International Journal on Recent Technologies in Mechanical and Electrical Engineering
ISSN: 2349-7947 Volume: 9 Issue: 3
Article Received: *28 June 2022* ***Revised:*** *24 August 2022* ***Accepted:*** *30 August 2022*

Investigations on PAPR and SER Performance Analysis of OFDMA and SCFDMA under Different Channels

Girraj Kumar Jangid[1], Ashish Kumar Sharma[2] and L. N. Balai[3]
[1]M. Tech. Scholar, Department of ECE, YIT, Jaipur
[2,3]Assistant Professor, Department of ECE, YIT Jaipur

Abstract: Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing are two multicarrier regulatory systems that have improved due to the growing demand in quick communication (OFDM). A frequency division multiplexing (FDM) plot called orthogonal frequency division multiplexing is utilized as a sophisticated multi carrier regulation approach.
Due to its excellent spectrum efficiency and low data rate, the single carrier multiple access system (SC-FDMA) is a unique radio transmission technique that is now employed in long-term evolution (LTE) technology for uplink. When compared to OFDM, reduced peak-to-average power ratio (PAPR) and error rate technique. PAPR performance has been obtained using Matlab simulation. Techniques using variable numbers of subcarriers include SC-FDMA and OFDMA. Two various subcarrier assignment strategies have been proposed, distributed FDMA Localized FDMA and (DFDMA) (LFDMA). IFDMA, or interleaved FDMA, is a DFDMA special situation when DFT results have been distributed consistently and at the same distance. When comparing the SC-FDMA variants, we discover that Localized has a higher PAPR than interleaved (FDMA) (FDMA). We also talk about the Performance of LFDMA and IFDMA's SER (Symbol Error Rate) and found that localized (FDMA) performs better in the SER than interleaved (IFDMA) method.

Keywords: *CDMA, SC-FDMA, PAPR, OFDMA, IFDMA, SER.*

1. INTRODUCTION

OFDM is an extraordinary type of multicarrier data carrier system used for information Exchange , which separates the whole frequency specific blurring channel into numerous orthogonal narrowband level blurring sub-channels, in which high-piece rate information stream is transmitted in equal over various lower information rate subcarriers in this way significantly lessening the ISI because of bigger image term. The key guideline of OFDM begins from the paper by Chang, and throughout the years various specialists have dealt with this method. Regardless of its calculated style, its utilization was at first restricted to military frameworks, for example, KINEPLEX, KATHRYN and ANDEFT because of its execution troubles. Weinstein and Ebert's proposition to utilize the Discrete Fourier Transform (DFT) to play out the subcarrier regulation with a solitary oscillator was a spearheading exertion. Ebert, Salz and Schwartz exhibited the adequacy of Cooley-Tukey fast Fourier transform (FFT) calculation to additionally decrease the computational unpredictability of DFT, in this way making it conceivable to use the OFDM procedure in business correspondence frameworks. Its utilization in business frameworks began with various wire-line norms, which included High piece rate Digital Subscriber Lines (HDSL), Asynchronous Digital Subscriber Lines (ADSL), and Very fast Digital Subscriber Lines (VDSL), to help a throughput upto 100Mbps. From that point, it has been used by remote gauges like DAB and WLAN, DVB and WMAN. In WMAN applications, OFDM is considered for the Worldwide Interoperability for Microwave Access (WiMax) usage by means of IEEE 802.16d, an, e norms. OFDM is additionally being considered for 3GPP Long term Evolution (LTE) and 3GPP LTE-Advanced. Without a doubt, OFDM can be a potential air interface possibility for group of people yet to come rapid remote correspondences frameworks. OFDM frameworks utilize cyclic prefix inclusion to wipe out the impact of ISI and require a basic one-tap equalizer at the less than desirable end. OFDM gets unmatched transfer speed reserve funds prompting higher otherworldly productivity. These properties make OFDM framework incredibly alluring for rapid remote applications. In OFDM frameworks diverse regulation plans can be utilized on singular sub-carriers which are adjusted to the transmission conditions on each sub-carrier.

Although OFDM is widely accepted, it also has disadvantages:

- OFDM signals with their high Peak to-Average power proportions (PAPRs) require exceptionally direct enhancers. Something else, execution debasement happens and out-of-band power necessity will be upgraded.
- OFDM frameworks are more delicate to Doppler spread than single-carrier balanced frameworks.
- Phase clamor brought about by the defects of the transmitter and recipient oscillators debases the framework execution.
- Accurate frequency and time synchronization is required.
- Loss in otherworldly proficiency because of cyclic-prefix (CP) activity happens in OFDM frameworks.

