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# Efficient Transmission of an Encrypted Image through a MIMO-OFDM System with Different Schemes

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***ABSTRACT***

*The rapid advancements in wireless communication systems have spurred the need for efficient and secure methods for transmitting sensitive data, including encrypted images. This study explores the integration of Multiple-Input Multiple-Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) systems to achieve high-throughput, robust, and secure transmission of encrypted images. The MIMO-OFDM framework is recognized for its ability to mitigate multipath fading, improve spectral efficiency, and support high data rates. However, ensuring data confidentiality while maintaining efficiency in such systems presents unique challenges.*

*This work investigates various encryption schemes tailored to image data, including traditional cryptographic methods, chaotic systems, and hybrid encryption techniques, emphasizing their compatibility with MIMO-OFDM systems. The performance of the proposed approach is evaluated under different channel conditions, considering factors like encryption overhead, transmission efficiency, and security resilience. Comparative analysis with existing systems demonstrates the effectiveness of optimized encryption techniques in maintaining image quality and reducing latency without compromising security.*

*The results highlight the potential of MIMO-OFDM systems for secure and efficient encrypted image transmission, paving the way for their application in areas such as medical imaging, secure surveillance, and real-time multimedia sharing. This study provides a comprehensive framework for balancing performance, security, and efficiency, offering a robust solution for the growing demands of next-generation wireless communication networks.*

## 1-INTRODUCTION

The transmission of large multimedia files, such as images, over wireless communication systems is essential for applications like medical imaging, surveillance, and remote sensing. Technologies like Multiple Input Multiple Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) offer effective solutions to meet the demands for high-speed and reliable data transmission. MIMO enhances communication reliability and data throughput using multiple antennas, while OFDM improves efficiency and resistance to interference by dividing the communication channel into sub-channels. However, the challenge remains in balancing efficient data transmission with the confidentiality of sensitive information.

Image encryption is crucial for securing sensitive data during transmission but often introduces overhead, impacting speed, energy consumption, and system performance. This work focuses on efficiently transmitting encrypted image data through a MIMO-OFDM system, aiming to optimize performance without compromising security. By exploring various encryption schemes, modulation techniques, and channel configurations, it seeks to develop a secure and reliable system for transmitting image data effectively.

In the era of next-generation wireless technologies like 5G and beyond, the demand for secure and high-speed multimedia transmission has grown exponentially. Sensitive image data—such as medical images, surveillance footage, and satellite photos—requires robust protection against unauthorized access during wireless transmission. However, encryption adds overhead that may impact latency, power efficiency, and throughput. This has led to the exploration of intelligent and adaptive encryption techniques that work seamlessly with wireless transmission protocols. Among these, the integration of Multiple-Input Multiple-Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) systems has proven to be highly efficient in combating multipath fading, enhancing spectral efficiency, and supporting parallel data transmission. When combined with lightweight and channel-aware encryption schemes, MIMO- OFDM becomes a powerful solution for real-time secure image transmission. Thus, this project investigates a system that not only transmits encrypted images effectively but also considers performance trade-offs and adaptability under various channel conditions.

## 2-EVOLUTION OF MIMO-OFDM SYSTEMS

Wireless communication has significantly improved over the past few decades, evolving from basic voice transmission to high-speed data services. Modern communication systems demand increased data rates, enhanced spectral efficiency, and robust performance in diverse environments. To meet these requirements, Multiple-Input Multiple-Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) have emerged as key technologies, forming the backbone of modern wireless standards such as LTE, 5G, and beyond.

**Overview of Wireless Communication Systems**

Wireless communication systems enable the transmission of information over a distance without the need for physical connections such as cables or optical fibers. These systems operate using electromagnetic waves and have evolved through multiple generations, each improving efficiency, capacity, and performance:

- 1G (First Generation) – Analog voice communication (AMPS, NMT).
- 2G (Second Generation) – Digital voice and SMS (GSM, CDMA).
- 3G (Third Generation) – Introduction of mobile internet and multimedia services (UMTS, HSPA).
- 4G (Fourth Generation) – High-speed mobile broadband with IP-based architecture (LTE, WiMAX).
- 5G (Fifth Generation) – Ultra-high-speed communication, low latency, and massive connectivity.

