جامعة بيرزيت

BIRZEIT UNIVERSITY

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Department of Electrical and Computer Engineering

Communication Systems

ENEE 3309

Project

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Section: **1**

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Abstract

This project focuses on gaining practical experience in digital modulation techniques, specifically Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), and Quadrature Phase Shift Keying (QPSK), using MATLAB Simulink. We aim to provide a straightforward and hands-on approach to understanding and simulating these key modulation methods, and offers a simplified and accessible entry point into the world of digital modulation for beginners and learners in the field of electrical and computer engineering.

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Introduction

Digital communication is when people send information using computers and other electronic gadgets. It's popular because it has many benefits. First, it helps make messages clearer by reducing noise. Second, it keeps your information safe. Lastly, it works well with other digital systems. Overall, digital communication makes it easier and more efficient for people to talk to each other using technology.

To send a signal to a digital device, analog signals must be converted into a stream of bits. This conversion process is accomplished using an Analog-to-Digital Converter (ADC). The ADC process initiates with the conversion of a continuous-time, continuous-amplitude signal into a discrete-time, continuous-amplitude signal through a process called sampling. Next, the amplitude of the sampled signal from sampling is quantized into a finite and countable set of possible values, a step known as quantization. Finally, each quantized level is represented using binary digits, achieved through a Binary Encoder.

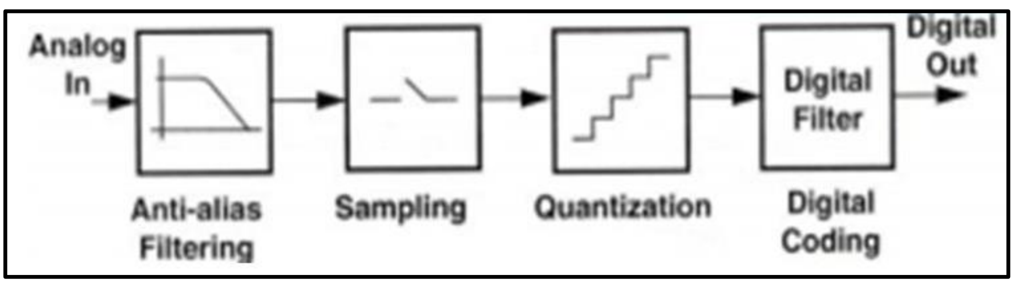


Figure 1 Analog to digital converter

To transmit the stream of bits that emerge from the ADC, two techniques are commonly employed. The first is baseband transmission, which involves sending the bits without modulation. This method is suitable for short distances. The second technique is bandpass transmission, which modulates the bits with a carrier signal. This modulation enables data to travel over longer distances.

As mentioned, bandpass data is used to modulate a high-frequency carrier, resulting in a modulated signal with a spectrum centered on the carrier frequency. There are four main types of bandpass transmission schemes: Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), and Quadrature Phase Shift Keying (QPSK).

- Amplitude Shift Keying (ASK)

In Binary Amplitude Shift Keying (ASK), the carrier's amplitude is alternated between two levels, often at the extremes of full-on and full-off. Consequently, ASK is sometimes referred to as Full On-Off Keying. In this modulation scheme, the "on" condition typically corresponds to a binary code 1, while the "off" condition corresponds to a binary code 0.

$$SASK(t) = \begin{cases} s1(t) = 0, \quad 0 \le t \le Tb, & binary\ 0 \\ s2(t) = A\cos(\omega t + \theta), \quad 0 \le t \le Tb, & binary\ 1 \end{cases}$$

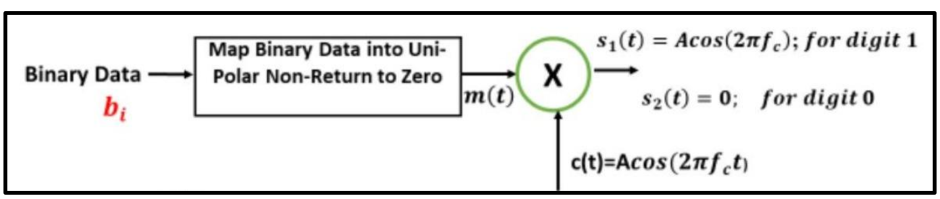


Figure 2 ASK Generation

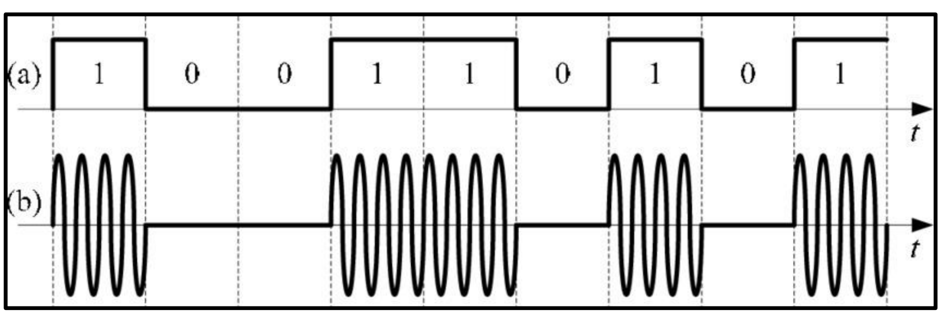


Figure 3 ASK modulated Signal

- ## Frequency Shift Keying (FSK)

In binary frequency shift keying (FSK), the frequency of the transmitted signal is switched between two values.

$$\omega 1 = \omega 0 - \Delta\,\omega$$

$$\omega 2 = \omega 0 + \Delta\,\omega$$

According to messages m1 and m2 (for binary 0 and 1), respectively. Here is $\omega 0$ represents a nominal carrier frequency, and $\Delta\,\omega$ represents a frequency deviation due to message modulation.

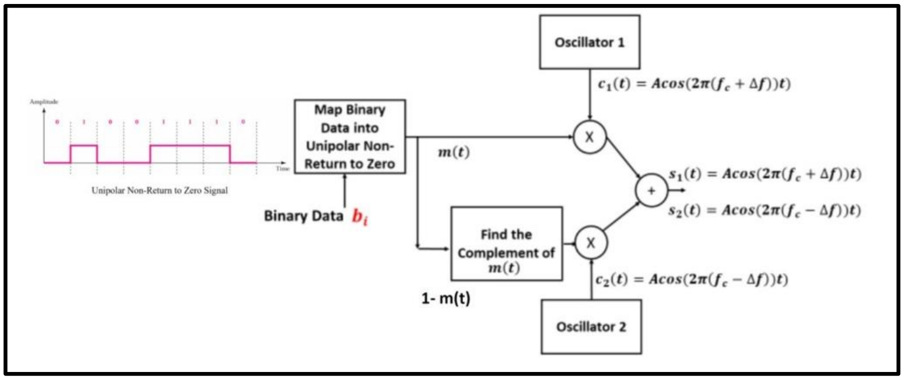


Figure 4 FSK Generator

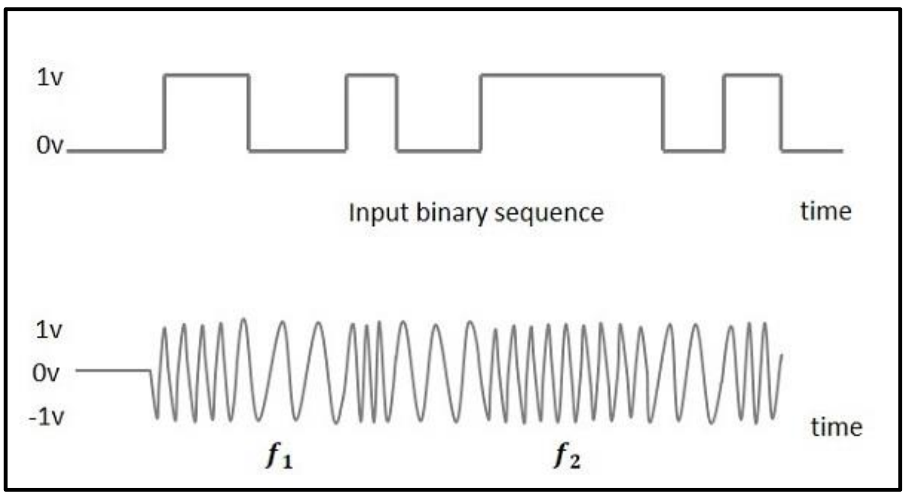


Figure 5 FSK Output Waveform

- ## Phase Shift Keying (PSK)

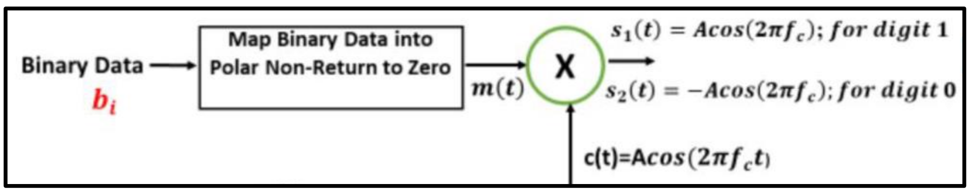
In binary shift keying (PSK) the phase of a carrier is switched between two values according to the two possible messages m_1 and m_2.

