OFDM Simulation for Different Modulation Techniques over an AWGN and Fading Channel

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ABSTRACT

This project investigates the performance of Orthogonal Frequency Division Multiplexing (OFDM) across various modulation techniques in both Additive White Gaussian Noise (AWGN) and fading channel environments. The study explores adaptive modulation, modulation in different channels, effects of multipath fading, channel estimation, and concludes with implications for modern wireless communication systems.

CONTENTS

INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a modulation technique that divides the available spectrum into multiple narrowband orthogonal subcarriers, allowing parallel transmission of data. OFDM efficiently tackles the challenges of channel interference and fading by maintaining orthogonality between these subcarriers. It is widely used in modern day wireless and broadband communication standards such as Wi-Fi, LTE etc. OFDM stands as the backbone of the 5G technology, enabling higher speeds, enhanced reliability, and versatile support for diverse services.

CHALLENGES IN WIRELESS COMMUNICATION

Additive White Gaussian Noise (AWGN):- It poses a significant challenge in wireless communication systems. This background noise, omnipresent in the environment, acts like a persistent chatter, degrading the quality of signals transmitted across the airwaves. Its disruptive influence directly impacts signal strength, compromising the accuracy and reliability of the transmitted data.

Channel fading:- When signals travel, they encounter multiple pathways due to reflections and interactions with surrounding objects. This multipath interference causes signal collisions, resulting in variations in both phase and amplitude. These fluctuations in signal strength over time create a sense of instability. This phenomenon hampers the consistency and reliability of signal reception, making it challenging for the intended message to reach its destination unaltered.

Both AWGN and channel fading act as formidable adversaries to clear and reliable communication. Understanding and mitigating these challenges become paramount in ensuring the smooth transmission of data across wireless networks.

ADAPTIVE MODEM

An adaptive modem serves as a dynamic conductor performing modulation schemes in real-time, according to channel conditions within wireless communication systems. This intelligent system possesses the capability to adjust and fine-tune modulation types based on the communication channel. Its primary role involves the adaptive alteration of modulation schemes to optimize data throughput. By intelligently adapting modulation types such as Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), 16-Quadrature Amplitude Modulation (16-QAM), etc. the adaptive modem ensures robustness in the face of varying channel characteristics.

Furthermore, this adaptive system balances data rates and error performance, maximizing the utilization of available bandwidth. It maintains equilibrium between speed and accuracy, optimizing the transmission process. An adaptive modem monitors and fine-tunes modulation parameters, striving for peak performance. It constantly tweaks settings for the best possible outcome in the communication process.

In essence, an adaptive modem stands as a crucial component in modern wireless communication systems, dynamically adapting and optimizing modulation strategies to ensure efficient and reliable data transfer in the fluctuating wireless channels.

