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Performance Analysis Of MIMO-OFDM Under Fading Channels

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ABSTRACT

The advancement of wireless communication has ushered in the era of fourth-generation (4G) systems, characterized by their reliance on sophisticated techniques like Multiple Input Multiple Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM). This paper focuses on the synergistic integration of these two technologies to create an enhanced communication framework known as the OFDM-MIMO system. This system is particularly renowned for its ability to significantly improve capacity and data rates, making it a cornerstone of modern wireless networks.

In this study, we investigate the Bit Error Rate (BER) performance of both traditional OFDM and the OFDM-MIMO system. A crucial aspect of our approach involves employing convolutional coding, a technique designed to encrypt and protect the data stream during transmission over varying communication channels. To thoroughly evaluate the performance of these systems, we conducted simulations using MATLAB, incorporating three distinct types of channels: Additive White Gaussian Noise (AWGN), Rician fading. The simulation results reveal a marked improvement in performance for the OFDM-MIMO system compared to the traditional OFDM system, underscoring the benefits of integrating MIMO technology.

Furthermore, the practical aspect of our research was executed using two Universal Software Radio Peripheral B210 (USRP B210) devices. This involved a hands-on experiment where we utilized two antennas for simultaneous transmission and reception. The results demonstrated that the transmitted signals were successfully recovered, validating the effectiveness of the OFDM- MIMO system in real-world scenarios.

This research not only contributes to the academic understanding of advanced wireless communication techniques but also provides valuable insights for future developments in high-capacity, reliable communication systems

1-INTRODUCTION

Wireless communication systems these days have to provide higher data rates to fulfill the high demand. MIMO is basically about improving the channel capacity by using multiple antennas. MIMO offers enhancement to data rate and channel capacity. MIMO-OFDM is an essential point of today's broadband wireless systems. In fact MIMO-OFDM technology has been being used in 4G, 4.5G and is going to be used in 5G. Current generation wireless systems, such as 4G, support data rates up to 1Gbps, which seems to be insufficient for high demand. In order to achieve this requested data rate, the near future generation 5G plans to use MIMO for signal processing and OFDM for radio technologies. Upcoming mobile and wireless applications will need significantly higher data rates and cut-price cost per transmitted bit compared to 3G systems. Systems using single antenna fail to meet the requirements on data rate, link quality, spectral efficiency etc. In MIMO technology high gain is ensured for both channel capacity and reliability. The use of multiple antennas instead of a single antenna allows to enhance coverage, data transfer rate, security of the radio networks . The BER of convolutional coded orthogonal frequency-division multiplexing system is analyzed in [3]. The BER is evaluated for different modulation schemes. This paper gives a generalized BER analysis of OFDM and MIMO-OFDM systems.

5G: Fifth-generation (5G) wireless technology offers significantly higher data rates compared to previous cellular standards. It utilizes millimeter wave (mm-Wave) frequencies in the range of 24 GHz to 100 GHz, as well as sub-6 GHz among which Multiple Input Multiple Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) stand out as pivotal enablers of modern communication systems.

MIMO technology harnesses the capabilities of multiple antennas at both the transmitter and receiver ends, leveraging spatial diversity to enhance signal quality and mitigate the effects of multipath fading. By transmitting multiple data streams simultaneously, MIMO can significantly increase throughput without requiring additional bandwidth, thus optimizing the available spectrum. This technology not only improves data rates but also enhances the reliability of the communication link by enabling better signal-to-noise ratios (SNR).

2-SOFTWARE REQUIREMENTS

The performance analysis of MIMO-OFDM systems requires robust simulation environments that can accurately model the complexities of wireless channels and signal processing. This chapter details the software tools used for the simulation, analysis, and hardware testing phases of the project.

MATLAB

Programming assignments in this course will frequencies. 5G networks leverage advanced techniques like beam forming, massive MIMO (Multiple-Input, Multiple-Output), and network slicing to achieve faster speeds, lower latency, and increased capacity.

