5G MIMO-OFDM System Simulation in MATLAB

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1. INTRODUCTION

Orthogonal Frequency Division Multiplexing combined with Multiple-Input Multiple-Output techniques forms the foundation of modern wireless communication systems such as 5G. OFDM efficiently mitigates inter-symbol interference caused by multipath propagation, while MIMO exploits spatial diversity to improve reliability and performance.

This project presents a MATLAB-based simulation of a 5G-inspired MIMO-OFDM physical layer system, with emphasis on Alamouti space-time block coding (stbc), pilot-based channel estimation, and MMSE-based receiver combining. System performance is evaluated using bit error rate (BER) versus signal-to-noise-ratio (SNR) analysis.

2. System Model

The simulated system employs OFDM modulation with **64 subcarriers** and a **cyclic prefix** to eliminate inter-symbol interference caused by multipath fading. Data symbols are mapped using **16-QAM modulation** with unit average power normalization to ensure fair performance comparison.

The wireless channel is modeled as **flat Rayleigh fading**, representing a non-line-of-sight propagation environment, along with **additive white Gaussian noise (AWGN)**. Perfect time and frequency synchronization is assumed. Monte-Carlo simulations are performed to obtain statistically reliable BER estimates.

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3. MIMO Configurations

Three system configurations are implemented and analyzed:

- **SISO OFDM**: A baseline single-antenna OFDM system.
- **Alamouti 2×1 OFDM**: Two transmit antennas and one receive antenna, providing transmit diversity.
- **Alamouti 2×2 OFDM**: Two transmit and two receive antennas, achieving both transmit and receive diversity.

These configurations allow direct comparison of diversity gain and performance improvement with increasing antenna dimensions.

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4. Alamouti Space-Time Block Coding

Alamouti space-time block coding is an orthogonal transmit diversity scheme that does not require channel state information at the transmitter. Two data symbols are transmitted over two time slots using two transmit antennas in a specific orthogonal structure.

In the **2×1 configuration**, diversity order of two is achieved using transmit diversity alone.
In the **2×2 configuration**, combining signals from two receive antennas increases the diversity order to four, significantly improving robustness against fading.

The orthogonality of the Alamouti code enables simple linear decoding at the receiver.

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5. Channel Estimation

Pilot-based **Least Squares (LS)** channel estimation is employed to estimate the channel coefficients at the receiver. Orthogonal pilot OFDM symbols are transmitted separately from each transmit antenna, allowing independent estimation of individual channel paths.

The LS method estimates the channel by dividing the received pilot symbols by the known transmitted pilot values. Although simple, LS estimation is effective and widely used as a baseline technique in wireless system simulations.

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6. Receiver Combining and MMSE Processing

At the receiver, Alamouti combining is applied **independently at each receive antenna**. The combined outputs from all receive antennas are then summed to exploit full spatial diversity.

To improve performance in noisy conditions, **Minimum Mean Square Error (MMSE)** normalization is applied. MMSE processing modifies the combining normalization factor by incorporating noise variance, resulting in better BER performance at low and moderate SNRs compared to zero-forcing approaches.

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7. Performance Evaluation

System performance is evaluated using **BER versus SNR curves**, obtained through Monte-Carlo simulations averaged over multiple OFDM frames. Results demonstrate that:

- Alamouti 2×1 OFDM significantly outperforms SISO OFDM due to transmit diversity.
- Alamouti 2×2 OFDM provides the best performance, achieving the lowest BER across all SNR values.
- MMSE-based combining further improves performance, particularly in low-SNR regimes.

These results confirm the effectiveness of spatial diversity and advanced receiver processing in MIMO-OFDM systems.

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8. Conclusion

This project successfully demonstrates a complete simulation of a 5G-inspired MIMO-OFDM physical layer using MATLAB. Through implementation of Alamouti STBC, pilot-based LS channel estimation, and MMSE receiver combining, the advantages of MIMO diversity in fading channels are clearly observed. The results validate the role of MIMO-OFDM as a key enabler for reliable high-data-rate wireless communication systems.