2. LITERATURE REVIEW

[A. Hindy, 2020]proposed method of improving the multi-user (MU) multi-user (MIMO) input (MU) device efficiency is probably the biggest guarantee for conveying fifth-generation (5 G) systems. Downlink preceding mechanisms that balance execution and uplink overhead criticism are being discussed in the third generation partner project (3GPP) new radio (NR) standardization efforts. Most recently, for the downlink NR Release (Reel.) 15, the high-resolution pre-coder (Type-II codebook) was displayed, wherein channel state information (CSI) input is packed through space by misusing a DFT-based codebook structure. Increase of the NR Rel Type-II codebook. 16 which also violence recurrence linked to lower overhead critical CSIs are already being investigated. A diagram of some of Rel's progressive reforms is given in this article. 16 Codebook type-II is given. A feature methodology that employs multi-stage codebook boundary quantization with a variable quantizing resolution is proposed, where the resolution is linked to the adequacy assessments of the coefficients. The CSI critique, contrasted and a similar quantization resolution is better used with this approach for all the coefficients. System-level simulation results show that the approach proposed effectively lowers the CSI input overhead, without any noticeable impact on output.[1]

[Jing guo, 2019] stated that these days, the commercialization of 5G is going all out everywhere throughout the world. Massive MIMO, as one of the promising advancements, will be applied in 5G systems. In any case, different Massive MIMO gear structures and various 5G sending situations (for example, Dense Urban/Urban/Suburban/Rural) make the arrangement of Massive MIMO systems extremely entangled. Accordingly, how to settle on sensible decisions of Massive MIMO gear structures for various pragmatic organization situations is a key issue. In this paper, top to bottom investigates on current items are directed first and afterward system-level simulations for various Massive MIMO sending situations are performed to give sensible advices to Massive MIMO hardware choice with thinking about the tradeoff among cost and system execution. [2]

[VM Baeza and Armada, 2019]in his paper defines the need to assess an enormous number of channels in massive MIMO (mMIMO) has prompted the proposition of noncoherent (NC) detection, where the channel state information (CSI) isn't important. In this paper, we talk about the tradeoff between NC structures dependent on stage detection (PD) and those dependent on energy-detection (ED) for mMIMO as far as execution and unpredictability. Thus, we break down NC plans concerning their coherent partner. As a rule, the outcomes show that the PD ones are the most ideal alternative in regards to execution against the ED. In addition, we break down the blend of the two detection plans as an alluring arrangement at the exhibition level confronting the plans dependent on energy or stage, in return for

International Journal on Recent Technologies in Mechanical and Electrical Engineering
ISSN: 2349-7947 Volume: 9 Issue: 3
***Article Received:** 28 June 2022 **Revised:** 24 August 2022 **Accepted:** 30 August 2022*

increasing the multifaceted nature of the recipient. Likewise, we propose new star grouping plans for stage based detection multiuser NC-mMIMO systems which permit to multiplex an expanded number of users in a simpler manner. [3]

[Jean Baptiste et al, 2014]in his papersuggests for5G to adapt to a high level of heterogeneity as far as administrations and prerequisites. Among these last mentioned, adaptable and effective utilization of all accessible non-adjacent spectra for various system arrangement situations is one test for the future 5G. To amplify range effectiveness, an adaptable 5G air interface innovation fit for planning different administrations to the best reasonable blends of recurrence and radio assets will likewise be required. In this work, a reasonable examination of a few 5G waveform applicants (UFMC, FBMC-OQAM, and FBMC-QAM) is proposed under a typical system. Ghastly productivity, power phantom thickness, top to average force proportion and execution as far as bit blunder rate under different reasonable channel conditions are surveyed. The waveforms are then thought about in an offbeat multi-user uplink transmission. In light of these outcomes, so as to build the ghastly productivity, a piece stacking calculation is proposed to adapt to the non-uniform conveyance of the obstruction over the transporters. The advantages of these new waveforms for the anticipated 5G use cases are unmistakably highlighted. It is additionally focused on that a few ideas despite everything should be improved to accomplish the full scope of expected advantages of 5G. [4]

[Parnika Kansal and Ashok Kumar, 2017] in his paper stated that the multicarrier transmission strategies have been the most overwhelming one for the advancement of remote correspondence systems like 4G, Long Term development and now the replacement 5G. For 5G or fifth generation remote correspondence, Orthogonal Frequency Division Multiplexing (OFDM) and Filter Bank Multi carrier modulation (FBMC) are the prevailing waveform competitors. In this exploration paper, the impediments of OFDM have been tended to and it has indicated that filter bank multicarrier (FBMC) could be a more powerful arrangement. The near examination of FBMC and OFDM has been performed in light of Power Spectral Densities, sub channels; computational intricacy and model filter correlation reproduced utilizing MATLAB. [5]

3. PROBLEM DEFINITION

High PAPR and inter-carrier interference (ICI) are the two significant issues in the execution of an OFDM framework. The postulation targets investigating and showing up at proficient, low unpredictability plans for PAPR decrease in OFDM based frameworks (with and without ICI abrogation) for use. The main issue need to address aggressively in this theory is the high PAPR of an OFDM signal which has curbed badly the efficient usability. We start by investigating the current PAPR reducing methods and to discover the methodology that would enhance their points of interest and significant impediments for executing a down to earth OFDM framework in more efficient manner. Examination of productive PAPR decrease plans for an OFDM framework is along these lines considered as one of the difficult zones investigated in this proposal. OFDM brings every single significant advantage of a multicarrier plot yet dissimilar to single carrier regulation plans, it experiences the issue of ICI. In this postulation, we investigate the current ICI undoing plans and play out an examination of CIR and BER exhibitions. As examined over, the PAPR is a significant boundary that must be contemplated while structuring an ICI abrogation plot for the OFDM arrangement of reasonable use. Thus examination of PAPR execution of OFDM frameworks using ICI ,wiping out plans is additionally considered as another territory to be investigated in this proposition. Last point of this proposal is to recommend a hybrid plan for concurrent PAPR decrease and ICI crossing out in OFDM frameworks.