Each generation has introduced new technologies to overcome the limitations of previous systems, with MIMO-OFDM being a crucial breakthrough for 4G, 5G, and future 6G networks. Importance of MIMO and OFDM:

MIMO and OFDM address key challenges in wireless communication, including multipath fading, spectral efficiency, and bandwidth utilization.

1. **MIMO (Multiple-Input Multiple-Output):**

- Utilizes multiple antennas at the transmitter and receiver to improve capacity and reliability.
- Offers spatial diversity to mitigate fading and spatial multiplexing to increase data rates.
- Enables techniques like beamforming, which enhances signal strength in a specific direction.

2. **OFDM (Orthogonal Frequency Division**

**Multiplexing):**

- A multi-carrier modulation technique that divides the transmission bandwidth into multiple subcarriers, reducing interference and improving efficiency.
- Provides resistance to inter-symbol interference (ISI) caused by multipath propagation.
- Improves spectral efficiency and simplifies equalization compared to traditional single-carrier systems.

The combination of MIMO and OFDM has revolutionized wireless communication, leading to the development of high-speed broadband systems like Wi-Fi 6, 4G LTE, and 5G NR.

**Need for High Data Rates, Spectral Efficiency, and Robust Communication** As data consumption continues to rise, modern networks must support:

**High Data Rates:**

The increasing demand for video streaming, gaming, cloud services, and IoT requires gigabitlevel speeds.

MIMO-OFDM achieves this by using spatial multiplexing and efficient spectrum utilization.

**Spectral Efficiency:**

With limited available bandwidth, maximizing bits per Hertz is crucial.

OFDM enables efficient frequency utilization, and MIMO further improves spectral efficiency through multi-user MIMO (MU-MIMO).

**Robust Communication in Harsh Environments:**

Wireless signals face multipath fading, interference, and Doppler shifts, especially in urban and mobile environments.

MIMO mitigates fading using diversity techniques, while OFDM combats ISI and maintains signal integrity.

## 3-MATHEMATICAL FOUNDATION AND ARCHITECTURE OF OFDM

The proposed system ensures secure and efficient transmission of digital images over wireless networks by integrating image encryption techniques with MIMO-OFDM (Multiple Input Multiple Output - Orthogonal Frequency Division Multiplexing) technology. Image encryption methods such as DES (Data Encryption Standard), AES (Advanced Encryption Standard), and Rubik's Cube Encryption are employed to scramble the image, ensuring its confidentiality and protection against unauthorized access. Once encrypted, the image data is transmitted using MIMO-OFDM, where MIMO utilizes multiple antennas at both the transmitter and receiver to enable parallel data streams, enhancing throughput, reliability, and spectral efficiency. Meanwhile, OFDM splits the data into multiple orthogonal subcarriers, reducing interference and combating multipath fading. To ensure efficient transmission, the encrypted image is modulated using BPSK (Binary Phase Shift Keying), which provides robust signal transmission. At the receiver end, the signals are demodulated, decrypted, and reconstructed to retrieve the original image. By combining strong encryption with advanced wireless transmission techniques, this system achieves a balance between security, reliability, and efficiency, making it well-suited for secure image transmission in modern wireless communication networks.

Orthogonal Frequency Division Multiplexing (OFDM) is a widely used modulation technique for high-speed wireless communications. It transforms a frequency-selective fading channel into multiple flat-fading subchannels, simplifying equalization and enhancing spectral efficiency. However, it suffers from issues like high Peak-to-Average Power Ratio (PAPR), Inter-Carrier Interference (ICI), and Inter-Symbol Interference (ISI), which require additional considerations in design.