MODULATION IN AWGN CHANNEL

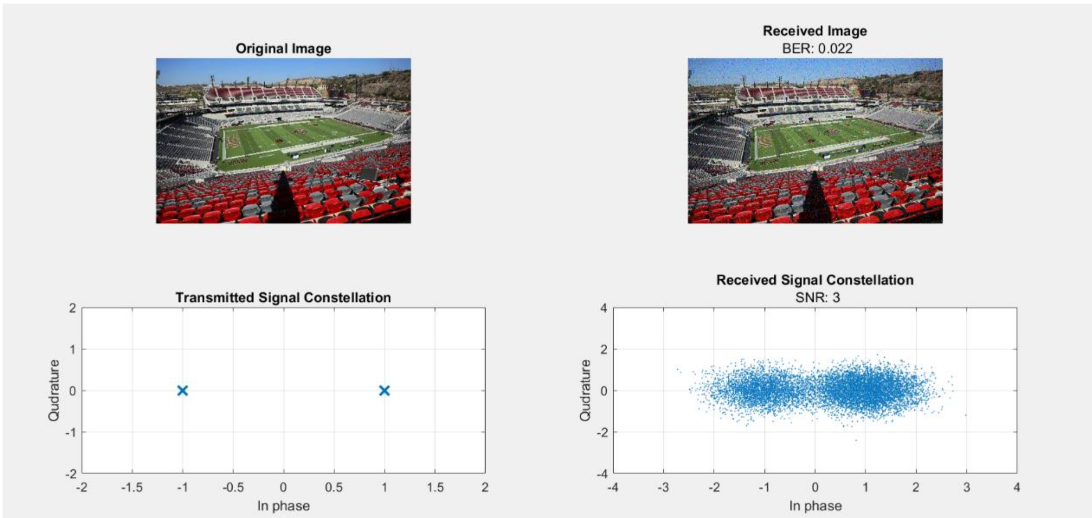


Figure 1. Output of BPSK Modulation

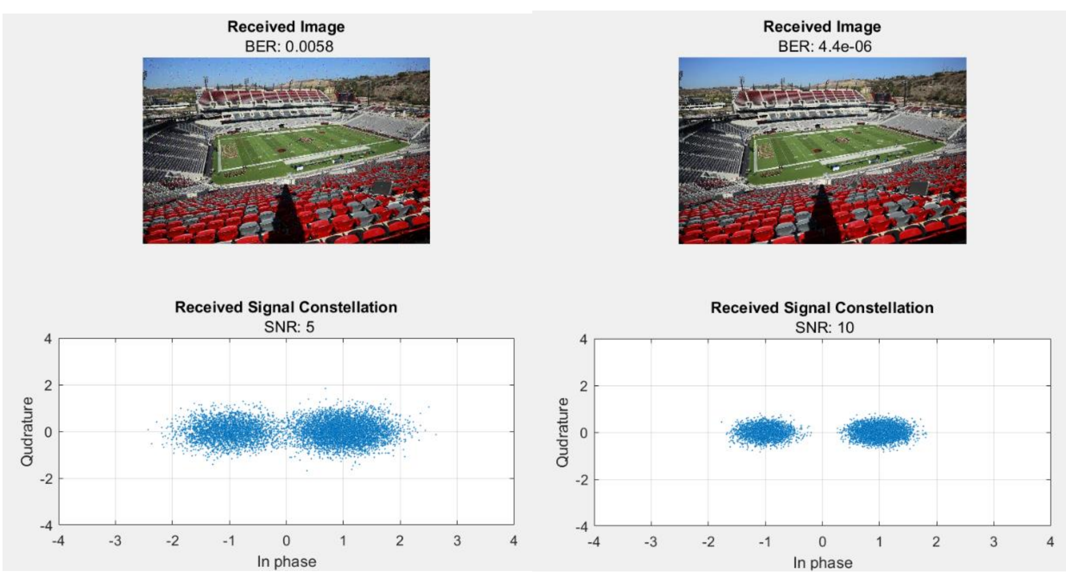


Figure 2. BPSK Modulation at 5dB and 10dB SNR

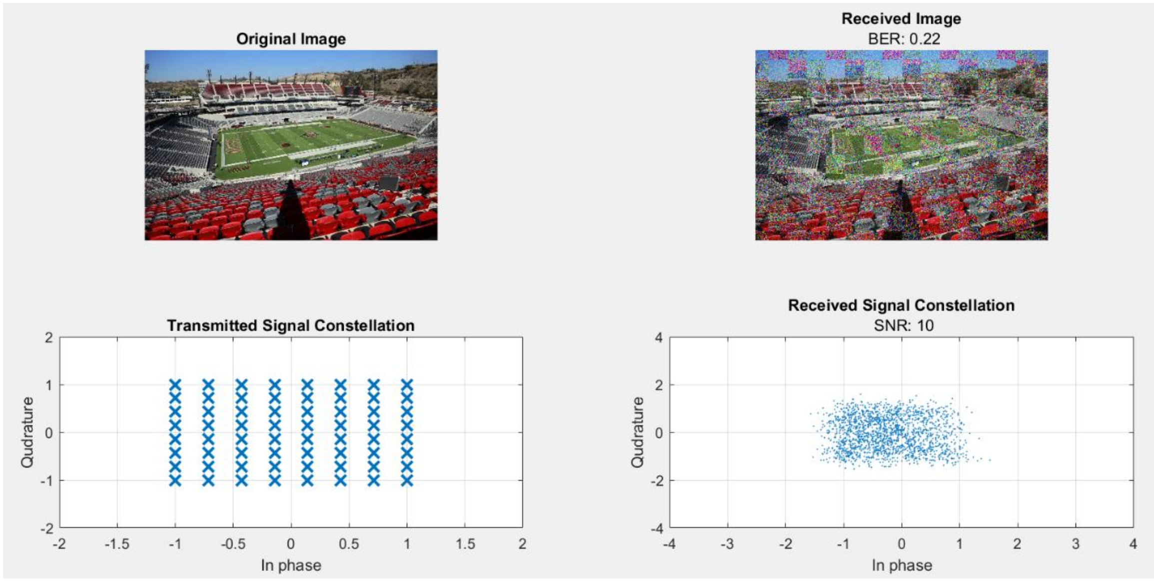


Figure 3. Output of 64-QAM Modulation

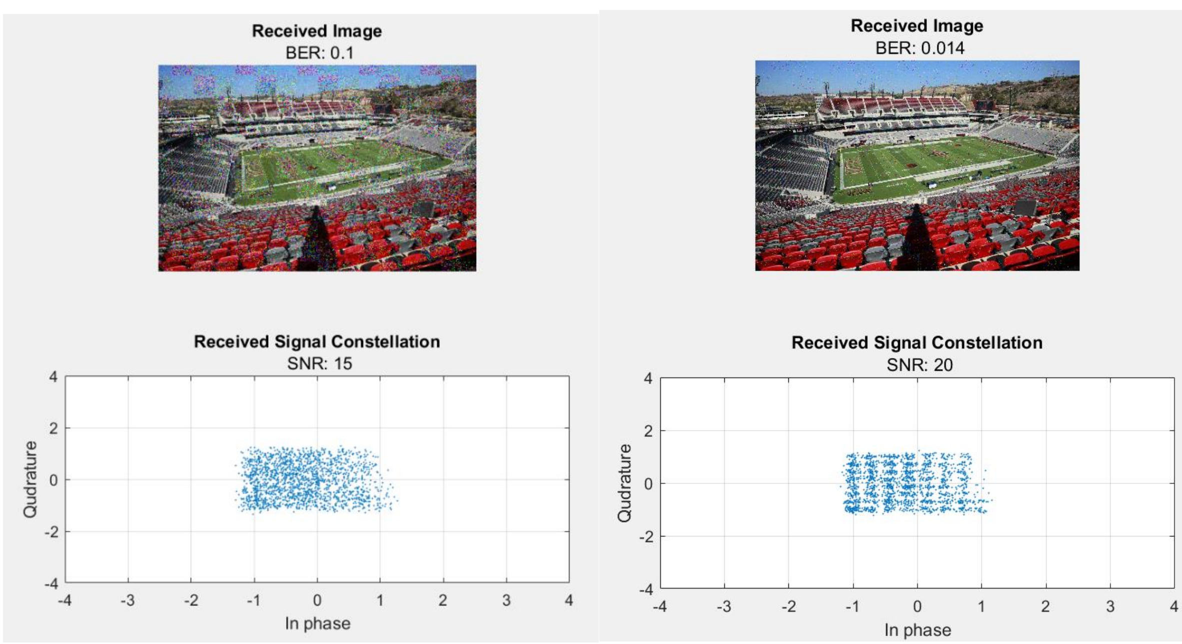


Figure 4. 64-QAM Modulation at 15dB and 20dB SNR

COMPARATIVE ANALYSIS OF SNR vs BER

Modulation Technique	SNR	BER
BPSK	10 20	4.4 x 10 ^ -6 Negligible
QPSK	10 20	0.002 Negligible
8-PSK	10 20	0.05 Negligible
16-QAM	10 20	0.073 1.8 x 10 ^ -6
32-QAM	10 20	0.2 0.001
64-QAM	10 20	0.22 0.014

The above tabular data shows that BPSK has the lowest BER at 10dB SNR and 64-QAM has the highest. As the modulation order increases, we need a better SNR to keep the BER lower.