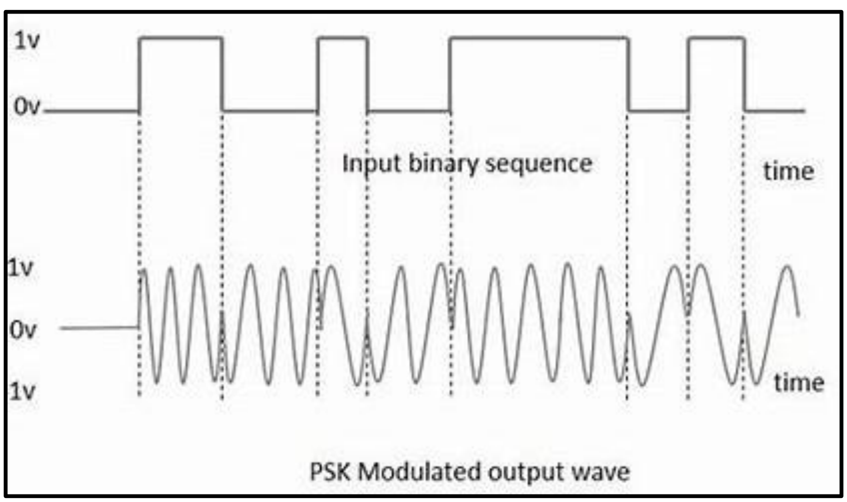
The two phases are usually separated by π radians, and this is the only case we consider; it is sometimes called phase reversal keying (PRK).

Phase reversal keying corresponds to the two possible transmitter waveforms.

$$SPSK(t) = \begin{cases} s1(t) = -A\cos(\omega o t + \theta o), & 0 \le t \le Tb, \quad m1\ sent \\ s2(t) = +\cos(\omega o t + \theta o), & 0 \le t \le Tb, \quad m2\ sent \end{cases}$$

The transmitted signal is equivalent to a double sideband suppressed-carrier amplitude-modulated waveform where the information signal is a digital waveform of polar format.





• Quadrature Phase Shift Keying (QPSK)

Quadrature Phase Shift Keying is a digital modulation technique employing four distinct phases of a carrier signal to encode two bits per symbol. This method is characterized by its bandwidth efficiency, requiring only half the spectrum of BPSK modulation.

Mathematically, QPSK modulation involves the use of two sinusoidal functions, sin(ωt) and cos(ωt), as basis functions for modulation.

Signal Representation:

1 1: S1(t) = $Acos\left(2\pi fct - \frac{\pi}{4}\right) = +\frac{A}{\sqrt{2}}\cos(2\pi fct) + \frac{A}{\sqrt{2}}\sin(2\pi fct)$

1 0: S2(t) = $Acos\left(2\pi fct + \frac{\pi}{4}\right) = +\frac{A}{\sqrt{2}}\cos(2\pi fct) - \frac{A}{\sqrt{2}}\sin(2\pi fct)$

0 1: S3(t) = $Acos\left(2\pi fct + \frac{3\pi}{4}\right) = -\frac{A}{\sqrt{2}}\cos(2\pi fct) - \frac{A}{\sqrt{2}}\sin(2\pi fct)$

0 0: S4(t) = $Acos\left(2\pi fct + \frac{5\pi}{4}\right) = -\frac{A}{\sqrt{2}}\cos(2\pi fct) + \frac{A}{\sqrt{2}}\sin(2\pi fct)$

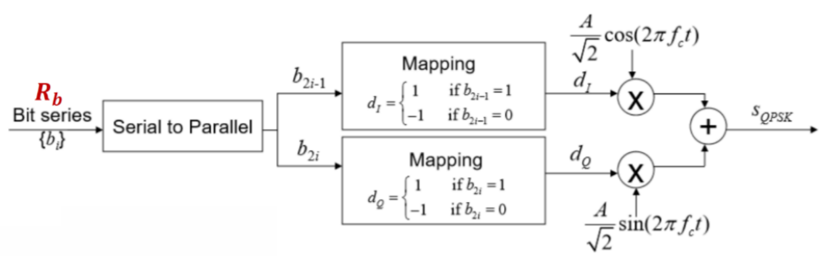


Figure 6 QPSK modulator

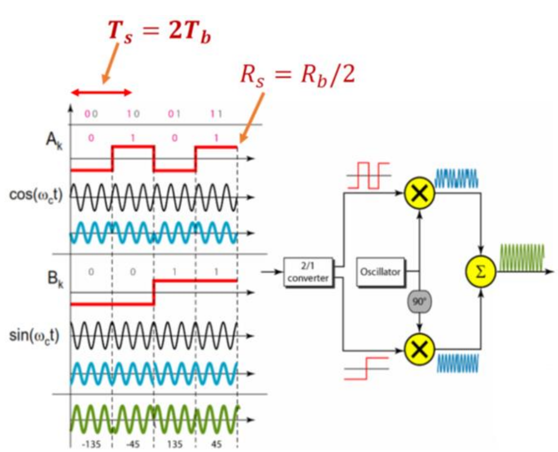


Figure 7 QPSK procedure

Procedure and Discussion

- Amplitude Shift Keying (ASK)

✓ Probability Of Error = $Q\left(\sqrt{\frac{A^2\tau}{4N}}\right)$

✓ Band Width = $2R_b = \frac{2}{\tau}$

➢ Modulation

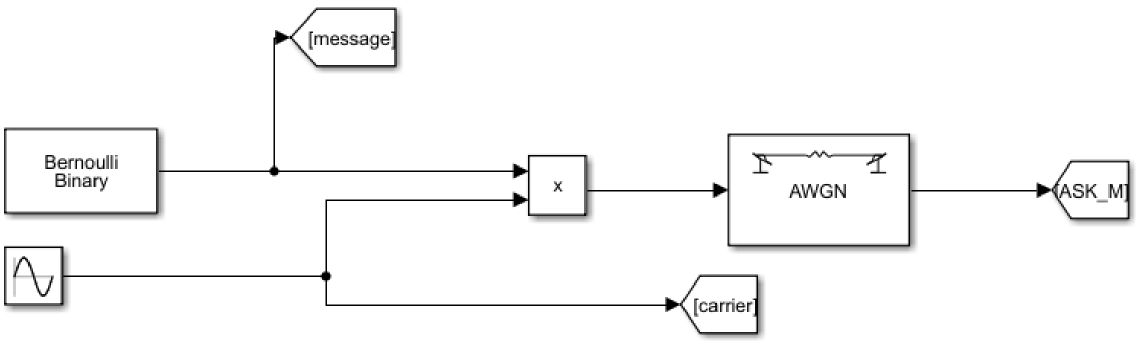


Figure 8 Frequency Shift Keying Modulation

The following figure shows the Message Signal in time domain.

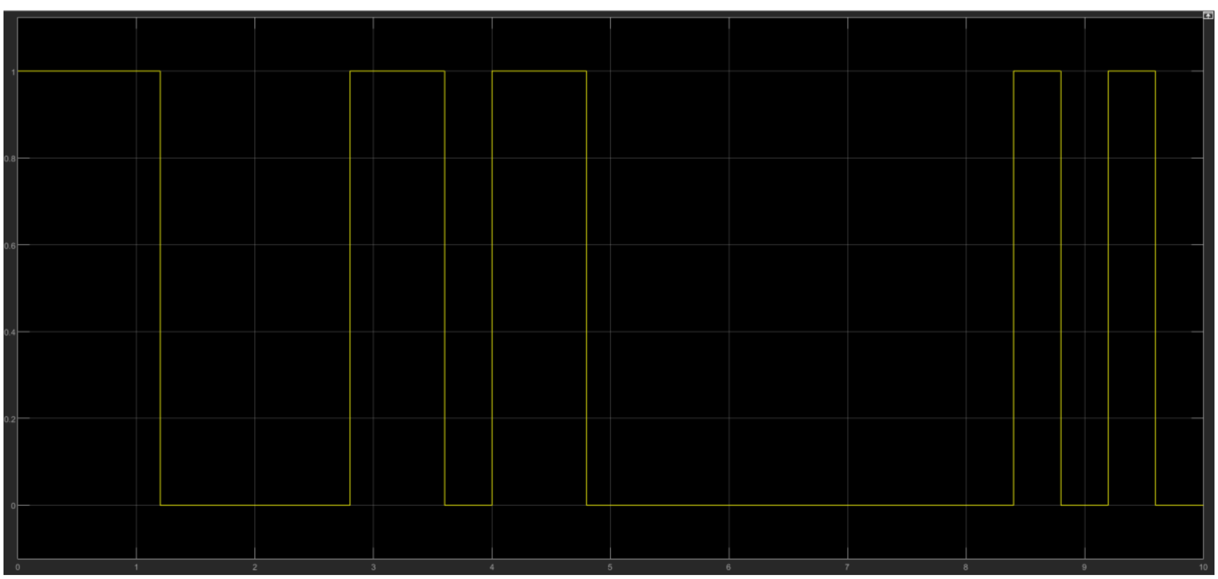


Figure 9 Message Signal

The following figure shows the Carrier Signal with frequency 5 Hz in time domain.