4. OBJECTIVES

- To implement system model for fourth generation multi input multi output OFDM System.
- To implement and visualize the performance of OFDMA and SC-FDMA in time domain on the basis of

International Journal on Recent Technologies in Mechanical and Electrical Engineering
ISSN: 2349-7947 Volume: 9 Issue: 3
***Article Received:** 28 June 2022 **Revised:** 24 August 2022 **Accepted:** 30 August 2022*

transmitted and received signal and characterization of power ratio.

- Design Simulation and investigation of different approaches of assigning subcarriers in the given system.
- To propose optimized solution for PAPR reduction and SER performance.

5. PROPOSED METHODOLOGY

Cellular communication has grown rapidly because of the demand of high data rates and throughputs. To support these demands of users a third generation partnership project (3GPP) has evolved a new technique called LTE/4G which uses orthogonal frequency division multiple access (OFDMA) technique for downlink communication and single carrier multiple access (SC-FDMA) technique for uplink communication. OFDMA and SC-FDMA techniques are modified forms of the orthogonal frequency division multiplexing (OFDM) and single carrier frequency division equalization (SC/FDE) techniques.

SC-FDMA is used in view of the fact that its peak-to-average-power-ratio (PAPR) is smaller and more constant. Moreover it has a similar throughput and essentially the same overall complexity as the orthogonal frequency division multiple access (OFDMA) system.

$$PAPR = \frac{\mathrm{m}\ |x(t)|^2}{E\{|x(t)|^2\}} \tag{5.1}$$

We analyze the different mapping schemes of OFDMA and SC-FDMA in time domain and compare their PAPR and SER characteristics. We see that IFDMA performs better in PAPR reduction but at a cost of high symbol error rate (SER) as compared to LFDMA.

5.1 System Model

The chain to generate an OFDMA signal starts by parallelizing the symbols that need to be transmitted, after they are modulated (in LTE the modulation can be QPSK, 16AQM, 64QAM). Then they are mapped to different subcarriers using either localised (LFDMA) or distributed (DFDMA) subcarrier mapping and then used as input bands for an inverse fast Fourier transform operation. This operation produces OFDMA symbols, which will be transmitted. Notice that a conversion from the frequency to the time domain was made when the IFFT was used. Before the transmission, however, a cyclic prefix is included in the OFDMA symbols as a guard interval to mitigate the inter-symbol interference through the transmission in the multipath channel.. These OFDMA symbols are then transmitted through a multipath channel and AWGN noise is added to simulate the noise in the channel. [22].

In SC-FDMA one extra module DFT is added before the IFFT module in the transmitter chain and IDFT is added in the receiver chain. This converts OFDMA chain into SC-FDMA chain. Without this two modules the chain is referred as OFDMA transmit and receive chain. At the receiver's end CP is removed which is further followed by FFT operation to convert the symbols from time domain back to frequency domain. Subcarrier demapping and demodulation is done to get back the original symbols. Also during simulation channel equalization was applied before demodulation to mitigate the effect of inter-symbol interference (ISI) introduced by the channel impulse response variation in order to decrease the probability of error.

International Journal on Recent Technologies in Mechanical and Electrical Engineering
ISSN: 2349-7947 Volume: 9 Issue: 3
***Article Received:** 28 June 2022 **Revised:** 24 August 2022 **Accepted:** 30 August 2022*

