HANOI UNIVERSITY OF SCIENCE AND TECHNOLOGY

MINI-PROJECT REPORT

INTRODUCTION TO COMMUNICATION ENGINEERING

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ABSTRACT

Digital modulation is the process of encoding a digital information signal into the amplitude, phase, or frequency of the transmitted signal. Common digital modulation techniques include amplitude-shift keying (ASK), frequency-shift keying (FSK), and phase-shift keying (PSK). In this project, we present a program to simulate the modulation and demodulation processes using different shift keying signal from a random binary sequence. Our program describes 3 stages: 1) Modulation, 2) Demodulation, 3) Investigating the processes under the effects of Gaussian noise. Each types of modulation shows its characteristic in processes.

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Abbreviation	Definition
ASK	Amplitude Shift Key
AWGN	Additive White Gaussian noise
BER	Bit Error Rate
FSK	Frequency Shift Key
PSK	Phase Shift Key
SER	Symbol Error Rate

CHAPTER 1. INTRODUCTION

In wireless communication systems, modulation is the crucial process of superimposing an information signal with a high-frequency carrier signal for transmission. There are two types of modulation: analog modulation and digital modulation. Analog approaches directly encode information from changes in a transmitted signal's amplitude, phase, or frequency. Digital modulation and demodulation methods, on the other hand, use the changes in amplitude, phase, and frequency to convey digital bits representing the information to be communicated.

With growing demands for voice, video, and data over communications networks of all kinds, digital modulation and demodulation have recently replaced analog modulation and demodulation methods in wireless networks to make the most efficient use of a limited resource: bandwidth. In this report, we discuss about digital modulation and demodulation techniques.

1.1 Problem Statement

The rapid growth of digital communication has led to an increasing demand for efficient, reliable, and robust transmission of digital signals over various communication channels. However, the communication channel can cause significant impairments to the digital signal, including noise, interference, fading, and dispersion, which can lead to errors and reduced data rate.

1.2 Organization of Thesis

In this report, we will divide it into six chapters in which the purpose is to provide a comprehensive overview of these digital modulation techniques and their applications in modern communication systems.

Chapter 2: A literature review. We provide a context and help to define three fundamental digital modulation techniques- Amplitude Shift Keying (ASK), Phase Shift Keying (PSK), and Frequency Shift Keying(FSK).

Chapter 3: Methodology. This section describes an overview of the solution including signal generation, channel modeling, demodulation and performance evaluation.

Chapter 4: Theoretical Analysis. This chapter involves understanding the Symbol Error Rate and Bit Error Rate computation for binary signal with error function

Chapter 5: Numerical results. In this chapter, we provide a quantitative evaluation of the performance of these techniques.

Chapter 6: Conclusion

CHAPTER 2. LITERATURE REVIEW

In wireless communication, information is transmitted by encoding voice and data on radio waves of certain frequencies.The process by which information is converted into electrical/digital signals for transferring that signal over a medium is called modulation. It increases strength for maximum reach of the signals. The various forms of modulation are designed to alter the characteristic of carrier waves. The most commonly altered characteristics of modulation include amplitude, frequency, and phase. The process of extracting information/data from the transmitted signal is called demodulation.

In this chapter, the scope of research is presented, as well as fundamental knowledge of the processes

2.1 Scope of Research

Simulation of ASK (Amplitude Shift Keying), FSK (Frequency Shift Keying), PSK (Phase Shift Keying) Modulation and Demodulation using Python

2.2 Modulation and Demodulation

The process of modulation involves two signals. Message signals also known as baseband signals are the band of frequencies representing the original signal. This is the signal to be transmitted to the receiver. The frequency of such a signal is usually low. The other signal involved with this is a high-frequency sinusoidal wave. This signal is called the carrier signal. The frequency of carrier signals is almost always higher than that of the baseband signal. The amplitude of the baseband signal is transferred to the high-frequency carrier. Such a higher frequency carrier is able to travel much farther than the baseband signal. Therefore, modulation can be defined as the process of superimposing a low-frequency signal on a high-frequency carrier signal.

Demodulation is the process of filtering the message signal from the carrier wave at the receiver end when the modulated signal is received. It is an important step to get correct information from the message signal.

2.3 Types of digital modulation

There are three major classes of digital modulation techniques used for transmission of digitally represented data:

Amplitude shift-keying (ASK), in which the carrier frequency and carrier phase are both maintained constant, the modulation process involves switching or keying the amplitude of the carrier signal in accordance with the incoming data.

Frequency shift-keying (FSK), a digital modulation method that utilizes the difference in the amplitude of analog signals to modulate digital signals by switching between low frequency and high frequency in order to represent 0 and 1.

Phase shift-keying (PSK), a process which conveys data by changing (modulating) the phase of a constant frequency reference carrier wave.

2.4 Channel model

Additive white Gaussian noise (AWGN) is a basic noise model used in information theory to mimic the effect of many random processes that occur in nature. The modifiers denote specific characteristics:

- Additive because it is added to any noise that might be intrinsic to the information system.
- White refers to the idea that it has uniform power across the frequency band for the information system. It is an analogy to the color white which has uniform emissions at all frequencies in the visible spectrum.
- Gaussian because it has a normal distribution in the time domain with an average time domain value of zero.

CHAPTER 3. METHODOLOGY

3.1 Overview

The program illustrates workflow of signal modulation and demodulation with typical forms including ASK, FSK, and PSK. Overall, there are 5 steps in the process, beginning with setting up parameters, input data sequence, carrier wave and culminating in plotting results from demodulation signal under the effects of Gaussian noise.

3.2 Setting up

The program runs using Python with NumPy and Matplotlib libraries - two fundamental packages for performing scientific computations

- Creating a random input binary sequence
- Setting up characteristics of digital transmission system
- Setting up signal constellation with cardinality of the set equals 2

3.3 Modulation

In modulation process, the pair of carrier waves, c1 and c2 are used to represent binary symbols 0 and 1, respectively. We declare a numpy data array for modulated wave signal where: if the input is 0, s1 is stored in array in corresponding index with that input and vice versa. The transmitted wave is formed by shifting between two carrier waves (i.e., there are parts that different in amplitude or frequency or phase) as the binary input signal changes.