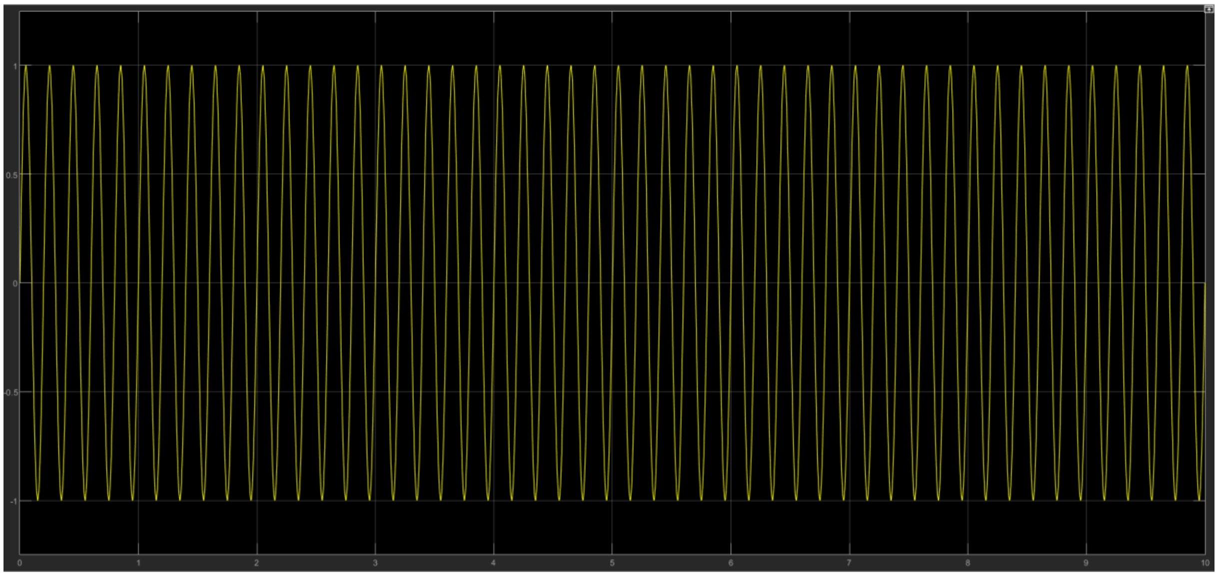


Figure 10 Carrier Signal

In ASK modulation, the message signal is multiplied by the carrier signal resulting in a modulated signal.

A noise with magnitude 10 Db is applied to the modulated signal.

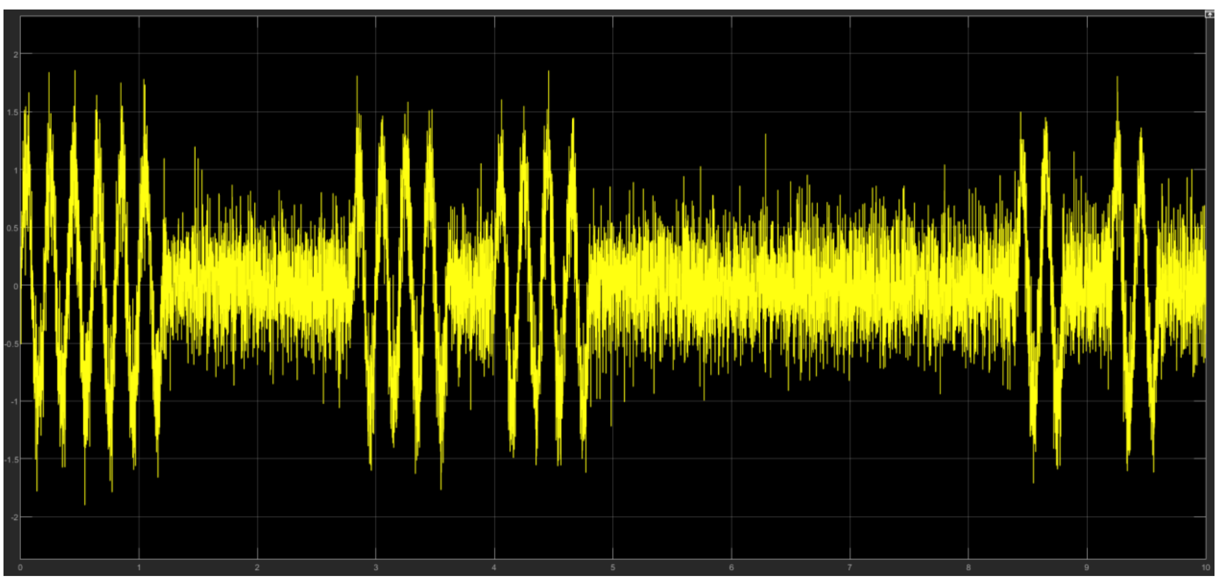


Figure 11 Modulated Signal

If the message signal is high the modulated signal is represented by a higher amplitude of the carrier signal, and if the message signal is low the modulated signal is represented by a lower amplitude of the carrier signal.

➢ Demodulation

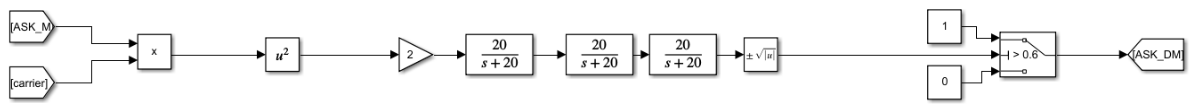


Figure 12 Frequency Shift Keying Demodulation

In ASK demodulation the modulated signal is first multiplied by the carrier signal then passed through an envelope detector then a thresh hold with value 0.6 to cancel the noise.

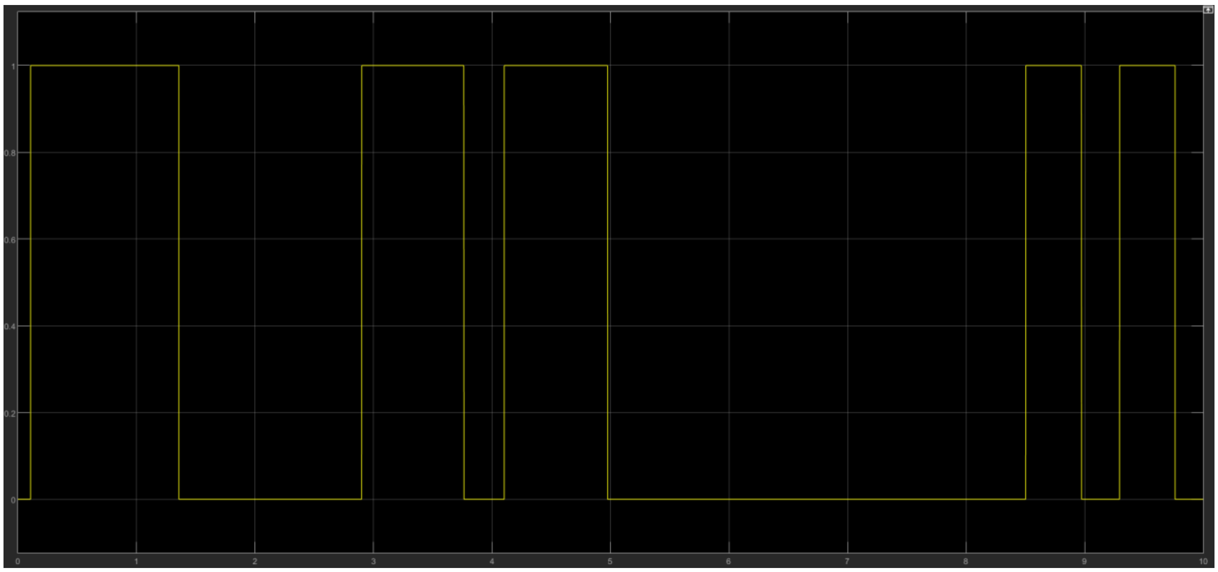


Figure 13 Demodulated Signal

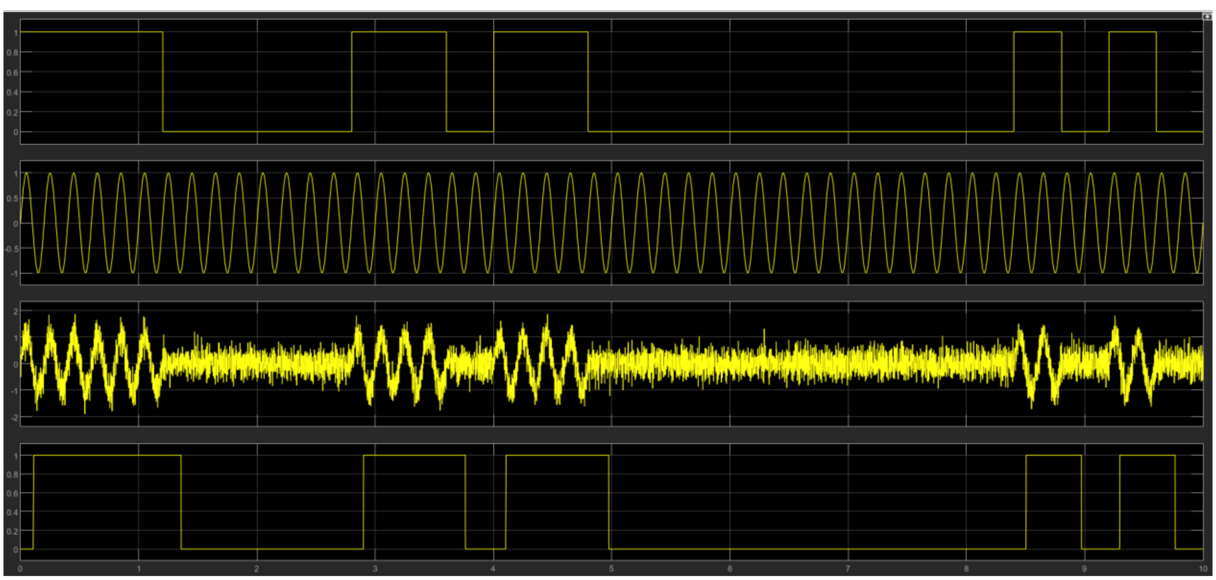


Figure 14 ASK full process

- ## Frequency Shift Keying (FSK)