System Architecture

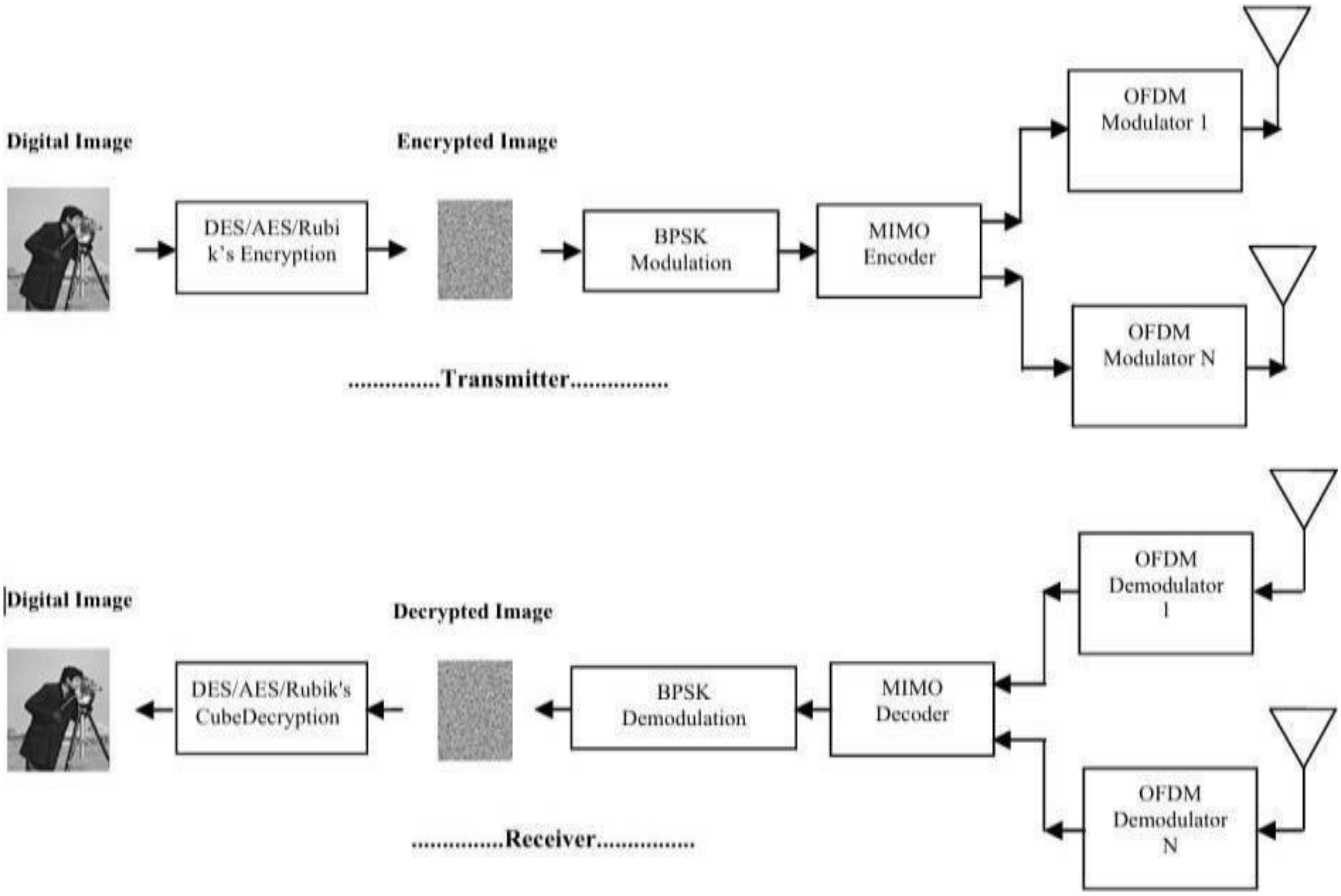


Fig: 1 Architectural Design of OFDM

**Transmitter Section**

1. Digital Image:

   This block represents the original image intended for transmission. The image can be in any digital format, such as JPEG or PNG, represented in binary form for processing.

2. DES/AES/Rubik's Cube Encryption:

   This block encrypts the digital image data to ensure confidentiality and security during transmission.

   Encryption Techniques:

   DES (Data Encryption Standard): A symmetric encryption algorithm that divides the data into fixed-size blocks and uses a secret key to transform the data.

