. Additionally, users will be able to download a 1080p HD movie on their mobile phone in around one second using this 5G mobile communication technology, as well as 50GB video games within a minute. In order to replace OFDM with a multicarrier system based on filterbanks at both the receiver and transmitter, a new waveform approach called filterbank multicarrier communication (FBMC) has been developed for use in future 5G mobile communication technologies. Additionally, OFDM's bandwidth efficiency is diminished due to the CP extension's need. Compared to FBMC, which is less sensitive to the carrier frequency offset, OFDM struggles to keep up with the growing number of mobile users. [5]

Jean-François D. Essiben et. All (2021) Authors have analyzed the efficiency of potential new waveform options for 5G mobile communication systems, including FBMC, UFMC, and F-OFDM. For 5G, we have modeled a number of critical metrics, including power spectrum density and peak-to-average power ratio, using our custom-built simulator. The power spectral density of the three choices has been proven to be less than that of OFDM. The ratio of their peak to average power has also been studied. All numerical findings save for F-OFDM demonstrate that the PAPR of the three waveform options is greater than that of OFDM. The FBMC appears to be the optimal compromise due to its reduced architecture and the obtained values of PAPR and PSD. However, the Bit Error Rate in Additive White Gaussian Noise (AWGN), the Rayleigh and Rician Fading Channel, and the complementary cumulative distribution function are all necessary for a comprehensive performance evaluation. [6]

Aasawari Gawali et. All (2019) In order to create a new waveform for 5G communications with a higher Spectra Efficiency ratio and a lower peak/average power ratio: This paper compares and contrasts the performance of orthogonal frequency division multiplexing (OFDM), filter bank multi-carrier (FBMC), and Universal multi-conveyor filtered (UFMC) in terms of packet error probability (PAPR). Because OFDM uses a cyclic prefix, its spectral efficiency is low, however this may be increased by FBMC or UFMC. Individualized filtering is used. As the number of subcarriers grows, the PAPR decreases even more, as the cyclic prefix is no longer present. The PAPR shifts when different modulation methods are used. Application / improvements: UFMC is the best waveform approach for 5Gwhen compared to OFDM and FBMC, which will have less PAPR and PAPR is further lowered by using Optimization techniques. The project's end result will be an evaluation of the efficacy of 5 G communications using FBMC, UFMC, and OFDM modulation techniques. This aided in the acquisition of modulation technique efficacy with respect to metrics like PAPR, BER, spectral density, and spectral efficiency. Applying the modulation methods to other forms of wireless communication may further improve the situation. The system's capacity to support many users might be evaluated by using the MIMO functionality. [7]

Shatrughna Prasad Yadav et. All (2022) Future communication systems must meet the demands of ever-increasing data rates, more mobility, lower latency, and superior quality of service. Time-sensitive/time-engineered applications and support for a fully realized holographic society are among its promised benefits. When compared to both 4G and 5G mobile communication networks, its performance across the board will be far superior. Since the initial generation of mobile devices allowed for just voice calls, a lot has changed in the world of mobile communication. Though now 5G is still in its infancy stage, it is necessary to consider beyond 5G or more specifically on 6G of mobile communication systems. 6G's offerings are designed to facilitate social and individual transformation by enhancing data throughput, latency, synchronization, security, and dependability. In this study, authors look at how well a pulse-shaping-based FBMC modulation approach may function. The achieved channel capacity, signal-to-noise ratio, time-and-frequency responsiveness, out-of-band leakage, etc., are all significantly improved with the FBMC system. [8]

Mohammed I. Al-Rayif et. All (2020) This work proposes a comparative probabilistic approach, dubbed Dcomp-SLM, to reduce PAPR distortion in UFMC systems, making them suitable for use in 5G communications and beyond. The suggested approach is able to cope with the disadvantage of high PAPR and OOB radiation, concurrently, which arise when transmitting a multi-carrier signals. When compared to a standard SLM, the Dcomp-SLM improves the PAPR reduction of the transmitted UFMC waveform by around 1 dB. It also demonstrates a performance improvement in PSD of around 5 dBW/Hz compared to a standard UFMC system. Even with AWGN and Rayleigh fading channels present, the suggested technique only slightly deviates from the theoretical results in terms of BER and EVM. These findings validate the viability of the UFMC system and its potential application in the context of the multiband transmission utilized by 5G technologies. To that end, UFMC is a promising alternative to OFDM, the waveform currently utilized in LTE 4G communications. Realizing the UFMC system using the Dcomp-SLM technique can also take use of this work to boost data transfer speeds. [9]

