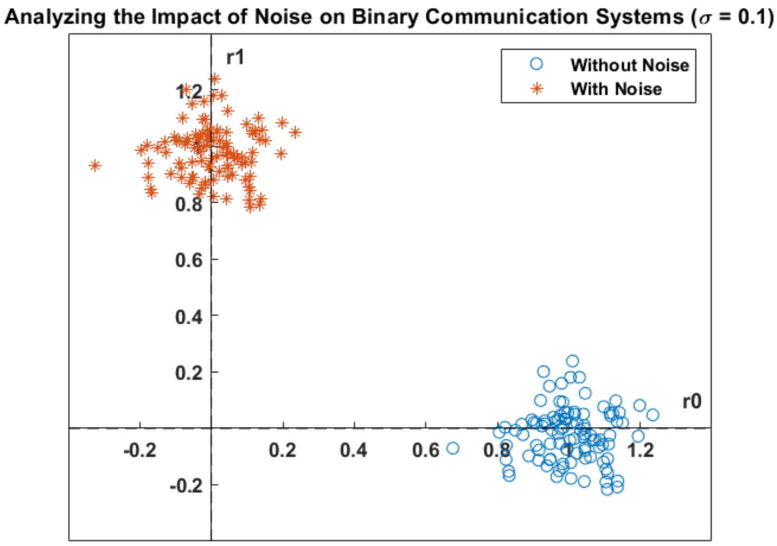
Assignment 5
Communication Theory

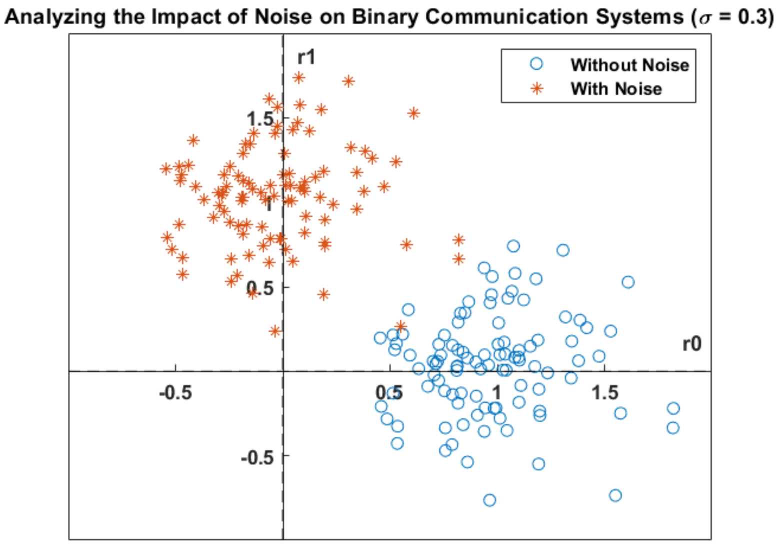
Name : Shaik Affan Adeeb
Roll No : 2022102054

Question 1 :

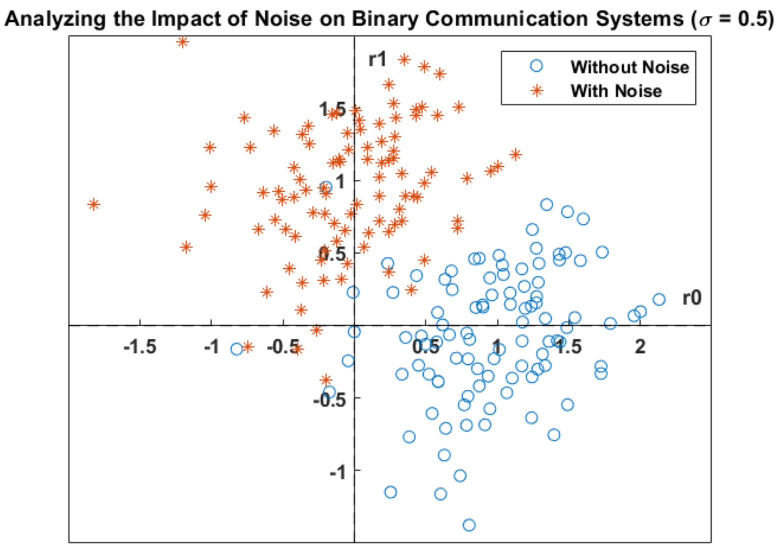
plots:



for sigma=0.1



for sigma=0.3



for sigma=0.5

Explanation :

