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Enhancing BER performance of Coded Wi-Max OFDM System for Higher Traffic and M-order Modulations Techniques



Abstract: - It is very time to investigate the impact of higher data size and traffic open coded –Wi-Max OFDM systems for futuristic 5G communication systems. This study investigated the Bit Error Rate (BER) performance of Wi-Max MIMO-OFDM systems using higher-order FFT sizes and lower-order modulation schemes. This study aims to find a balance between utilizing a higher-order FFT and selecting a relatively lower modulation order for M-PSK and QAM modulation without compromising the BER performance. A Trellis-coded interleaved OFDM system is proposed for Wi-Max higher-data-rate transmissions. The system adopts an adaptive modulation approach that dynamically adjusts the modulation scheme based on the channel conditions. Simulations were conducted in two passes to evaluate the impact of higher FFT sizes and data rates on BER performance. The first experiment iteratively increased the FFT sizes and compared the BER results for the BPSK, QPSK, and 4-QAM modulations. The second experiment investigated the impact of higher data rates on BER performance using reduced-order FFT sizes. The results showed that increasing the FFT size improved the BER performance, but required a higher SNR range. Reducing the modulation order for bigger FFT sizes allows for equivalent BER performance. When data size was raised tenfold the BER performance is improved by significant folds. The best BER of 3×10^{-7} was achieved for BPSK with an FFT size of 128. Overall, the study concludes that using a lower modulation order with a higher FFT size is preferred for systems with an SNR lower than 16 dB, whereas QPSK with an FFT size of 16 offers the best trade-off between data capacity and SNR requirements.

Key Words: Wi-Max, MIMO-OFDM, Modulation Order, Bit Error Rate (BER), FFT Size, Data Size, Trellis Code, Interleaving, M-PSK, M-QAM.

I.INTRODUCTION

As the Wireless communication speed increases, it forces a higher Bit Error Rate (BER), which makes channel noise more severe, and is always required to remove channel noise for efficient communication. Considering the exponentially increasing demand of future systems, the frequency shifting property of FFT in the multi-carrier system is developed as a combination of MIMO and other works. The high time required investigating the MIMO-OFDM system. This is a multicarrier system and the orthogonality of the subcarriers in OFDM must be maintained. The experimental outcomes reveal that for both the PSK and QAM modulation schemes in Wi-Max-OFDM systems, the BER performance typically worsens as the modulation order increases. This deterioration is particularly evident at higher signal-to-noise ratios (SNRs), where the BER disparity between lower- and higher-order modulations becomes more significant. Therefore, the objective of this research is to create a balance between utilizing a higher-order FFT and opting for a comparatively lower modulation order for M-PSK and QAM modulation. However, this approach does not sacrifice the need for an improved BER performance. Nevertheless, when choosing the appropriate modulation scheme for a specific Wi-Max OFDM application, it is essential to carefully weigh the balance between the spectral efficiency and BER performance. Although higher-order modulation schemes in OFDM systems provide enhanced spectral efficiency and increased data rates, they also become more susceptible to noise and interference, thereby requiring a delicate equilibrium between performance enhancements and system reliability. Although there are many challenges for the implementing the OFDM system as illustrated in the Figure 1.

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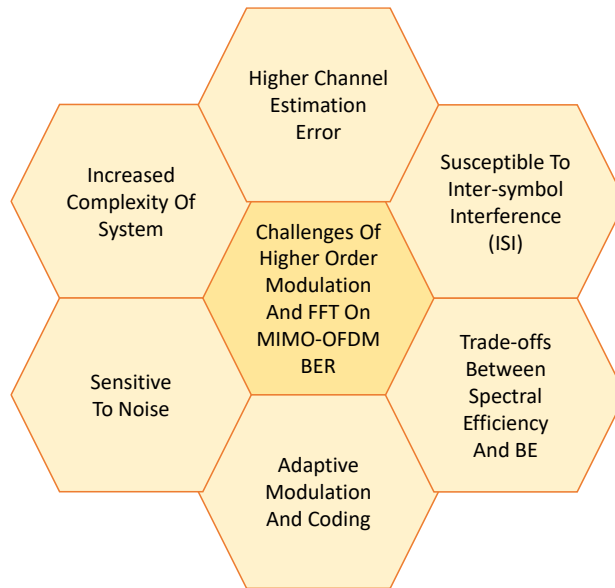


Figure 1 challenge of the higher order MIMO OFDM BER analysis

These challenges include cyclic prefix insertion, FFT implementation and Fading effects of channel. Increasing FFT size may offer higher capacity but may also tends to have higher probability of inter symbol errors. Thus it may Higher-order MIMO-OFDM systems face challenges in evaluating Bit Error Rate (BER) due to increased complexity, channel estimation errors, interference management, noise sensitivity, hardware impairments, simulation time, analytical complexity, trade-offs between spectral efficiency and BER, adaptive modulation and coding, and realistic channel modeling. These factors make it difficult to isolate the impact of system parameters on BER performance, requiring more sophisticated models to accurately represent real-world channel conditions and achieve statistically significant results.

