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Beamforming-Aided NOMA-OFDM Systems with Successive Interference Cancellation for Enhanced Connectivity

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Abstract: Orthogonal Frequency Division Multiplexing (OFDM) is widely used in wireless communication because of its ability to handle multipath propagation. However, conventional OFDM uses orthogonal resource allocation, which can limit spectral efficiency when multiple users need to share the available resources. This work investigates a beamforming-aided Non-Orthogonal Multiple Access (NOMA)-OFDM system that integrates power-domain NOMA, superposition coding, convolutional coding, Least Mean Square (LMS) adaptive equalization, and Successive Interference Cancellation (SIC). The proposed system allows two users to share the same time-frequency resources through power allocation, assigning a power coefficient of 0.8 to the far user and 0.2 to the near user. The system performance is evaluated under Additive White Gaussian Noise (AWGN), Rayleigh fading, and Rician fading channel conditions. Bit Error Rate (BER), spectral efficiency, sum rate, fairness index, and outage probability are used as performance metrics, with conventional OFDM serving as the reference system. The simulation results reported in the thesis indicate that the proposed NOMA-OFDM system achieves lower BER and outage probability, along with improvements in spectral efficiency, sum rate, and fairness index compared with conventional OFDM. The study demonstrates the potential of integrating NOMA, adaptive signal processing, and SIC to improve the reliability and resource utilization of wireless communication systems.

Keywords: NOMA, OFDM, power allocation, LMS adaptive equalization, Successive Interference Cancellation (SIC), convolutional coding, Bit Error Rate (BER), AWGN, Rayleigh fading, Rician fading.

I. INTRODUCTION

The increasing demand for reliable wireless communication has created a need for systems that support higher data rates, multiple users, and efficient spectrum utilization. Orthogonal Frequency Division Multiplexing (OFDM) is widely used to handle multipath channel effects; however, its conventional orthogonal resource allocation can limit spectral efficiency.

Non-Orthogonal Multiple Access (NOMA) allows multiple users to share the same time-frequency resources through power-domain allocation. Superposition coding combines user signals at the transmitter, while Successive Interference Cancellation (SIC) separates them at the receiver. This work investigates a beamforming-aided NOMA-OFDM system integrating power allocation, OFDM modulation, convolutional coding, Least Mean Square (LMS) adaptive equalization, and SIC. Two users share the available resources, with power coefficients of 0.8 for the far user and 0.2 for the near user. Convolutional coding and Viterbi decoding are used to support error correction. The system is evaluated under Additive White Gaussian Noise (AWGN), Rayleigh fading, and Rician fading channels. Performance is assessed using Bit Error Rate (BER), spectral efficiency, sum rate, Jain's fairness index, and outage probability, with conventional OFDM serving as the baseline. The simulation results reported in the thesis indicate improvements in error performance, spectrum utilization, data rate, fairness, and communication reliability.

The objective of this work is to evaluate the performance of the proposed communication system under different channel conditions using these performance metrics.

The main objective of this work is to investigate the performance of a two-user NOMA-OFDM communication system under different wireless channel conditions. The study considers power-domain NOMA, convolutional coding, LMS-based adaptive equalization, and successive interference cancellation. The system performance is examined using BER, sum rate, spectral efficiency, Jain's fairness index, and outage probability. The evaluated configurations are compared to understand the effects of power allocation, channel conditions, and receiver processing on communication performance. The contribution of this work is evaluated through MATLAB simulations using the selected system parameters and performance metrics.

II. LITERATURE REVIEW

Several studies have investigated techniques for improving the reliability, error performance, and spectral efficiency of wireless communication systems. The research discussed in this section focuses on OFDM, channel coding, and error correction, which provide the background for the proposed beamforming-aided NOMA-OFDM system.

A. Performance Analysis of OFDM Systems

Elsanousi and Ozturk (2018) investigated the performance of OFDM and MIMO-OFDM communication systems under Additive White Gaussian Noise (AWGN), Rayleigh, and Rician channel conditions [1]. Their study highlighted the benefits of convolutional coding and spatial diversity in reducing the bit error rate (BER). Although MIMO-OFDM can improve communication reliability, its additional hardware requirements increase implementation complexity. This motivates the investigation of alternative techniques for improving communication performance. Borra and Chaparala (2013) examined OFDM performance under different channel conditions [3]. Their work provided a basis for understanding how channel characteristics affect transmission errors. The comparison of AWGN, Rayleigh, and Rician channels is relevant to evaluating the proposed system under different wireless propagation environments.

B. Forward Error Correction in OFDM

Sethy and Swain (2013) studied forward error correction techniques in OFDM systems by comparing convolutional coding and turbo coding [2]. Their findings, as summarized in the thesis, indicated that both coding techniques improve transmission reliability, while turbo coding can provide lower BER at the cost of greater computational complexity. However, the study primarily focused on error correction rather than multi-user resource sharing. This leaves scope for investigating coding together with NOMA to support multiple users sharing the same time-frequency resources. Bhuyan et al. (2016) investigated convolutionally coded OFDM using modulation schemes such as QPSK and QAM [4]. Their study emphasized the role of channel coding and modulation selection in improving transmission performance. The work provides relevant background for the use of convolutional coding and QPSK modulation in the proposed system. The integration of these techniques with power-domain NOMA and successive interference cancellation is considered in the present work.