3.4 Demodulation

Given the modulated signal, we use correlation receiver to compare the signal received with the set of previously known signal constellation to generate decision variables. By comparing correlation values obtained from the reference carrier and information-bearing signals, information bits can be recovered.
Starting from the Euclidean distance criterion:

$$s_R = \arg\min_{s_i \in M} d_E^2(\rho, s_i) \tag{3.1}$$

Then the maximum likelihood criterion based on correlation is:

$$s_R = \arg\max_{s_i \in M}[\int_0^T \rho(t).s_i(t)\,dt - \frac{1}{2}E_(s_i)] \tag{3.2}$$

Using (3.2) for choosing $s_R \in M$

3.5 Adding Gaussian noise

Additive white Gaussian noise (AWGN) is a basic noise model used in information theory to mimic the effect of many random processes that occur in nature. In this section, Gaussian noise generated randomly with zero mean and variance $\mathcal{N}_{/}/2$ is added to the transmitted waveform as $r(t) = s(t) + n(t)$

3.6 Demodulation under the effects of Gaussian noise

In this section, applying the same method of demodulation to the new transmitted waveform to recover the input bits and plotting the results.

The error probability is calculated by comparing the original binary sequence with the demodulated data under the effects of noise. The number of incompatible bits between input and output, divided by the number of bits shows percentage of signal error.

4.1 BER of a Gaussian channel using ASK

Used signal constellation is:

$$M = \{s_1(t) = cos(2\pi f_0 t); s_2 = 2cos(2\pi f_0 t)\}$$

Build an orthonormal basis B:

$$b_1^*(t) = s_1(t) = cos(2\pi f_0 t)$$

$$E(b_1^*(t)) = \int_{-\infty}^{\infty} s_1^2(t)\,dt = \int_0^T cos^2(2\pi f_0 t)\,dt = \frac{T}{2}$$

Thus

$$b_1(t) = \frac{s_1(t)}{\sqrt{\frac{T}{2}}}$$

We can see that $s_2(t)$ is a linear combination of $b_1(t)$

Thus,

$$B = \left\{ b_1(t) = \frac{s_1(t)}{\sqrt{\frac{T}{2}}} \right\}$$

Constellation M as a vector set:

$$M = \left\{ \underline{s_1} = \sqrt{\frac{T}{2}}; \underline{s2} = \sqrt{2T} \right\}$$

The Voronoi regions are:

$$V(\underline{s_1}) = \left\{ \rho = (\rho_1), \rho_1 \leq \frac{3\sqrt{2T}}{4} \right\}$$

$$V(\underline{s_2}) = \left\{ \rho = (\rho_1), \rho_1 \geq \frac{3\sqrt{2T}}{4} \right\}$$

We have:

$$P_s(e) = \frac{1}{m}\sum_{i=1}^{m} P_s(e|\underline{s_T} = \underline{s_i}) = \frac{1}{2}[P_s(e|\underline{s_T} = \underline{s_1}) + P_s(e|\underline{s_T} = \underline{s_2})]$$

With $P_s(e|\underline{s_T} = \underline{s_1})$:

$$P(\underline{\rho} \in V(s_2)|\underline{s_T} = \underline{s_1}) = P\left(\rho_1 > \frac{3\sqrt{2T}}{4}|\underline{s_T} = \underline{s_1}\right)$$

Where: $\underline{\rho} = (\rho_1); \underline{s_1} = \sqrt{\frac{T}{2}}; \underline{n} = (n_1)$

Follow: $\rho_1 = \sqrt{\frac{T}{2}} + n_1$

Thus:

$$\begin{aligned} P\left(\rho_1 > \frac{3\sqrt{2T}}{4}|\underline{s_T} = \underline{s_1}\right) &= P\left(\sqrt{\frac{T}{2}} + n_1 > \frac{3\sqrt{2T}}{4}\right) \\ &= P\left(n_1 > -\sqrt{\frac{T}{2}} + \frac{3\sqrt{2T}}{4}\right) \\ &= \frac{1}{2}erfc\left(\frac{\sqrt{2T}}{4\sqrt{N_0}}\right) \end{aligned}$$

With $P_s(e|\underline{s_T} = \underline{s_2})$:

$$P(\underline{\rho} \in V(s_1)|\underline{s_T} = \underline{s_2}) = P\left(\rho_1 < \frac{3\sqrt{2T}}{4}|\underline{s_T} = \underline{s_2}\right)$$

Where: $\underline{\rho} = (\rho_1); \underline{s_2} = \sqrt{2T}; \underline{n} = (n_1)$

Follow: $\rho_1 = \sqrt{2T} + n_1$

Thus:

$$\begin{aligned} P(\rho_1 < \frac{3\sqrt{2T}}{4}|\underline{s_T} = \underline{s_2}) &= P\left(\sqrt{2T} + n_1 < \frac{3\sqrt{2T}}{4}\right) \\ &= P\left(n_1 < -\sqrt{2T} + \frac{3\sqrt{2T}}{4}\right) \\ &= P\left(n_1 > \sqrt{2T} - \frac{3\sqrt{2T}}{4}\right) \\ &= \frac{1}{2}erfc\left(\frac{\sqrt{2T}}{4\sqrt{N_0}}\right) \end{aligned}$$

So:

$$\begin{aligned} P_s(e) &= \frac{1}{2}[P_s(e|\underline{s_T} = \underline{s_1}) + P_s(e|\underline{s_T} = \underline{s_2})] \\ &= \frac{1}{2}\left[\frac{1}{2}erfc\left(\frac{\sqrt{2T}}{4\sqrt{N_0}}\right) + \frac{1}{2}\left(\frac{\sqrt{2T}}{4\sqrt{N_0}}\right)\right] \\ &= \frac{1}{2}erfc\left(\frac{\sqrt{2T}}{4\sqrt{N_0}}\right) \end{aligned}$$