The selection of modulation order is contingent upon the particular requirements of the communication system, including the target data rate, available bandwidth, and tolerable error rate. In scenarios prioritizing high data rates, higher order modulations such as 64-QAM or 256-QAM might be favored despite their increased error susceptibility. Conversely, in challenging channel environments or situations demanding strict reliability, lower order modulations like QPSK or 16-QAM may be more appropriate to sustain acceptable BER performance. Another crucial factor influencing BER performance is the FFT size of OFDM. MIMO-OFDM systems utilize FFT for effective signal processing, and the size of the FFT can have a substantial influence on the system's performance, including its BER. It can be clearly observed from the Figure 2 that using the higher order FFT may be capable of maintaining the better orthogonally between ODFM multiple carries. Thus this paper is aimed to design a compromise between higher order FFT and selecting relatively lowered modulation order of M-PSK and QAM modulation. But in turn don't compromise on the better BER requirement.

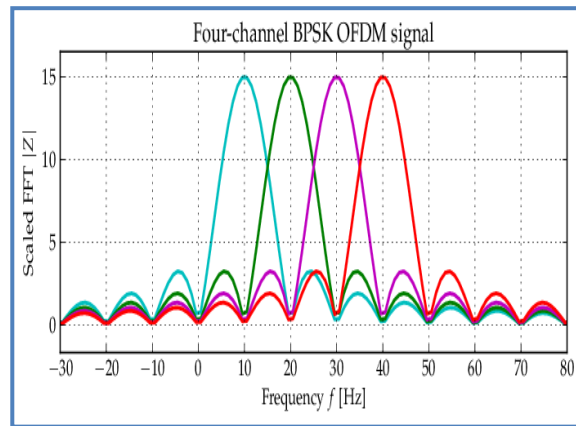


Figure 2 Example of OFDM for BPSK with four orthogonal channels.

(A) Contribution of Research This study primarily contributed to apply various modulation techniques to the Wi-Max MIMO-OFDM system for the IEEE 802.16e physical layer standards. Additionally, it seeks to enhance BER performance in 5G Wi-Max communication, addressing the challenges of extremely high traffic density and data rates anticipated in the future. The research also involves assessing the BER performance of OFDM using higher-order PSK and QAM modulation techniques. As an solution method adopts lower modulation order but higher FFT size as the traffic and data rates are increased. The proposed approach is practically much fusible to implement.

II.Survey of Work

The selection of FFT size influences the system's capacity to address multipath fading and inter-symbol interference (ISI) (Leus&Moonen, 2003; Stuber et al., 2004).). Research has shown that expanding the FFT size in MIMO-OFDM systems can improve BER performance through enhanced frequency resolution, reduced inter-carrier interference, longer symbol duration, and increased noise averaging. However, this approach comes with potential drawbacks, including higher computational complexity, greater sensitivity to phase noise, increased peak-to-average power ratio, and reduced flexibility in allocating resources. These factors must be carefully weighed when selecting the FFT size for a MIMO-OFDM system, as they can affect the system's adaptability to rapidly changing channel conditions. As a result, thorough evaluation is crucial when determining the appropriate FFT size in MIMO-OFDM systems. Notably, decreasing the FFT size can result in lower latency for massive MIMO systems. A study by (Mahdavi et al., 2019) introduces an FFT processor that leverages OFDM guard bands to reduce the number of required calculations, achieving a 42% latency reduction for a 2048-point IFFT compared to traditional pipelined methods. This technique demonstrates that smaller FFT sizes can enhance system efficiency without significantly compromising performance. It is observed that the FFT size impacts the BER performance of MIMO-OFDM systems, with larger sizes generally yielding better results due to improved frequency resolution and ISI mitigation. However, smaller FFT sizes offer advantages such as decreased latency and reduced hardware complexity. The ideal FFT size is dependent on the specific application requirements, necessitating a balance between factors like BER performance, latency, and implementation complexity (Mahdavi et al., 2019; Yang et al., 2013).