  - Probability Of Error = $Q\left(\sqrt{\frac{A^2\tau}{2N}}\right)$
  - Band Width = $2R_b + 2\,\Delta f$

➢ Modulation

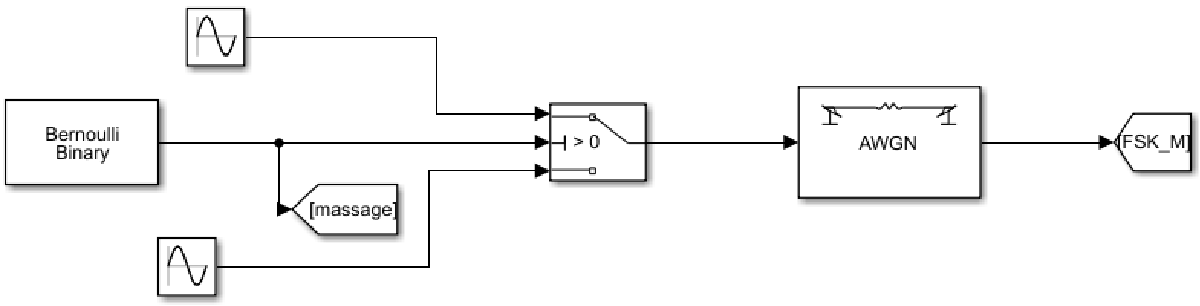


Figure 15 FSK Modulation diagram

The following figure shows the message signal in time domain.

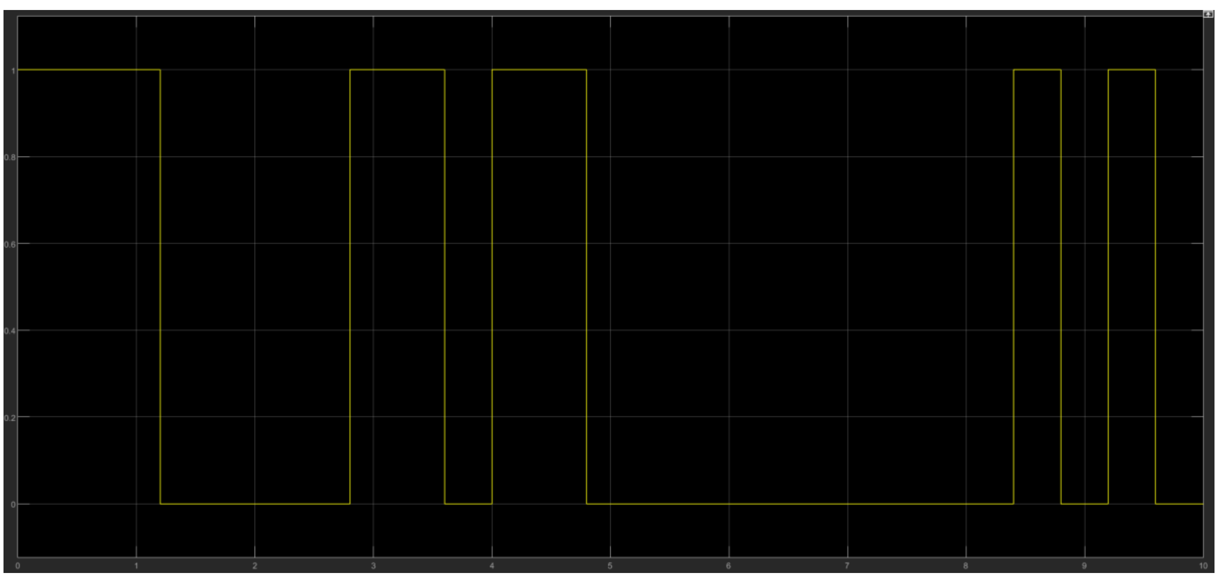


Figure 16 Message Signal

Δf a multiple of R_b, $\Delta f = 2 * 5 = 10$ Hz.

The following signal shows the carrier signal with frequency $f_c + \Delta f$ (5 + 10) 15 Hz

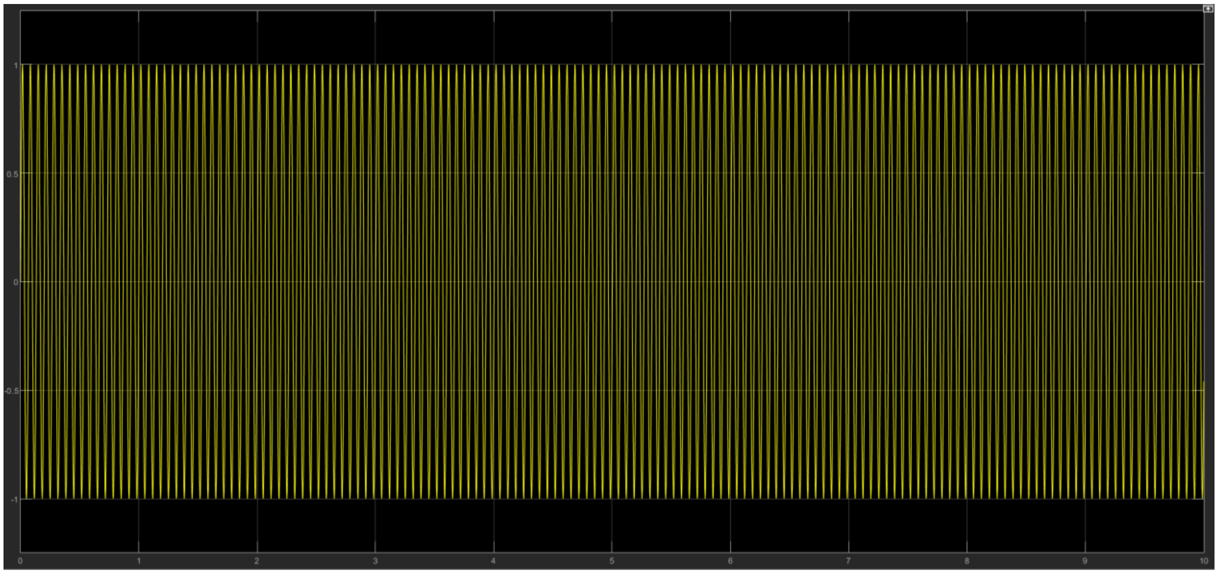


Figure 17 carrier signal with frequency 15 Hz

The following signal shows the carrier signal with frequency $f_c – \Delta f$ (5 - 10) 5 Hz:

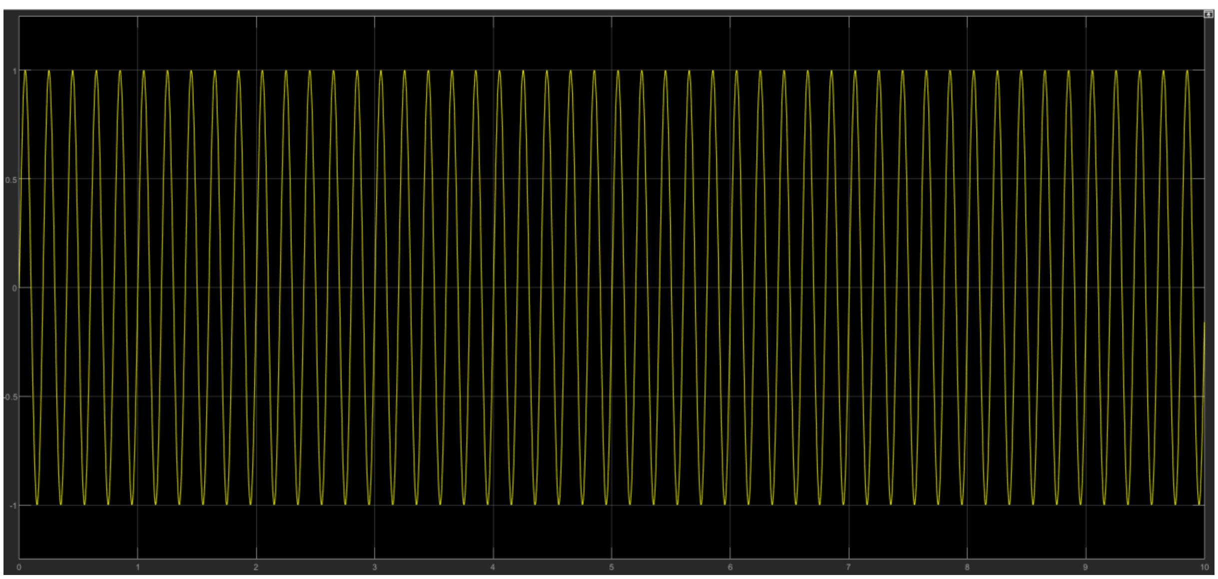


Figure 18 carrier signal with frequency 5 Hz

In FSK modulation if the message signal is high then the modulated signal is set to the carrier with frequency $f_c + \Delta f$ (15 Hz), else if the message signal is low the modulated signal is set to the carrier with frequency $f_c – \Delta f$ (5 Hz).