   AES (Advanced Encryption Standard): A more secure block cipher algorithm with variable key lengths (128, 192, or 256 bits). It transforms the data using multiple rounds of substitution and permutation.

   Rubik's Cube Encryption: A novel algorithm where the image pixels are scrambled based on Rubik's cube-like operations. It adds complexity to the encryption, making it resistant to attacks. Output: The original image data is converted into an encrypted, unintelligible format, ensuring it cannot be intercepted or understood by unauthorized users.

3. Encrypted Image:

   This represents the encrypted output from the previous block. The image now looks like random data securing its content from interception.

4. BPSK Modulation:

Binary Phase Shift Keying (BPSK) is a digital modulation scheme used to encode the encrypted binary data into a phase-shifted carrier wave. o A binary '0' is represented by one phase. A binary '1' is represented by another phase (e.g., 180°).

Purpose: Converts the encrypted binary data into a waveform suitable for wireless transmission. Advantage: BPSK is simple and robust against noise, making it ideal for secure image transmission.

5. MIMO Encoder:

MIMO (Multiple Input Multiple Output) technology uses multiple transmitting and receiving antennas to improve data throughput and reliability.

The MIMO encoder splits the BPSK-modulated data stream into multiple sub-streams and sends each stream to a different transmit antenna.

## 4-SOFTWARE REQUIREMENTS

Efficient transmission of encrypted images through a MIMO-OFDM system involves several critical software requirements. Key components include robust signal processing for FFT, modulation, and MIMO channel modeling, along with OFDM simulation capabilities. Security is paramount, requiring the integration of strong encryption algorithms (e.g., AES, RSA) and secure key management. Error control mechanisms, including error detection (CRC) and correction (Reed-Solomon, LDPC), are essential for reliable communication. Performance optimization is achieved through adaptive modulation and coding (AMC), efficient resource allocation, and beamforming techniques to enhance signal quality. A user-friendly graphical interface allows configuration and monitoring of system performance. Compliance with communication standards (e.g., IEEE 802.11) ensures interoperability, and a robust simulation environment validates system performance under varying conditions. These software requirements collectively ensure secure, efficient, and high-performance transmission of encrypted images over MIMO-OFDM systems.

**MATLAB Software**

MATLAB (Matrix Laboratory) is a high-level programming and interactive environment primarily used for numerical computation, visualization, and algorithm development. Developed by MathWorks, it is widely utilized in engineering, scientific research, and academia. MATLAB provides a versatile platform for solving complex mathematical problems, simulating systems, and developing algorithms.

MATLAB is a high-level programming environment used for numerical computation, data analysis, and visualization. It supports matrix operations, algorithm development, and simulation, with specialized toolboxes for various engineering and scientific applications. MATLAB is widely used for its ease of use, robust functionality, and integration capabilities with other languages and hardware.

## 5-RESULT AND SIMULATION

This chapter focuses on evaluating the performance of the proposed system through various simulated experiments. It presents key performance metrics such as throughput, bit error rate (BER), signal-to-noise ratio (SNR), and overall system efficiency. Simulations are conducted under different conditions, including varying channel models and modulation schemes, to assess the system's performance in realistic environments. This chapter aims to validate the theoretical concepts and demonstrate the practical applicability of the system. It provides insights into its capabilities, highlighting areas for improvement and optimization for future development.

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**Simulation and Analysis of MIMO-OFDM Channel Performance.**

**OFDM Carriers on Designated IFFT Bins**

OFDM carriers are mapped to designated IFFT bins, maintaining orthogonality between subcarriers. Each bin holds a data symbol, ensuring efficient frequency-domain to time-domain conversion for reliable data transmission.