A study by (Chen et al., 2016) explores a non-Hermitian symmetry OFDM (NHS-OFDM) approach for MIMO-VLC systems. The research indicates that NHS-OFDM outperforms traditional Hermitian symmetry-based OFDM (HS-OFDM) in terms of BER performance within a 2×2 MIMO-VLC setup. The experimental findings reveal that NHS-OFDM extends communication coverage by approximately 30% compared to HS-OFDM, given a target BER of 3.8×10^{-3} in a 400 Mb/s system utilizing an imaging receiver (Chen et al., 2016). Notably, (Del

Puerto-Flores et al., 2023) introduces an effective index modulation (IM)-based MIMO-OFDM system designed for vehicle-to-vehicle (V2V) channels. Their findings demonstrate that this system achieves BER performance gains of up to 3 dB when compared to conventional MIMO-OFDM systems under identical conditions and parameters (Del Puerto-Flores et al., 2023). The researchers have developed several methods to enhance BER performance in MIMO-OFDM systems. These include NHS-OFDM for VLC systems and IM-based MIMO-OFDM for V2V communications. The research demonstrates considerable improvements in BER performance, underscoring the potential of these advanced techniques to boost the reliability and efficiency of wireless communication systems.

The performance of MIMO-OFDM systems using higher-order PSK modulation generally deteriorates in terms of the bit error rate (BER) as the modulation order increases. This is primarily because of the increased susceptibility to noise and interference in higher-order modulation schemes (Effendi et al., 2024). Several techniques have been proposed to improve the BER performance of MIMO-OFDM systems with higher-order modulation. For instance, the incorporation of fractal wavelet packet transform within M-ary PSK OFDM systems, known as M-ary PSK OWDM, has shown better performance than conventional M-ary PSK OFDM and basic modulation systems. Specifically, QPSK OWDM with 16 subcarriers achieved a BER improvement from 1.5×10^{-3} to 1×10^{-4} at an E_b/N_0 of 20 dB (Effendi et al., 2024). Channel estimation techniques play a crucial role in improving the BER performance. The DFT-LS-WIENER channel estimation approach demonstrated superior performance in terms of BER and symbol error rate (SER). At 15 dB SNR, this technique reduced the BER by 48.19%, 38.19%, 14.8%, and 14.03% compared to the LS, LS-DFT, MMSE, and MMSE-DFT methods, respectively (S et al., 2022). Additionally, optimizing the number and placement of pilot symbols, as well as the power allocation between the pilot and information symbols, can minimize the SER in OFDM systems with M-PSK modulation (Cai&Giannakis, 2004). In conclusion, while higher-order PSK modulation in MIMO-OFDM systems generally leads to degraded BER performance, various techniques, such as wavelet transforms, advanced channel estimation methods, and optimal pilot symbol strategies, can significantly improve the performance of the system. These advancements enable the use of higher-order modulation schemes while maintaining acceptable bit error rate (BER) levels, thus increasing the spectral efficiency and data rates in wireless communication systems.

The BER performance of MIMO-OFDM systems is significantly influenced by higher-order M-QAM modulation and increased FFT size. While elevating the modulation order in M-QAM schemes can boost data rates, it often results in higher BER. Research by (Otsuka et al., 2019) explores the application of 1024- and 4096-QAM in OFDM-based systems for 5G, showing that these higher-order modulations can achieve faster data transmission within constrained bandwidth. However, these advanced modulations are more vulnerable to noise and channel distortions, potentially leading to increased BER (Otsuka et al., 2019). In a similar vein, (Li et al., 2014) documents the successful transmission of a 31.7-Gbit/s 2048QAM OFDM signal across 20-km fiber, underscoring the capacity of high-order QAM to attain high data rates. Notably, enlarging the FFT size can positively affect BER performance. (Li et al., 2014) indicates that employing a large FFT size strengthens the system's resistance to intersymbolinterference, which can contribute to improved BER performance. This proves especially advantageous in systems using higher-order modulations, as it helps address some of the challenges linked to increased sensitivity to channel impairments.

Several papers have discussed BER performance in various OFDM systems. (Ko, 2014) presented a tight closed-form approximation of the BER for multicarrier index keying in OFDM systems, considering both perfect and imperfect detection of active multi-carrier indices (Ko, 2014). (Wang et al., 2023) investigated the BER performance of constant-envelope OFDM (CE-OFDM) using maximum likelihood detection in MIMO configurations (Wang et al., 2023). These studies provide general insights into BER evaluation methods for OFDM systems, which can also be applied to WiMAX OFDM systems. Interestingly, some studies have highlighted the benefits of

