VISVESVARAYA TECHNOLOGICAL UNIVERSITY

BELAGAVI-590018, KARNATAKA

<u>MINI PROJECT REPORT</u>

ON

"Simulation of Data Modulation Techniques using MATLAB & Simulink"

<u>Submitted by</u>

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

CERTIFICATE

This is to certify the Mini Project Report entitled "**Simulation of Data Modulation Techniques using MATLAB & Simulink**", prepared by **Mr. Adithya.C, Mr. Daniel George Ashok**, and **Mr. Adarsh Vinod** bearing **USN: 1CR21EC260, 1CR21EC064 and 1CR21EC252** respectively, bona fide students of **CMR Institute of Technology, Bengaluru** in partial fulfillment of the requirements for the award of **Bachelor of Engineering in Electronics and Communication Engineering** of the V**isvesvaraya Technological University, Belagavi-590018** during the academic year 2022-23.

This is certified that all the corrections and suggestions indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The Mini Project has been approved as it satisfies the academic requirements prescribed for the said degree.

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Signature of Guide	**Signature of HOD**
Prof./Dr. Preethi A	**Dr. R Elumalai**
Asst. Professor/Assoc. Professor	**Professor & HoD**
Dept. of ECE, CMRIT	**Dept. of ECE, CMRIT**

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Adithya C

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ABSTRACT

This project explores the simulation of various data modulation techniques, including Amplitude Modulation (AM), Frequency Modulation (FM), Phase Modulation (PM), Pulse Amplitude Modulation (PAM), Pulse Width Modulation (PWM), and Pulse Position Modulation (PPM), using MATLAB and Simulink. Modulation is a crucial process in communication systems, enabling the transmission of information over various media. Each modulation technique is modeled mathematically and implemented in MATLAB, followed by simulation using Simulink to visualize the modulated signals. The project analyzes the time-domain and frequency-domain characteristics of each modulation method, comparing their bandwidth requirements, power efficiency, and noise performance. The findings provide insights into the advantages and limitations of each technique, aiding in the selection of appropriate modulation methods for different communication applications. This study serves as a comprehensive resource for understanding and applying modulation techniques in modern communication systems. The project aims to provide a detailed examination of both the time-domain and frequency-domain characteristics of these modulation techniques. The simulations facilitate a comparative analysis based on critical performance metrics such as bandwidth utilization, power efficiency, and noise robustness. By scrutinizing these aspects, the project highlights the strengths and limitations of each modulation method, offering insights into their suitability for different communication scenarios.

Through this comprehensive study, the project enhances understanding of how these modulation techniques function and their practical applications in modern communication systems. The findings serve as a valuable resource for selecting the appropriate modulation strategy tailored to specific requirements, thereby contributing to the design and optimization of efficient communication networks.

Contents

Introduction

Objective: The primary objective of this project is to simulate and analyze various data modulation techniques, including Amplitude Modulation (AM), Frequency Modulation (FM), Phase Modulation (PM), Pulse Amplitude Modulation (PAM), Pulse Width Modulation (PWM), and Pulse Position Modulation (PPM), using MATLAB and Simulink. By doing so, the project aims to provide a deeper understanding of these techniques, their implementation, and their respective advantages and disadvantages in communication systems.

Background: In modern communication systems, modulation is a fundamental process that involves varying a carrier signal to transmit data. Modulation techniques are categorized into two main types: analog modulation and pulse modulation. Each type has unique characteristics and is suitable for different applications:

- **Analog Modulation Techniques:**
    - **Amplitude Modulation (AM):** Involves varying the amplitude of the carrier signal in proportion to the message signal.
    - **Frequency Modulation (FM):** Involves varying the frequency of the carrier signal in accordance with the message signal.
    - **Phase Modulation (PM):** Involves varying the phase of the carrier signal based on the message signal.
- **Pulse Modulation Techniques:**
    - **Pulse Amplitude Modulation (PAM):** Varies the amplitude of pulse signals to represent the message signal.
    - **Pulse Width Modulation (PWM):** Varies the width of pulse signals to encode the message signal.
    - **Pulse Position Modulation (PPM):** Varies the position of pulse signals to convey the message signal.

These modulation techniques are crucial for different types of communication systems, such as radio broadcasting, digital communication, and data transmission in embedded systems.