We want to write it as a function of $\frac{E_b}{N_0}$

$$\begin{aligned} E(\underline{s_1}) &= \frac{T}{2} \\ E(\underline{s_2}) &= 2T \end{aligned}$$

$$\begin{aligned} E_s &= \frac{E(\underline{s_1}) + E(\underline{s_2})}{2} = \frac{5T}{4} \\ E_b &= \frac{E_s}{k} = \frac{E_s}{1} = \frac{5T}{4} \end{aligned}$$

Result:

$$P_b(e) = P_s(e) = \frac{1}{2}erfc\left(\frac{\sqrt{2E_b}}{2\sqrt{5N_0}}\right)$$

4.2 BER of a Gaussian channel using FSK

Signal constellation:

$$M = \{s_1(t) = \cos(2\pi f_0 t); s_2(t) = \cos(2\pi 2 f_0 t)\}$$

Since,

$$\begin{aligned} \int_{-\infty}^{\infty} s_1(t)s_2(t)dt &= \int_0^T \cos(2\pi f_0 t)\cos(2\pi 2 f_0 t)dt \\ &= \int_0^T \frac{\cos(2\pi 3 f_0 t) + \cos(2\pi f_0 t)}{2}dt \\ &= \frac{\sin(2\pi 3 f_0 t)}{12\pi f_0}\Bigg|_{t=0}^{t=T} + \frac{\sin(2\pi f_0 t)}{12\pi f_0}\Bigg|_{t=0}^{t=T} \\ &= 0 \end{aligned}$$

$s_1(t)$ and $s_2(t)$ is orthogonal.

Choose the basis B is:

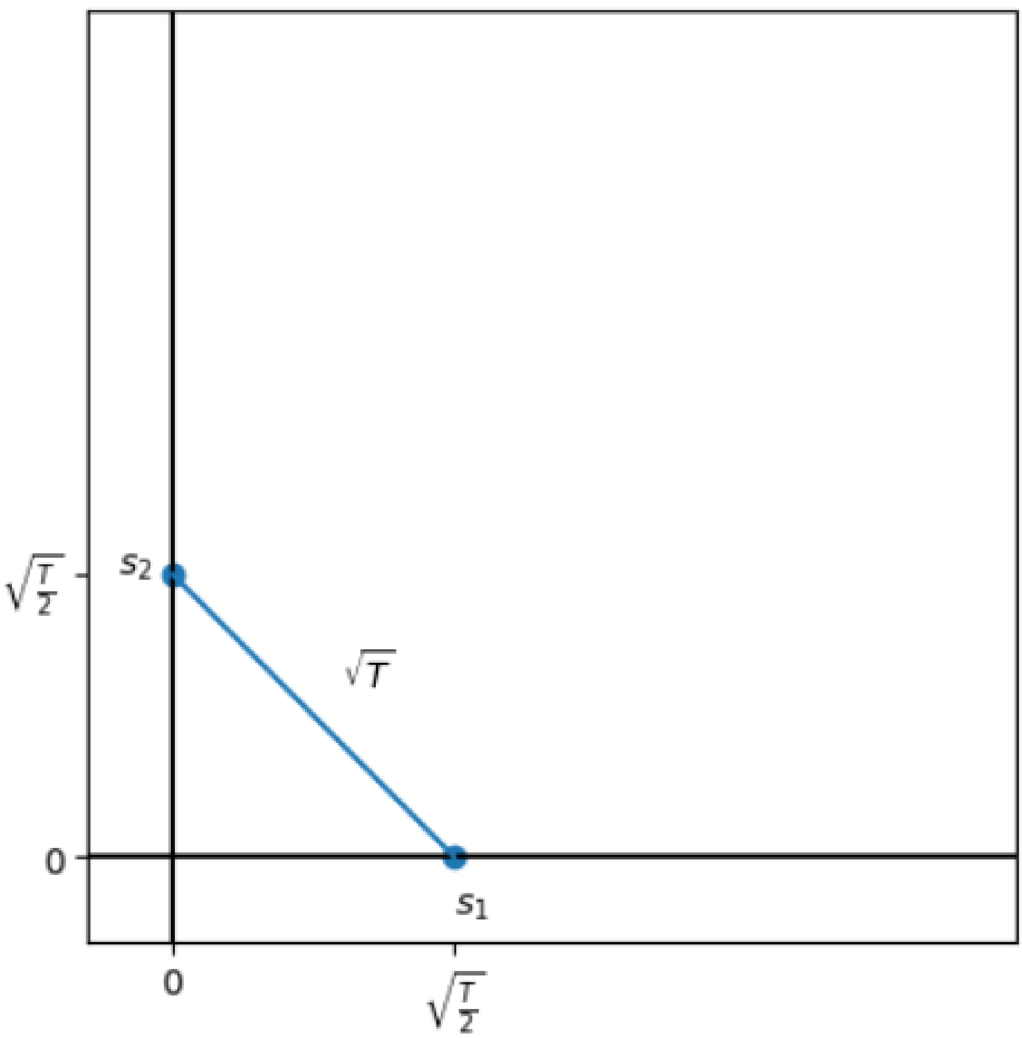
$$B = \left\{ b_1(t) = \frac{s_1(t)}{\sqrt{E(s_1(t))}}; b_2(t) = \frac{s_2(t)}{\sqrt{E(s_2(t))}} \right\}$$

$$E(s_1(t)) = E(s_2(t)) = \frac{T}{2}$$

Thus, constellation M as a vector set:

$$M = \left\{ \underline{s_1} = \left(\sqrt{\frac{T}{2}}, 0 \right); \underline{s2} = \left(0, \sqrt{\frac{T}{2}} \right) \right\}$$

Visualize on graph:



Project to the line which connects s_1 and s_2 (length of line is equal to $\sqrt{T}$), choose the midpoint as origin 0. We obtained new axis and new vector set:

$$M' = \left\{ \underline{s_1}' = \frac{\sqrt{T}}{2}; \underline{s2}' = -\frac{\sqrt{T}}{2} \right\}$$