Yukikatsu Fukuda et. All (2014) Four sets of people, two of whom were young and two of whom were older, provided the data. Due to the small sample sizes (17-20 patients per dataset) and the potentially large number of uncertainty contained, great care had to be taken in developing the machine learning system. Bayesian analysis and Markov chain Monte Carlo (MCMC) constitute the basis of the suggested technique. Across the four data sets, the range of prediction errors was 4.50-6.62. Since the STAI score might be anywhere from 20 to 80, the accuracy of the predictions seems to be rather good. There seems to be no major distinction between the young and the old in terms of their ability to forecast outcomes. The approach is useful since the gadget is lightweight (weighing just 100 g) and simple to set up. We are now working on a project to build a new algorithm to increase the reliability of predictions. In the future, we will provide an update on this. [10]

Rashmi B S et. All (2021) This project used OFDM, FBMC, and UFMC MIMO systems, all of which are 5G modulation methods. When compared to the previous generation's OFDM modeling technique, it is shown that FBMC and UFMC mimo systems perform better on a number of fronts, including bit error rate (BER), packet error rate (PAPR), spectral containment (where the FBMC and UFMC power spectral density was well located compared to OFDM), power consumption, throughput, and the ability to implement MIMO systems with only minor tweaks. Therefore, the complexity issue may be solved using a simple interference cancellation approach that yields satisfactory results in the usable practical SNR ranges. Since the BER output exhibits respectable behavior with the Iterative interference canceled on the FBMC and UFMC receivers, they may be suggested as a successor to the CP-OFDM. The BER efficiency may be improved to the point that interference is no longer a problem with very few repetitions. [11]

3. METHODOLOGY

3.1 MIMO-OFDM System

Several Inputs Several Results Multiple antennas are used for both transmission and reception in orthogonal frequency division multiplexing.

The MIMO channel is frequency-selective due to the multipath nature of the settings where greater throughputs are sought. OFDM might turn a frequency-selective MIMO channel like this into a collection of parallel frequency-flat MIMO channels and boosts the frequency efficiency also. As a result, MIMO-OFDM has been studied as a potential foundation for future wireless networks.

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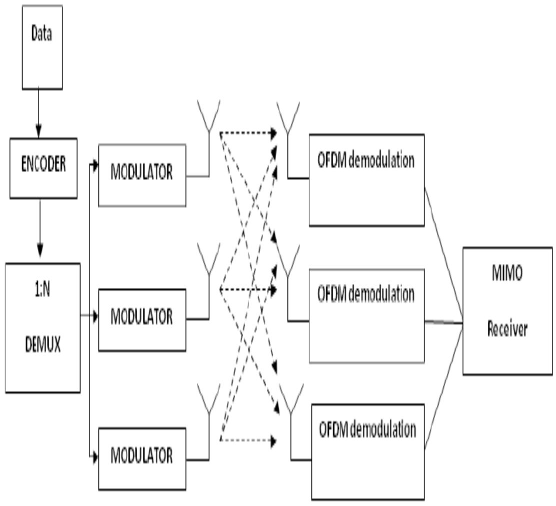

Figure: 1 "Block diagram of MIMO-OFDM System"

Transmission of symbols in space, time, and frequency is now stress-free thanks to MIMO wireless systems and orthogonal frequency division multiplexing (OFDM). The MIMO-OFDM technology takes advantage of the advantages of both MIMO and OFDM in multi-hop situations without the need for a base station's antennas. Mixing MIMO and OFDM processes will effect wireless LAN growth and is a primary choice for possible 4 G wireless communications systems. As a result, 4 G mobile communication systems that utilize MIMO-OFDM are increasingly popular. The result is a decreased Bit Error Rate (BER), increased communication dependability, and increased spectrum efficiency.

3.2 Transmission and reception of MIMO OFDM

The transmitting end makes use of a large number of antennas. In order to transmit data, OFDM modifies the incoming bit stream before sending it to the antennas. The received signal is analyzed by a signal detector until the original signal is restored.