Importance of Modulation: Modulation serves several essential purposes in communication systems:

- **Efficient Transmission:** Modulation allows signals to be transmitted over long distances without significant loss of quality.
- **Bandwidth Utilization:** Modulation techniques optimize the use of available bandwidth, enabling the transmission of multiple signals simultaneously.
- **Noise Immunity:** Certain modulation techniques improve the robustness of the signal against noise and interference, ensuring reliable communication.
- **Compatibility with Media:** Modulation adapts the signal to be compatible with different transmission media, such as coaxial cables, fiber optics, and wireless channels.

Methodology: This project employs MATLAB and Simulink to simulate and analyze the aforementioned modulation techniques. The approach involves:

1. **Mathematical Modeling:** Develop mathematical equations representing each modulation technique.
2. **Implementation in MATLAB:** Code the mathematical models in MATLAB to generate modulated signals.
3. **Simulation in Simulink:** Create Simulink models to visualize and simulate the modulation processes.
4. **Analysis:** Evaluate the time-domain and frequency-domain characteristics of the modulated signals and compare their performance metrics, such as bandwidth efficiency, power consumption, and noise resilience.

Principle of the Modulation

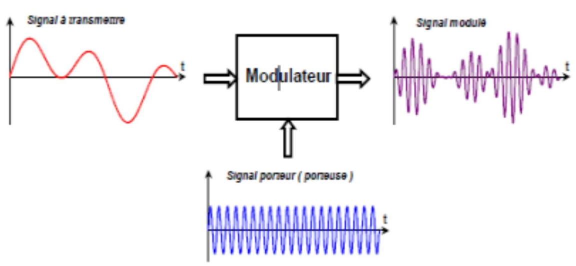


Fig 1: Modulator Block

Table 1: Comparison of the Continuous Analogical Modulations

	Type of modulation	Band-width	Carrier	Power
Radio long waves (amplitude)	AM	4,5 KHz	[150 KHz; 285 kHz]	[1 MW ; 2 MW]
Local radio (frequency)	FM	15 kHz	[88 KHz ; 108 kHz]	[1 MW ; 2 MW]
Television (phase)	AM (image)	6 MHz	[470 MHz ; 860 MHz]	[10 W; 50W]

AMPLITUDE MODULATION

Introduction

Amplitude Modulation (AM) is one of the most straightforward and widely used analog modulation techniques. It involves varying the amplitude of a high-frequency carrier wave in proportion to the instantaneous amplitude of the message signal (baseband signal). This section provides a comprehensive overview of AM, including its principles, mathematical representation, implementation in MATLAB, simulation in Simulink, and analysis of the results.

Principles of Amplitude Modulation

In AM, the carrier signal is a high-frequency sinusoidal wave defined by: c(t)=Acos(2πfct), c(t) = A_c \ cos(2 /pi f_c t), c(t)=Accos(2πfct) where:

- Ac is the amplitude of the carrier signal.
- fc is the frequency of the carrier signal.
- t is time.

The message signal (baseband signal) is typically a lower frequency signal defined by: m(t)m(t)m(t)

The AM signal s(t)s(t)s(t) is generated by varying the amplitude of the carrier signal in accordance with the message signal: s(t)=[Ac+m(t)]cos(2πfct)s(t) = [A_c + m(t)] \cos(2 \pi f_c t)s(t)=[Ac+m(t)]cos(2πfct)

Mathematical Representation

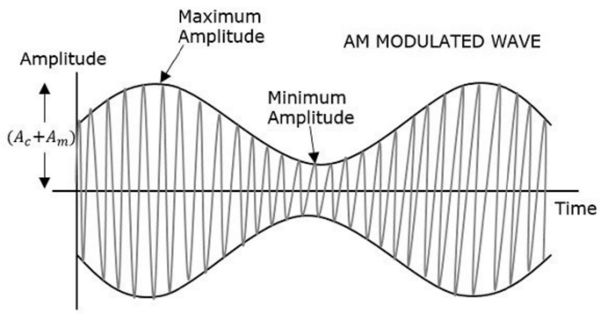
The standard form of the AM signal can be expressed as: s(t)=Accos(2πfct)+m(t)cos(2πfct)s(t) = A_c \ cos(2 \pi f_c t) + m(t) \cos(2 \pi f_c t)s(t)=Accos(2πfct)+m(t)cos(2πfct)