The Voronoi regions are:

$$V(\underline{s_1}') = \{\rho = (\rho_1), \rho_1 \geq 0\}$$

$$V(\underline{s_2}') = \{\rho = (\rho_1), \rho_1 \leq 0\}$$

We have:

$$P_s(e) = \frac{1}{m} \sum_{i=1}^{m} P_s(e|\underline{s_T} = \underline{s_i}) = \frac{1}{2}[P_s(e|\underline{s_T} = \underline{s_1}') + P_s(e|\underline{s_T} = \underline{s_2}')]$$

With $P_s(e|\underline{s_T} = \underline{s_1}')$:

$$P(\underline{\rho} \in V(s_2')|\underline{s_T} = \underline{s_1}') = P(\rho_1 < 0|\underline{s_T} = \underline{s_1}')$$

Where: $\underline{\rho} = (\rho_1); \underline{s_1}' = \frac{\sqrt{T}}{2}; \underline{n} = (n_1)$

Follow: $\rho_1 = \frac{\sqrt{T}}{2} + n_1$

Thus:

$$\begin{aligned} P(\rho_1 < 0|\underline{s_T} = \underline{s_1}') &= P\left(\frac{\sqrt{T}}{2} + n_1 < 0\right) \\ &= P\left(n_1 < -\frac{\sqrt{T}}{2}\right) \\ &= P\left(n_1 > \frac{\sqrt{T}}{2}\right) \\ &= \frac{1}{2} erfc\left(\frac{\sqrt{T}}{2\sqrt{N_0}}\right) \end{aligned}$$

With $P_s(e|\underline{s_T} = \underline{s_2}')$:

$$P(\underline{\rho} \in V(s_1')|\underline{s_T} = \underline{s_2}') = P(\rho_1 > 0|\underline{s_T} = \underline{s_2}'))$$

Where: $\underline{\rho} = (\rho_1); \underline{s_2}' = -\frac{\sqrt{T}}{2}; \underline{n} = (n_1)$

Follow: $\rho_1 = -\frac{\sqrt{T}}{2} + n_1$

Thus:

$$\begin{aligned}
P(\rho_1 > 0|\underline{s_T} = \underline{s_2}') &= P\left(-\frac{\sqrt{T}}{2} + n_1 > 0\right) \\
&= P\left(n_1 > \frac{\sqrt{T}}{2}\right) \\
&= \frac{1}{2} erfc\left(\frac{\sqrt{T}}{2\sqrt{N_0}}\right)
\end{aligned}$$

So:

$$\begin{aligned}
P_s(e) &= \frac{1}{2}[P_s(e|\underline{s_T} = \underline{s_1}') + P_s(e|\underline{s_T} = \underline{s_2}')] \\
&= \frac{1}{2}\left[\frac{1}{2} erfc\left(\frac{\sqrt{T}}{2\sqrt{N_0}}\right) + \frac{1}{2} erfc\left(\frac{\sqrt{T}}{2\sqrt{N_0}}\right)\right] \\
&= \frac{1}{2} erfc\left(\frac{\sqrt{T}}{2\sqrt{N_0}}\right)
\end{aligned}$$

We want to write it as a function of $\frac{E_b}{N_0}$

$$E(\underline{s_1}) = E(\underline{s_2}) = 0^2 + \left(\sqrt{\frac{T}{2}}\right)^2 = \frac{T}{2}$$

$$\begin{aligned}
E_s &= \frac{E(\underline{s_1}) + E(\underline{s_2})}{2} = \frac{T}{2} \\
E_b &= \frac{E_s}{k} = \frac{E_s}{1} = \frac{T}{2}
\end{aligned}$$

Result:

$$P_b(e) = P_s(e) = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{2N_0}}\right)$$

4.3 BER of a Gaussian channel using PSK

Used signal constellation is:

$$M = \{s_1(t) = cos(2\pi f_0 t); s_2 = cos(2\pi f_0 t + \pi)\}$$

$$M = \{s_1(t) = cos(2\pi f_0 t); s_2 = -cos(2\pi f_0 t)\}$$

Build an orthonormal basis B:

$$b_1^*(t) = s_1(t) = cos(2\pi f_0 t)$$

$$E(b_1^*(t)) = \int_{-\infty}^{\infty} s_1^2(t)\,dt = \int_0^T cos^2(2\pi f_0 t)\,dt = \frac{T}{2}$$

Thus

$$b_1(t) = \frac{s_1(t)}{\sqrt{\frac{T}{2}}}$$

We can see that $s_2(t)$ is a linear combination of $b_1(t)$

Thus,

$$B = \left\{ b_1(t) = \frac{s_1(t)}{\sqrt{\frac{T}{2}}} \right\}$$

Constellation M as a vector set:

$$M = \left\{ \underline{s_1} = \sqrt{\frac{T}{2}}; \underline{s_2} = -\sqrt{\frac{T}{2}} \right\}$$

The Voronoi regions are:

$$V(\underline{s_1}) = \{\rho = (\rho_1), \rho_1 \geq 0\}$$

$$V(\underline{s_2}) = \{\rho = (\rho_1), \rho_1 \leq 0\}$$

We have:

$$P_s(e) = \frac{1}{m}\sum_{i=1}^{m} P_s(e|\underline{s_T} = \underline{s_i}) = \frac{1}{2}[P_s(e|\underline{s_T} = \underline{s_1}) + P_s(e|\underline{s_T} = \underline{s_2})]$$

With $P_s(e|\underline{s_T} = \underline{s_1})$:

$$P(\underline{\rho} \in V(s_2)|\underline{s_T} = \underline{s_1}) = P(\rho_1 < 0|\underline{s_T} = \underline{s_1})$$

Where: $\underline{\rho} = (\rho_1); \underline{s_1} = \sqrt{\frac{T}{2}}; \underline{n} = (n_1)$

Follow: $\rho_1 = \sqrt{\frac{T}{2}} + n_1$

Thus:

$$\begin{aligned}
P(\rho_1 < 0|\underline{s_T} = \underline{s_1}) &= P\left(\sqrt{\frac{T}{2}} + n_1 < 0\right) \\
&= P\left(n_1 < -\sqrt{\frac{T}{2}}\right) \\
&= P\left(n_1 > \sqrt{\frac{T}{2}}\right) \\
&= \frac{1}{2} erfc\left(\frac{\sqrt{T}}{\sqrt{2N_0}}\right)
\end{aligned}$$