A noise with magnitude 10 dB is applied to the modulated signal.

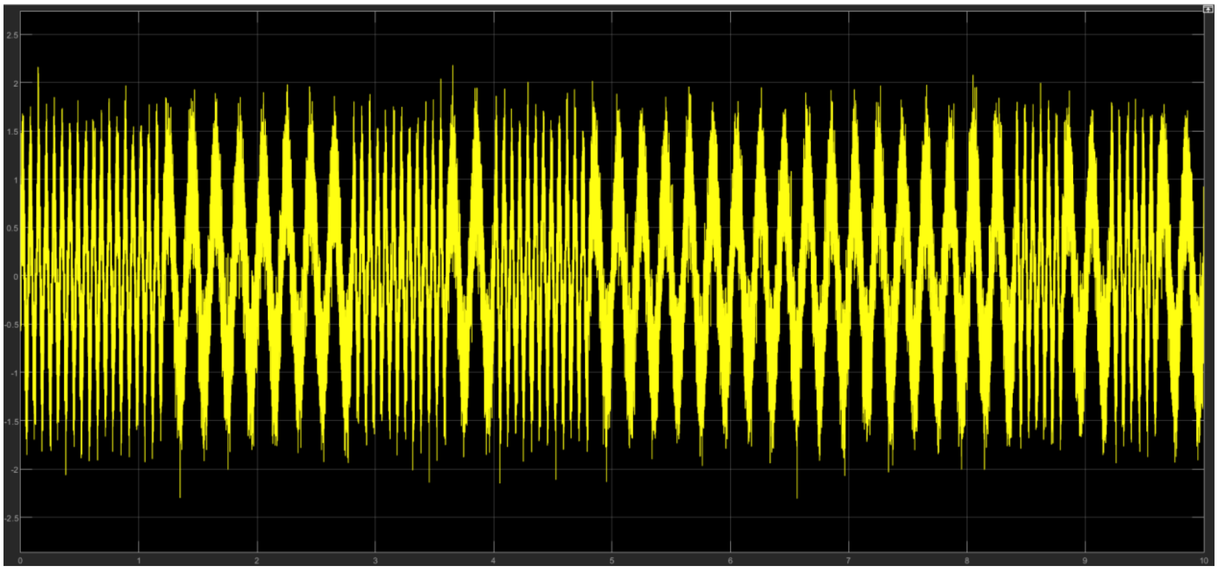


Figure 19 FSK modulated signal

➢ Demodulation

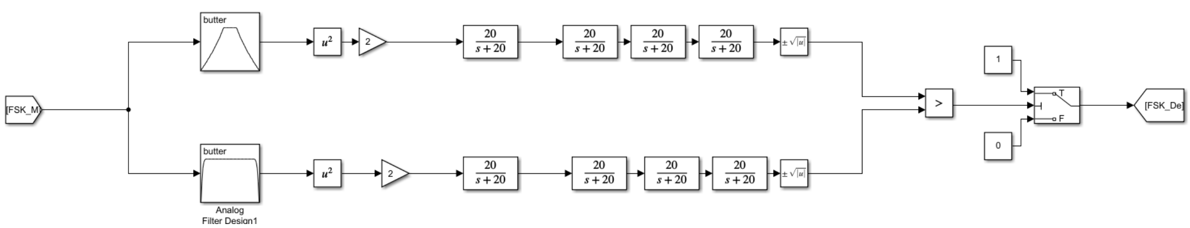


Figure 20 FSK demodulation diagram

The modulated signal is split to two signals one with frequency $f_c + \Delta f$ (15 Hz) and one with frequency $f_c - \Delta f$ (Hz) using bandpass filters, then they are passed through envelope detectors then to threshold point with magnitude 0.

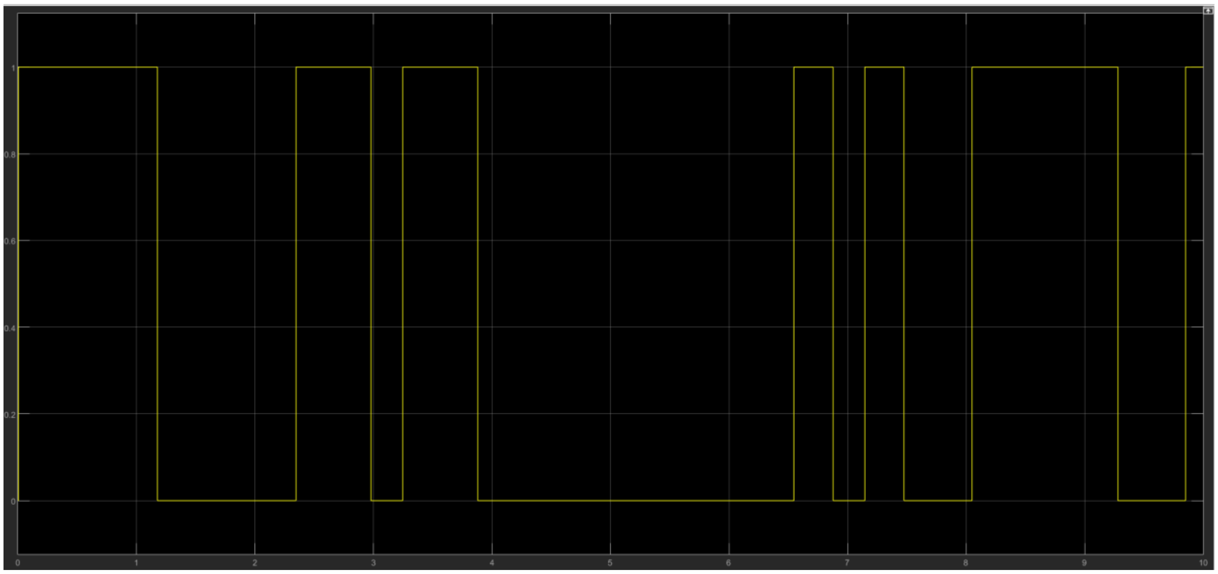


Figure 18 FSK Demodulated Signal

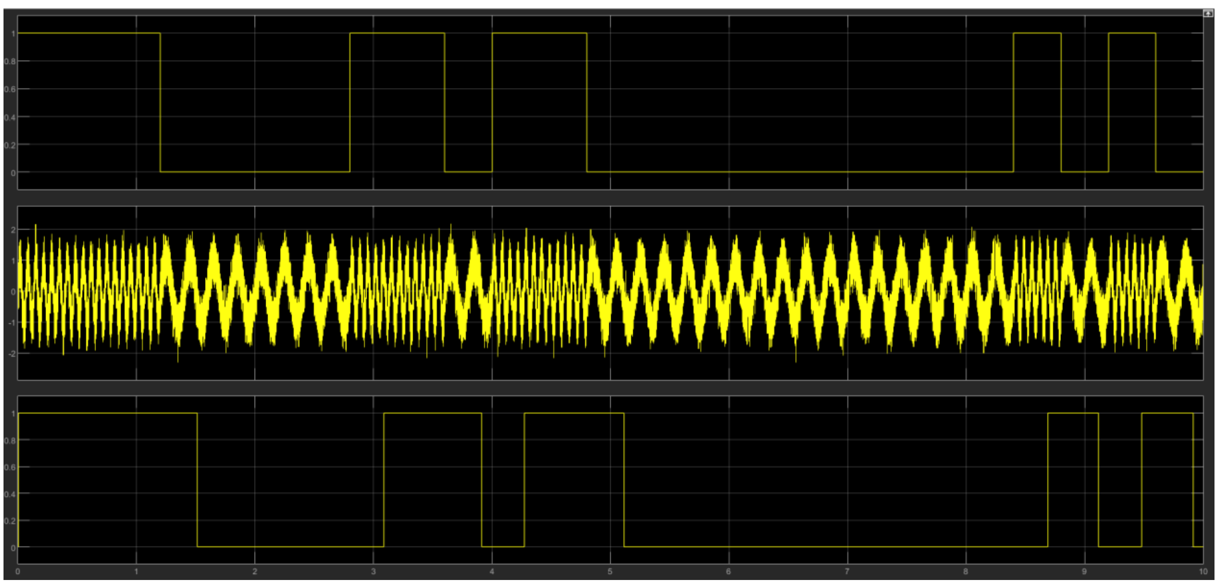


Figure 21 FSK Full Process

• Phase Shift Keying (PSK)

- Probability Of Error = $Q\left(\sqrt{\frac{A^2\tau}{N}}\right)$
- Band Width = $2R_b = \frac{2}{\tau}$