C. Convolutional Coding and Viterbi Decoding

Kumar (2014) studied convolutional coding with Viterbi decoding, including hard-decision and soft-decision decoding approaches [5]. The study, as described in the thesis, demonstrated the importance of error-correction coding in improving the reliability of a communication link. However, the investigation did not address the combined use of power allocation, adaptive equalization, and multi-user interference cancellation.

D. Research Gap

The reviewed studies address important aspects of wireless communication, including OFDM performance under different channel conditions and the benefits of channel coding. However, the thesis identifies a need to investigate these techniques in an integrated framework that also incorporates power-domain NOMA, adaptive beamforming, LMS-based equalization, and successive interference cancellation. To address this research gap, the present work investigates a beamforming-aided NOMA-OFDM system for two users sharing the same time-frequency resources. The system incorporates power allocation, superposition coding, convolutional coding, LMS equalization, and SIC. Its performance is evaluated under AWGN, Rayleigh, and Rician channel conditions using BER, spectral efficiency, sum rate, fairness index, and outage probability.

III. PROPOSED SYSTEM MODEL AND METHODOLOGY

The proposed system integrates power-domain Non-Orthogonal Multiple Access (NOMA) with Orthogonal Frequency Division Multiplexing (OFDM) to support simultaneous communication between two users over shared time-frequency resources. The system incorporates convolutional encoding, QPSK modulation, fixed power allocation, NOMA superposition coding, OFDM modulation, LMS adaptive equalization, Successive Interference Cancellation (SIC), QPSK demodulation, and Viterbi decoding.

A. User Data Generation and Convolutional Encoding

Two independent binary data streams are generated for the far and near users. The information bits are encoded using a rate-1/2 convolutional encoder to introduce redundancy for error correction. The convolutional code is defined by the trellis structure $\text{poly2trellis}(7,[171\ 133])$, with constraint length 7 and generator polynomials 171 and 133 in octal notation.

B. QPSK Modulation

The encoded bits are mapped into QPSK symbols using four constellation points. The modulation order is (M=4), corresponding to two bits per symbol. Unit-average-power normalization is used in the MATLAB implementation.

C. Power Allocation and NOMA Superposition

Fixed power allocation is employed to distinguish the two users. The far user is assigned 80% of the total transmit power, while the near user receives the remaining 20%.

The total transmit power is

$$P = P_f + P_n \quad (1)$$

The power allocation coefficients are

$$\alpha_f = 0.8, \quad \alpha_n = 0.2 \quad (2)$$

The corresponding user powers are

$$P_f = \alpha_f P = 0.8P \quad (3)$$

$$P_n = \alpha_n P = 0.2P \quad (4)$$

The QPSK symbols are combined using NOMA superposition coding:

$$x = \sqrt{\alpha_f s_f} + \sqrt{\alpha_n s_n} \quad (5)$$

$$x = \sqrt{0.8} s_f + \sqrt{0.2} s_n \quad (6)$$

where s_f and s_n represent the far-user and near-user symbols. This expression follows the normalization used in the second MATLAB script, where the total power factor (P) is not explicitly included.

D. OFDM Modulation

In the OFDM implementation, the frequency-domain symbols are converted into a time-domain waveform using the Inverse Fast Fourier Transform (IFFT). QPSK modulation is employed to map the input data into complex-valued symbols. The cyclic prefix is added before transmission to help mitigate inter-symbol interference caused by multipath propagation. The system performance is evaluated over an SNR range of 0–30 dB in the first simulation and 0–10 dB in the second simulation, with increments of 2 dB in both cases.

E. Wireless Channel Models

The system is evaluated under AWGN, Rayleigh fading, and Rician fading channel conditions. For the Rician model, the second MATLAB script uses a K-factor of 4.

The general received-signal model for a fading channel is expressed as

$$y(n) = h(n) * x(n) + w(n) \quad (1)$$

For an AWGN channel without fading, the received signal is

$$y(n) = x(n) + w(n) \quad (2)$$

The Rician K -factor is defined as

$$K = \frac{P_{LOS}}{P_{NLOS}} = 4 \quad (3)$$

where $y(n)$ denotes the received signal, $h(n)$ represents the channel impulse response, $x(n)$ is the transmitted signal, and $w(n)$ represents additive noise. The symbol $*$ denotes convolution. P_{LOS} and P_{NLOS} represent the line-of-sight and non-line-of-sight powers, respectively.