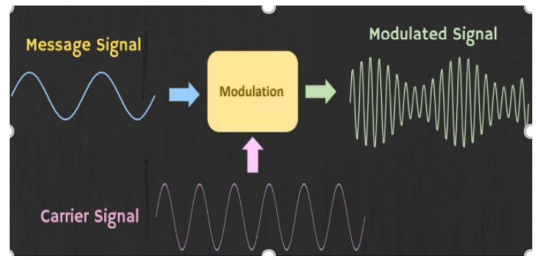
If the message signal m(t)m(t)m(t) is a simple sinusoid, m(t)=Amcos(2πfmt)m(t) = A_m \cos(2 \pi f_m t)m(t)=Amcos(2πfmt), the AM signal becomes: s(t)=Accos(2πfct)+Amcos(2πfmt)cos(2πfct)s(t) = A_c \ cos(2 \pi f_c t) + A_m \cos(2 \pi f_m t) \cos(2 \pi f_c t)s(t)=Accos(2πfct)+Amcos(2πfmt)cos(2πfct)

Using the trigonometric identity: cos(2πfmt)cos(2πfct)=12[cos(2π(fc+fm)t)+cos(2π(fc−fm)t)]\cos(2 \pi f_m t) \cos(2 \pi f_c t) = \frac{1}{2} [\cos(2 \pi (f_c + f_m) t) + \cos(2 \pi (f_c - f_m) t)]cos(2πfm t)cos(2πfct)=21[cos(2π(fc+fm)t)+cos(2π(fc−fm)t)]

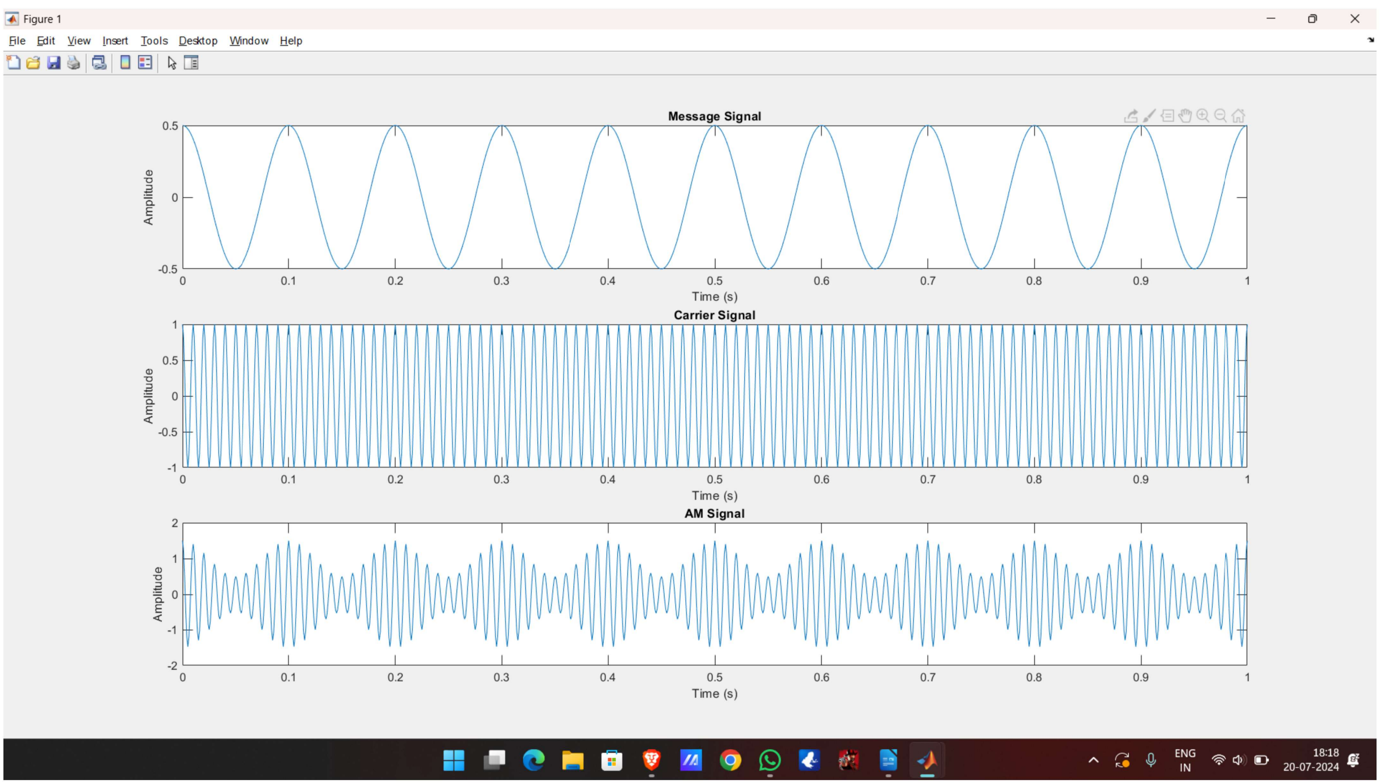
The AM signal can be rewritten as: s(t)=Accos(2πfct)+Am2[cos(2π(fc+fm)t)+cos(2π(fc−fm)t)]s(t) = A_c \ cos(2 \pi f_c t) + \frac{A_m}{2} \left[\cos(2 \pi (f_c + f_m) t) + \cos(2 \pi (f_c - f_m) t) \right]s(t)=Ac cos(2πfct)+2Am[cos(2π(fc+fm)t)+cos(2π(fc−fm)t)].