• Modulation

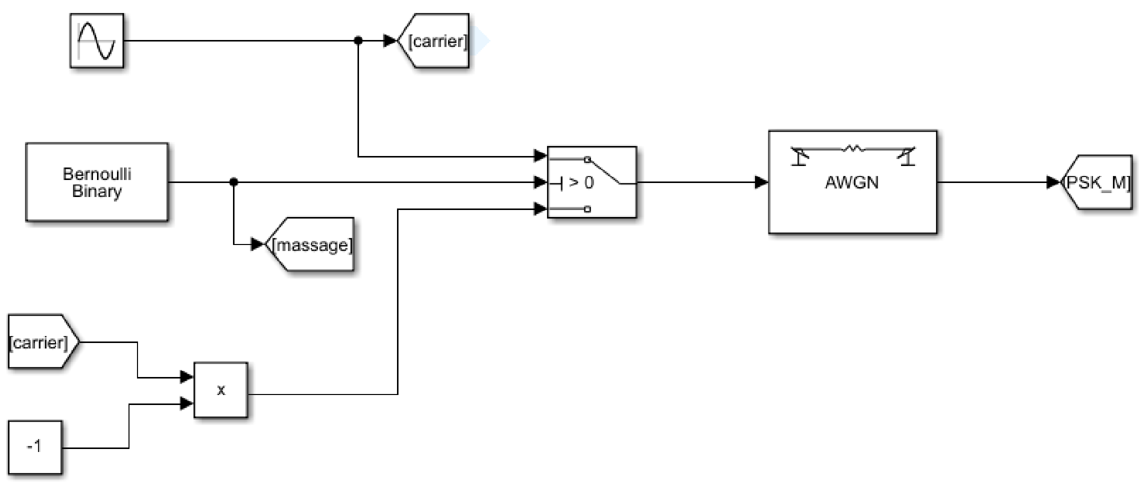


Figure 22 PSK modulation diagram

The following figure shows the message signal in time domain.

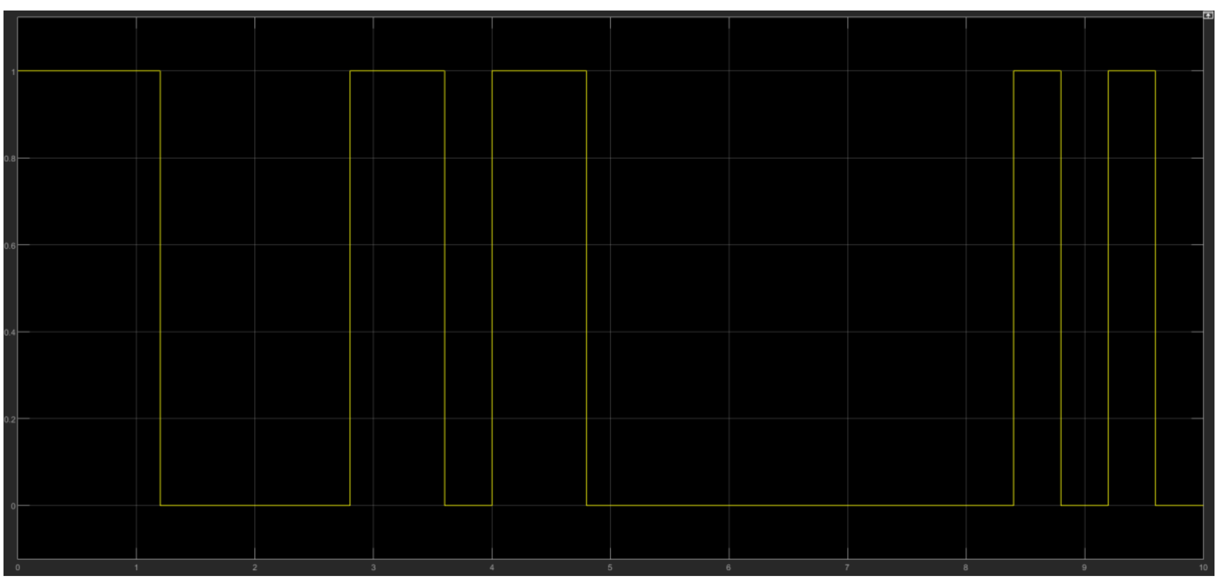


Figure 23 Message Signal

The following figure shows the carrier signal with frequency 5 Hz in time domain.

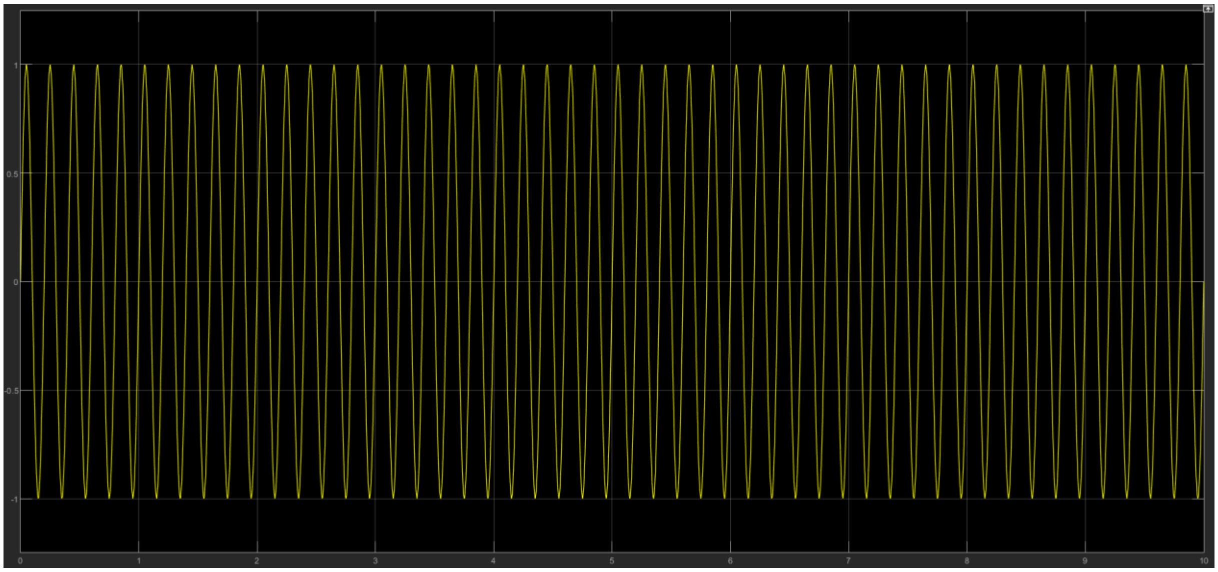


Figure 24 Carrier Signal

In PSK modulation if the message signal is high then the modulated signal becomes the carrier signal else if the message signal is low then the modulated signal becomes minus the carrier signal.

A noise with magnitude 10 dB is applied to the modulated signal.

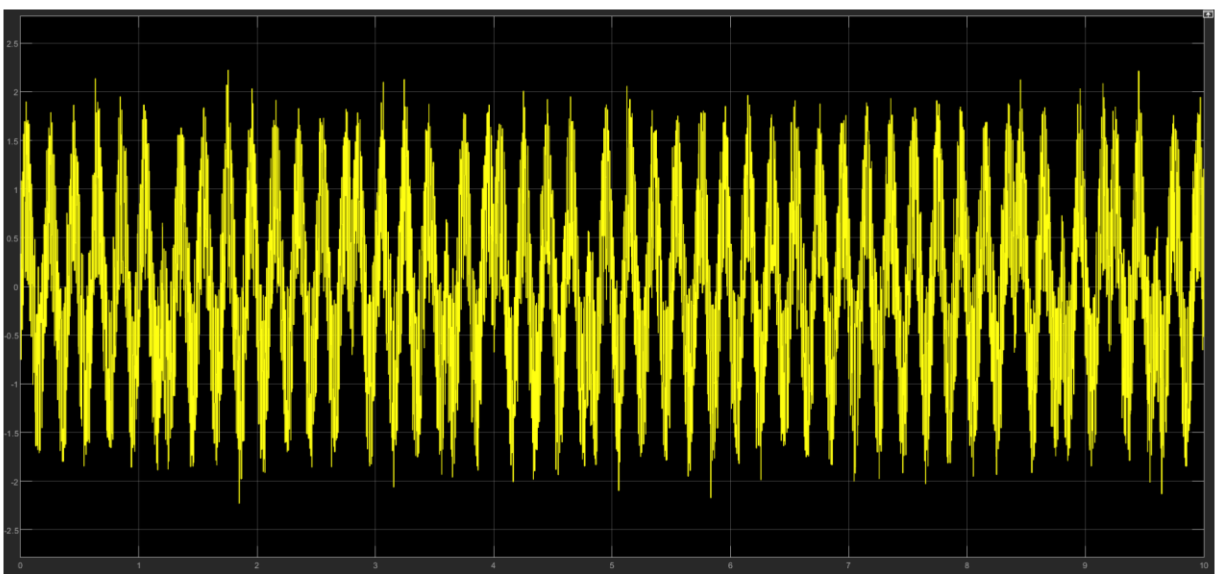


Figure 25 PSK modulated signal

➢ Demodulation

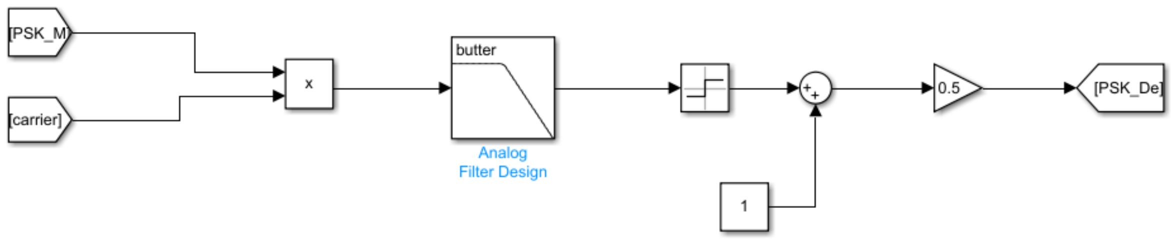


Figure 26 PSK demodulation diagram

In PSK demodulation the modulated signal is multiplied by the carrier signal followed by low pass filter to filter noise, then to a sign detector we get the message signal, the summation and gain blocks are to fix amplitude of the demodulated signal.