With $P_s(e|\underline{s_T} = \underline{s_2})$:

$$P(\underline{\rho} \in V(s_1)|\underline{s_T} = \underline{s_2}) = P(\rho_1 > 0|\underline{s_T} = \underline{s_2}))$$

Where: $\underline{\rho} = (\rho_1); \underline{s_2} = -\sqrt{\frac{T}{2}}; \underline{n} = (n_1)$

Follow: $\rho_1 = -\sqrt{\frac{T}{2}} + n_1$

Thus:

$$\begin{aligned}
P(\rho_1 > 0|\underline{s_T} = \underline{s_2}) &= P\left(-\sqrt{\frac{T}{2}} + n_1 > 0\right) \\
&= P\left(n_1 > \sqrt{\frac{T}{2}}\right) \\
&= \frac{1}{2} erfc\left(\frac{\sqrt{T}}{\sqrt{2N_0}}\right)
\end{aligned}$$

So:

$$\begin{aligned}
P_s(e) &= \frac{1}{2}[P_s(e|\underline{s_T} = \underline{s_1}) + P_s(e|\underline{s_T} = \underline{s_2})] \\
&= \frac{1}{2}\left[\frac{1}{2} erfc\left(\frac{\sqrt{T}}{\sqrt{2N_0}}\right) + \frac{1}{2} erfc\left(\frac{\sqrt{T}}{\sqrt{2N_0}}\right)\right] \\
&= \frac{1}{2} erfc\left(\frac{\sqrt{T}}{\sqrt{2N_0}}\right)
\end{aligned}$$

We want to write it as a function of $\frac{E_b}{N_0}$

$$E(\underline{s_1}) = \frac{T}{2}$$
$$E(\underline{s_2}) = \frac{T}{2}$$

$$E_s = \frac{E(\underline{s_1}) + E(\underline{s_2})}{2} = \frac{T}{2}$$
$$E_b = \frac{E_s}{k} = \frac{E_s}{1} = \frac{T}{2}$$

Result:

$$P_b(e) = P_s(e) = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\right)$$

5.1 Evaluation Parameters

We choose f, f1, f2 which are the frequency of carried signal have the value of $5000Hz$, $5000Hz$ and $10000Hz$, respectively. $Spb = 100$ is determined by the number of samples per bit used for the modulation scheme.

5.2 Simulate Modulation

- Generating and plotting the Carrier Signals:

- For ASK modulation, 2 carrier signals is $cos(2\pi fx)$ and $2cos(2\pi fx)$. If the binary data is 0, the carrier signal is $cos(2\pi fx)$, and if the binary data is 1, the carrier signal is the other.
- For FSK modulation, we choose 2 signals $cos(2\pi f_1 x), cos(2\pi f_2)x$. If the binary data is 0, the carrier signal is $cos(2\pi f_1 x)$, and if the binary data is 1, the carrier signal is the other.
- For PSK modulation, we choose 2 signals $cos(2\pi fx), cos(2\pi fx + \pi)$. If the binary data is 0, the carrier signal is $cos(2\pi fx)$, and if the binary data is 1, the carrier signal is the other.

These carrier signals are then plotted to visualize the waveform.