This shows that the AM signal consists of the carrier frequency fcf_cfc, the upper sideband fc+fmf_c + f_mfc+fm, and the lower sideband fc−fmf_c - f_mfc−fm.





MATLAB IMPLEMENTATION



USING SIMULINK:

Blocks Required:

Analyzing the equation we need,

1.Carrier Signal Source

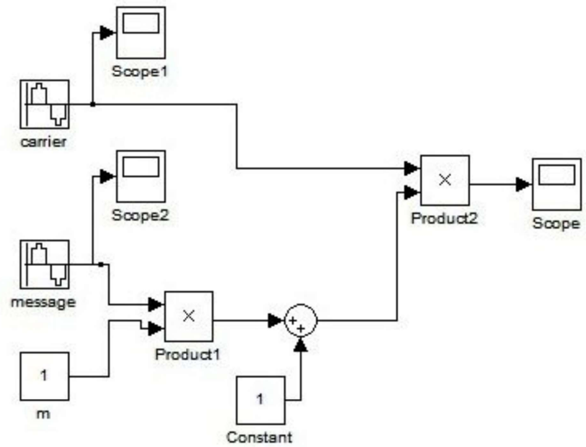
2.Message Signal Source

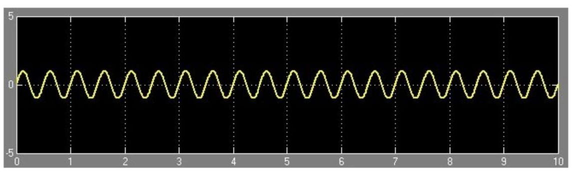
3.Blocks for viewing the signals – Scope