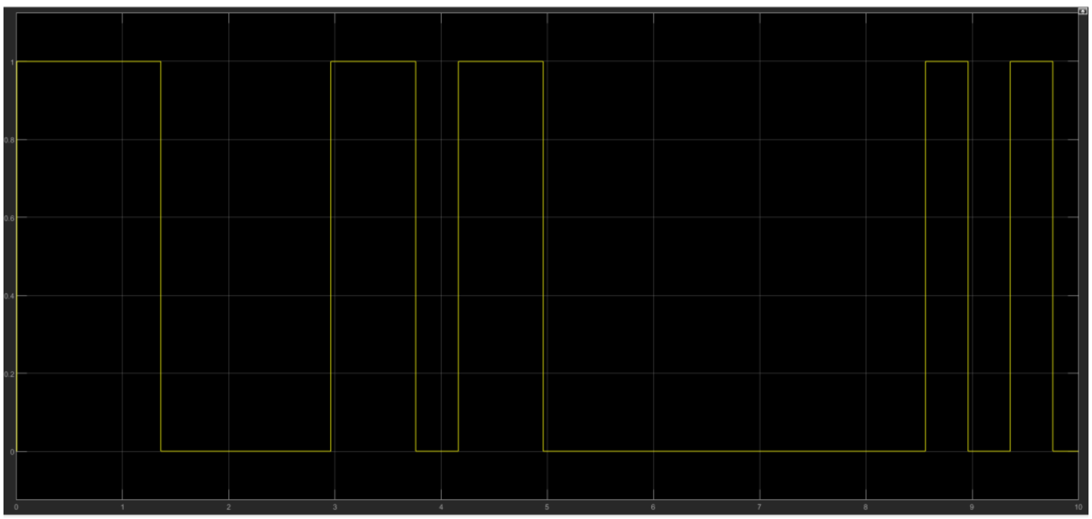


Figure 27 PSK demodulated signal

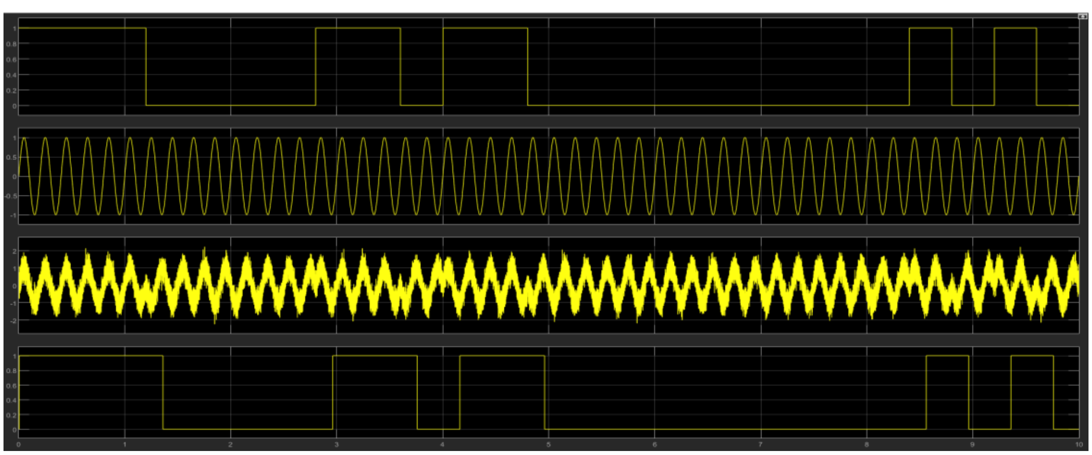


Figure 28 PSK full process

- Quadrature Phase Shift Keying (QPSK)

  - Probability Of Error = $Q\left(\sqrt{\frac{A^2\tau}{N}}\right)$
  - Band Width = $R_b = \frac{1}{\tau}$

➢ Modulation and Demodulation

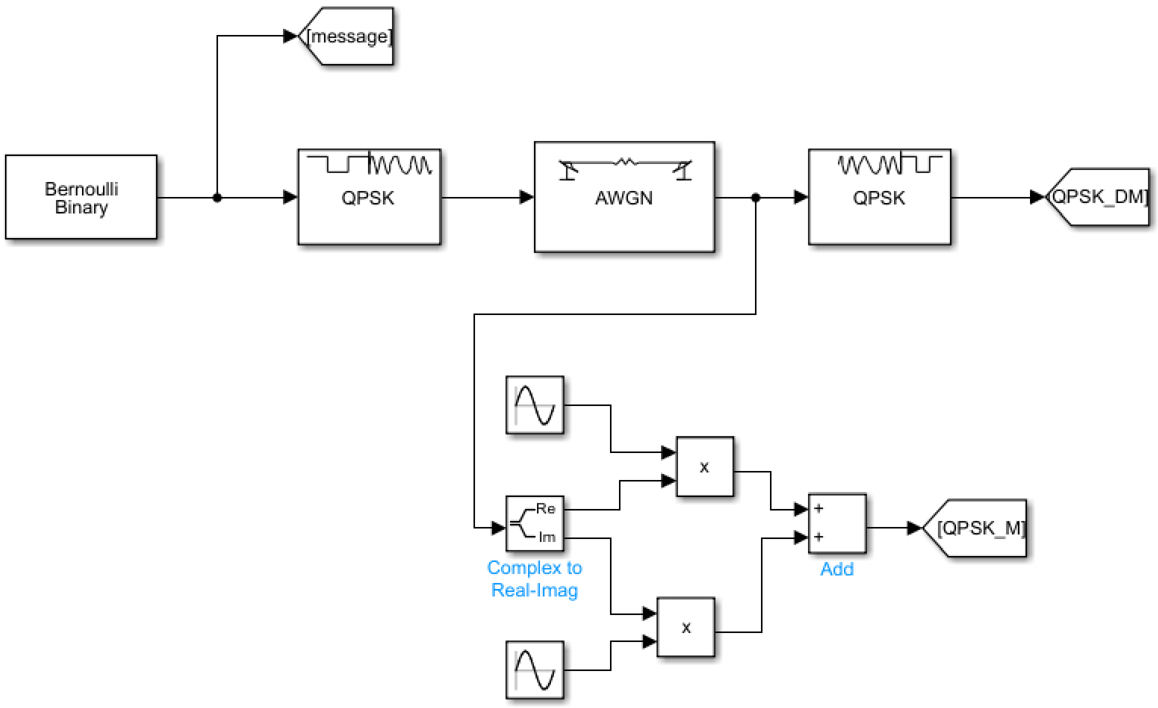


Figure 29 QPSK modulation and demodulation diagram

The following figure shows the message signal in time domain.

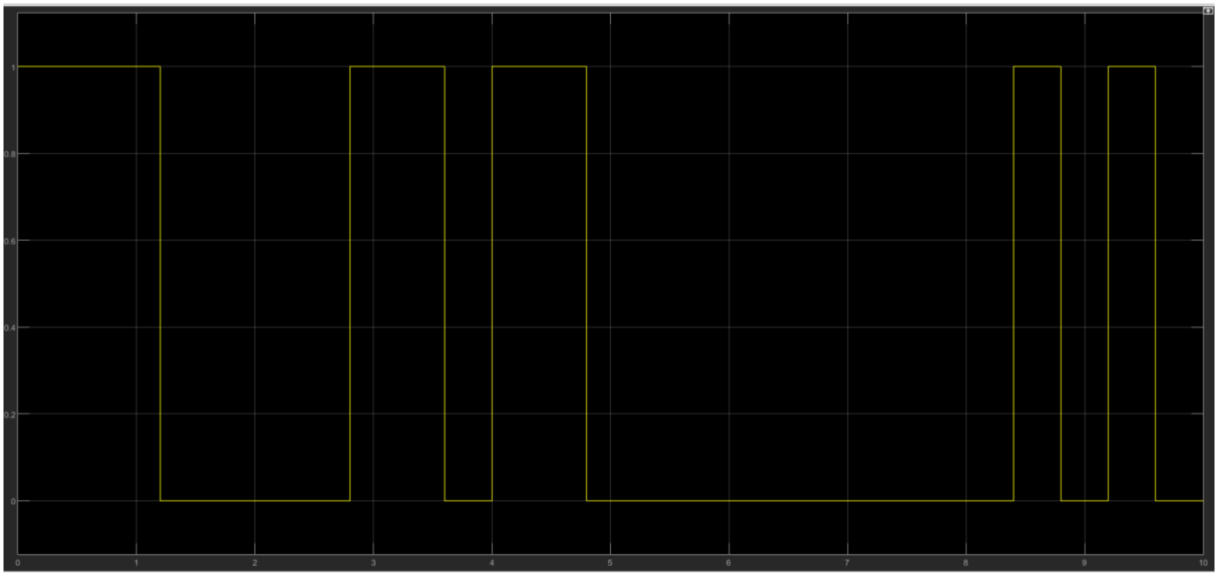


Figure 30 Message Signal

QPSK Modulated signal in time domain.