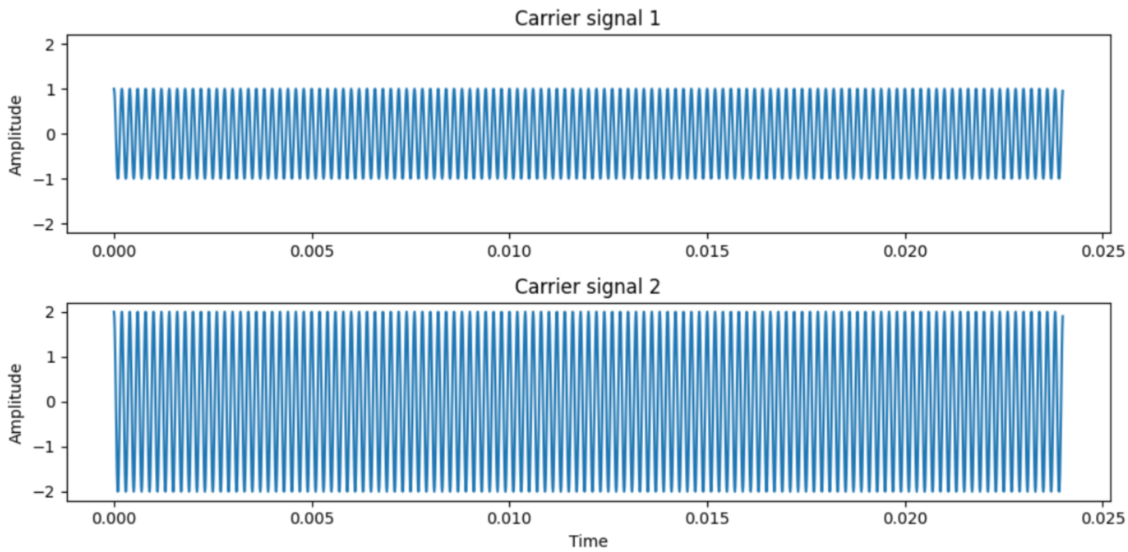


Figure 5.1: ASK carrier signal

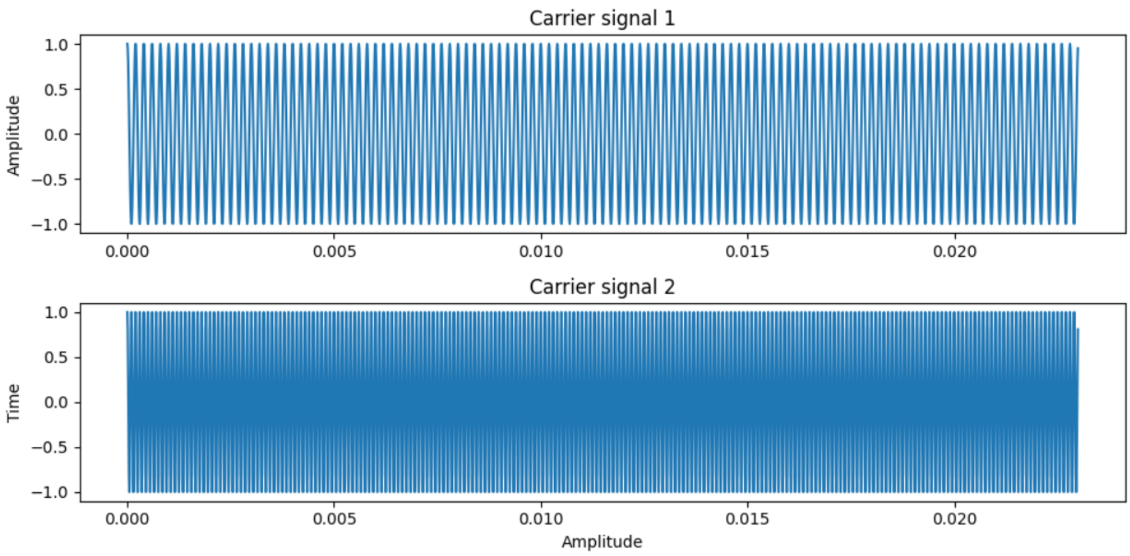


Figure 5.2: FSK carrier signal

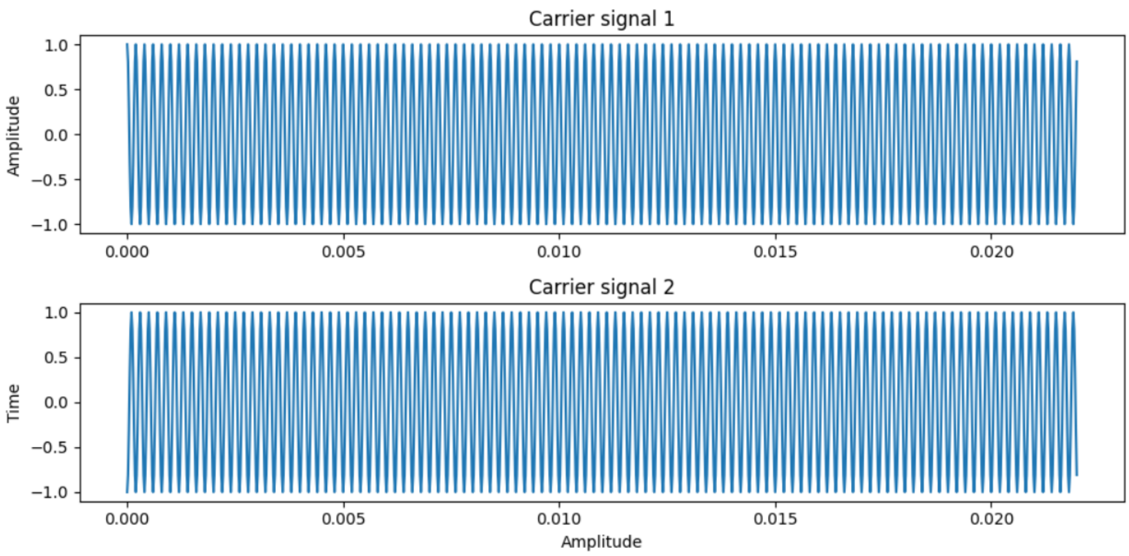


Figure 5.3: PSK carrier signal

- Generating and Plotting the Binary Data Sequence: The next step is to generate a random binary data sequence, which consists of 1s and 0s. We use stream bit random with length between 20 and 30. The binary data sequence is then plotted to visualized the pattern of data.

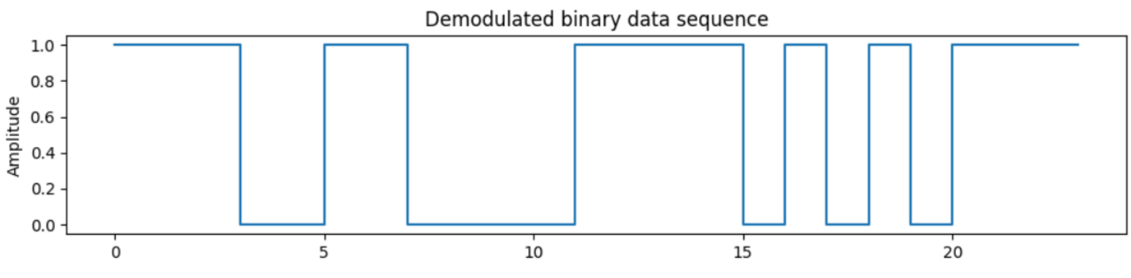


Figure 5.4: Binary data sequence

- Performing Modulation and Plotting Modulated Signal: The final step is to perform the modulation of the binary data sequence using carrier signals with the help of mathplotlib library.