combining OFDM with various coding techniques to improve BER performance. (Jiang et al., 2006) discussed the use of turbo trellis-coded modulation (TTCM) in SDMA-OFDM systems, showing significant improvements in BER performance (Jiang et al., 2006). (Liu et al., 2017) demonstrated the advantages of polar coding in coherent optical OFDM systems, achieving a net coding gain of more than 10 dB at a BER of 10^{-3} compared with conventional CO-OFDM (Liu et al., 2017). These findings suggest that trellis coding could potentially offer benefits similar to WiMAX OFDM systems. In conclusion, although the provided papers do not specifically address trellis-coded WiMAX OFDM, they offer valuable insights into BER evaluation methods for OFDM systems and the potential benefits of combining OFDM with advanced coding techniques. Further research focusing on this specific combination is necessary to accurately (evaluate the BER performance of trellis-coded WiMAX OFDM. Good reviews of the Wi-Max IEEE standard are provided by the (Yogendra Patel et al 2014). The MIMO-OFDM system performance based on BER is evaluated by (Vidhya, K. et al. 2014). Again (Yogendra Patel et al 2015) have concluded that for 16 FFT points and BPSK modulation for 60000 bits of data. The ideal BER value is found to be between 10^{-6} and 10^{-7} .

NishaSachan, et al have designed the sparse channel estimation (CE based OFDM system for performance improvement, The Alamouti-STBC code was adopted by the (Bahrti and Rawat 2015) for BER investigation of MIMO-OFDM system. But they achieved BER of order of 10^{-4} only. Finally (Rishi Choubey 2023) have presented BER evaluation of MIMO-OFDM system using Treills coded system. To summarize, although higher-order M-QAM modulation can enhance data rates in MIMO-OFDM systems, it typically results in higher BER due to greater susceptibility to noise and channel distortions. Nevertheless, strategies such as increasing FFT size can help alleviate some of these issues, enabling a compromise between faster data rates and acceptable BER performance. The ideal selection of modulation order and FFT size is contingent upon the particular system requirements and channel conditions.

III. Wi-Max-OFDM System Representation

This study have proposed to design the Trellis coded interleaved OFDM system for the Wi-Max higher data rate transmissions. It can be observed from the system as in Figure 3 that Tralliss coded interleaved system is proposed at the front end of Wi-Max system using OFDM trasreceivers. The random data initialization is preferred for the performance evaluation. The additive white Gaussian noise (AWGN) channel is preferred with addition of cyclic prefixes (CP). The CP is added for restricting the possibilities of inter-symbol interferes. The proposed system is expected to adopt the compromise between FFT size and modulation order

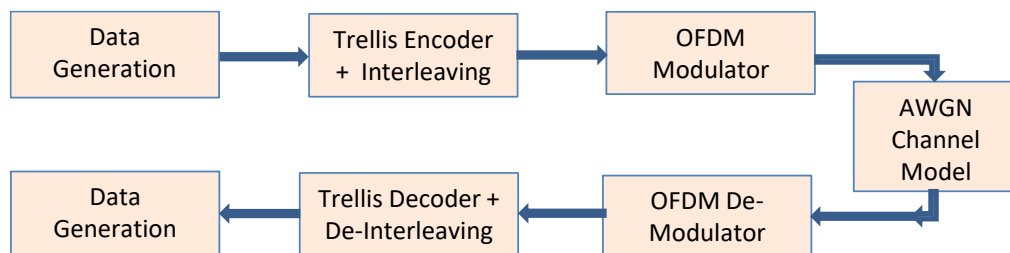


Figure 3 Proposed Wi-Max– coded-OFDM System Diagram

IV. Proposed Simulation Methodology

The proposed flow chart of the adaptive lower order modulation approach is illustrated in the Figure 4.