A noise with magnitude 15 dB is applied to the modulated signal.

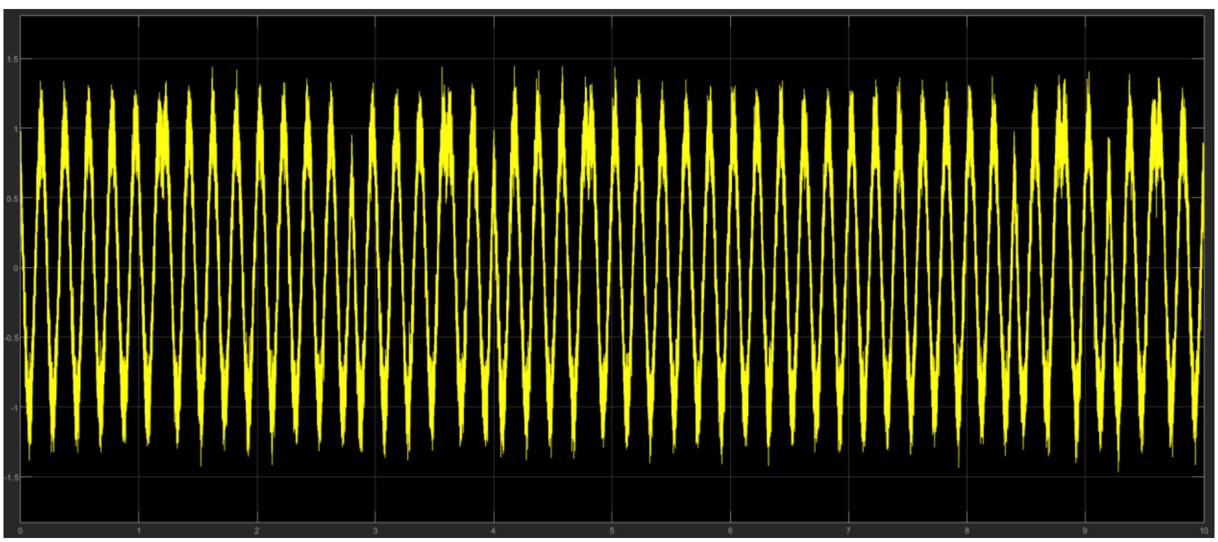


Figure 31 QPSK modulated signal

QPSK Demodulated signal in time domain.

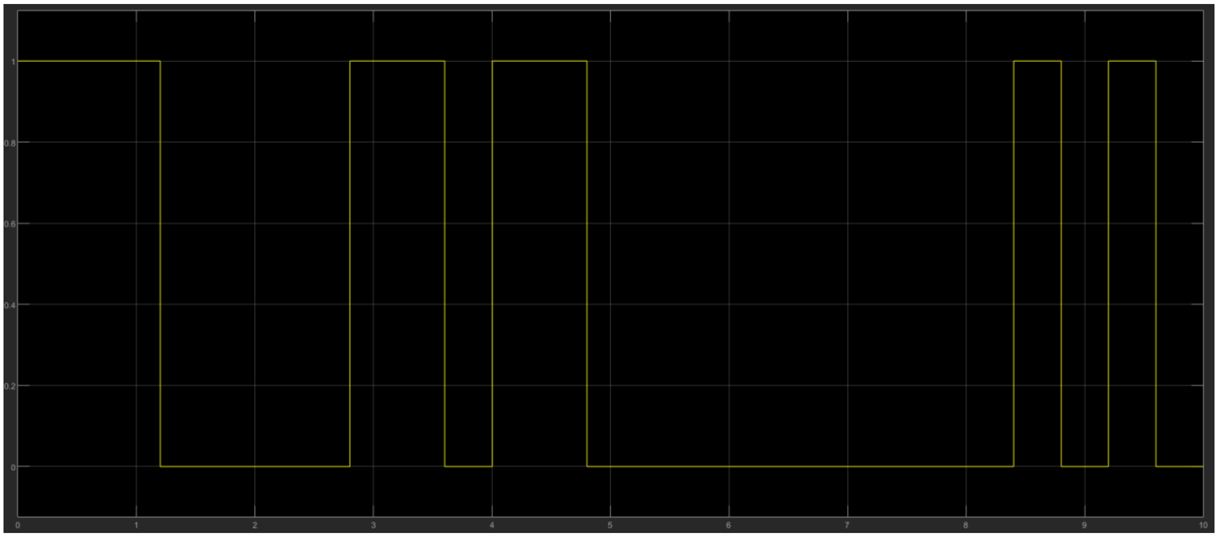


Figure 32 QPSK demodulated signal

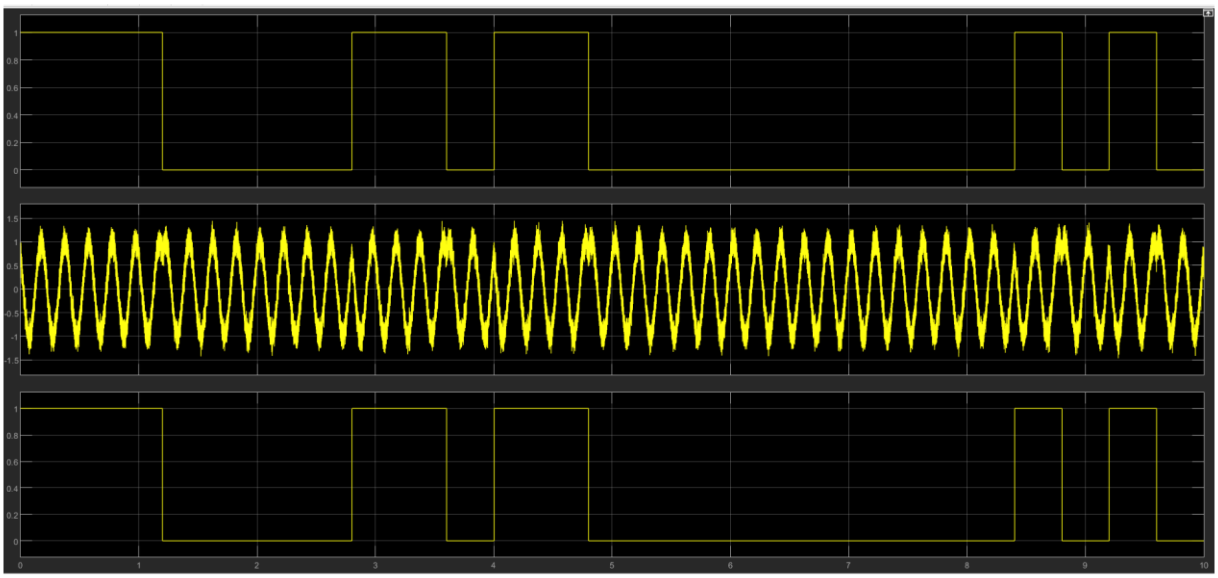


Figure 33QPSK full process

Summary

- ✓ Amplitude Shift Keying (ASK):

Our ASK simulation showed that it's sensitive to changes in amplitude and noise. Higher-order ASK gives faster data rates but is even more affected by noise. ASK is easy to set up but not as robust as other modulation methods.

- ✓ Frequency Shift Keying (FSK):

FSK showed improved resistance to amplitude variations, making it less affected by noise. It is well-suited for applications where signal quality is a concern. We observed that FSK is particularly effective in scenarios with limited bandwidth.

- ✓ Phase Shift Keying (PSK):

PSK demonstrated robust performance in terms of noise tolerance. Its ability to maintain signal quality in the presence of noise makes it a preferred choice in many communication systems. The simulation showed that PSK is especially suitable for high-speed data transmission.

- ✓ Quadrature Phase Shift Keying (QPSK):

QPSK, a variation of PSK, offers an optimal balance between data rate and noise resistance. Our simulation indicated that QPSK is a versatile choice for various communication applications, particularly in scenarios where both data rate and signal quality are critical.

Conclusion

In conclusion, this project aims to provide a practical and accessible introduction to digital modulation techniques, including Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), and Quadrature Phase Shift Keying (QPSK), using MATLAB Simulink. It serves as a valuable hands-on experience for beginners and learners in the field of electrical and computer engineering, offering a simplified approach to grasp these fundamental modulation methods.

References

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[2] Prof. Wasel Ghanem Slides, Birzeit University

[3] Digital Communication Systems PEYTON Z. PEEBLES, JR., PH.D.