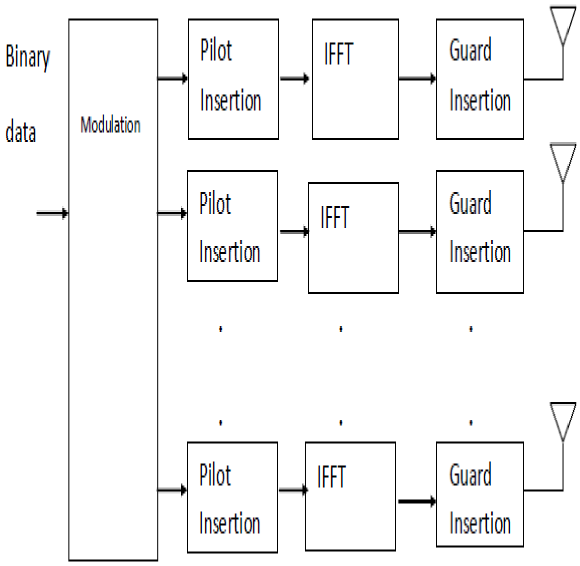

Figure: 2 "Transmission of MIMO OFDM System"

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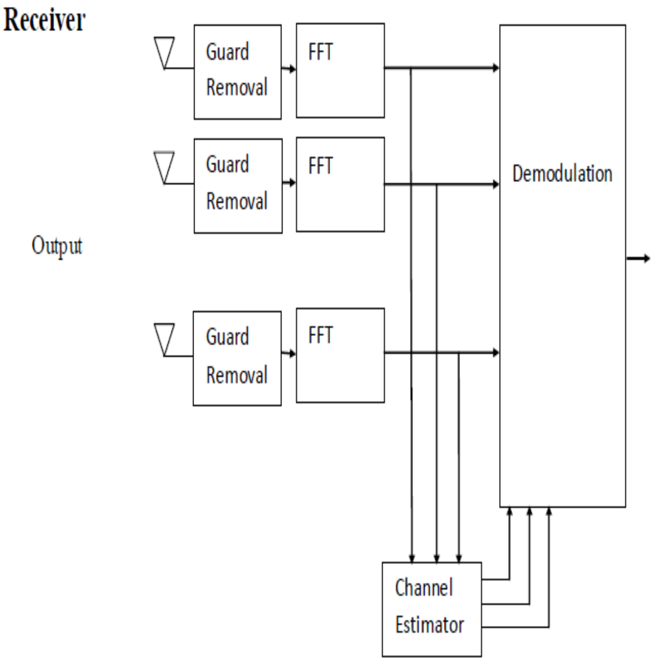

Figure: 3 "Reception of MIMO OFDM System"

In the realm of wireless communications, MIMO-OFDM is a tried-and-true, tried-and-true technique. The main benefit is the use of highly selective frequency channels to transmit a signal with low Bit Error Rates (BERs). One of the most valuable features of OFDM transmissions is its resistance to the propagation of multipath delays. This is achieved by using symbols with a very lengthy duration, which prevents any interference from occurring. The SNR or data rate can be improved by using MIMO. High-capability mobile wireless networks may be constructed using OFDM and MIMO. OFDM transforms the selective broadband frequency channel into a series of parallel flat fading channel, making it easier for the receiver to process the critical signal while increasing the channel power, or the maximum transmission rate.

Internet and multimedia services benefit greatly from MIMO OFDM's high bandwidth, extended reach, and dependability. Improve spectral electricity efficiency and optimize power efficiency in radio communications systems with a changeable, multi-way fading canal that increases variety and expands device capabilities over time. This system ensures that all users are treated fairly by maintaining uniformity in service standards and inaccurate bit rate and data rate.

3.3 UFMC

The UFMC community hypothesizes that FBMC and filtered OFDM (Filter Bank Multi-Carrier) are equivalent. Each subcontractor filters into the FBMC as part of the OFDM format, while the UFMC is a collection of subcontractor groups. In comparison to FBMC, filter length is reduced because to this list of subcontractors. UFMC can employ QAM that is compatible with already established MIMO strategies.

The whole N-band of subcontracting is broken down into smaller groupings. Not all of the subcontractors available for a given transmission should be used, as there is a finite number for each sub band. An IFFT n-point is shown for each sub band, with bear nulls embedded. Each sub-band's responses are summed together, and the filter length L is used to separate them apart. The filtering is designed to lessen the intensity of the band's dramatic discharges.