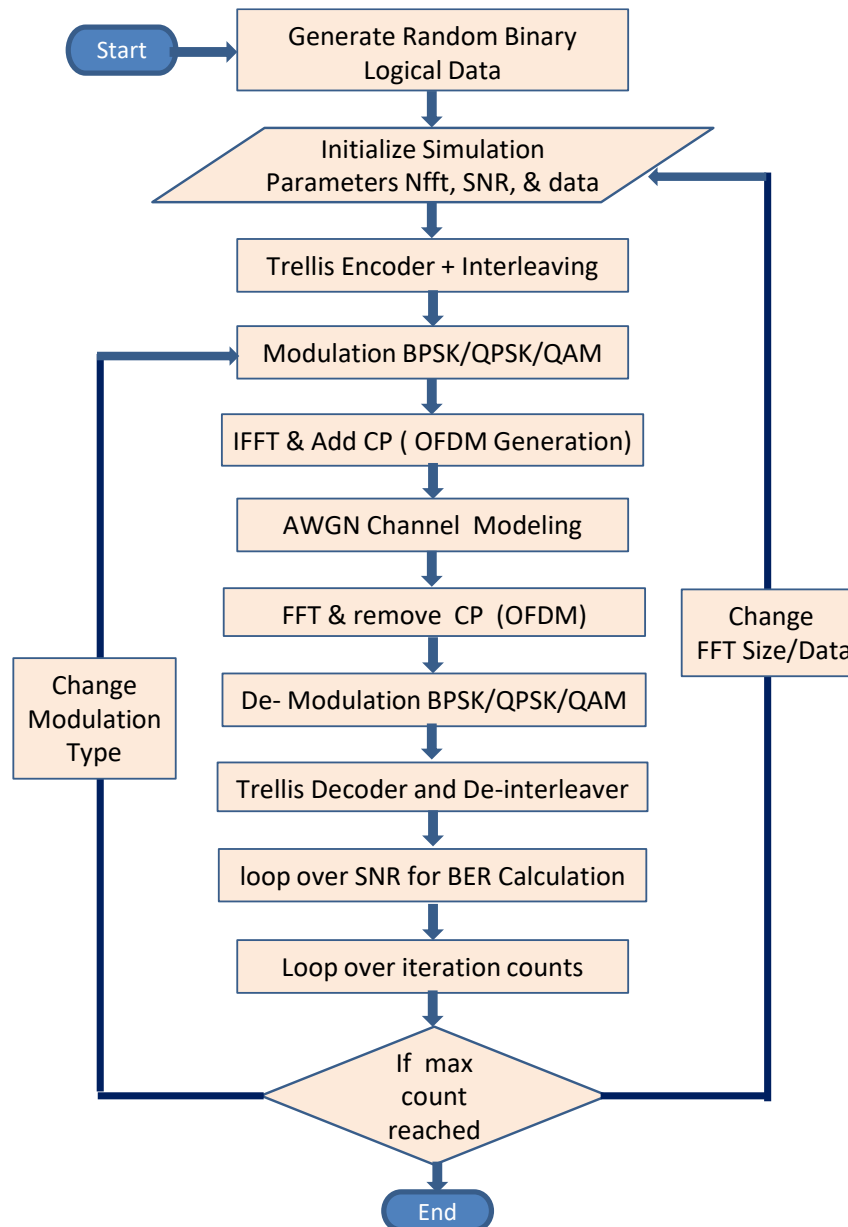


Figure 4 Flow chart of the proposed adaptive coded Wi-Max OFDM system design

The flowchart in Figure 4 illustrates the steps in the proposed adaptive coded Wi-Max OFDM system, design, representing different stages and their sequential order. In the proposed system, the BER is evaluated for three modulations: BPSK, QPSK, and 4 QAM. The order of modulation was selected as the lowest order. However, to calculate the capacity, the FFT size was adopted iteratively.

Figure 4 proposed to use a slightly higher-order FFT size with reduced modulation. The logical data streams are randomly generated using the randomizer function. For the initial evaluation higher number of iterations counts were set to 60 for the BER evaluation. As the data rates were increased by 10 times, the titration counts were reduced from 60 to 30. The mean BER for each modulation type are calculated for all iterations and for 0 to 30 dB SNR range.

The proposed adaptive modulation approach aims to optimize system performance by dynamically adjusting the modulation scheme based on channel conditions. By selecting the lowest order modulation among BPSK, QPSK, and 4 QAM, the system prioritizes reliability over data rate in challenging environments. The iterative process of adjusting the FFT size allows for fine-tuning of the system's capacity, striking a balance between spectral efficiency and error resilience.

V. Results and Discussion

This research has presented the BER evaluation is two pass. The first experiment is performed by increasing the number of iterations and FFT sizes are increased and set as [64,128, 256, and 1024]. The second pass of experiment is performed to investigate the impact of the higher data rates and traffic on the BER performance of Wi-Max –OFDM system.

(A) Experiment 1: Impact of Higher FFT size

An experiment is performed for enhancing the BER performance of the Wi-Max-OFDM system the Trellis coded OFDM system is simulated using the interleaved coded data. The random 10000 bits are generated and the FFT sizes are proposed to increase in the order of 2 as [64,128, 256, and 1024].