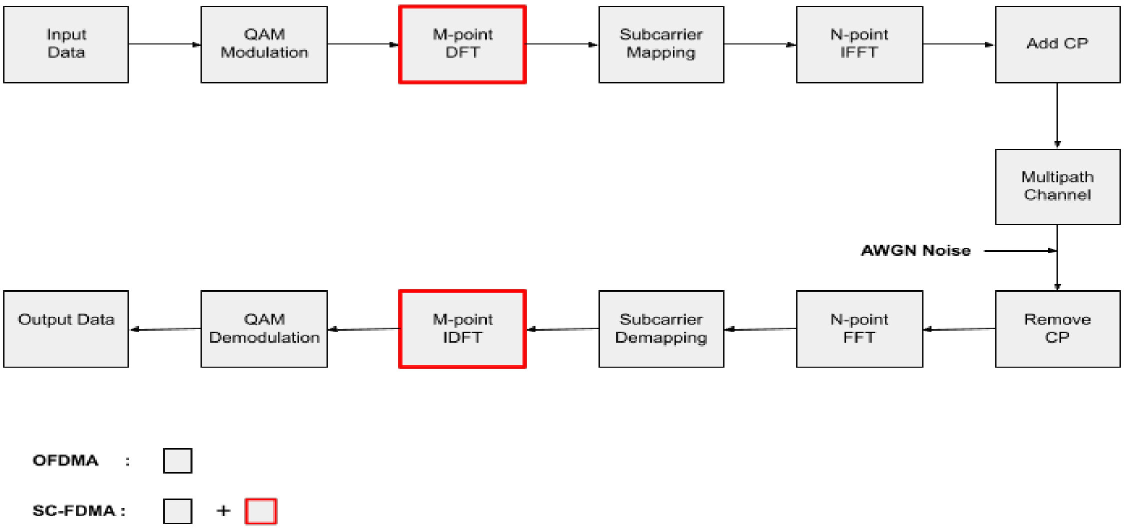

Figure 5.1 Model of OFDMA and SC-FDMA

In SC-FDMA before applying the IFFT, the symbols are pre coded by a DFT (Discrete Fourier Transform). This way each subcarrier after IFFT will contain part of each symbol. Also, intersymbol interference will be reduced since all subcarriers on a period of time represent the same symbol. Subcarrier mapping is one of the major considerations for LTE as multiple mobile terminals i.e. users are assigned by partitioned subcarriers in OFDMA system. In SCFDMA a subset of subcarriers is used to transmit its own data. The unoccupied carriers which are not used for transmitting its own data are filled with zero. If M is the number of subcarriers allocated to each user then, M point DFT is used for spreading purpose which will further be applied to the subcarriers of inverse DFT and the way of assigning the subcarriers to each terminal is the main key factor of the PAPR reduction. There are three subcarrier mapping schemes available for assigning M frequency domain symbols to the subcarriers in SCFDMA. They are - localized, distributed and interleaved subcarrier mapping. (interleaved is special case of distributed subcarrier mapping) DFT outputs are allocated to M consecutive subcarriers in the total N numbers of subcarriers (where N>M) in LFDMA. In contrast, in DFDMA, the M numbers of DFT outputs are distributed into the entire band. In both DFDMA and LFDMA zero amplitude is assigned to (N-M) unoccupied subcarriers. If the DFT outputs are distributed with an equidistance N/M=Q between the occupied subcarriers then the mapping mode is referred as the interleave FDMA (IFDMA), where Q is named as bandwidth spreading factor.

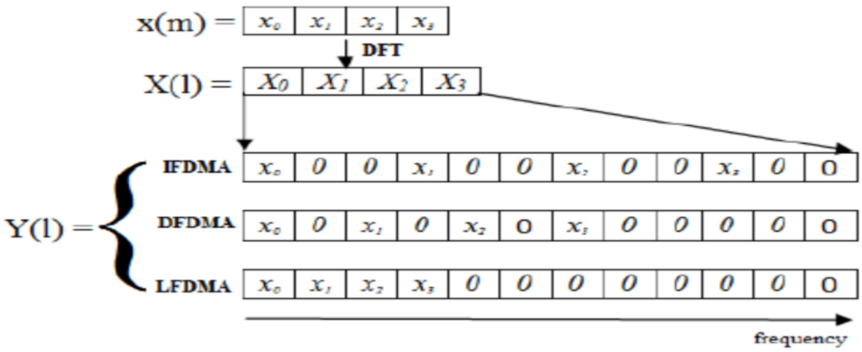

Figure 5.2 Example of different subcarrier mapping modes for M=4, Q=3 and N=12

In this work we have focused on the performance analysis of OFDMA and SCFDMA systems in terms of SER and PAPR. Three types of channel (pedAchannel, vehAchannel and AWGN channel) were introduced along with two types of subcarrier mapping (localised and distributed, IFDMA is a special case of DFDMA). For all types of channel , it was observed that LFDMA subcarrier mapping shows better SER performance than IFDMA and DFDMA subcarrier mapping because of its better immunity to multiple access interference (MAI). Also the SER performance for IFDMA subcarrier mapping is almost similar to that of DFDMA subcarrier mapping. Furthermore, in case of OFDMA system LFDMA sub-carrier mapping gave similar SER performance for pedAchannel and vehAchannel but a slightly better performance with AWGN channel. IFDMA subcarrier mapping and DFDMA shows similar performance with vehAchannel and AWGN channel but a slightly better performance with pedAchannel. In the SCFDMA system LFDMA subcarrier mapping gave best SER performance with vehAchannel with slightly reduced performance with pedAchannel and least performance with AWGN channel. IFDMA subcarrier mapping and DFDMA subcarrier mapping gave best performance with AWGN channel with slightly reduced performance with pedAchannel and least performance with vehAchannel. It was also observed that for all types of channel and subcarrier mapping, SER performance of SCFDMA is better than OFDMA systems. For OFDMA system, the PAPR performance of LFDMA and DFDMA is almost similar and IFDMA gives a better performance as compared to LFDMA and DFDMA in OFDMA. In case of SCFDMA system, the PAPR performance of LFDMA and DFDMA is almost similar in case of SCFDMA and IFDMA gives a better performance as compared to LFDMA and DFDMA in OFDMA. It was concluded that the PAPR performance of SCFDMA was significantly better in all three subcarrier mapping techniques i.e LFDMA, IFDMA and DFDMA, when compared to their counterparts in OFDMA.