4.Product Block

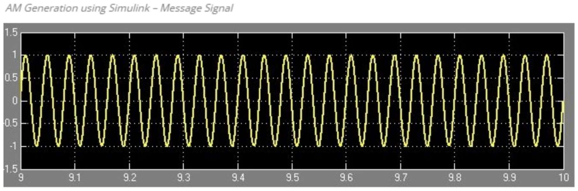
5.Summer Block

6.Constant Block

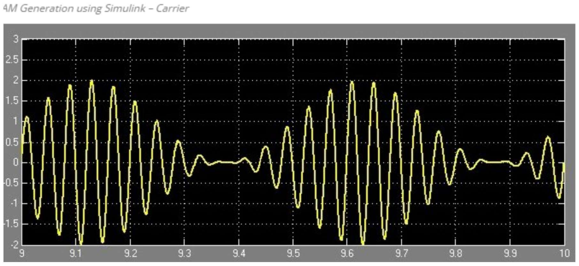


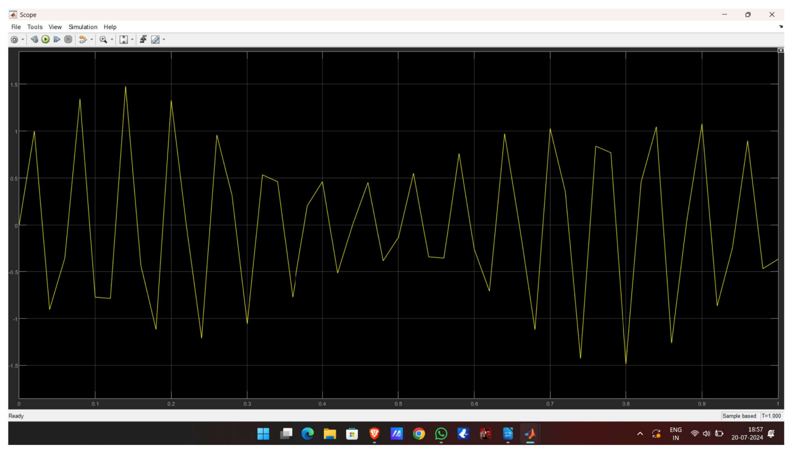


AM Generation using Simulink – Message Signal



AM Generation using Simulink – Carrier





FREQUENCY MODULATION

Introduction

Frequency Modulation (FM) is a widely used analog modulation technique where the frequency of the carrier wave is varied in proportion to the instantaneous amplitude of the message signal. This modulation method is extensively employed in radio broadcasting due to its superior noise immunity and better sound quality compared to Amplitude Modulation (AM). This section provides a comprehensive overview of FM, including its principles, mathematical representation, implementation in MATLAB, simulation in Simulink, and analysis of the results.

Principles of Frequency Modulation

In FM, the carrier frequency is varied according to the message signal. The carrier signal is defined as: c(t)=Accos(2πfct)c(t) = A_c \cos(2 \pi f_c t)c(t)=Accos(2πfct) where:

- Ac is the carrier amplitude.
- fc is the carrier frequency.
- T is time.

- The frequency-modulated signal s(t)s(t)s(t) is given by: s(t)=Accos(2πfct+βsin(2πfmt))s(t) = A_c \cos \left(2 \pi f_c t + \beta \sin(2 \pi f_m t) \right)s(t)=Accos(2πfct+βsin(2πfmt)) where:

- β\betaβ is the modulation index, which determines the extent of frequency variation.
- fmf_mfm is the frequency of the message signal.
- m(t)=sin(2πfmt)m(t) = \sin(2 \pi f_m t)m(t)=sin(2πfmt) is the message signal.

Mathematical Representation

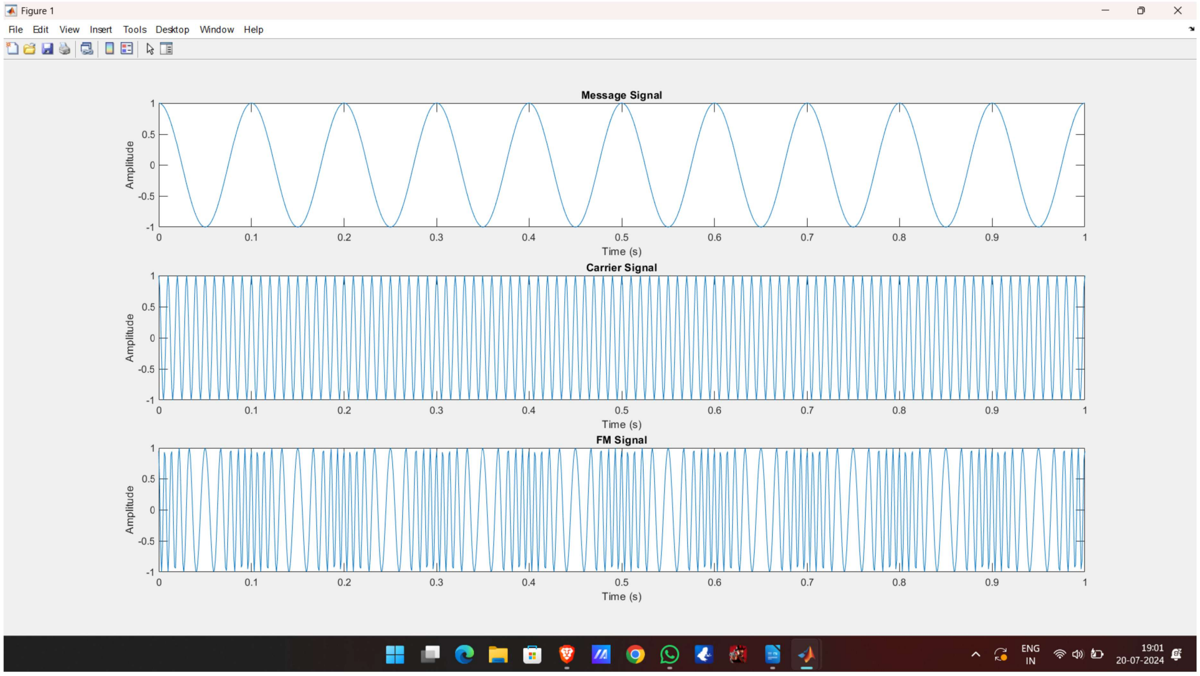
The instantaneous frequency of the FM signal is given by: fi(t)=fc+kfm(t)f_i(t) = f_c + k_f m(t)fi(t)=fc+kf m(t) where kfk_fkf is the frequency sensitivity of the modulator.