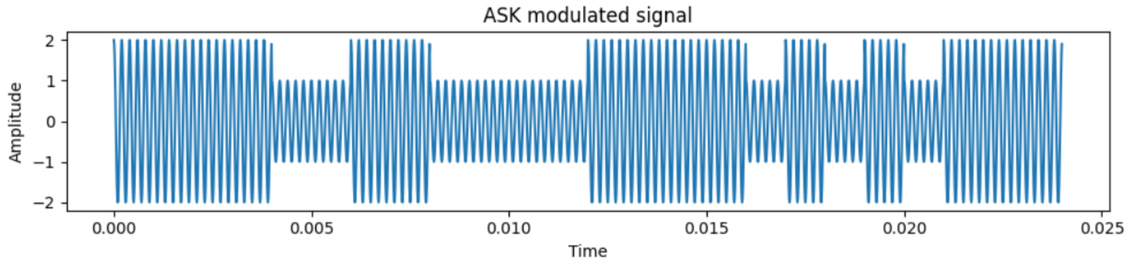


Figure 5.5: ASK modulation

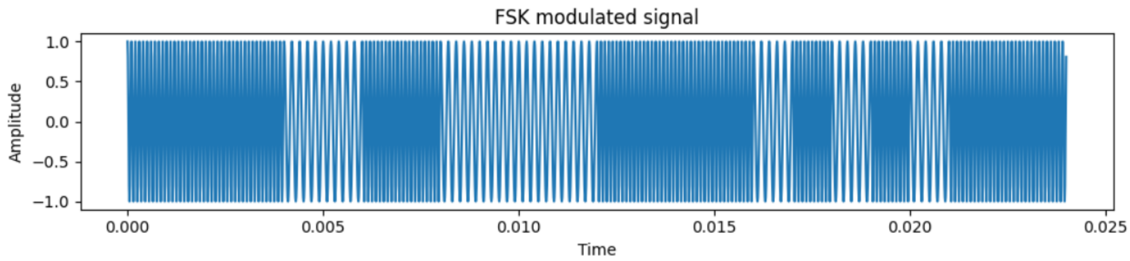


Figure 5.6: FSK modulation

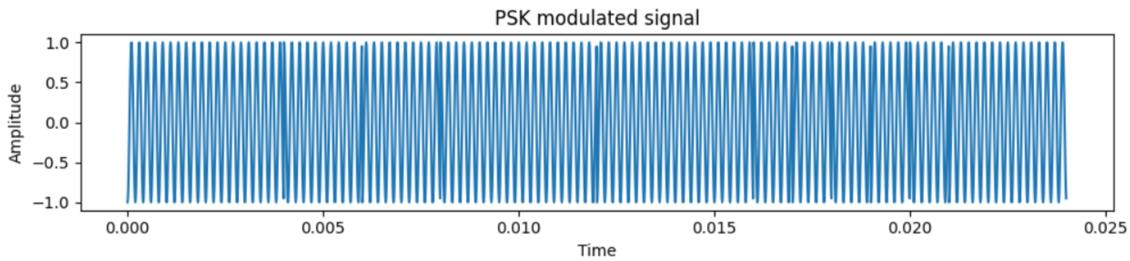


Figure 5.7: PSK modulation

5.3 Simulate Demodulation

The method in demodulation is to correlate the modulated signal with the carrier signals.The correlation is performed using the Maximum Likelihood Criterion to determine the most likely value of the demodulated binary data based on the modulated signal and the carrier signals. This will define whether the demodulated binary data is 0 or 1.

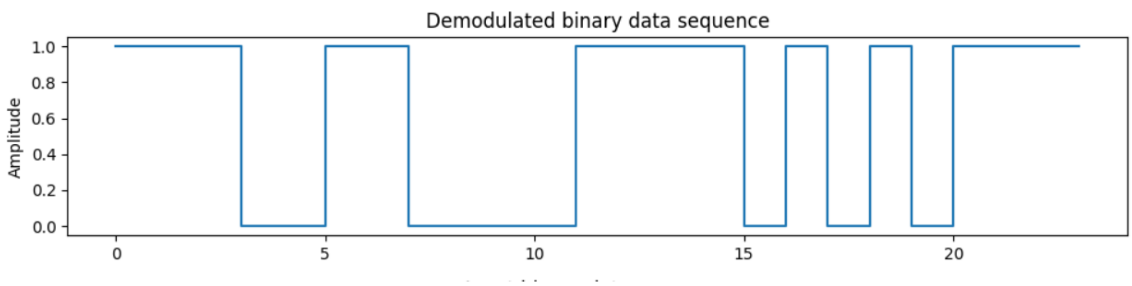


Figure 5.8: Demodulated binary data sequence

5.4 Modulation and demodulation under effects of noise

The noise is added to the transmitted waveform as $r(t) = s(t) + n(t)$, where $s(t)$ is the transmitted waveform and $n(t)$ is the Gaussian noise. In this project, we choose $N = 0$ and $standard\ deviation = 1$