Notwithstanding in this paradigm, numerous filters can be arranged per sub-band. The corresponding filter is employed for each frequency band. The IFFT output for each sub band is filtered using a Chebyshev window with a specified side-projection constraint.

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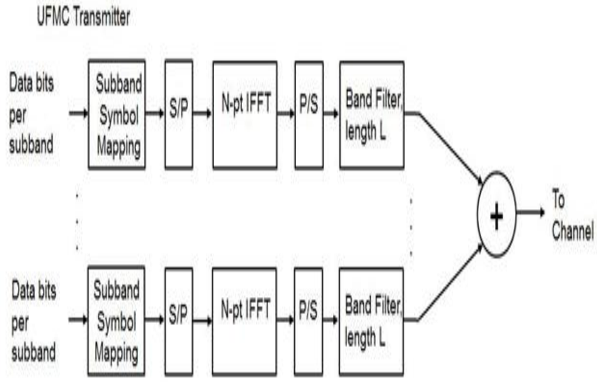

Figure: 4. "UFMC Transmitter"

The following illustration will show you the fundamentals of UFMC processing using FFT and OFDM. By filtering off the sub band, the window may be made to span the next power of two in the fast Fourier transform. One of the major lobes of the subcontractor is represented by each of the possible frequency values. In typical circumstances, the equalisation of the channel joint effect and the sub-band filtering are employed by a sub-carrier. Since channel effects are not modeled here, philtre equalization is the sole option. The chart below depicts the reception's processing.

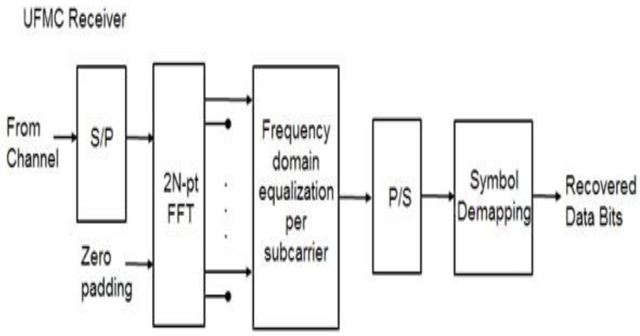

Figure: 5 "UFMC Receiver"

With improved spectral efficiency When compared to OFDM, UFMC is seen as preferable. The lower safeguards between sub bands and shorter philtre length make sub band filtering an attractive technology for quick explosions. This last quality distinguishes FBMC favorably from FBMC's lengthy filtering time.

4.4 FBMC:

FBMC filters a multi-carrier system for any subcarrier modulated signal. As with the other sub-filters, the prototype philtre is utilized for the zero-frequency carrier. The amount of overlapping multi-carrier symbols, denoted by K, is featured in the filters. The philtre represents the best of the best. The prototype philtre order is up for user discretion. In the most recent iteration of FBMC, frequency spreading is implemented. To do this, it employs an IFFT with N*K-length symbols that overlap N/2-delays, where N is the total number of suppliers. Because of its wide variety of features, evaluating FBMC and comparing it to other modulation systems is a breeze. Offset quadrature amplitude (OQAM) processing is utilized for full power. Because the imaginary portion of a complex data symbol is delayed by half the sign's duration, the symbol fails to express both the actual and imagined portions at the same time. The processing on the receiving end is depicted in the accompanying diagram.

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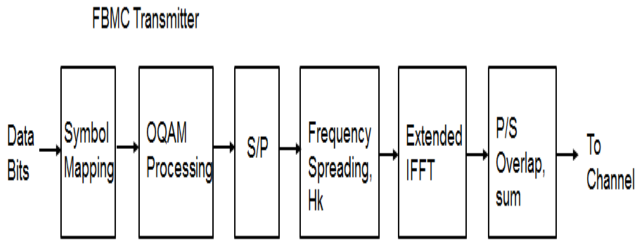

Figure: 6 “FBMC Transmitter”

In this example, we'll create a simple FBMC demodulator and calculate the BER without a channel. OQAM is filtered out and separated from the other received symbols as part of the processing. The rate of bit error that results from this breakdown is then defined. In the presence of the channel, linear multitap equalizers can be used to reduce the negative impacts of frequency-selective fading. The flowchart below details the reception processing.