The phase of the carrier signal varies as: θ(t)=2πfct+2πkf∫0tm(τ)dτ\theta(t) = 2 \pi f_c t + 2 \pi k_f \int_0^t m(\tau) d\tauθ(t)=2πfct+2πkf∫0tm(τ)dτ

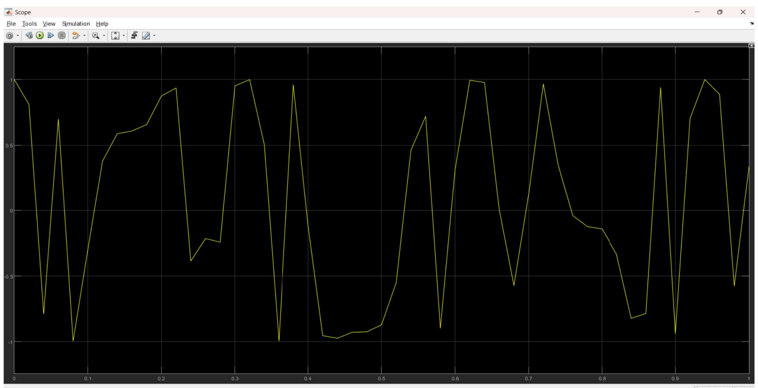
The FM signal can be expressed as: s(t)=Accos(2πfct+2πkf∫0tm(τ)dτ)s(t) = A_c \cos \left(2 \pi f_c t + 2 \pi k_f \int_0^t m(\tau) d\tau \right)s(t)=Accos(2πfct+2πkf∫0tm(τ)dτ)

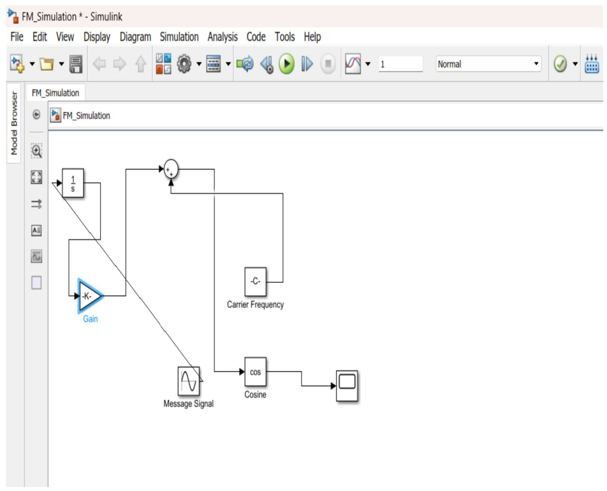
For a simple sinusoidal message signal m(t)=Amcos(2πfmt)m(t) = A_m \cos(2 \pi f_m t)m(t)=Am cos(2πfmt), the FM signal becomes: s(t)=Accos(2πfct+βsin(2πfmt))s(t) = A_c \cos \left(2 \pi f_c t + \beta \sin(2 \pi f_m t) \right)s(t)=Accos(2πfct+βsin(2πfmt)) where β=kfAmfm\beta = \frac{k_f A_m}{f_m}β=fm kfAm is the modulation index.

MATLAB IMPLEMENTATION



SIMULINK IMPLEMENTATION:





PULSE MODULATION:

Pulse Modulation is a technique where the message signal is transmitted using a series of pulses. It includes several types such as Pulse Amplitude Modulation (PAM), Pulse Width Modulation (PWM), and Pulse Position Modulation (PPM). Each type of pulse modulation has unique characteristics and applications.

Types of Pulse Modulation

1. **Pulse Amplitude Modulation (PAM):** The amplitude of each pulse is varied in proportion to the amplitude of the message signal.
2. **Pulse Width Modulation (PWM):** The width (duration) of each pulse is varied in accordance with the amplitude of the message signal.
3. **Pulse Position Modulation (PPM):** The position of each pulse within a fixed time slot is varied according to the amplitude of the message signal.