MULTIPATH FADING

A radio signal travels via multiple indirect paths (reflections, scattering) in addition to the direct path, arriving at the receiver with various delays and attenuations. Depending on the relative phases, these delayed replicas can add up constructively (boosting signal) or destructively (causing dips and fading). Multipath fading degrades signal quality, causing signal strength variations, bit errors, data corruption and channel capacity reduction. Some common types of multipath fading are: -

- **Rayleigh Fading** - All paths have equal strength and random phases, leading to an exponentially decaying signal envelope. Its probability density function is:
  $$P(x) = (2x/\sigma^2) * \exp(-x^2/\sigma^2)$$
  Where x is the signal amplitude and σ^2 is the average power.
- **Rician Fading** - When a strong direct path exists alongside scattered paths. Its PDF becomes:
  $$P(x) = (2x/\sigma^2) * \exp(-(x^2 + K^2)/\sigma^2) * I(2Kx/\sigma^2)$$
  Where K represents the ratio of direct-to-scattered power, and I is the modified Bessel function of the first kind.
- **Nakagami Fading** - It encompasses various fading severity levels, including Rayleigh and Rician, with a tunable parameter m defining the fading intensity:
  $$P(x) = (2m^m x^{(m-1)} * \exp(-mx^2)/\Gamma(m) * \sigma^m)$$
  Where $\Gamma(m)$ is the gamma function. This allows modeling "worse-than-Rayleigh" ($m < 1$) and "better-than-Rayleigh" ($m > 1$) scenarios.