Wireless communication has witnessed a remarkable transformation over the past few decades, driven by an insatiable demand for higher data rates, improved spectral efficiency, and enhanced reliability in data transmission. As the landscape of communication continues to evolve, several technological advancements have emerged to address these challenges,

almost exclusively be performed in MATLAB, a widely used environment for technical computing with a focus on matrix operations. The name MATLAB stands for “Matrix Laboratory” and was originally designed as a tool for doing numerical computations with matrices and vectors. It has since grown into a high-performance language for technical computing. MATLAB integrates computation, visualization, and programming in an easy-to-use environment, and allows easy matrix manipulation, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs in other languages. Typical areas of use include:

- Math and Computation
- Modeling and Simulation
- Data Analysis and Visualization
- Application Development
- Command Window: Run MATLAB statements.
- Current Directory: To view, open, search for, and make changes to MATLAB related directories and files.
- Command History: Displays a log of the functions you have entered in the Command Window. You can copy them, execute them, and more.

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Workspace: Shows the name of each variable, its value, and the Min and Max entry if the variable is a matrix. In case that the desktop does not appear with the default layout, you can change it from the menu Desktop → Desktop Layout → Default. 1.3 Editor

Figure 2.1: MATLAB Desktop (default layout)

MATLAB editor (Figure 2) can be used to create and edit M–files, in which you can write and save MATLAB programs. A file can take the form of a script file or a function. A script file contains a sequence of MATLAB statements; the statements contained in a script file can be run in the specified order, in the MATLAB command window simply by typing the name of the file at the command prompt. M–files are very useful when you use a sequence of commands over and over again, in many different MATLAB sessions and you do not want to manually type these commands at the command prompt every time you want to use them.

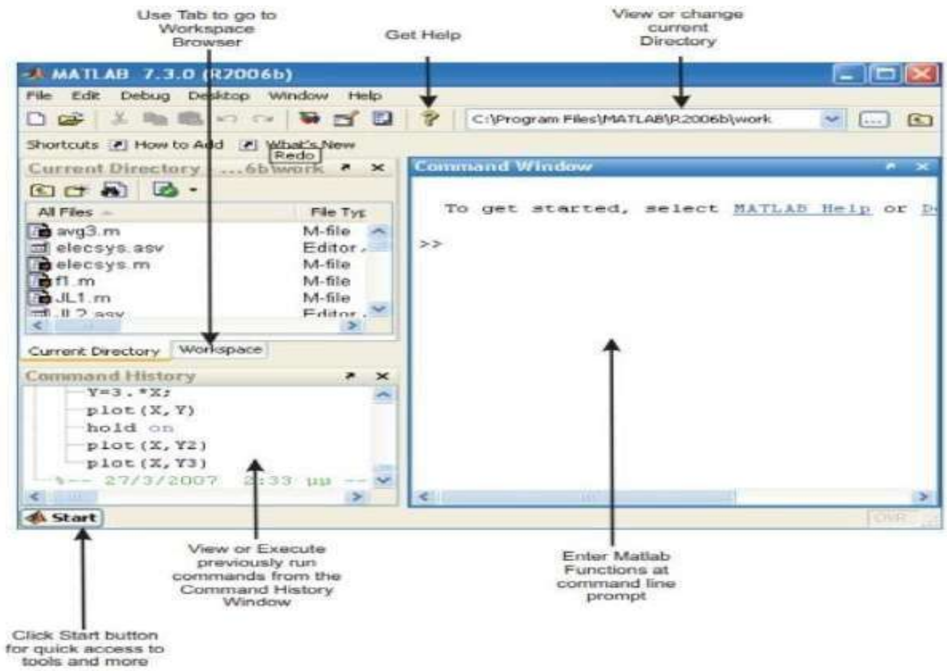

Figure 2.1: MATLAB Desktop (default layout)

3-MIMO-OFDM UNDER FADING CHANNELS

Existing System

Overview of Current Wireless Communication Systems

In contemporary wireless communication, achieving high data rates is paramount due to the increasing demand for bandwidth-intensive applications such as video streaming, online gaming, and Internet of Things (IoT) devices. Traditional systems, primarily based on Single Input Single Output (SISO) technology, are limited in their ability to provide the necessary data throughput and link quality. SISO systems utilize a single antenna at both the transmitter and receiver, making them susceptible to various challenges including multipath fading, limited spectral efficiency, and inadequate coverage. As a result, these systems struggle to meet the burgeoning requirements for data transmission in modern networks.