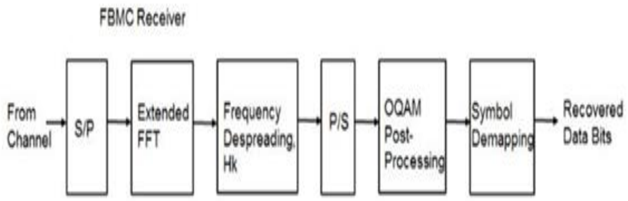

Figure: 7 “FBMC Receiver”

When compared to OFDM, FBMC is preferred because of the improved spectrum efficiency it offers. Subcarrier filtering causes a longer delay in filtering (in compared to UFMC), necessitating OQAM processing, which in turn necessitates adjustments to MIMO processing.

OFDM

OFDM is a method of transmitting multiple carriers over a frequency range that is separate for each of the substrates. Multiplexing often requires a series of filters to keep frequencies apart and prevent interference between different contractors. The OFDM, on the other hand, employs signal processing technology to get rid of this issue and the requirement for several filters altogether. This kind of OFDM is orthogonal. The OFDM system incorporates both a transmitter and a receiver. The signal is mapped to the proper constellation via a variety of modulation methods. In order to make use of OFDM, this serial data is transformed into a parallel data stream. There are N intermediaries involved in transporting the signs. Of course, an OFDM transmitter would have an IFFT section in it.

4. RESULT

4.1 Modeling Simulation and PAPR Reduction in 4G-OFDM System

We have modeled an OFDM network using the following settings in our testbed:

SNR=12, SPB=10, SPB/Carrier=10

The PAPR in this system can be kept to a minimum with the help of the PTS and the PAPR reduction algorithm we've devised. We've created SLM (Selective Mapping System) for that purpose. The lowered PAPR was compared to the original PAPR of the approach.

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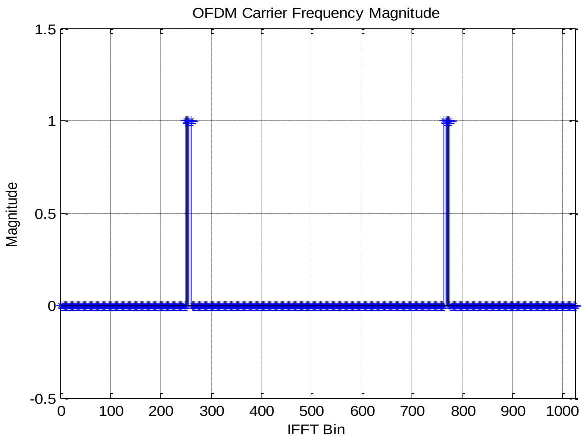

Figure: 8 "Plot of OFDM Carrier Frequency Magnitude"

The horizontal axis in Figure 7 is the IFFT bin, and the vertical axis is the OFDM Carrier frequency map. The magnitude is zero in all but two instances.

When the IFFT Bin size is 250 and the IFFT Bin size is 780, both have a magnitude of 1.

Figure 8 depicts the plot of the magnitude of the OFDM Carrier phases where the horizontal axis indicates the IFFT bin.

The process's size shifts between 250 and 780 between two different IFFT bin settings, as seen in figure 5.1.

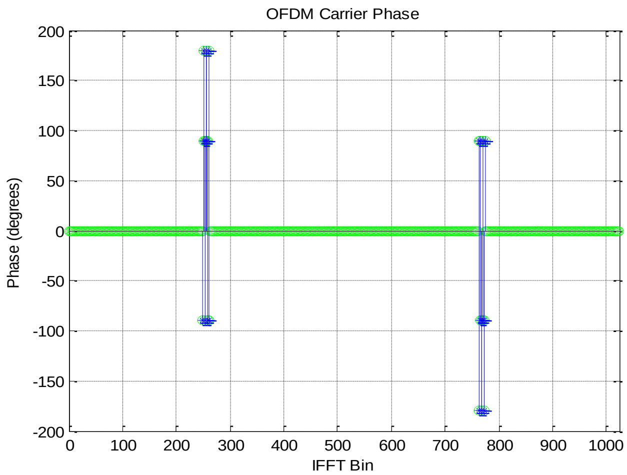

Figure: 8 "Plot of OFDM Carrier Phase Magnitude"