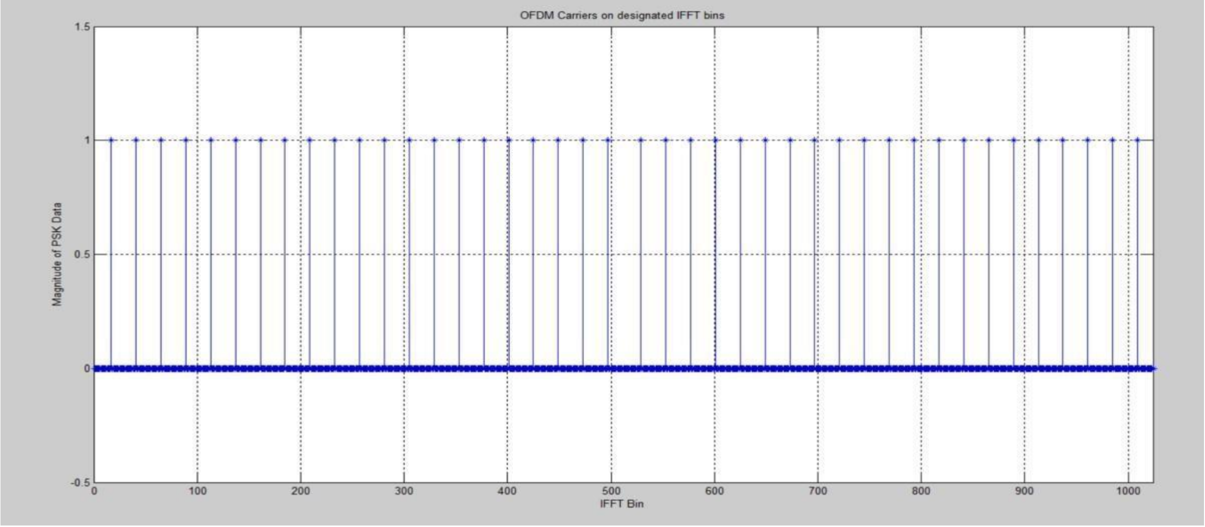


**Fig 5.2.1 OFDM Carriers on Designated IFFT bins. (Snapshot from MATLAB Software)**

***Phases of the OFDM modulated Data***

The phases of OFDM-modulated data include symbol generation, IFFT transformation, addition of cyclic prefix, and transmission. These steps ensure orthogonality, minimize interference, and prepare data for efficient transmission over the channel.