Limitations of SISO Technology

SISO technology fundamentally restricts the capacity and reliability of wireless networks. The transmission power and bandwidth must be increased to enhance system performance, which can lead to higher operational costs. Furthermore, SISO systems are prone to interference from other signals, resulting in degraded performance, particularly in urban environments where buildings and other obstacles can cause significant multipath fading. As users become increasingly mobile and the number of connected devices grows exponentially, the limitations of SISO systems become more pronounced, necessitating the exploration of advanced technologies.

Enhancing Data Throughput: By employing multiple antennas, the system aims to significantly increase the data transfer rates beyond those achievable with traditional SISO systems.

PROPOSED SYSTEM

Integration of MIMO and OFDM Technologies

The proposed system aims to integrate MIMO technology with OFDM to create a robust communication framework capable of addressing the shortcomings of existing systems. By utilizing multiple antennas in conjunction with OFDM, this system seeks to leverage the benefits of both technologies, ultimately improving data rates, spectral efficiency, and reliability in wireless communication.

Objectives of the Proposed System

The primary objectives of the proposed MIMO-OFDM system include:

Improving Reliability: The integration of convolutional coding with MIMO-OFDM is intended to provide enhanced error correction, thereby reducing the Bit Error Rate (BER) in various fading environments.

BLOCK DIAGRAM

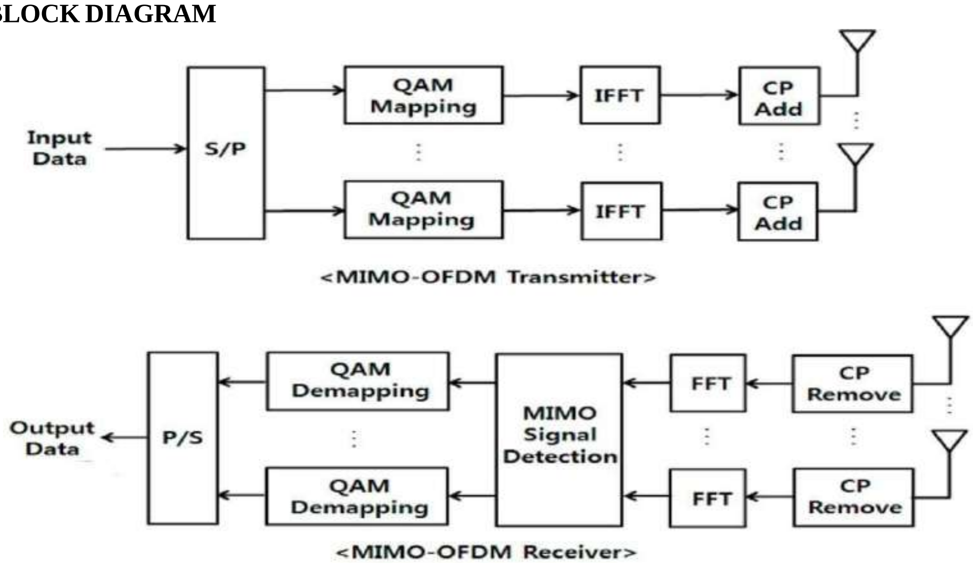

Figure 3.2: Block Diagram of MIMO-OFDM

4-ADVANTAGES, DISADVANTAGES AND APPLICATIONS

1. Higher Data Rates: MIMO-OFDM can achieve significantly higher data rates compared to traditional single-antenna systems due to the use of multiple antennas and sub-carrier

multiplexing.

2. Increased Capacity: By utilizing multiple antennas for transmission and reception, MIMO systems improve the overall capacity of the wireless channel.

3. Robustness Against Fading: MIMO-OFDM systems are more resilient to multi-path fading, enhancing signal quality in challenging environments.

3.Interference Management: MIMO systems need to manage interference between multiple signals, which can complicate network design and operation.

APPLICATIONS

1. 4G and 5G Mobile Networks: MIMO-OFDM is essential in the architecture of modern mobile communication networks,

DISADVANTAGES

1.Complexity: The implementation of MIMO-OFDM systems is more complex than single-input single-output (SISO) systems, requiring advanced algorithms and processing power.

2.Higher Power Consumption: The use of multiple antennas and signal processing increases the power consumption of MIMO-OFDM systems.

providing high data rates and low latency.

2. Wireless Local Area Networks (WLANs): Used in Wi-Fi standards to improve data throughput and reliability in indoor and outdoor environments.