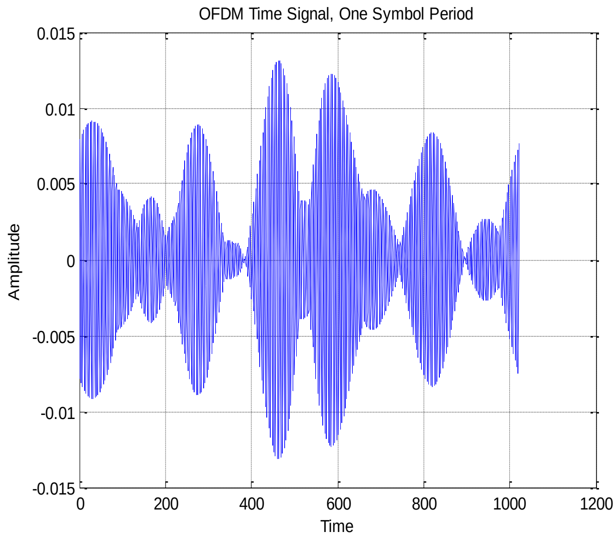

Figure: 9 "Plot of Period of Symbol"

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A plot of symbol duration is displayed in Figure 9. The horizontal axis represents time in seconds, while the vertical axis represents the strength of the signal. If you change the time by 0 degrees to 120 degrees per second, the amplitude will change from -0.015 to 0.015. The standard deviation of amplitude is about 600 seconds on average.

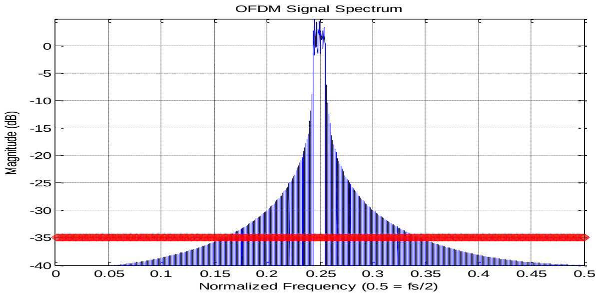

Figure: 10 “Plot of OFDM Signal Spectrum”

Figure 10 displays a spectral signal map for OFDM. The vertical axis shows the amplitude (in dB) of the signal while the horizontal axis shows the normalization frequency. There is a rise in magnitude of at least 0.5 now. The increase persists until the 0.25 Hz frequency is achieved, at which point the value is 5 dB. This value is currently decreasing and will soon reach the -40dB at 0.5 value at the lowest frequency.

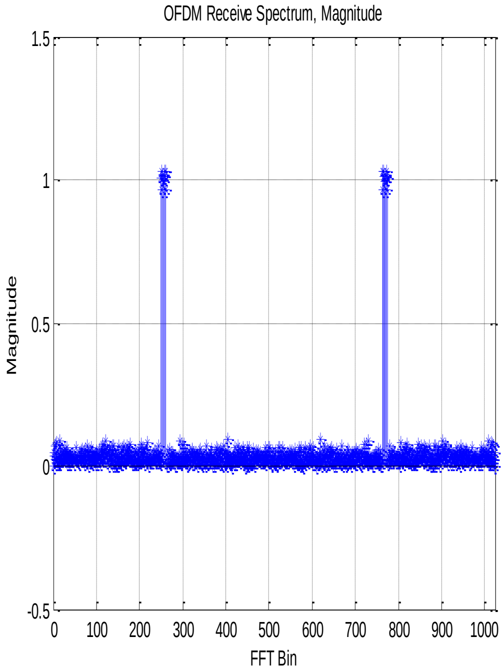

Figure: 11 "Plot of Received OFDM Signal Spectrum”

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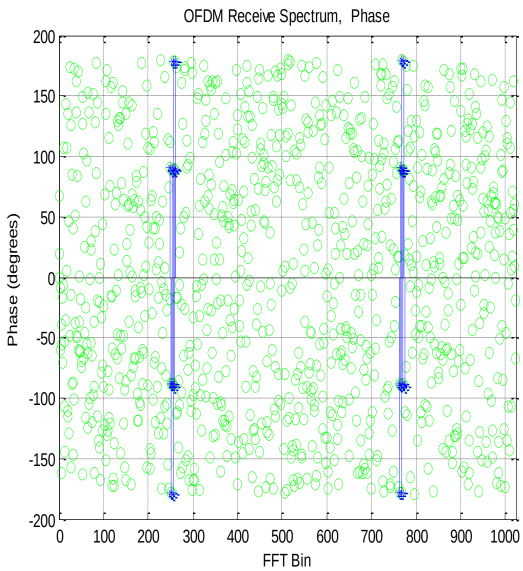