- Part I:We will follow MAP rule (Maximum A Posteriori) along with a binary orthogonal detector for our binary communication. This means we have a method to make decisions based on the most probable outcome given the received signal.

- In binary communication systems, a detector is like a decision-maker. It figures out which of the two signals was sent based on what it receives. These signals are special because they're like opposites, making them easy to tell apart. Imagine the detector as someone comparing what they got with two pictures they already have. It's like holding each picture up to what they received and seeing which one looks more similar. That's how the detector works—it checks which picture, or signal, matches better and picks that one.

- Part II: When we raise the variance value, the Signal-to-Noise Ratio (SNR) of the signal goes down. This makes sense because as the variance increases, there's more uncertainty or error in the signal.

- Increasing variance also spreads out the signal's distribution in the plots. This means the signal isn't as focused in certain areas. This spread-out nature could lead to more false detections by the decoder because it becomes harder to distinguish the true signal from noise or interference.

In simple terms, increasing variance makes it harder to clearly detect the signal, leading to more errors in decoding.

Question 2:

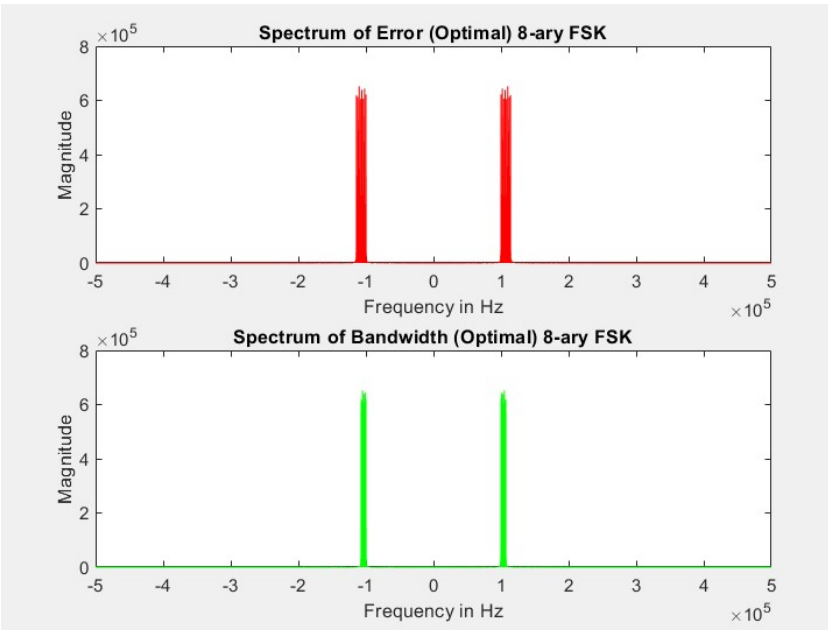
- When we talk about the frequency spectrum of a signal, it's like looking at how much space that signal takes up in terms of different frequencies. If a signal spreads out over a wider range of frequencies, it means it's using more bandwidth. For example, in Frequency Shift Keying (FSK), where we switch between different frequencies to send data, if those frequencies are far apart, we'll see clear peaks in the spectrum, each peak representing a different frequency used in the communication.

- Now, when we have larger gaps between these frequencies, it generally makes the system perform better, especially when the signal is weak compared to the noise (Eb/N0 is low). But there's a catch: wider frequency separations mean using up more bandwidth, which might not be efficient.