6. RESULTS AND SIMULATION

The results have been simulated by taking into account the standard requirements. We have used the following data for our analysis:

- 64-QAM modulated signals
- FFT/IFFT length = 512
- Input-data block size = 32
- Cyclic Prefix (CP) Length = 20
- SNR ∈ [0, 30 dB]

To evaluate the SER performance of OFDMA System three different channels were used, which are pedAchannel, vehAchannel and AWGN channel. Furthermore, the SER vs SNR [dB] plots were plotted for 3 different subcarrier mapping : localised FDMA (LFDMA), interleaved FDMA (IFDMA) and distributed FDMA (DFDMA).

A. pedAchannel

International Journal on Recent Technologies in Mechanical and Electrical Engineering
ISSN: 2349-7947 Volume: 9 Issue: 3
***Article Received:** 28 June 2022 **Revised:** 24 August 2022 **Accepted:** 30 August 2022*

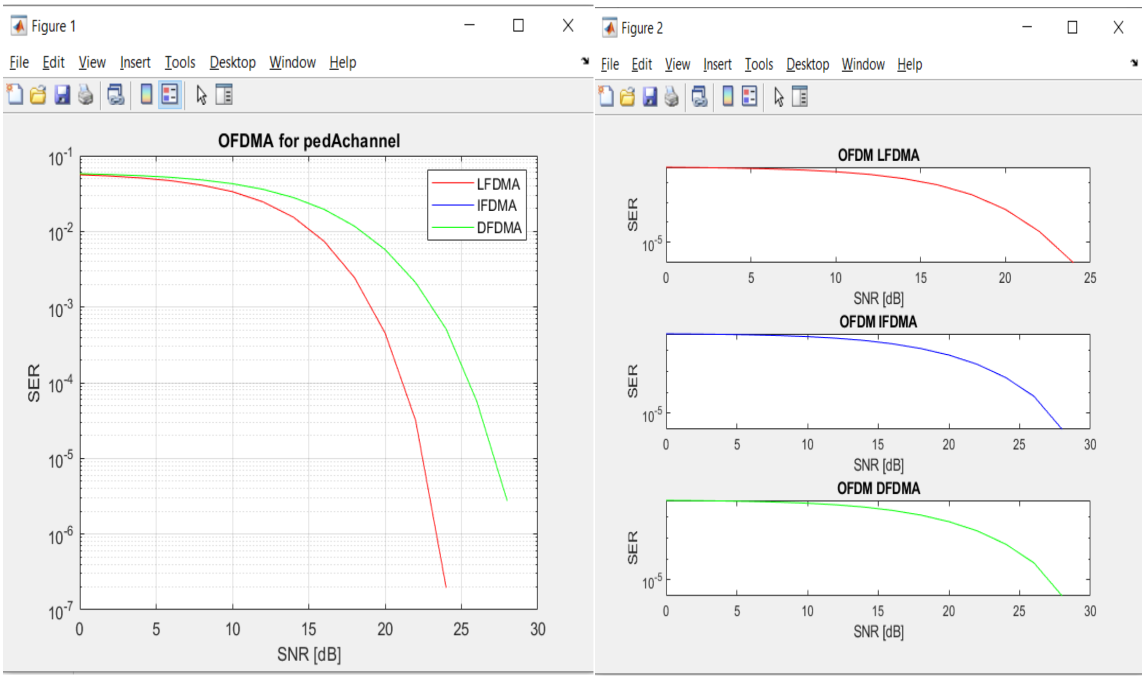

Figure 6.1: SER vs SNR [dB] for OFDMA in pedAchannel using LFDMA, IFDMA and DFDMA subcarrier mapping. (right side figure is added as a subplot to show the values as they are overlapped in left one)

While using pedAchannel for OFDMA we observe that the SER performance of LFDMA is better than IFDMA and DFDMA technique because of its robustness against multiple carrier interference. Also DFDMA and IFDMA are almost the same in their SER performance (and hence are overlapped when plotted in single figure).