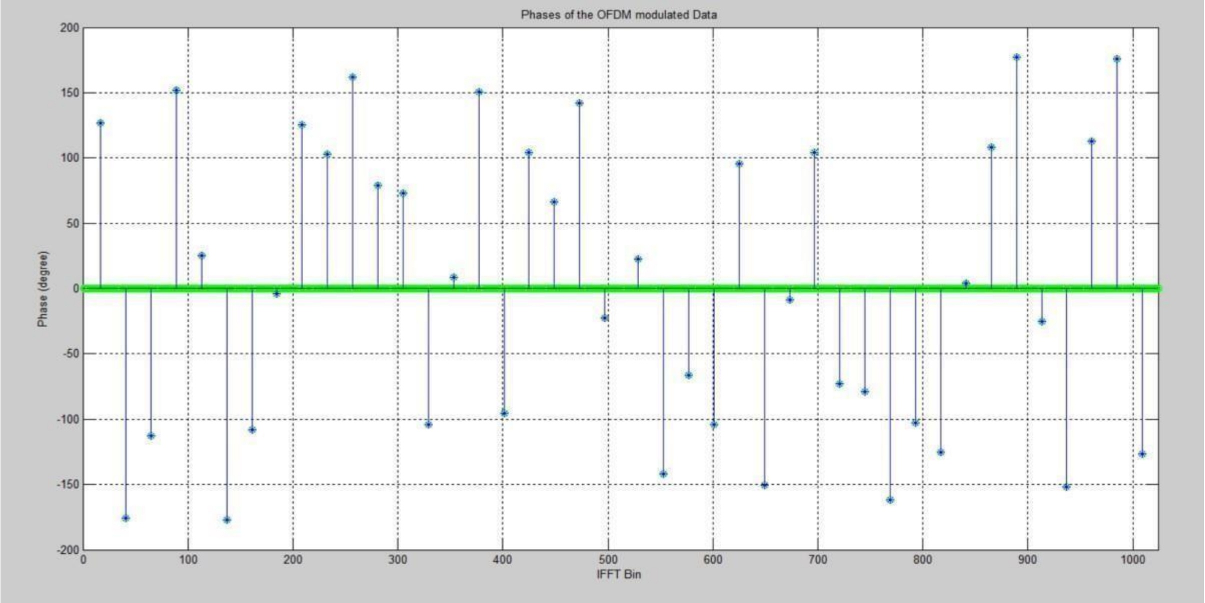


**Fig 5.2.2 Phases of the OFDM modulated Data. (Snapshot from MATLAB Software)**

**OFDM Time Signal (one symbol period in one carrier)**

In OFDM, one symbol period is transmitted over a single carrier. Each symbol spans one carrier's time duration, ensuring efficient use of the available bandwidth and maintaining orthogonality between subcarriers.

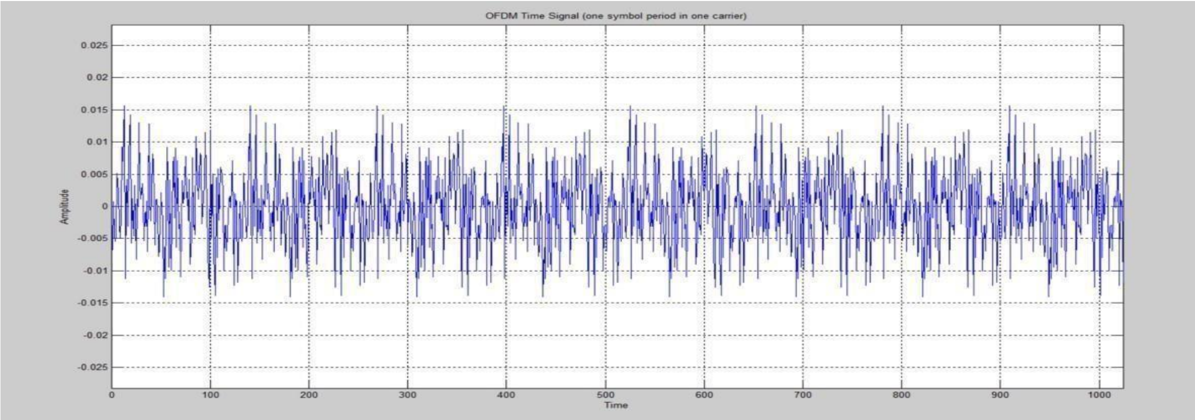


**Fig 5.2.3 OFDM Time Signal. (Snapshot from MATLAB Software)**

**Samples of OFDM Time Signals Over One Symbol Period**

Samples of OFDM time signals over one symbol period consist of a combination of multiple subcarriers, each carrying data symbols. These signals are combined after IFFT, forming a timedomain waveform for transmission.