MODULATION IN FADING CHANNEL

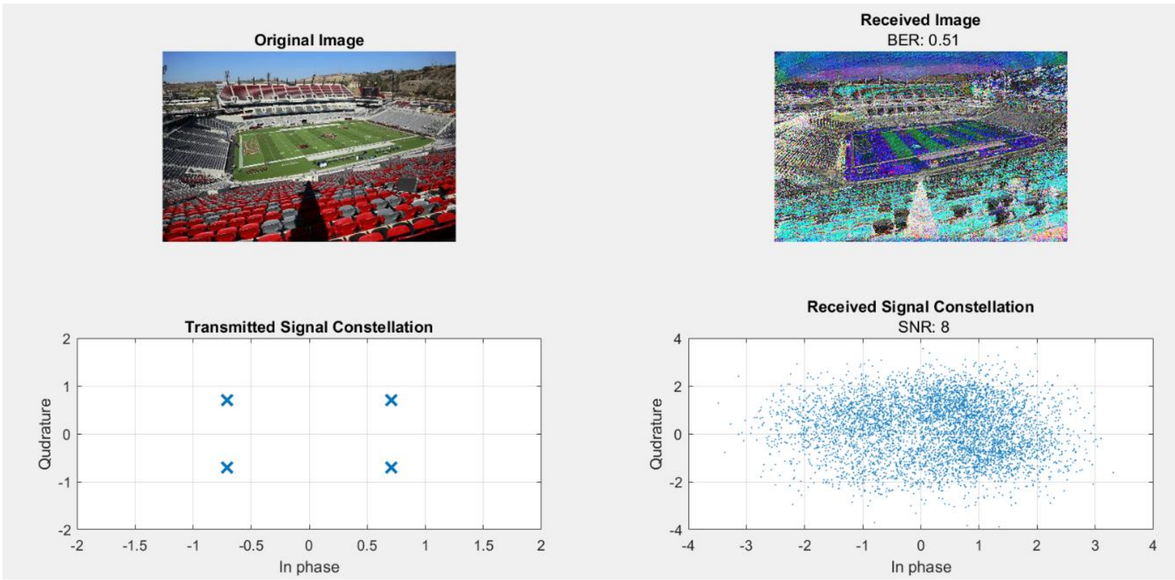


Figure 5. Output of QPSK Modulation

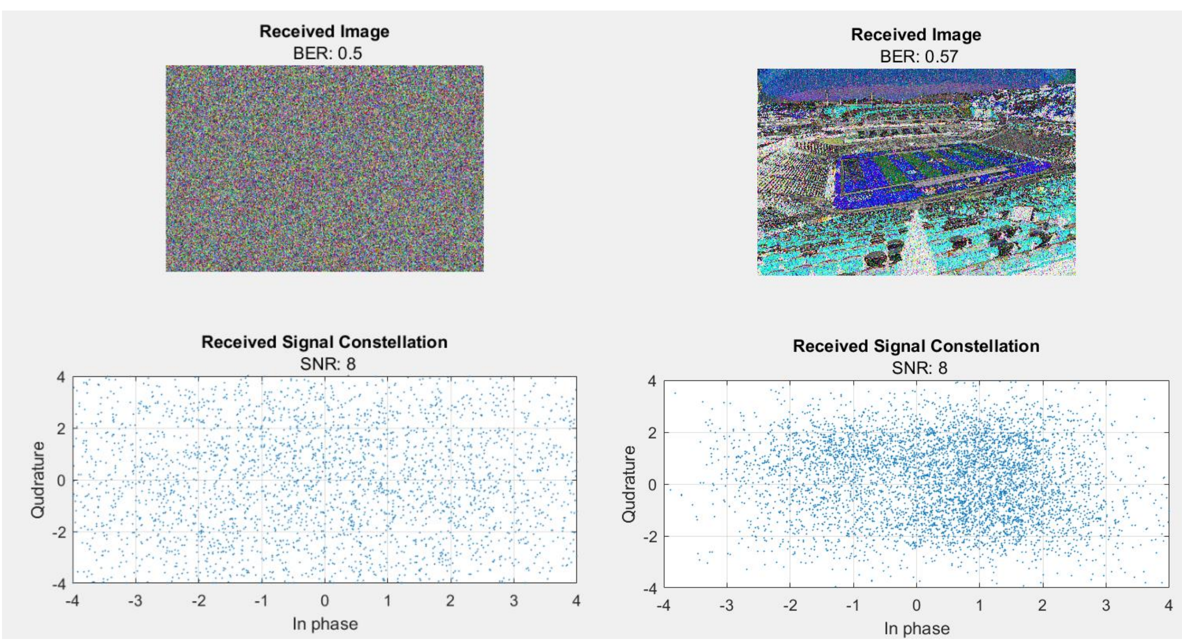


Figure 6. QPSK Modulation in Rayleigh and Nakagami Fading Channel