B. vehAchannel

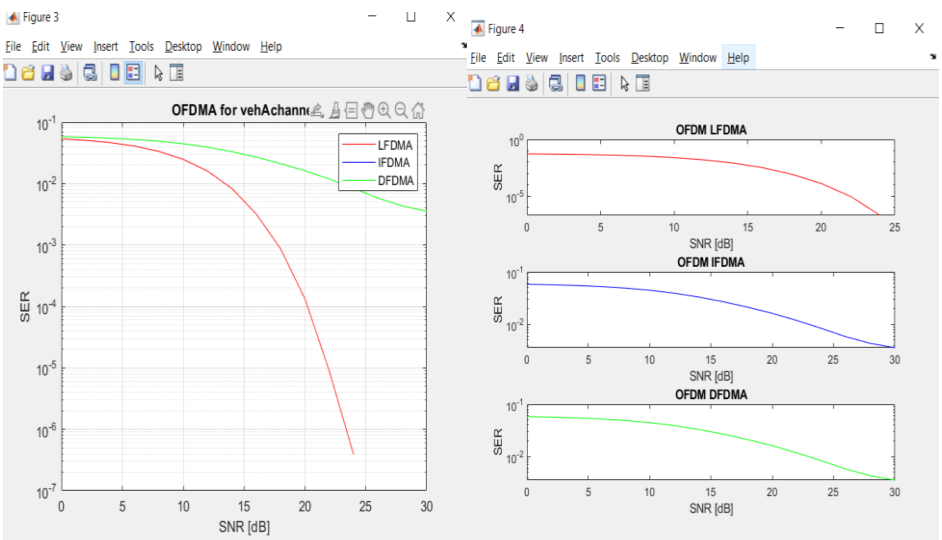

Figure 6.2: SER vs SNR [dB] for OFDMA in vehAchannel using LFDMA, IFDMA and DFDMA subcarrier mapping. (right side figure is added as a subplot to show the values that are overlapped in left one)

International Journal on Recent Technologies in Mechanical and Electrical Engineering
ISSN: 2349-7947 Volume: 9 Issue: 3
***Article Received:** 28 June 2022 **Revised:** 24 August 2022 **Accepted:** 30 August 2022*

While using vehAchannel for OFDMA we observe that the SER performance of LFDMA is better than IFDMA and DFDMA technique because of its robustness against multiple carrier interference. Also DFDMA and IFDMA are almost the same in their SER performance (and hence are overlapped when plotted in single figure).

When compared to pedAchannel , the LFDMA SER performance is the same as in vehAchannel but IFDMA and DFDMA SER performance is better for pedAchannel.

C. AWGN Channel

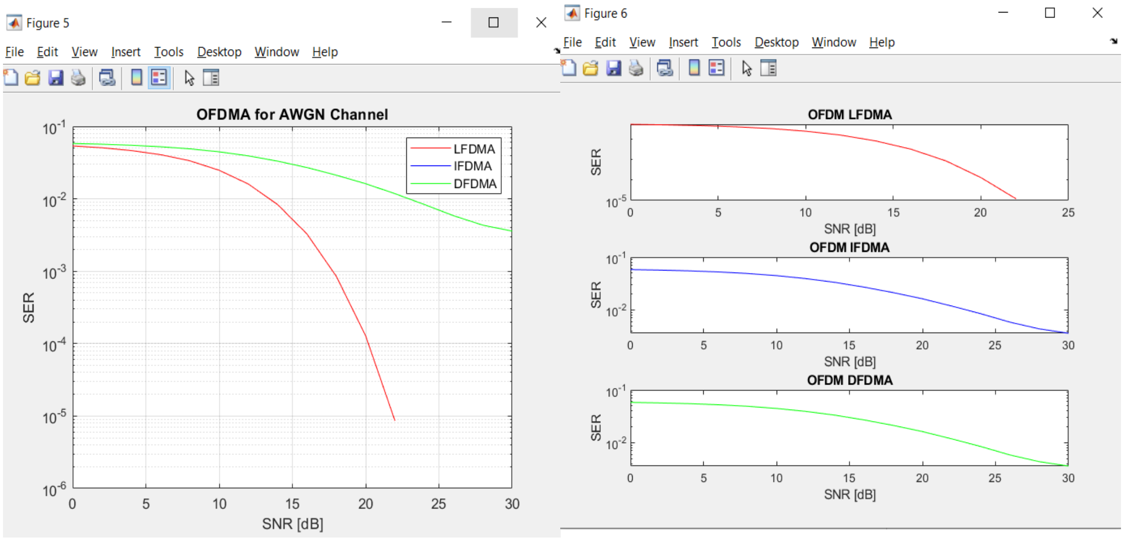

Figure 6.3: SER vs SNR [dB] for OFDMA in AWGN Channel using LFDMA, IFDMA and DFDMA subcarrier mapping. (right side figure is added as a subplot to show the values as they are overlapped in left one**)**

While using AWGN channel for OFDMA we observe that the SER performance of LFDMA is better than IFDMA and DFDMA technique because of its robustness against multiple carrier interference. Also DFDMA and IFDMA are almost the same in their SER performance(and hence are overlapped when plotted in single figure).

When compared to pedAchannel , the LFDMA performance is slightly better in AWGN channel but IFDMA and DFDMA performance is better for pedAchannel.

When compared to vehAchannel , the SER performance of LFDMA is slightly better while IFDMA and DFDMA SER performance is almost same.