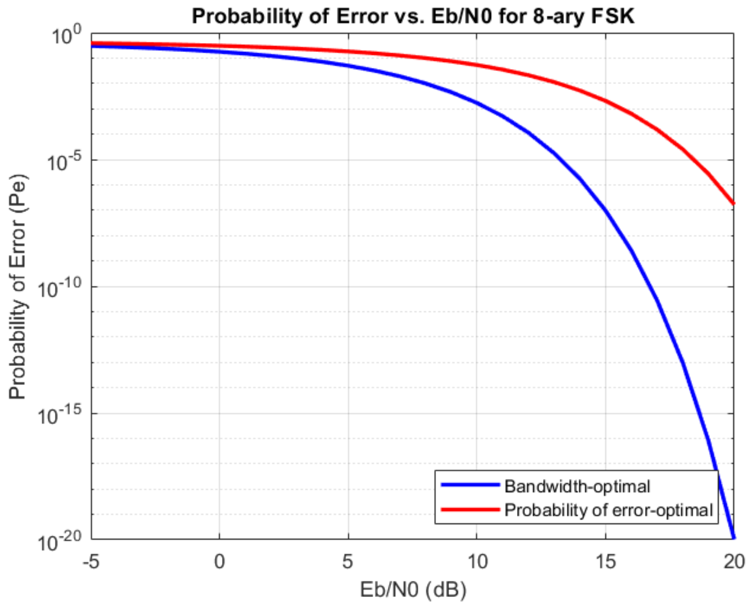
- On the flip side, if we have smaller gaps between frequencies, the spectrum might start to overlap, which can lead to interference between channels. While this can be more bandwidth-efficient, it can also cause errors, particularly when the signal is weak compared to the noise.

- To make decisions about how to set up our communication system, we need to consider both the frequency spectrum plots, which show us how much space our signal is taking up and if there might be interference issues, and the error rate vs Eb/N0 plots, which tell us how well our system can handle noise at different frequency separations. By analyzing both together, we can find a balance between using bandwidth efficiently and keeping error rates low.

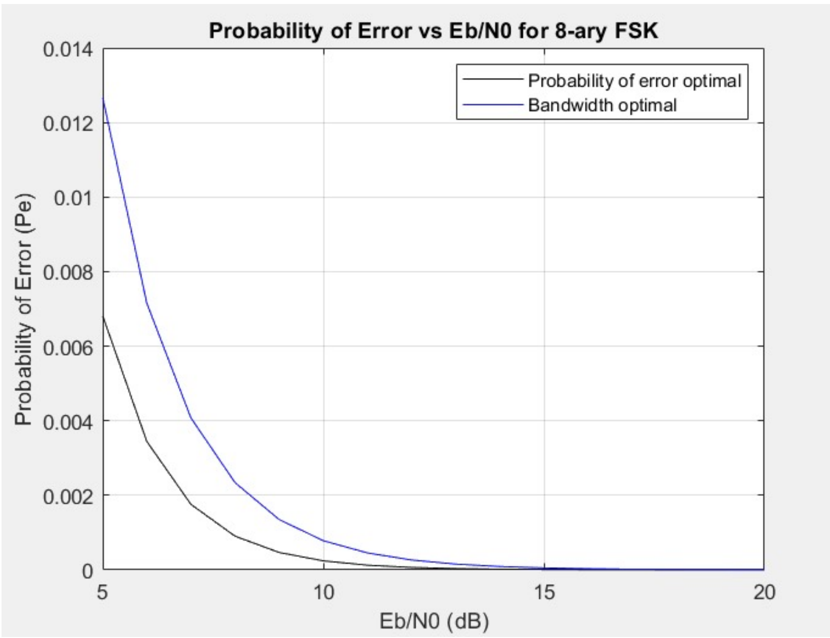
plots:



Spectrum



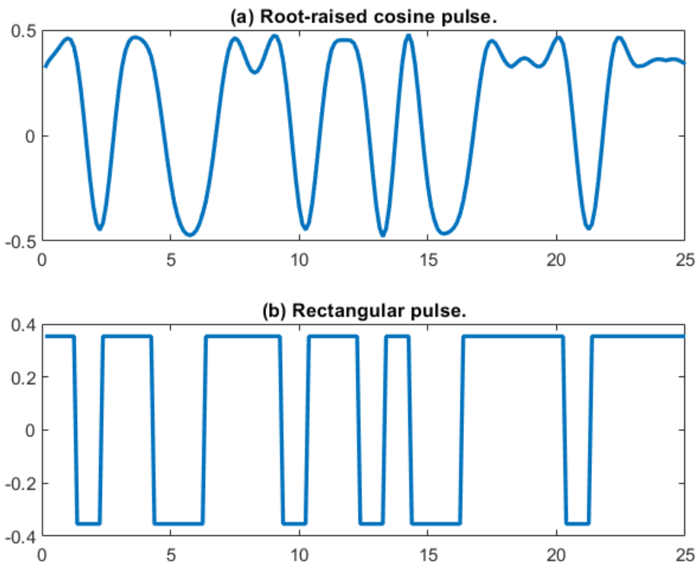
plot of Probablity of error vs Eb/N0



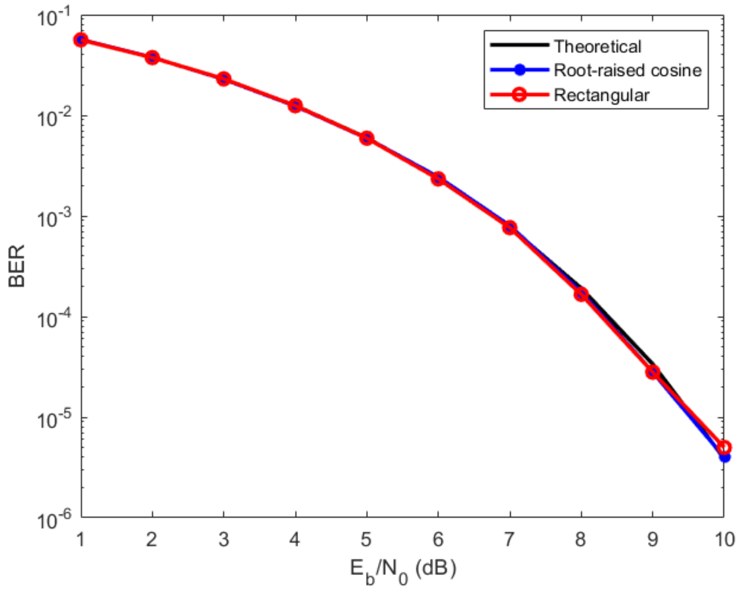
Another Probablity of error vs Eb/N0

Question 3:

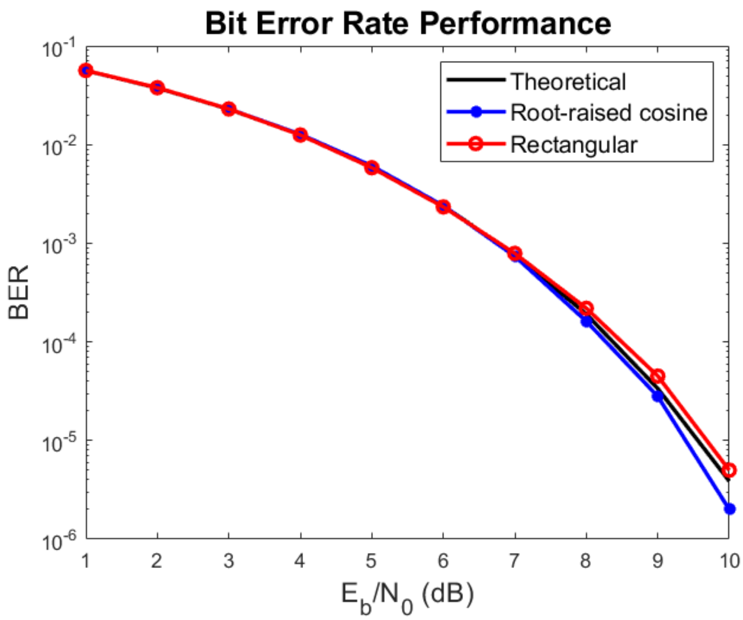
- Rectangular pulse $p(t) = u(t) - u(t - T)$.
- Root-raised cosine pulse with roll-off factor $r = 0.5$ (or bandwidth $0.75/T$).
- The 2 different waveforms are the direct results of their different pulse shapes. Nevertheless, their bit error rate (BER) performances are identical, as shown in Fig below.
- This confirms the results that the polar signal performance is independent of the pulse shape
- From Figures below, we can see that the root-raised cosine pulse clearly requires the least bandwidth. The sharp-edged rectangular pulse is the least bandwidth efficient. Thus, despite registering the same BER from simulation, the two different polar modulations require drastically different amounts of channel bandwidth.