F. Receiver Processing and LMS Equalization

The Least Mean Square (LMS) algorithm adaptively updates the equalizer coefficient based on the difference between the desired signal and the equalizer output. The equalizer output is represented as

$$\hat{y}(n) = w(n)y(n) \quad (1)$$

The estimation error is

$$e(n) = d(n) - \hat{y}(n) \quad (2)$$

The coefficient update is expressed as

$$w(n+1) = w(n) + \mu y^*(n)e(n) \quad (3)$$

where $w(n)$ is the equalizer coefficient, $y(n)$ is the received signal, $d(n)$ is the desired reference signal, $e(n)$ is the estimation error, and (μ) is the step size. In this study, the selected LMS step size is $(\mu=0.01)$.

G. Successive Interference Cancellation

At the receiver, the composite NOMA signal contains the superimposed signals of the far and near users. Assuming the far-user signal is decoded first, the received signal can be expressed as

$$y = h(\sqrt{\alpha_f} s_f + \sqrt{\alpha_n} s_n) + w \quad (1)$$

After estimating the far-user symbol, its contribution is reconstructed and subtracted from the received signal. The residual signal is

$$y_{\text{res}} = y - h\sqrt{\alpha_f} \hat{s}_f \quad (2)$$

where $\hat{s}_f$ is the detected far-user symbol. The residual signal is then used to detect the near-user symbol. The accuracy of interference cancellation depends on the reliability of the first-stage detection and the channel estimate.

H. Demodulation and Viterbi Decoding

The detected symbols are converted into encoded bits using QPSK demodulation. Viterbi decoding is used with the convolutional-code trellis to recover the original information bits in the convolutionally coded simulation.

I. Performance Metrics

The performance of the simulated system configurations is evaluated using Bit Error Rate (BER), sum rate, spectral efficiency, Jain's fairness index, and outage probability. The BER simulations consider AWGN, Rayleigh, and Rician channels, while the second script also calculates the rate and fairness metrics.

The overall architecture of the proposed system is illustrated in Fig. 1. The transmitter consists of two user data sources, convolutional encoding, QPSK modulation, power allocation, NOMA superposition coding, and OFDM modulation. The composite signal is transmitted through AWGN, Rayleigh, or Rician channel models. At the receiver, OFDM demodulation, channel equalization, LMS adaptive equalization, and successive interference cancellation are performed, followed by QPSK demodulation and Viterbi decoding. The system performance is evaluated using the selected communication performance metrics.

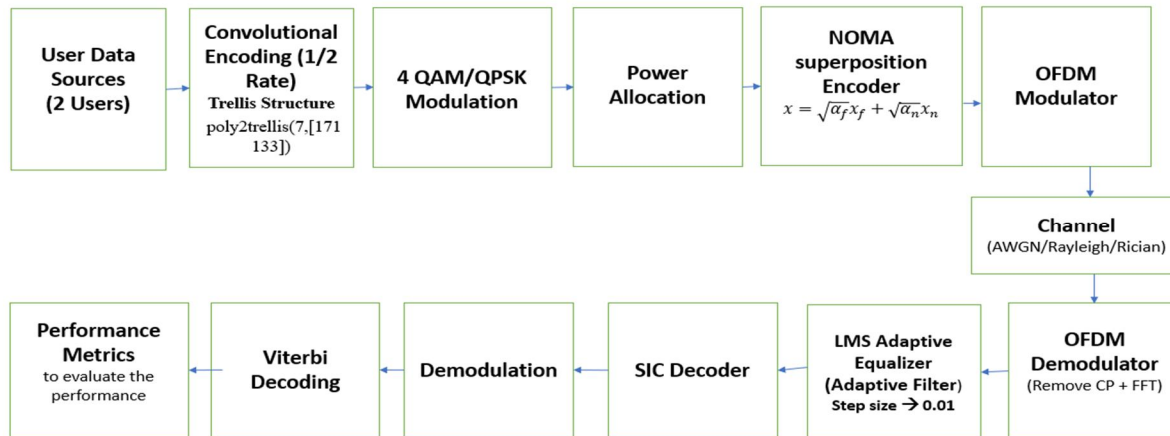


Fig. 1. Proposed Method System Architecture

IV. SIMULATION SETUP

The performance of the proposed NOMA-enhanced SISO-OFDM communication system is evaluated using MATLAB simulations under different wireless channel conditions. The system employs QPSK modulation, convolutional channel coding, NOMA-based power allocation, LMS adaptive equalization, and Successive Interference Cancellation (SIC). Two users share the communication resources through power-domain NOMA, with different power allocation coefficients assigned to the far and near users. The system performance is investigated under AWGN, Rayleigh fading, and Rician fading channel models. The simulation parameters used in the study are summarized in Table I.