7. CONCLUSION & FUTURE SCOPE

7.1 Conclusion

In this paper, we develop a new strategy for the optimization of the PAPR-reduction cost function-based issue. Productive performance has been demonstrated by the performance of the proposed PAPR reduction method for MIMO OFDM. Results have shown a comparative comparison of the proposed approach with the traditional PAPR method based on side-related details, such as the selective mapping and the partial sequence of transmission better known as SLM or PTS. In this project we have focused on the performance analysis of OFDMA and SCFDMA systems in terms of SER and PAPR. Three types of channel (pedAchannel, vehAchannel and AWGN channel) were introduced along with two types of subcarrier mapping (localised and distributed, IFDMA is a special case of DFDMA).For all types of channel , it was observed that LFDMA subcarrier mapping shows better SER performance than IFDMA and DFDMA subcarrier mapping because of its better immunity to multiple access interference (MAI). Also the SER performance for IFDMA subcarrier mapping is almost similar to that of DFDMA subcarrier mapping.

Furthermore, in case of OFDMA system LFDMA sub-carrier mapping gave similar SER performance for pedAchannel and vehAchannel but a slightly better performance with AWGN channel. IFDMA subcarrier mapping and DFDMA shows similar performance with vehAchannel and AWGN channel but a slightly better performance with pedAchannel.

In the SCFDMA system LFDMA subcarrier mapping gave best SER performance with vehAchannel with slightly reduced performance with pedAchannel and least performance with AWGN channel. IFDMA subcarrier mapping and DFDMA subcarrier mapping gave best performance with AWGN channel with slightly reduced performance with pedAchannel and least performance with vehAchannel .It was also observed that for all types of channel and subcarrier mapping, SER performance of SCFDMA is better than OFDMA systems. For OFDMA system, the PAPR performance of LFDMA and DFDMA is almost similar and IFDMA gives a better performance as compared to LFDMA and DFDMA in OFDMA.

In case of SCFDMA system, the PAPR performance of LFDMA and DFDMA is almost similar in case of SCFDMA and IFDMA gives a better performance as compared to LFDMA and DFDMA in OFDMA.

It was concluded that the PAPR performance of SCFDMA was significantly better in all three subcarrier mapping techniques i.e LFDMA, IFDMA and DFDMA, when compared to their counterparts in OFDMA.

7.2 Future Work

A reflection on the MIMO-OFDM systems exhibition and on different antenna arrangements is being incorporated in the present work. The system can also be tested under various channels and configuration of MIMO-OFDM system. Using higher order modulation, the system MIMO-OFDM can be modified to achieve enormous data limitation. Whatever the case, the BER (bit error) problem increases as the modulation request increases. Since the demodulator selection district in the group of stars decreases additionally when expanding the modulation request, the demodulator delivers incorrect results at its efficiency. The channel will drag the signal even harder on lower SNR (noise proportion signal) figures. These pressures would cause the community of stars to shift the signal and cause the demodulator to yield the corrupt results. Whatever the case, with the increase in the influence of the SNR bends offered by the channel, the effect of the BER will also decrease. Along these lines, enormous data limits can be reached via the current channels by higher demand modulation, the most important thing to note is the extent to which the SNR calculations can be defined.

REFERENCES

[1] Hindy, Ahmed, Udar Mittal, and Tyler Brown. "CSI Feedback Overhead Reduction for 5G Massive MIMO Systems." In 2020 10th Annual Computing and Communication Workshop and Conference (CCWC), pp. 0116-0120. IEEE, 2020.

[2] Guo, Jing, Nanxi Li, Zheng Jiang, Shengnan Liu, and Peng Chen. "System-level Evaluation on Practical Massive MIMO Deployment Scenarios for 5G." In 2019 IEEE 5th International Conference on Computer and Communications (ICCC), pp. 993-998. IEEE, 2019.

[3] Baeza, Víctor Monzón, and Ana García Armada. "Noncoherent Massive MIMO." Wiley 5G Ref: The Essential 5G Reference Online (2019): 1-28.

[4] Dore, Jean-Baptiste, Robin Gerzaguet, and Dimitri Ktenas. "5G cellular networks with relaxed synchronization: Waveform comparison and new results." In 2016 IEEE 83rd Vehicular Technology Conference (VTC Spring), pp. 1-5. IEEE, 2016.

[5] Kansal, Parnika, and Ashok Kumar Shankhwar. "FBMC vs OFDM waveform contenders for 5G wireless communication system." Wireless Engineering and Technology 8, no. 4 (2017): 59-70.

[6] Gupta, Namrata, Ankush Gupta, Santosh Kumar, Rajeev Mishra, Chhaya Singh, and Anil Kumar Tripathi. "Cross-talk between cognate and noncognate RpoE sigma factors and Zn2+-binding anti-sigma factors regulates photooxidative stress response in Azospirillum brasilense." Antioxidants & redox signaling 20, no. 1 (2014): 42-59.

[7] Khademi, Seyran, and Alle-Jan Van Der Veen. "Constant modulus algorithm for peak-to-average power ratio (PAPR) reduction in MIMO OFDM/A." IEEE Signal Processing Letters 20, no. 5 (2013): 531-534.