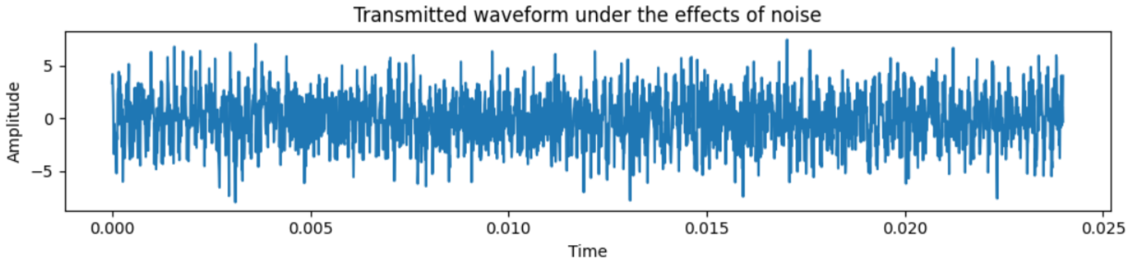


Figure 5.9: ASK transmitted wave under effect of Gaussian noise

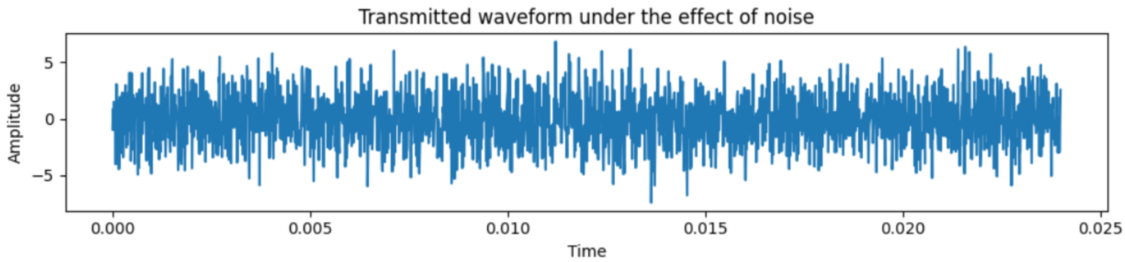


Figure 5.10: FSK transmitted wave under effect of Gaussian noise

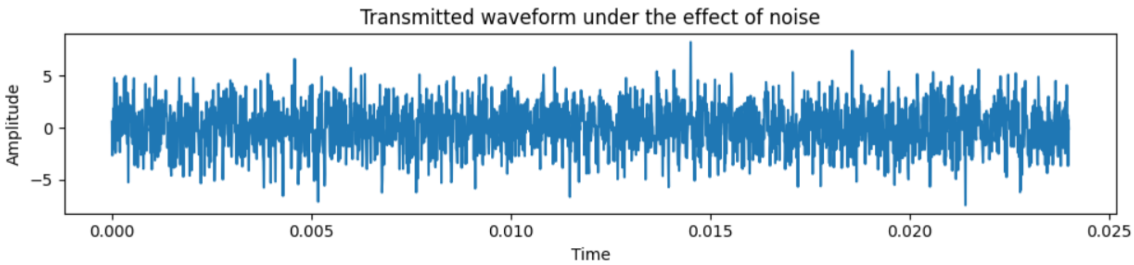


Figure 5.11: PSK transmitted wave under effect of Gaussian noise

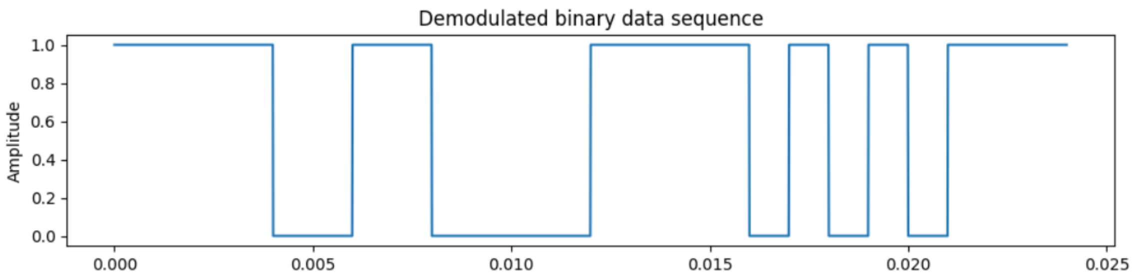


Figure 5.12: ASK Demodulated binary sequence under effect of Gaussian noise

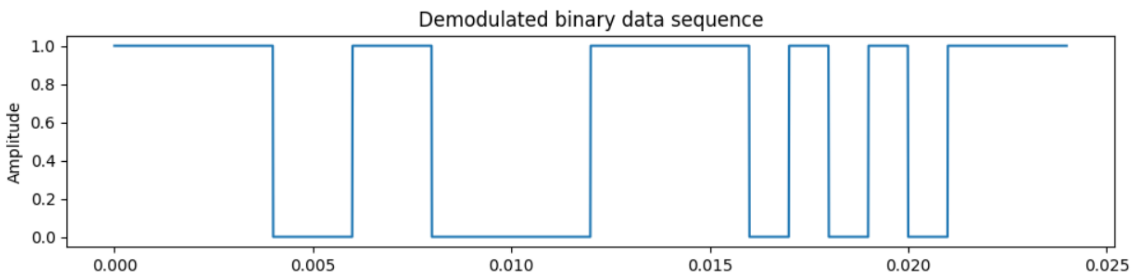


Figure 5.13: FSK Demodulated binary sequence under effect of Guassian noise

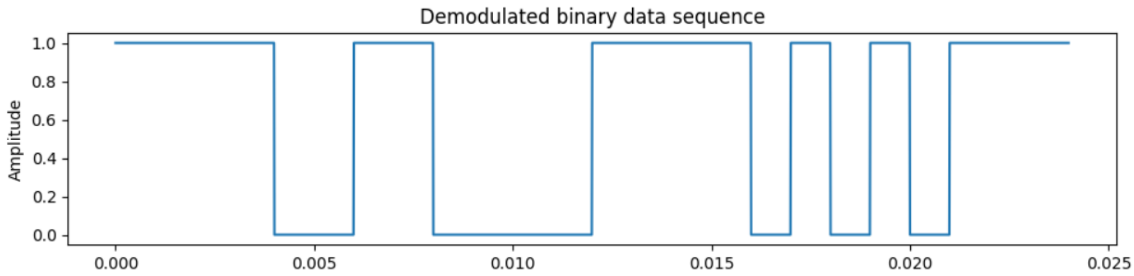


Figure 5.14: PSK Demodulated binary sequence under effect of Gaussian noise

5.5 Compute the Error rate

The error probability is calculated by comparing the original binary data sequence with the demodulated binary data under the effect of noise. The number of difference bits between the input and output bits divided by the total number of input bits represent the bit error rate.

Bit error rate: $BER = \frac{1}{n}\sum_{i=1}^{n}(u[i] \neq r[i])$, where n is the total number of bits.

From the above experiment:

- ASK demodulation:It can be seen that there are no difference between the input binary sequence and the demodulated signal after adding the noise (when t =100ms), therefore the $BER = 0\%$
- FSK demodulation: $BER = 0\%$
- PSK demodulation: $BER = 0\%$

CHAPTER 6. CONCLUSIONS

6.1 Summary

In conclusion, digital modulation and demodulation techniques, such as Amplitude Shift Keying (ASK), Phase Shift Keying (PSK), and Frequency Shift Keying (FSK), play a crucial role in the field of communication systems. Each of these techniques has its own advantages and disadvantages, and the choice of a particular technique depends on the requirements of the communication system. ASK is a simple and low-cost modulation technique, but it is sensitive to noise and interference. PSK is more robust against noise and interference compared to ASK, but it requires a higher bandwidth for the same data rate. FSK is used for low-data rate applications and is also robust against interference, but it requires a larger bandwidth compared to PSK. In summary, digital modulation and demodulation techniques provide a convenient way to transmit digital information over a communication channel with the help of the modulation and demodulation process. The selection of the appropriate technique depends on the specific requirements of the communication system and the trade-off between its performance and complexity