Table I. Simulation Parameters

Parameters	Value
Simulation Software	MATLAB
Communication System	Proposed NOMA-Enhanced SISO-OFDM
Number of Users	2
Multiple Access Technique	NOMA
OFDM Subcarriers (FFT Size)	64
Cyclic Prefix (CP)	16
Channel Coding	Convolutional Coding
Constraint Length	7
General Polynomial	[171, 133]
Modulation Scheme	QAM/QPSk
Near-User Power Coefficient	0.2
Far-User Power Coefficient	0.8
LMS Step Size (μ)	0.01
Wireless Channel Models	AWGN, Rayleigh, Rician
Performance Metrics	BER, Spectral Efficiency, Sum Rate, Fairness Index, Outage Probability

The simulations use two-user power-domain NOMA with far-user and near-user power coefficients of 0.8 and 0.2, respectively. The OFDM configuration uses an FFT size of 64 and a cyclic prefix length of 16 samples. QPSK modulation and a rate-1/2 convolutional code with constraint length 7 and generator polynomials [171, 133] are specified for the coded OFDM experiment. The LMS step size is set to 0.01, and the wireless channel models considered are AWGN, Rayleigh fading, and Rician fading. The SNR range and number of iterations depend on the simulation experiment and should be reported separately for each set of results.

V. RESULTS AND DISCUSSION

The performance of the proposed communication system is evaluated through MATLAB simulations under AWGN, Rayleigh, and Rician channel conditions. The BER performance of coded and uncoded OFDM systems is analyzed over an SNR range of 0–30 dB, while conventional OFDM, SISO-LMS, and the proposed NOMA-SISO system are compared over an SNR range of 0–10 dB. The analysis focuses on the effect of convolutional coding, channel fading, and the proposed NOMA-SISO approach on transmission reliability. The simulation results are presented graphically to illustrate the variation in BER with increasing SNR. In addition to BER, sum rate, Jain's fairness index, and outage probability are considered to assess the overall communication performance under different channel conditions.

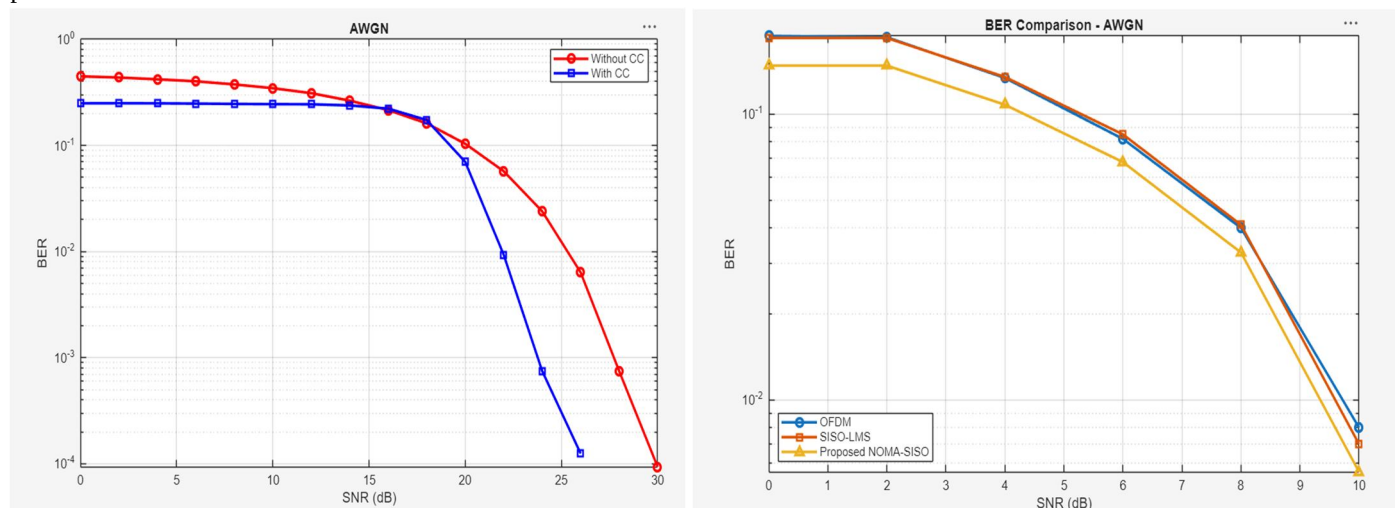


Fig. 5. BER performance under AWGN channel: (a) with and without convolutional coding; (b) comparison of OFDM, SISO-LMS, and proposed NOMA-SISO.

Fig. 5(a) illustrates the BER performance of coded and uncoded OFDM systems under AWGN channel conditions over an SNR range of 0–30 dB. The BER decreases as the SNR increases, with convolutional coding providing better error performance, particularly at higher SNR values. Fig. 5(b) compares conventional OFDM, SISO-LMS, and the proposed NOMA-SISO system over an SNR range of 0–10 dB. All three methods exhibit decreasing BER with increasing SNR. The SISO-LMS method provides a slight improvement over conventional OFDM, while the proposed NOMA-SISO system achieves the lowest BER among the three methods. These results demonstrate the benefits of convolutional coding and the improved BER performance observed with the proposed NOMA-SISO approach under AWGN channel conditions.