3. Digital Broadcasting: MIMO-OFDM is used in digital television and radio broadcasting to enhance signal quality and coverage.

5-RESULTS

Figure 5.1:BER vs SNR of MIMO-OFDM under AWGN (64 bit QAM)

The graph illustrates the performance of an OFDM system with 64-bit QAM under AWGN by plotting the Bit Error Rate (BER) against various Signal-to-Noise Ratio (SNR) values.

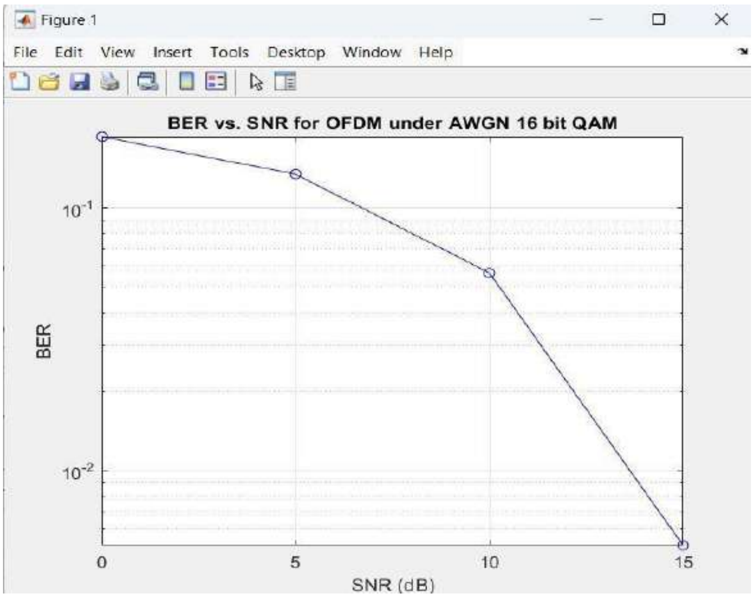

Figure 5.2:BER vs SNR of MIMO-OFDM under AWGN (16 bit QAM)

The graph illustrates the performance of an OFDM system with 16-bit QAM under AWGN by plotting the Bit Error Rate (BER) against various Signal-to-Noise Ratio (SNR) values. As SNR increases, the BER decreases significantly, indicating improved system performance.

Figure 5.3: BER vs SNR of MIMO-OFDM under AWGN (16 and 64 bit QAM)

The graph compares the Bit Error Rate (BER) versus Signal-to-Noise Ratio (SNR) for 16-QAM and 64-QAM under Additive White Gaussian Noise (AWGN). As SNR increases, the BER for both schemes decreases, though 64-QAM has a consistently higher BER at the same SNR, reflecting a trade-off between data rate and error rate. 16-QAM is more resilient to noise and performs better at lower SNR, making it suitable for noisier environments, while 64-QAM requires higher SNR for acceptable performance but offers higher data rates.

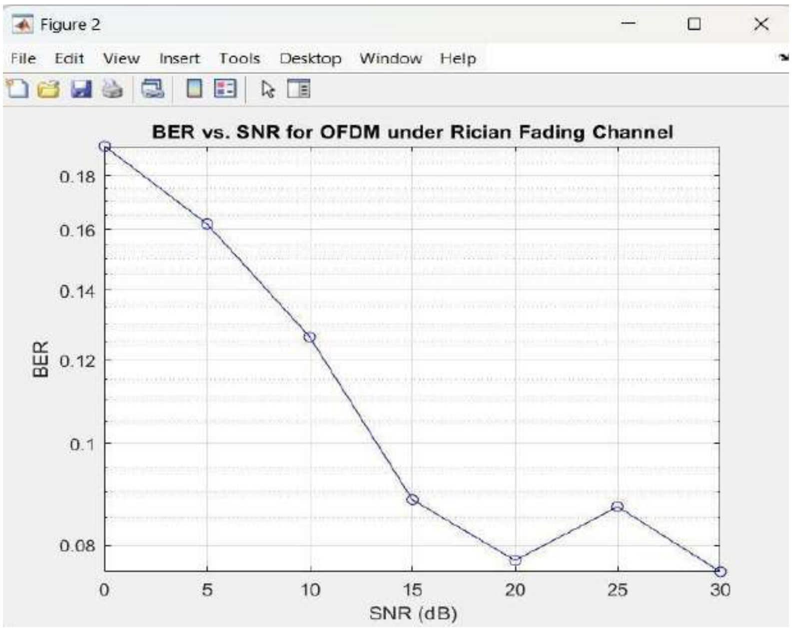

Figure 5.4: BER vs SNR of MIMO-OFDM under Rician (16 QAM)