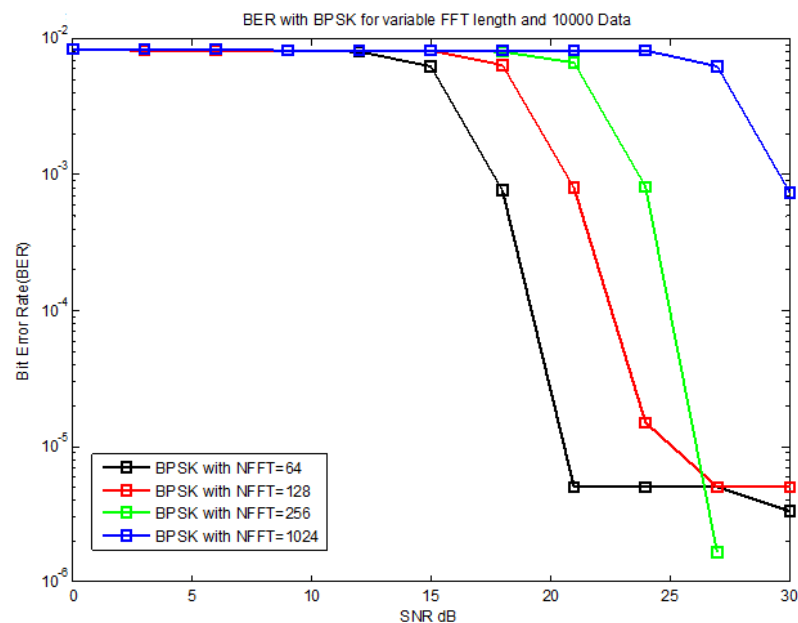


Figure 5 Evaluation of BER for BPSK with higher FFT sizes and data rate of 10000 bits

The BER results are first compared for the different FFT sizes using BPSK modulation as illustrated in the Figure 5. It can be clearly observed that as the SNR increases, the BER decreases for all FFT lengths.

The higher the FFT size the minimum BER is achieved at respective higher SNR range. The BER for all FFT size are ranging on the order of 10^{-6} . The best BER performance is achieved for the FFT size of 256 as 3×10^{-6} at 27 dB SNR range. It is to be noted that increasing the NFFT size is capable of increasing the capacity of system but for lower SNR range than 15 dB mark it offers relatively lower BER performance. Thus it is concluded that increasing FFT size is good enough but at the cost of higher SNR range of system.

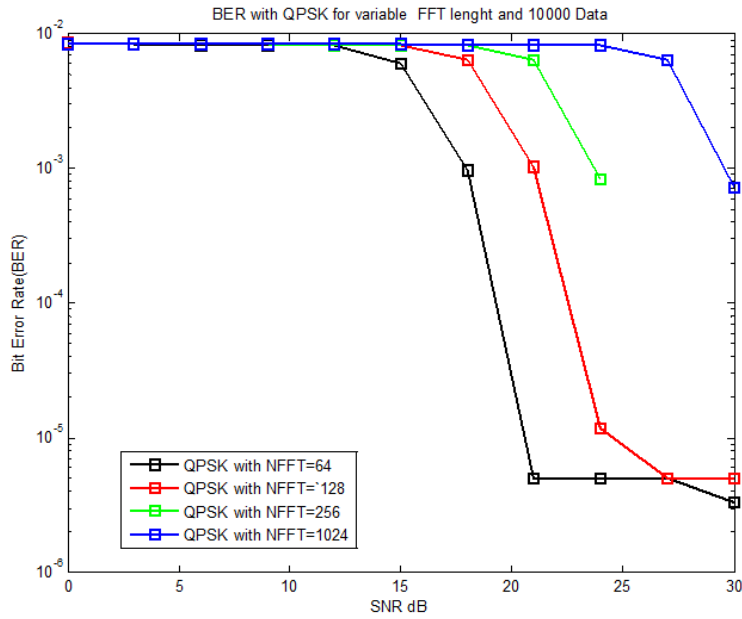


Figure 6 Results of BER for QPSK with higher FFT sizes for data size of 10000

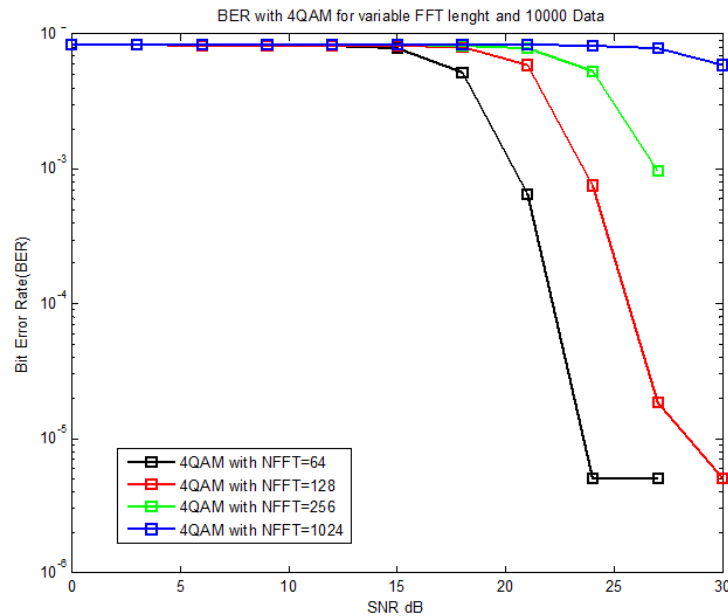


Figure 7 Results of BER for 4-QAM with different FFT sizes for data size of 10000