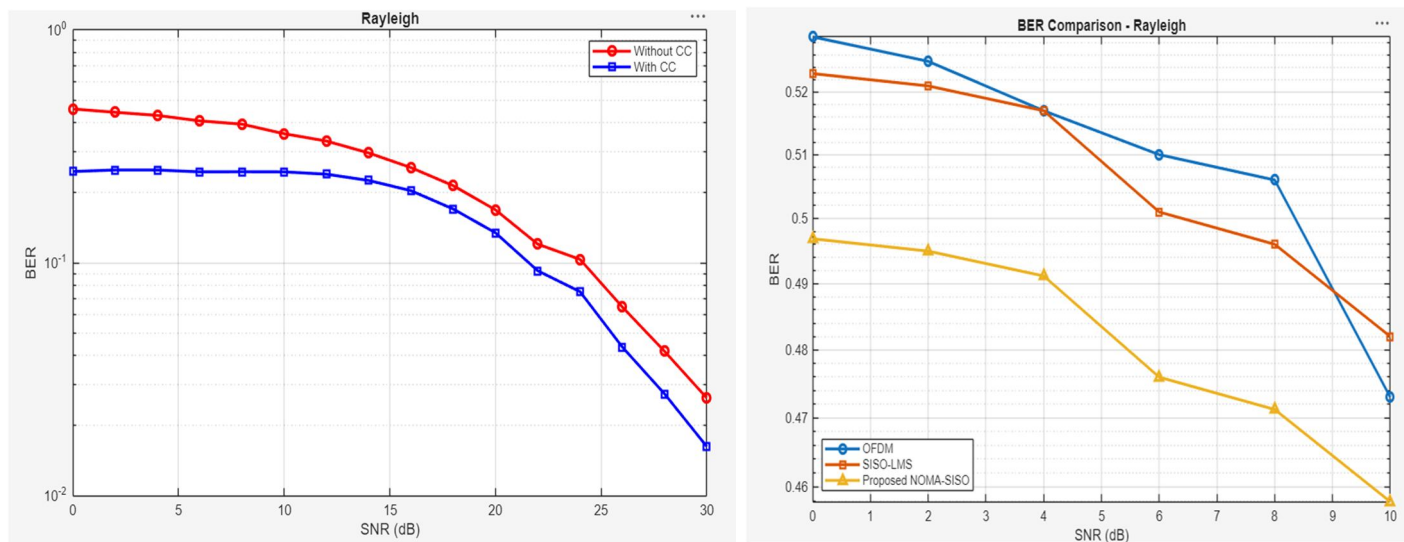


Fig. 6. BER performance under Rayleigh fading: (a) with and without convolutional coding; (b) comparison of OFDM, SISO-LMS, and proposed NOMA-SISO

Fig. 6(a) illustrates the BER performance of coded and uncoded OFDM systems under Rayleigh fading over an SNR range of 0–30 dB. The BER decreases as the SNR increases, with the convolutionally coded system achieving a lower BER than the uncoded system. This improvement is due to the error-correction capability of convolutional encoding and Viterbi decoding, which enhances communication reliability under multipath fading. Fig. 6(b) compares conventional OFDM, SISO-LMS, and the proposed NOMA-SISO system under Rayleigh fading over an SNR range of 0–10 dB. The BER decreases with increasing SNR for all three methods. The SISO-LMS system improves performance through adaptive equalization, while the proposed NOMA-SISO system achieves the lowest BER among the plotted methods. These results indicate that the proposed approach provides improved error performance under Rayleigh fading conditions.

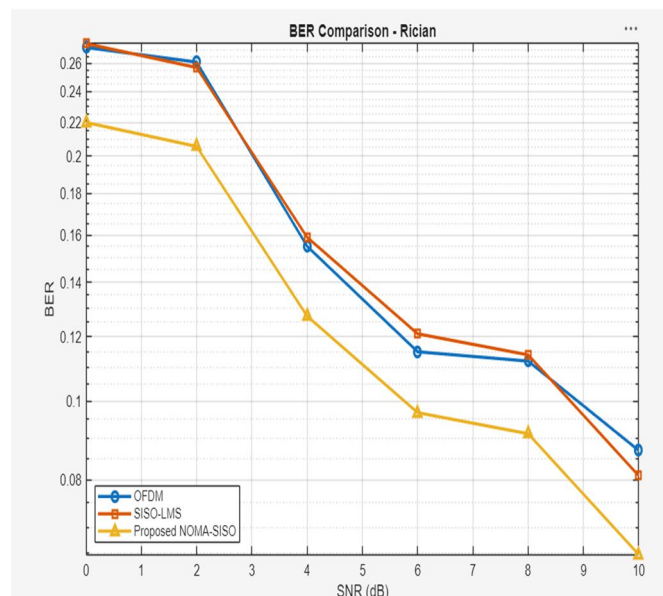
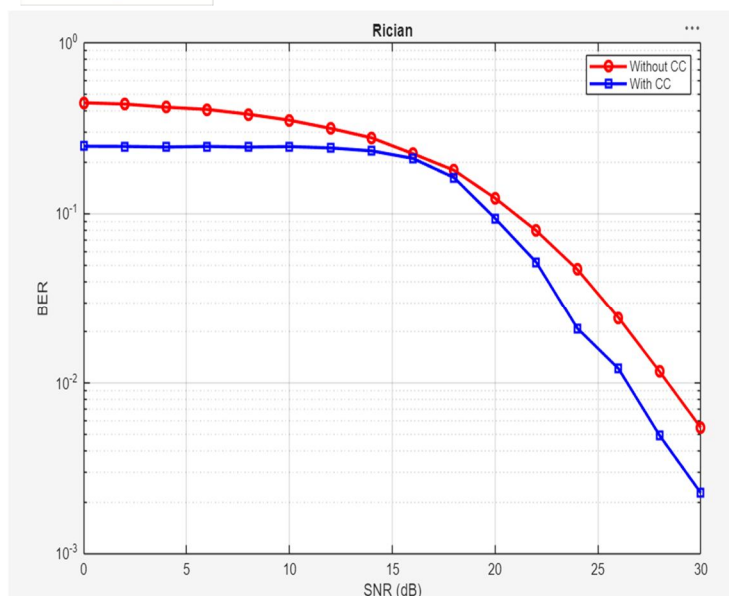