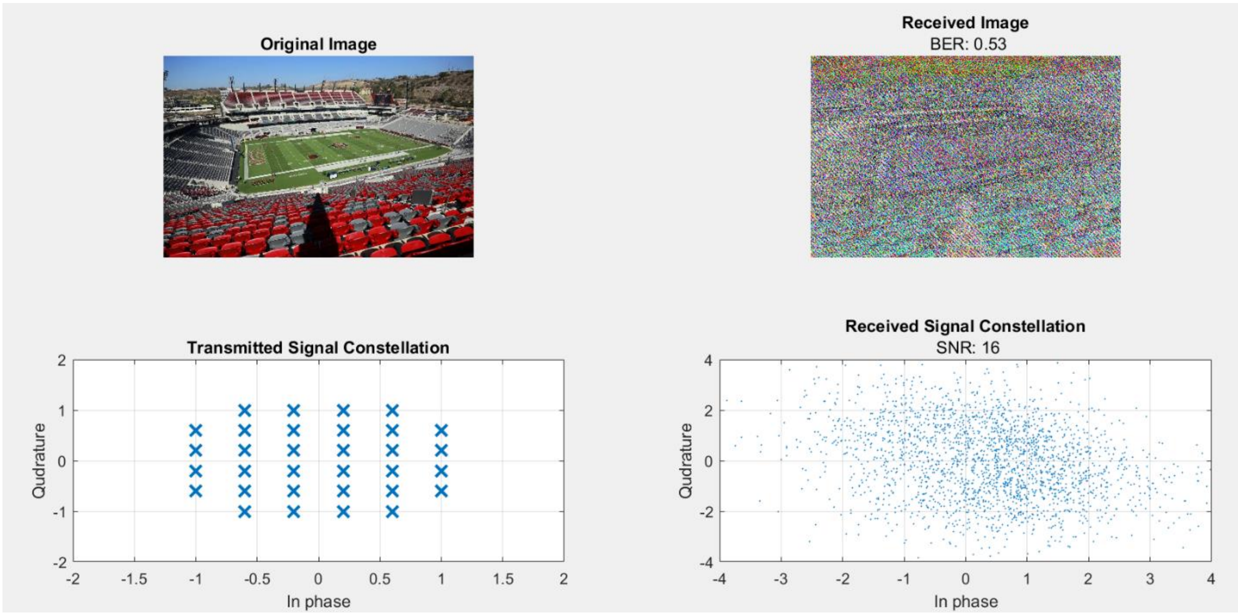


Figure 7. Output of 32-QAM Modulation

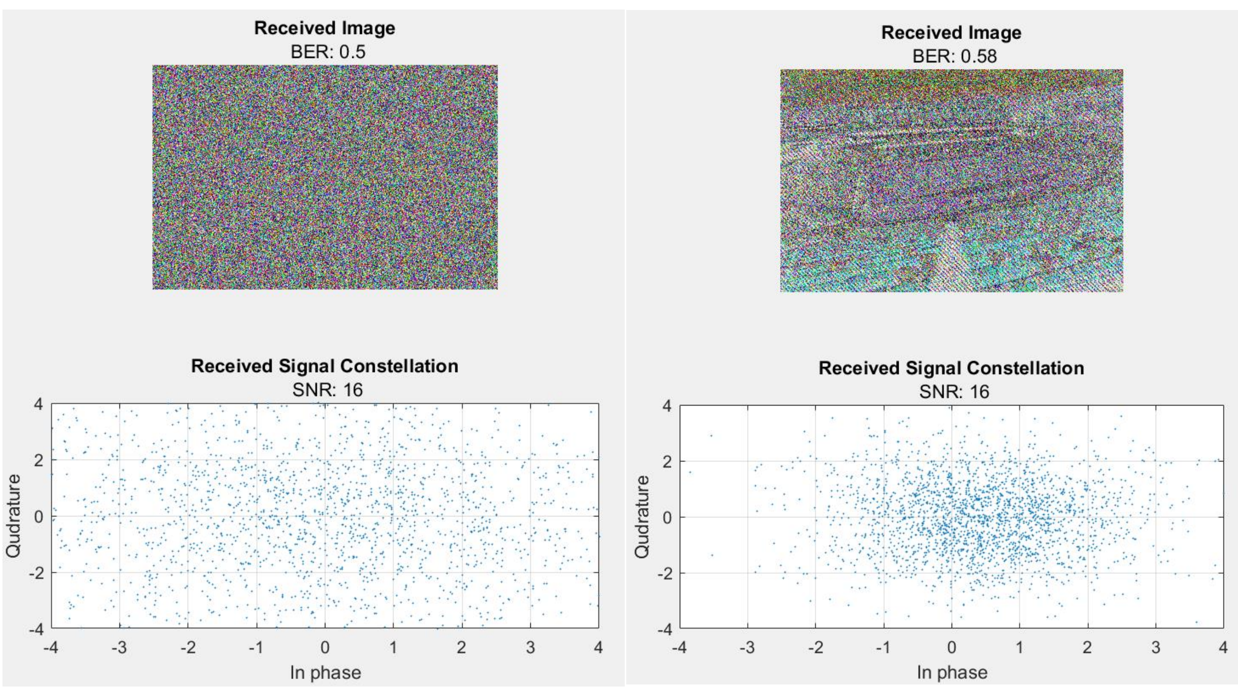
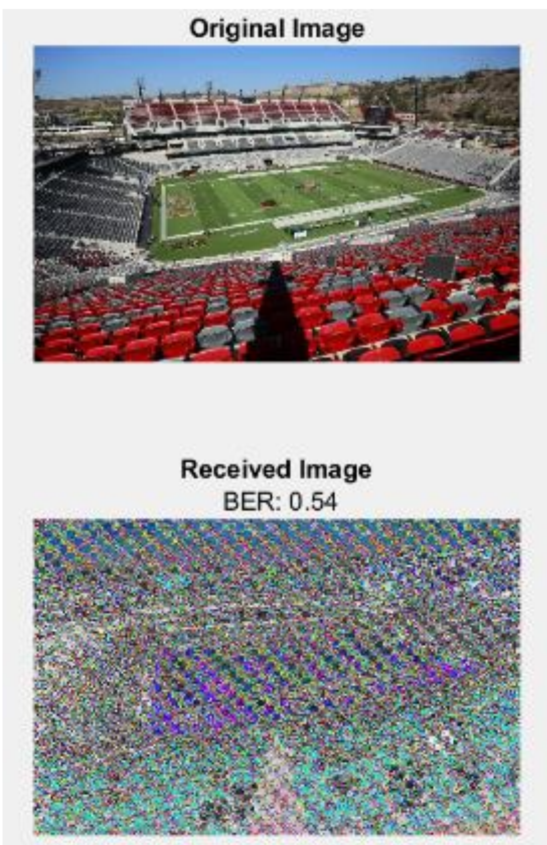