The results of the BER comparison for the different higher FFT sizes for the QPSK modulation are illustrated in the Figure 6. It can be observed that for the FFT size of 64 and 128 the BPSK and QPSK modulation performs similarly. But for the higher FFT sizes of 256 and 1024 the BER performance is reduced significantly for QPSK modulation. This signifies that increasing FFT size might require reducing order of modulations.

Similarly the results of BER for 4-QAM modulation with different higher OFDM FFT sizes for data size of 10000 are presented in the Figure 7. comparing the performance it can be observed that 4-QAM modulation offers 2 dB hicks in the required SNR than that of QPSK modulation. Minimum BER performance is offers by FFT size of 64 and 128 and of the order of 8×10^{-6} . The FFT size of 128 requires nearly 6 dB more SNR compared to FFT size of 64.

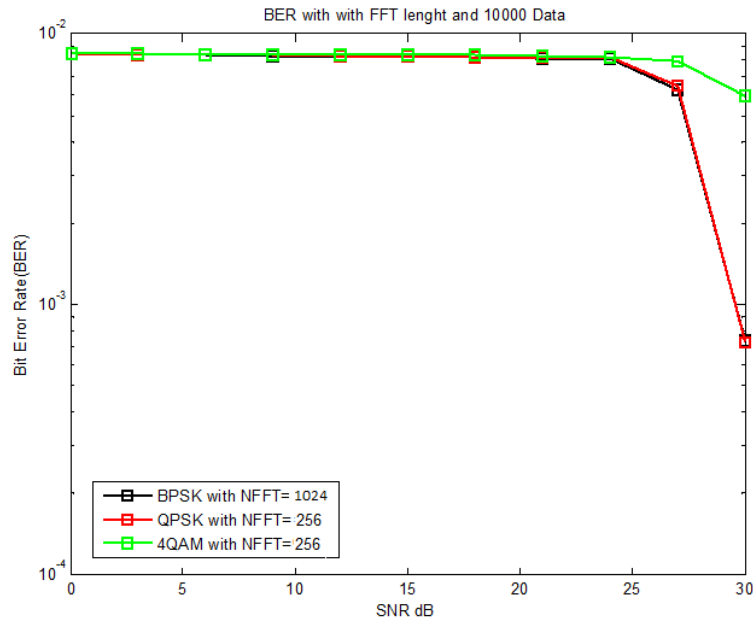


Figure 8 BER for higher FFT sizes and lower order of modulations for data size of 10000

Further simulations were conducted to evaluate how reducing the order of modulation for larger FFT sizes affects BER performance, as illustrated in Figure 8. The results show that for an FFT size of 256, the BER performance is identical for QPSK and 4-QAM, with both achieving a BER of approximately 10^{-3} . However, to achieve a comparable performance using BPSK modulation, an FFT size of 1024 is necessary.

(B) Experiment 2: Impact of Higher Data Size

In the experiment, the random data size was increased by 10 times to 100000 bits and the reduced-order FFT size was adopted as [16, 64, 128, and 256]. To reduce the computational cost, the number of iteration counts was reduced from 60 to 30. The impact of higher data size on BER performance was evaluated for different FFT sizes using BPSK modulation technique as shown in Figure 9. It can be observed that there is 10 times increment in BER performance is observed compared to that of experiment 1. The BER of the order of 10^{-7} is achieved for the higher FFT sizes. It can also be observed that lower FFT size of $N=16$ achieved the minimum BER performance at relatively 2 -3 dB less SNR than $N=64$. The best BER of the 3×10^{-7} is achieved for the $N=128$ with BPSK.

The impact of higher data size on BER for lowered FFT sizes using QPSK and 4-QAM modulation are respectively shown in Figure 10. Based on the comparison of the Figure 10 a) and Figure 10 b) it can be observed that similar BER performance of 9×10^{-7} is achieved for $N=16$, by the QPSK modulation but at the 6 dB lower SNR than 4-QAM. It is clear that using 4-QAM offers more data capacity but also requires higher SNR performance of system. Thus over all it is also concluded that QPSK with $NFFT=16$ is preferred for system with SNR lower than 16 dB.