Fig. 7. BER Performance under Rician Fading Channel: (a) With and Without Convolutional Coding; (b) Comparison of OFDM, SISO-LMS, and Proposed NOMA-SISO.

Fig. 7(a) illustrates the BER performance of coded and uncoded OFDM systems under Rician fading over an SNR range of 0–30 dB. The BER decreases as the SNR increases, with the convolutionally coded system achieving a lower BER than the uncoded system due to the error-correction capability of convolutional encoding and Viterbi decoding. The Rician channel provides better performance than Rayleigh fading because it includes a line-of-sight component, which reduces the severity of fading. Fig. 7(b) compares conventional OFDM, SISO-LMS, and the proposed NOMA-SISO system under Rician fading over an SNR range of 0–10 dB. The BER decreases with increasing SNR for all three methods. OFDM and SISO-LMS show similar performance, while the proposed NOMA-SISO system achieves the lowest BER. These results indicate improved error performance and communication reliability for the proposed method under Rician fading conditions.

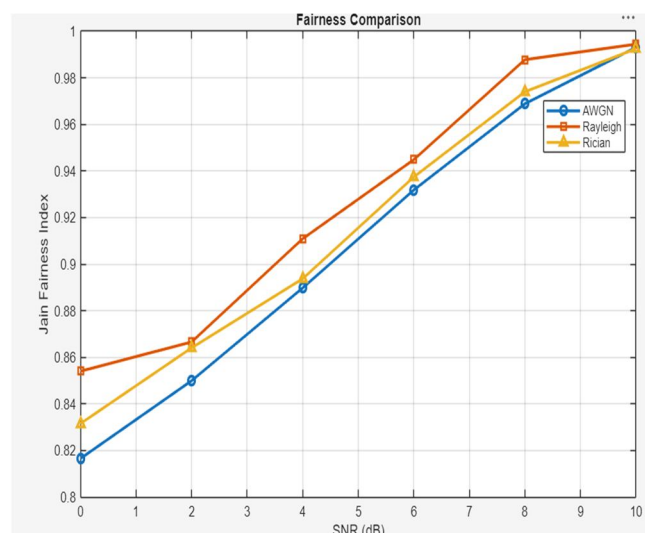
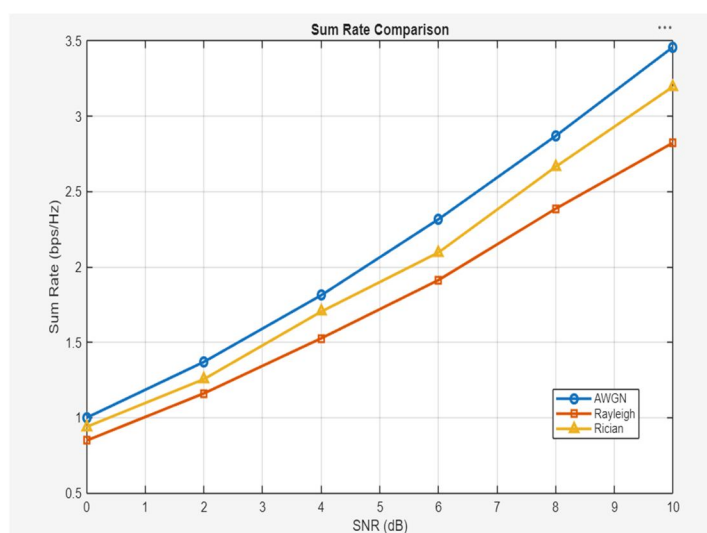


Fig. 8. (a): Sum Rate Comparison (b): Fairness Index Comparison.

Fig. 8(a) illustrates the spectral efficiency under AWGN, Rayleigh, and Rician channel conditions as the SNR increases. Spectral efficiency improves with increasing SNR for all three channels. The AWGN channel achieves the highest spectral efficiency, followed by the Rician channel, while the Rayleigh channel records the lowest performance due to multipath fading. Fig. 8(b) presents the sum rate performance under the same channel conditions. The sum rate increases with increasing SNR as the signal quality improves and both users achieve higher data rates. The AWGN channel provides the highest sum rate, followed by the Rician and Rayleigh channels. Overall, the results indicate that channel conditions significantly influence spectral efficiency and achievable sum rate in the proposed communication system.