Figure: 12 "Phase of Received OFDM Signal Spectrum"

Until now, we had just plotted the graphs from the transmitter's end. We will now monitor comparable maps on the receiving end. Now the signal strength is shown along the vertical axis and the FFT Bin values along the horizontal axis. Obtaining an OFDM spectrum and plotting it is depicted graphically in Figure 11. The FFT bin values are plotted along the horizontal axis, while the time increments are shown along the vertical axis. Above, you can see the data for both steps 250 and 780.

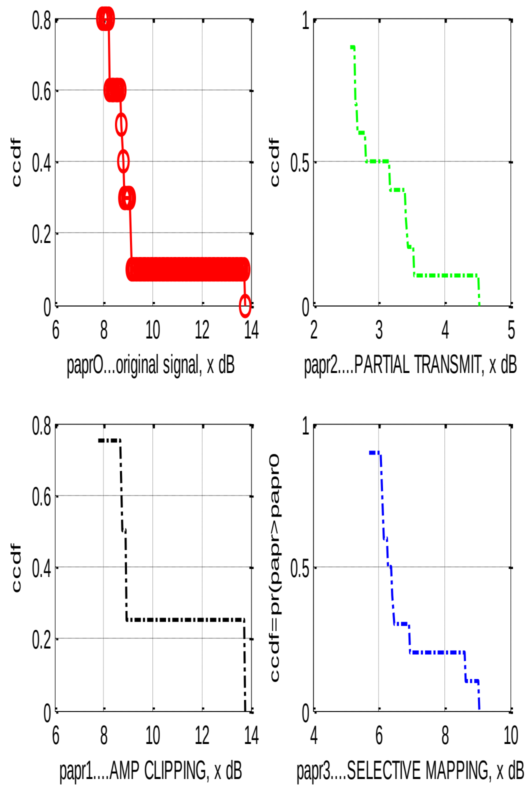

Figure: 12 "Performance Analysis of PAPR Reduction Techniques for the test system model"

Figure 12 displayed four plots of three separate techniques of PAPR reduction showing performance analysis

- Papr0- original signal
- Papr1-partial transmit

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- Papr2-AMP Clipping
- Papr3-Selective Mapping

5. CONCLUSION AND FUTURESCOPE

5.1 Conclusion

The goal of the project is to conduct in-depth research on the performance of several modulation schemes used in 5G communication systems, such as FBMC, UFMC, and OFDM. Utilizing metrics including Peak-to-Average Power Ratio (PAPR), Bit Error Rate (BER), Spectral Density, and Spectral Efficiency, this methodology helped evaluate the efficacy of various modulation schemes. Furthermore, the potential for advancement exists by expanding the application of these modulation approaches across varied wireless communication channels. To further assess the system's scalability, the option of implementing Multiple Input Multiple Output (MIMO) capabilities is being considered.

5.2 Future scope

Multiple promising future directions for this project are included in its current scope. First, as 5G networks develop, it will be important to expand the study of modulation schemes in 5G communicators to account for new modulation techniques and standards. For this, you'll need to be aware of and adapt to new developments in the industry.

More extensive and realistic testing can also help improve the assessment of modulation efficiency, which now takes into account characteristics including PAPR, BER, spectral density, and spectral efficiency. The performance of various modulation schemes under diverse settings and scenarios may be better understood with the addition of comprehensive simulations and field testing.

One possible direction is to use these modulation techniques in a larger variety of wireless communication channels. IoT, smart cities, and satellite communication are just a few examples of use cases that might benefit from modifying and enhancing the schemes.

The use of MIMO (Multiple Input Multiple Output) technology is another promising avenue for research. Assessing the system's ability to serve many users in different settings, such as highly crowded cities and sparsely populated rural areas, can yield useful information for expanding and bettering the network as a whole.

To sum up, this project's future goals include the ongoing growth of research and implementation of modulation schemes in 5G communication, with a particular emphasis on flexibility to new standards, field testing, a wide variety of use cases, and cutting-edge technologies like multiple-input multiple-output (MIMO). This continuing research and development will play a vital role in molding the ever-advancing environment of wireless communication.

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