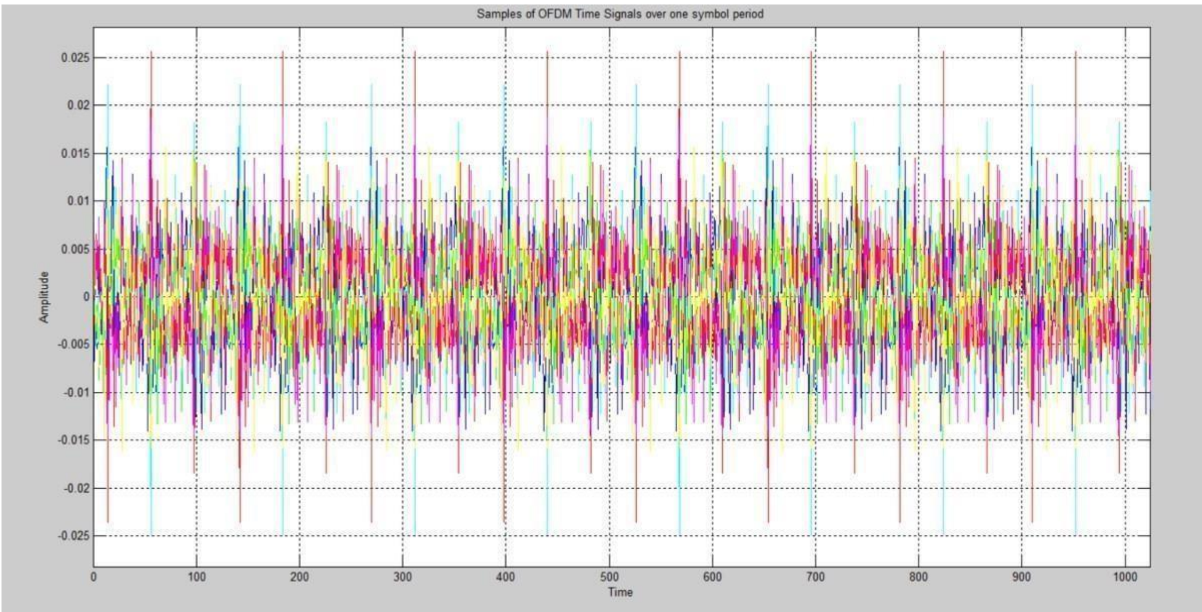


**Fig 5.2.4 Samples of OFDM Time Signals Over One Symbol Period. (Snapshot from MATLAB Software)**

**Magnitude of Received OFDM Spectrum**

The magnitude of the received OFDM spectrum represents the power distribution across subcarriers. It reveals the strength of each subcarrier signal, affected by channel conditions and noise during transmission.

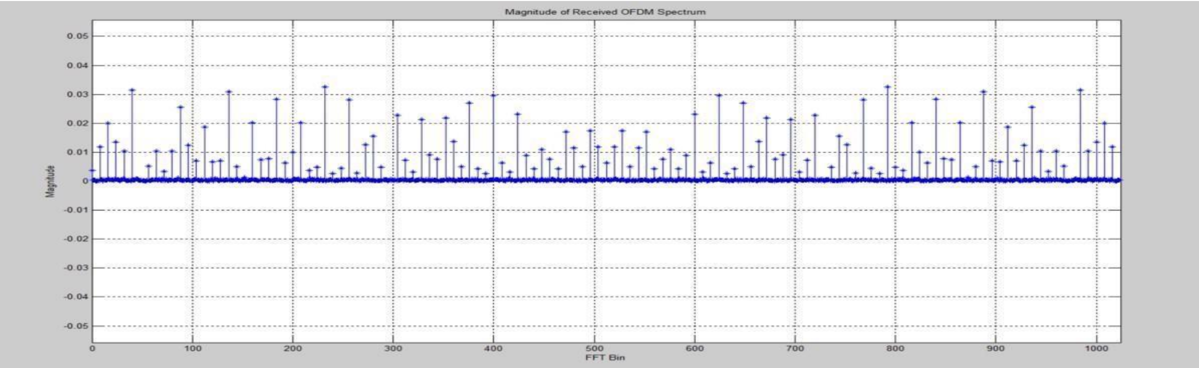


**Fig 5.2.5 Magnitude of Received OFDM Spectrum. (Snapshot from MATLAB Software)**

**Phase of Receive OFDM Spectrum**

The phase of the received OFDM spectrum indicates the phase shifts of each subcarrier after transmission. It is crucial for accurate demodulation and detecting any phase distortions due to channel effects.