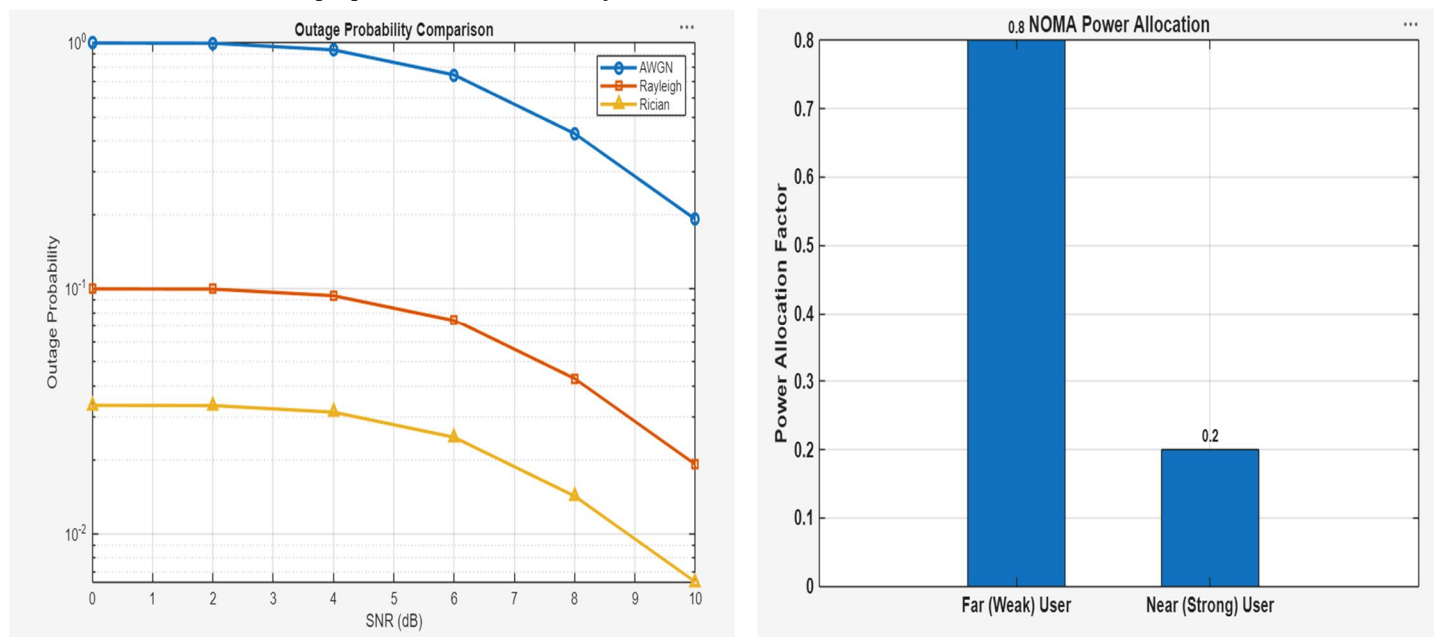


Fig. 9. (a): Outage Probability Comparison under Different Channel Conditions. (b): NOMA Power Allocation for Far and Near Users.

Fig. 9(a) shows the outage probability under AWGN, Rayleigh, and Rician channel conditions over an SNR range of 0–10 dB. The outage probability decreases as the SNR increases, with the Rician channel showing the lowest outage probability, followed by Rayleigh and AWGN. Fig. 9(b) illustrates the NOMA power allocation strategy, where 80% of the total power is assigned to the far user and 20% to the near user. This allocation provides higher transmission power to the far user to compensate for its weaker channel conditions while enabling both users to share the same time-frequency resources.

The performance comparison under AWGN, Rayleigh, and Rician channel conditions highlights the influence of channel characteristics on communication reliability. As shown in Fig. 9(a), the Rician channel exhibits the lowest outage probability, followed by the Rayleigh and AWGN channels in the simulation results. The outage probability decreases with increasing SNR for all three channels, indicating improved communication reliability at higher SNR values. This comparison demonstrates the importance of evaluating the proposed communication system under different channel conditions.

VI. CONCLUSION

This dissertation presented a beamforming-aided NOMA-OFDM communication system that integrates power-domain NOMA, OFDM, convolutional coding, LMS equalization, and Successive Interference Cancellation (SIC) to improve wireless communication performance. The proposed system was developed and evaluated under AWGN, Rayleigh, and Rician channel conditions. By allowing two users to share the same time-frequency resources through appropriate power allocation, the proposed framework improves spectrum utilization while maintaining reliable data transmission.