Figure 8. 32-QAM Modulation in Rician and Nakagami Fading Channel

CHANNEL ESTIMATION

Channel estimation determines the characteristics of the wireless communication channel. It is vital for demodulation and decoding at the receiver end. It employs various methods such as pilot-based estimation, least squares estimation, and Kalman filtering. There are known symbols or pilot symbols within the transmitted data to gauge the channel response, aiding in estimating the unknown channel characteristics.

Null Subcarrier Channel Estimation Technique – The modem identifies and isolates 16 null subcarrier indices within the signal matrix and derives a channel estimation vector by computing the mean across the null subcarrier columns of the noisy signal. Then it applies signal normalization by dividing the entire noisy signal matrix by the computed channel estimation vector. Finally, it prepares the signal for subsequent processing steps by addressing channel effects, which compensates for channel induced distortions, ensuring a more homogeneous and higher-quality signal.



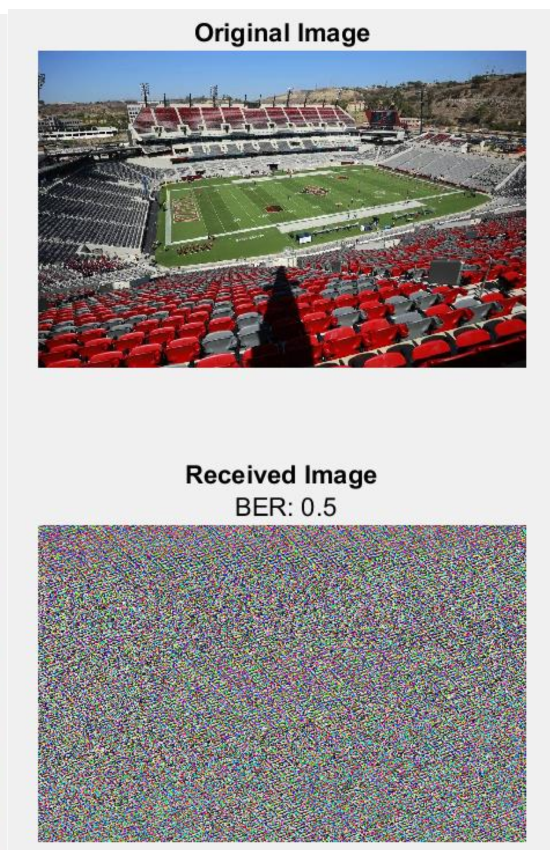


Figure 9. Channel Estimation(left) vs No Channel Estimation(right)

CONCLUSION

OFDM proves robustness across diverse modulation techniques, exhibiting resilience in both AWGN and Fading Channels. Modulation schemes influence performance, with higher order schemes offering increased data throughput at the expense of greater susceptibility to errors. In an AWGN channel, BER remains consistent for various modulations, showcasing comparable performance under noise. Fading channels introduce varying impacts on different modulation schemes, altering their error rates and resilience. OFDM's adaptability to diverse channel conditions validates its prominence in modern wireless communication systems. Future endeavors include optimizing OFDM parameters and exploring adaptive modulation strategies for enhanced performance in dynamic channel environments.

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