[8] Salh, Adeeb, Nor Shahida M. Shah, Lukman Audah, Qazwan Abdullah, Waheb A. Jabbar, and Mahathir Mohamad. "Energy-Efficient Power Allocation and Joint User Association in Multiuser-Downlink Massive MIMO System." IEEE Access 8 (2019): 1314-1326.

[9] Hossain, Tamanna, Md Munjure Mowla, and Md Yeakub Ali. "Energy Efficiency Investigation in Massive MIMO 5G System using Nakagami-m Fading Channel." In 2019 22nd International Conference on Computer and Information Technology (ICCIT), pp. 1-5. IEEE, 2019.

[10] Pedram, Massoud, and Luhao Wang. "Energy Efficiency in 5G Cellular Network Systems." IEEE Design & Test 37, no. 1 (2019): 64-78..

[11] Ohno, Shuichi, Emmanuel Manasseh, and Masayoshi Nakamoto. "Preamble and pilot symbol design for channel estimation in OFDM systems with null subcarriers." EURASIP Journal on Wireless Communications and Networking 2011, no. 1 (2011): 2.

[12] Gangwar, Arun, and Manushree Bhardwaj. "An overview: Peak to average power ratio in OFDM system & its effect." International Journal of Communication and Computer Technologies 1, no. 2 (2012): 22-25.

[13] Ali, Moaaz Elhag, Khaizuran Abdullah, Mohammad Umar Siddiqi, and Ahmad Fadzil Ismail. "Impulsive noise mitigation in Haar DWT based OFDM systems." In 2013 IEEE 11th Malaysia International Conference on Communications (MICC), pp. 321-325. IEEE, 2013.

[14] Gheorghe, Cristina-Gabriela, Radu Dragomir, and Dan Alexandru Stoichescu. "Massive MIMO technology for 5G adaptive networks." In 2019 11th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), pp. 1-4. IEEE, 2019.

[15] Chen, Jung-Chieh. "Application of quantum-inspired evolutionary algorithm to reduce PAPR of an OFDM signal using partial transmit sequences technique." IEEE transactions on Broadcasting 56, no. 1 (2009): 110-113.

[16] Al-Jawhar, Yasir Amer, Khairun Nidzam Ramli, Aida Mustapha, Salama A. Mostafa, Nor Shahida Mohd Shah, and Montadar Abas Taher. "Reducing PAPR with low complexity for 4G and 5G waveform designs." IEEE Access 7 (2019): 97673-97688..

[17] Ben CheikhBattikh, D.; Kelif, J.-M.; Coupechoux, M.; Godlewski, P., "Dynamic system performance of SISO, MISO and MIMO Alamouti schemes," 34th IEEE Sarnoff Symposium, 2011, vol., no., pp.1-5, 2011.

[18] Ho-Jung An; Hyoung-Kyu Song, "Cooperative Communication in SIMO Systems with Multiuser-OFDM," IEEE Transactions on Consumer Electronics, vol.53, no.2, pp.339-343, 2007.

[19] JingLv; Blasco-Serrano, R.; Jorswieck, E.A.; Thobaben, R.; Kliks, A., "Optimal beamforming in MISO cognitive channels with degraded message sets," IEEE Wireless Communications and Networking Conference (WCNC), 2012, vol., no., pp.538-543, 2012.

[20] M. Borgmann and H. Bölcskei, "On the Capacity of Noncoherent Wideband MIMO-OFDM Systems," IEEE International. Symposium.Info. Theory, Adelaide, Australia, pp. 651–55,Sept 2005.

[21] HiroshiKaiho and Takeshi Hattori, "Reduced Complexity of Spread Spectrum OFDM for PAPR Reduction and Its Basic Performance," Information and Communication Sciences,pp.1-5,2009.

[22] Tao Jiang; Yiyan Wu, "An Overview: Peak-to-Average Power Ratio Reduction Techniques for OFDM Signals," IEEE Transactions on Broadcasting, vol.54, no.2, pp.257,268, June 2008.

[23] Shao Lulu, Song Qijun, Zhang Hongshun, Zhang Jiaping, "Research on Application of OFDM Technology in Cooperative Spectrum Sensing," pp. 254,257, 16-20 Sept 2009.

[24] VanDuc Nguyen; Kuchenbecker, H.-P., "Intercarrier and intersymbol interference analysis of OFDM systems on time-varying channels," Signal Processing Advances in Wireless Communications, 2003. 4th IEEE Workshop on SPAWC 2003., vol., no., pp.140,144, 15-18 June 2003.

[25] Rodrigues, M. R D; Wassell, I.J., "A novel coding strategy to improve the error probability performance of non-linearly distorted OFDM signals," Vehicular Technology Conference, 2003. VTC 2003-Fall. 2003 IEEE 58th , vol.1, no., pp.294,298 Vol.1, 6-9 Oct. 2003.

[26] Kaiho, H.; Hattori, T., "Novel Scheme of Oversampling Spread Spectrum Roll-Off OFDM for PAPR Reduction," Vehicular Technology Conference, 2009. VTC Spring 2009. IEEE 69th , vol., no., pp.1,5, 26-29 April 2009.