The performance of the proposed system was evaluated using Bit Error Rate (BER), spectral efficiency, sum rate, fairness index, and outage probability. The results indicate that the proposed NOMA-OFDM system provides lower BER, higher spectral efficiency, improved sum rate, better fairness, and lower outage probability compared with the conventional OFDM system. Among the evaluated channel models, the AWGN channel achieved the best overall performance, followed by the Rician channel, while the

Rayleigh channel showed comparatively higher BER due to severe multipath fading. These results demonstrate that the proposed framework effectively enhances communication reliability and bandwidth utilization, making it a suitable approach for next-generation wireless communication systems.

VII. FUTURE WORK

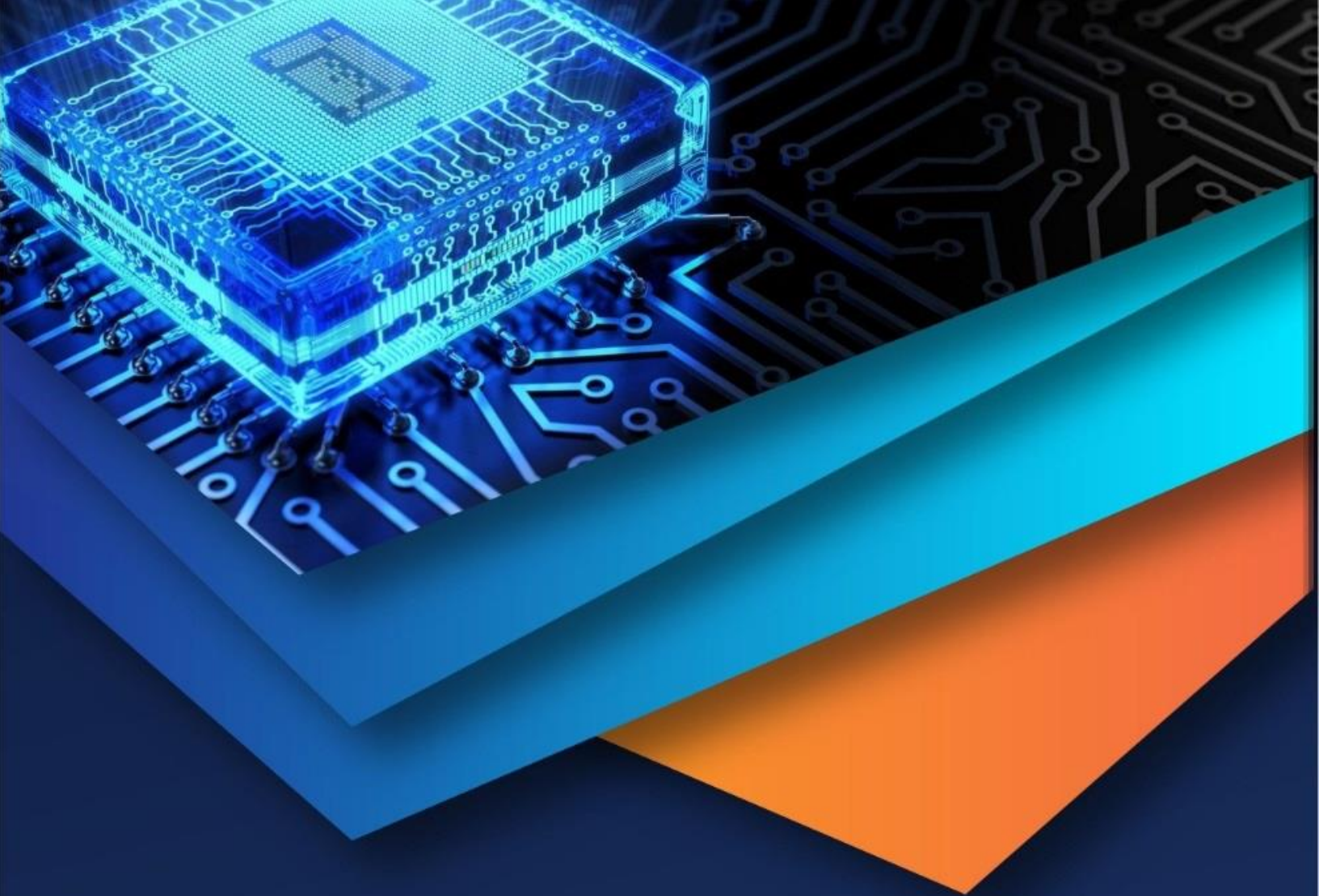
The future scope of this research includes extending the proposed NOMA-OFDM system to support multiple users and large-scale wireless communication networks. MIMO beamforming techniques can be integrated to improve system capacity, coverage, signal reception, and communication reliability. Machine learning algorithms can also be explored for intelligent power allocation, user pairing, and dynamic resource management to enhance overall system performance. Furthermore, Intelligent Reflecting Surfaces (IRS) can be incorporated to improve signal quality and reduce interference under different channel conditions. Future investigations may evaluate the proposed framework in emerging 6G communication scenarios, particularly in high-mobility environments and dense user networks. Finally, implementation using Software-Defined Radio (SDR) platforms can enable real-time testing and validation, helping assess the practical applicability, computational complexity, and energy efficiency of the proposed system.

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