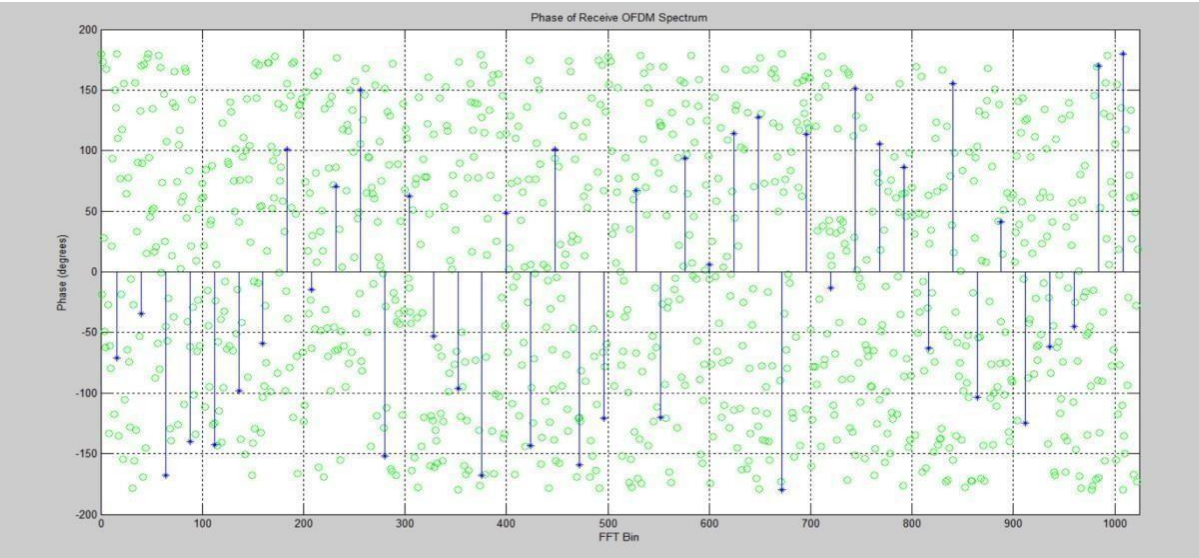


**Fig 5.2.6 Phase of Receive OFDM Spectrum. (Snapshot from MATLAB Software)**

**Received Phases**

Received phases refer to the phase shifts of the transmitted signals after passing through the communication channel. These shifts are crucial for accurate signal decoding and detecting any channel-induced distortions.

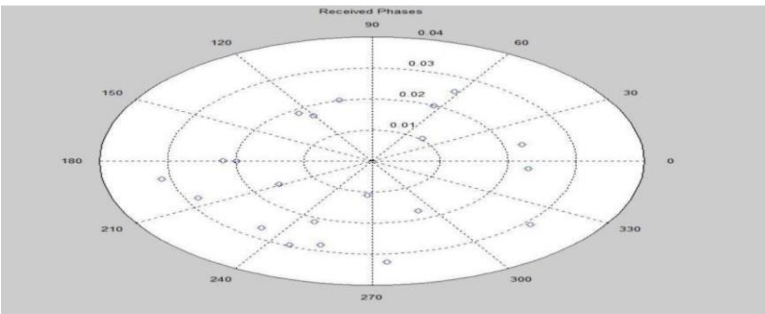


**Fig 5.2.7 Received Phases. (Snapshot from MATLAB Software)**

## 6-CONCLUSION

This chapter has summarized the critical findings of the study, presenting a thorough analysis of the techniques and methodologies employed for the efficient transmission of encrypted images using a MIMO-OFDM system with various schemes. The study demonstrated how these approaches effectively balance security, performance, and efficiency while mitigating challenges such as channel fading, interference, and system complexity. The use of advanced encryption techniques, combined with adaptive modulation and error correction strategies, was particularly successful in ensuring robust and reliable image transmission across diverse communication scenarios.

In addition to validating the proposed system's capabilities, this research also highlights areas for future exploration. The integration of emerging technologies such as massive MIMO, beamforming, and machine learning for channel estimation and resource allocation can further enhance system performance. Leveraging quantum cryptography and post-quantum encryption methods presents an opportunity to address evolving security threats in next-generation communication systems. Furthermore, exploring the use of intelligent reflecting surfaces (IRS) could significantly improve signal propagation and coverage in complex environments. Incorporating energy-efficient design principles, including low-power hardware and green communication strategies, may also contribute to sustainable deployment. Additionally, real-time implementation and testing of the system in practical settings would provide valuable insights into performance under real-world conditions, facilitating refinement and scalability. Finally, cross-layer optimization and integration with Internet of Things (IoT) frameworks could open new avenues for secure multimedia transmission in smart applications.