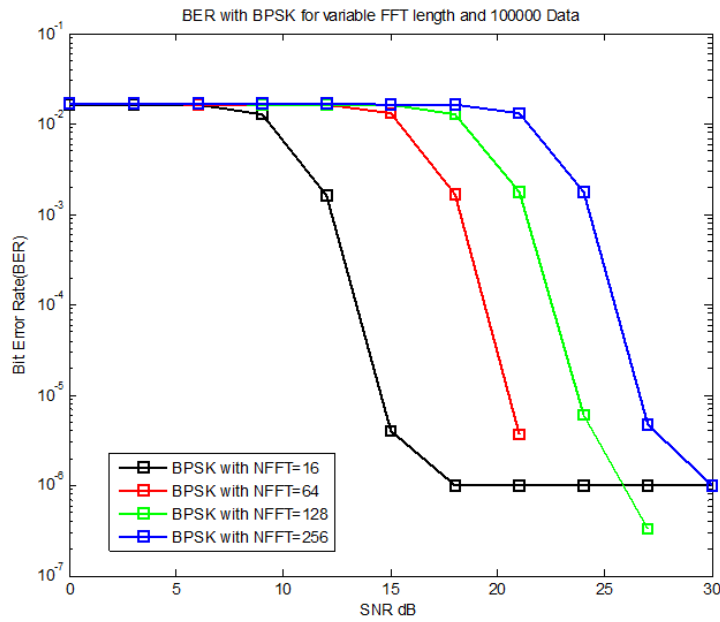
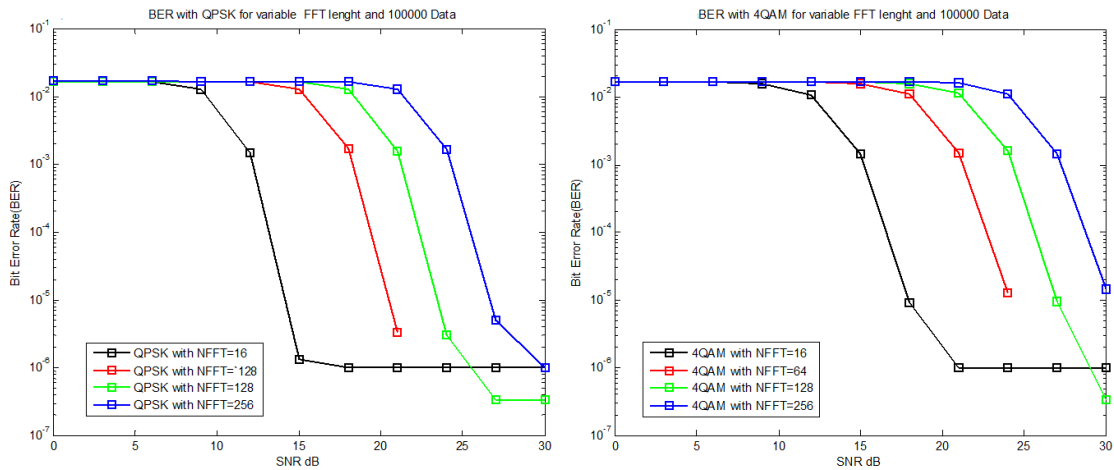


Figure 9 Impact of higher data size on BER performance for BPSK modulation



a) For QPSK Modulation

b) for 4 QAM modulation

Figure 10 Impact of high data size and reduced FFT size on BER for Wi-Max OFDM 5G communication system

From the Figure 10 b) it is clear the best minimum BER of 2.7×10^{-7} is offer by the 4-QAM modulation with NFFT=128 but at 30 dB SNR. Overall it is observed that increasing data size might increase the BER performance also.

VI. Conclusions and Future Scopes.

This research investigates the BER performance of Wi-Max based OFDM systems using higher-order FFT and lower-order modulation schemes like BPSK, QPSK, and 4-QAM. The study aims to find a balance between higher FFT size and lower modulation order to achieve better BER performance without compromising on data rates. Experiments were conducted by increasing the FFT size and data rates to evaluate the impact on BER. Results showed that increasing the FFT size improves BER performance, but at the cost of higher SNR. Lower-order modulations like BPSK and QPSK performed better than 4-QAM for higher FFT sizes. Increasing the data size by 10 times also improved BER performance, with QPSK and NFFT=16 being preferred for systems with SNR lower than 16 dB. The best minimum BER of 2.7×10^{-7} was achieved using 4-QAM with NFFT=128 at 30 dB SNR. Overall, the research concludes that using a slightly higher-order

FFT size with reduced modulation order can enhance BER performance in Wi-Max MIMO-OFDM systems for 5G communications. In future the impact of MIMO size can be investigated on system BER performance. Additionally, interlayer size impacts can also be scope of research in future.

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