Modulated signals



Bit error rate performance

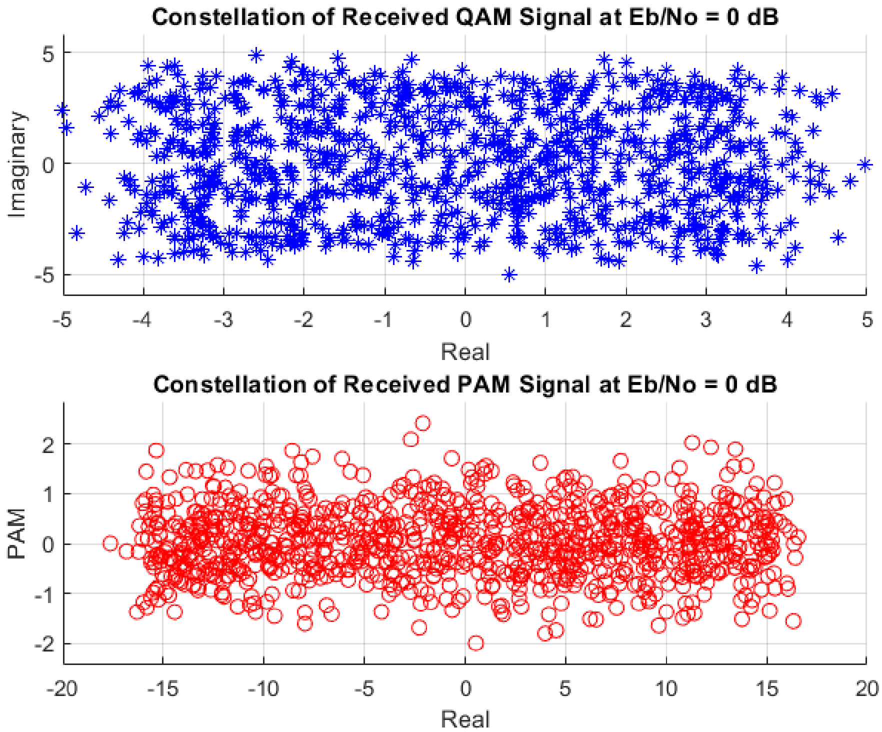


Bit error rate performance

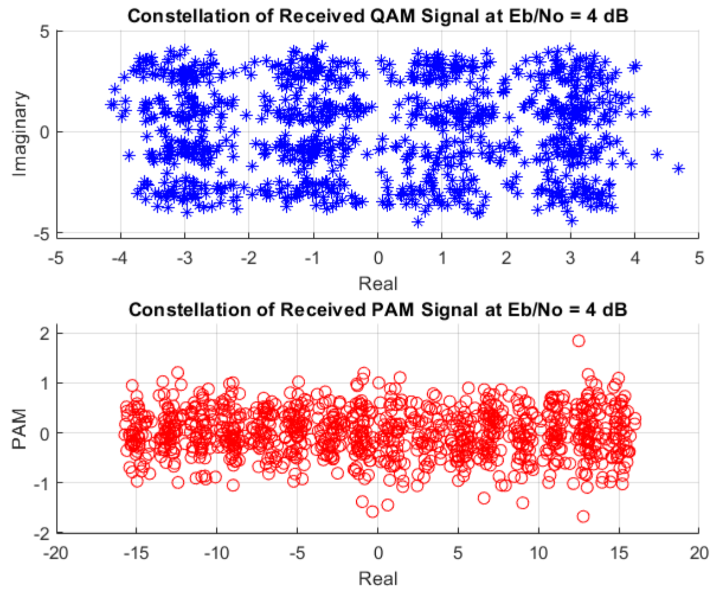
Question 4 :