The graph illustrates the relationship between Bit Error Rate (BER) andSignal-to-Noise Ratio (SNR) for OFDM under a Rician Fading Channel. As SNR increases, the BER generally decreases, but there is a slight performance dip around 20 dB. This indicates some sensitivity to fading effects, although the overall trend shows improvement in BER with increasing SNR

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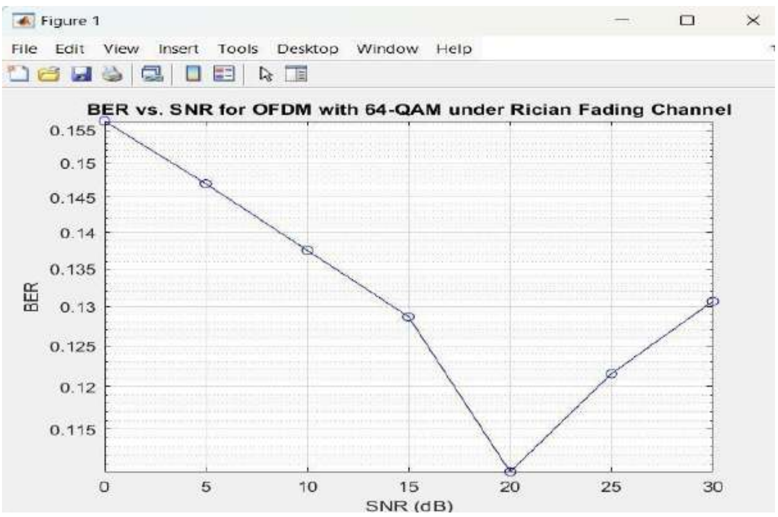

Figure 5.5: BER vs SNR of MIMO-OFDM under Rician(64 QAM)

In a graph of BER (Bit Error Rate) vs SNR (Signal-to-Noise Ratio) for MIMO-OFDM under AWGN fading, the BER typically decreases as SNR increases, indicating improved signal quality. The curve generally shows a steep drop in BER at higher SNR values, highlighting the effectiveness of MI MO-OFDM in mitigating the effects of AWGN fading, which represents multi-path interference in wireless communication systems

6-CONCLUSION

The research conducted in this paper successfully demonstrates the significant performance improvements achieved by the OFDM-MIMO system compared to traditional OFDM systems. Through both simulation and practical implementation using USRP B210 devices, we evaluated the Bit Error Rate (BER) across various channel conditions, including AWGN, Rician fading. The findings reveal that the incorporation of MIMO technology not only enhances data rates but also improves signal reliability, making it a vital component of modern wireless communication systems. The use of convolutional coding further fortifies the data stream, providing an effective means of encryption and protection against transmission errors. Overall, the results affirm the viability of MIMO-OFDM systems as a foundation for next- generation wireless networks, including 5G and beyond, addressing the increasing demands for higher data capacity and better quality of service.

REFERENCES

Looking ahead, several avenues for further research and exploration can be identified:

1. Advanced Modulation Techniques: Future studies could explore the integration of advanced modulation schemes, such as higher-order QAM (Quadrature Amplitude Modulation), to assess their impact on BER performance and system capacity in MIMO-OFDM frameworks.

2. Enhanced Channel Models: Further investigation into complex fading environments, including urban and rural scenarios, would provide deeper insights into the robustness of MIMO-OFDM systems in real-world applications.

3. Network Integration: Exploring the integration of MIMO-OFDM systems with emerging technologies, such as Internet of Things (Io T) devices and vehicular networks, would be crucial for the deployment of seamless and high-capacity wireless networks.

4. Implementation of 5G Technologies: Research into the practical implementation of MIMO-OFDM in 5G networks, focusing on ultra-reliable low-latency communications (URLLC) and massive machine-type communications (mMTC), would be beneficial in understanding its impact on future applications.

5. By pursuing these areas, we can further enhance the capabilities of MIMO-OFDM systems and ensure they meet the growing demands of future wireless communication technologies.

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