- MATLAB code for MAP detector for detecting the received 16-ary QAM and 16-ary ASK, 16-ary FSK signal over AWGN channel is written in $q4_a$ file in codes folder

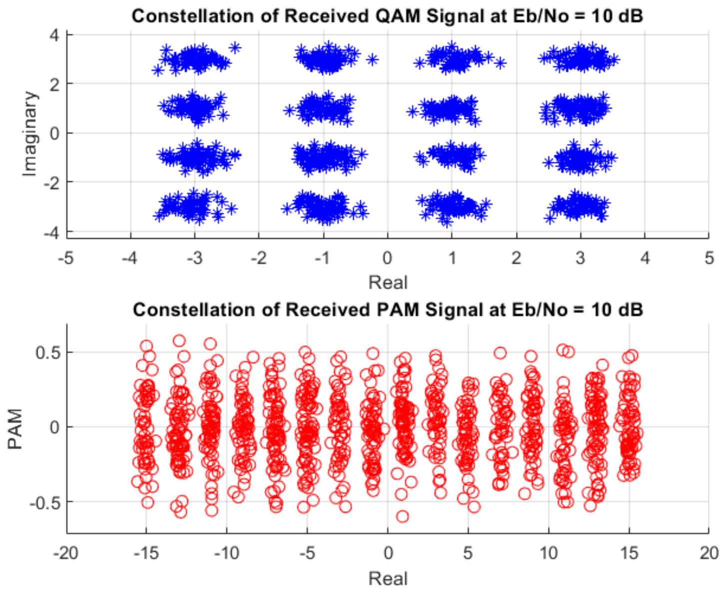
Plots :



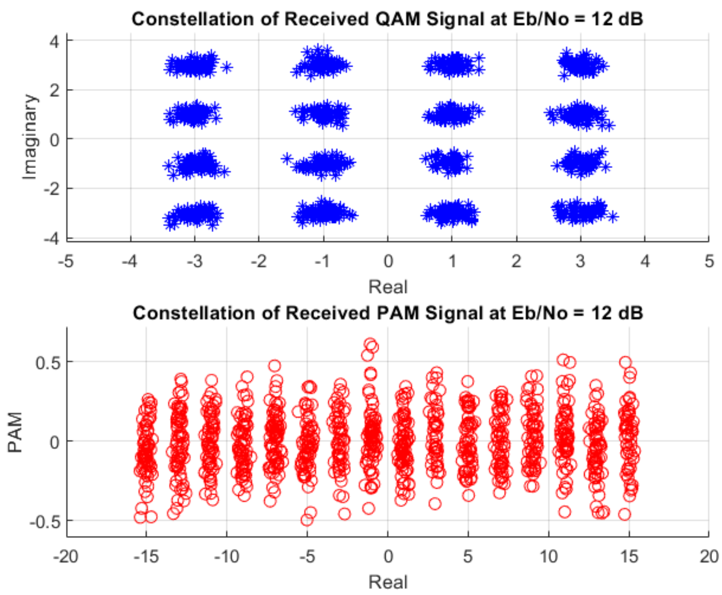
For 0 dB



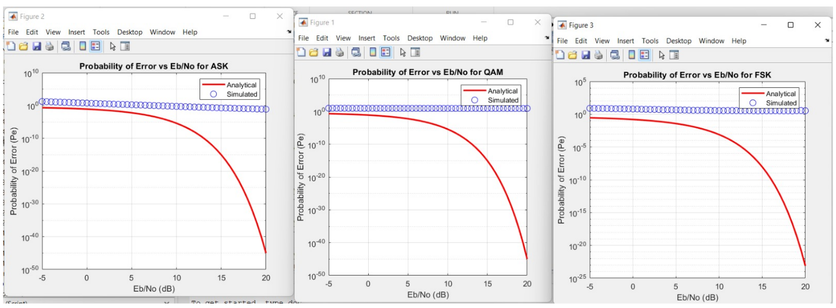
For 4 dB



For 10 dB



For 12 dB



B part

C part :

Understanding of Modulation Schemes and Observations from Simulations

Introduction

In digital communication systems, modulation schemes play a crucial role in transmitting digital data over a communication channel. Each modulation scheme has its own advantages and disadvantages in terms of bandwidth efficiency, power efficiency, complexity, and robustness to noise. In this report, we explore three modulation schemes: Quadrature Amplitude Modulation (QAM), Frequency Shift Keying (FSK), and Amplitude Shift Keying (ASK). We will discuss their principles, characteristics, and observations gained through simulations.

1. Quadrature Amplitude Modulation (QAM):

Principle:

QAM is a modulation scheme that combines both amplitude and phase modulation. It uses two carriers that are 90 degrees out of phase with each other, allowing for the transmission of two independent signals simultaneously.

Characteristics:

- **Bandwidth Efficiency**: QAM provides high bandwidth efficiency by packing multiple bits into a single symbol.
- **Robustness to Noise**: QAM is robust against noise due to its ability to transmit multiple bits per symbol, providing better error performance compared to simpler modulation schemes like ASK.
- **Complexity:** QAM requires more complex modulation and demodulation techniques compared to ASK and FSK.

Observations:

- As the signal-to-noise ratio (Eb/No) increases, the probability of error decreases, as seen in both analytical and simulation results.
- The received signal tessellation plot demonstrates how the constellation points spread out and become clearer as Eb/No increases, indicating improved performance in noisy conditions.

2. Frequency Shift Keying (FSK):

Principle:

FSK is a modulation scheme where the frequency of the carrier signal is varied to represent different symbols. It is commonly used in wireless communication systems.

Characteristics

:

- **Spectral Efficiency**: FSK provides moderate spectral efficiency, especially in binary FSK where each symbol represents one bit.

- **Robustness to Noise**: FSK is less sensitive to noise compared to amplitude-based modulation schemes like ASK, but it is generally not as robust as QAM.

- **Implementation Simplicity:** FSK implementation is relatively simple compared to QAM, making it suitable for low-complexity systems.

Observations:

- The probability of error vs. Eb/No plot for FSK shows a gradual decrease in error probability with increasing Eb/No, similar to QAM but generally with a higher error probability due to its lower spectral efficiency.

- The received signal tessellation plot for FSK demonstrates the separation of constellation points as Eb/No increases, indicating improved performance.

3. Amplitude Shift Keying (ASK):

Principle:

ASK is a modulation scheme where the amplitude of the carrier signal is varied to represent different symbols. It is one of the simplest modulation schemes.

Characteristics:

- **Simplicity:** ASK is the simplest modulation scheme among the three discussed here, making it easy to implement.
- **Spectral Efficiency:** ASK provides low spectral efficiency since each symbol typically represents one bit.
- **Sensitivity to Noise:** ASK is more sensitive to noise compared to QAM and FSK due to its reliance on amplitude variations.

Observations:

- The probability of error vs. Eb/No plot for ASK shows a faster increase in error probability compared to QAM and FSK, indicating its higher sensitivity to noise.
- The received signal tessellation plot for ASK demonstrates how the constellation points become less distinguishable as Eb/No decreases, leading to higher error rates.

Conclusion :

In conclusion, the choice of modulation scheme depends on various factors such as bandwidth efficiency, robustness to noise, complexity, and implementation simplicity. QAM offers high bandwidth efficiency and robustness to noise but requires more complex implementation. FSK provides moderate spectral efficiency and robustness to noise, making it suitable for certain applications. ASK, while simple to implement, has lower spectral efficiency and is more sensitive to noise. Through simulations, we observed how different modulation schemes behave under varying noise conditions, providing valuable insights into their performance characteristics.