Pulse Amplitude Modulation (PAM)

Introduction

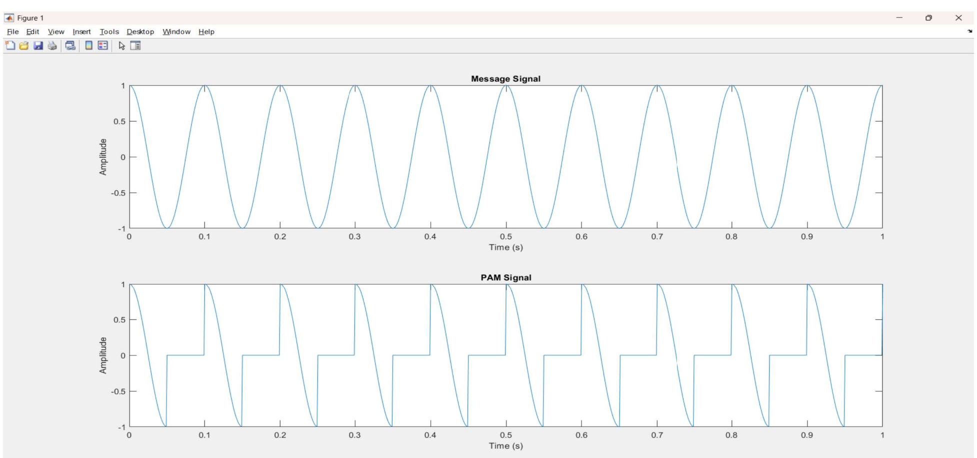
Pulse Amplitude Modulation (PAM) is a form of signal modulation where the amplitude of each pulse in a pulse train is proportional to the instantaneous amplitude of the message signal. PAM is used in various digital communication systems.

Mathematical Representation

The PAM signal can be represented as: s(t)=∑nm(nT) · p(t−nT)s(t) = \sum_{n} m(nT) \cdot p(t - nT)s(t)=∑nm(nT) · p(t−nT) where:

- m(nT) is the sampled message signal at time nTnTnT.
- p(t) is the pulse shape.
- T is the sampling period.

MATLAB IMPLEMENTATION:



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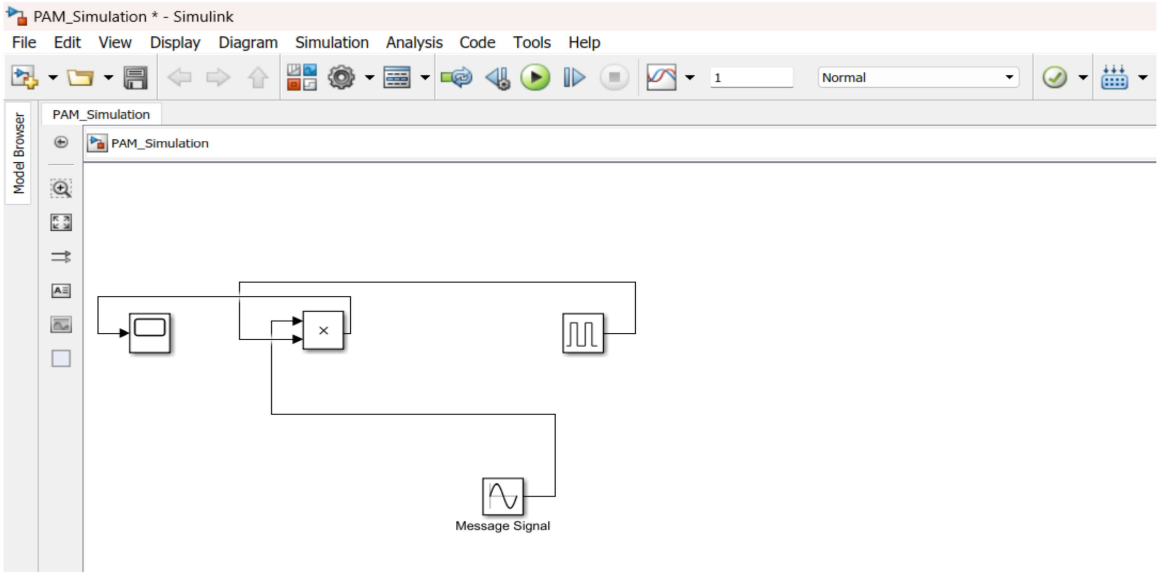
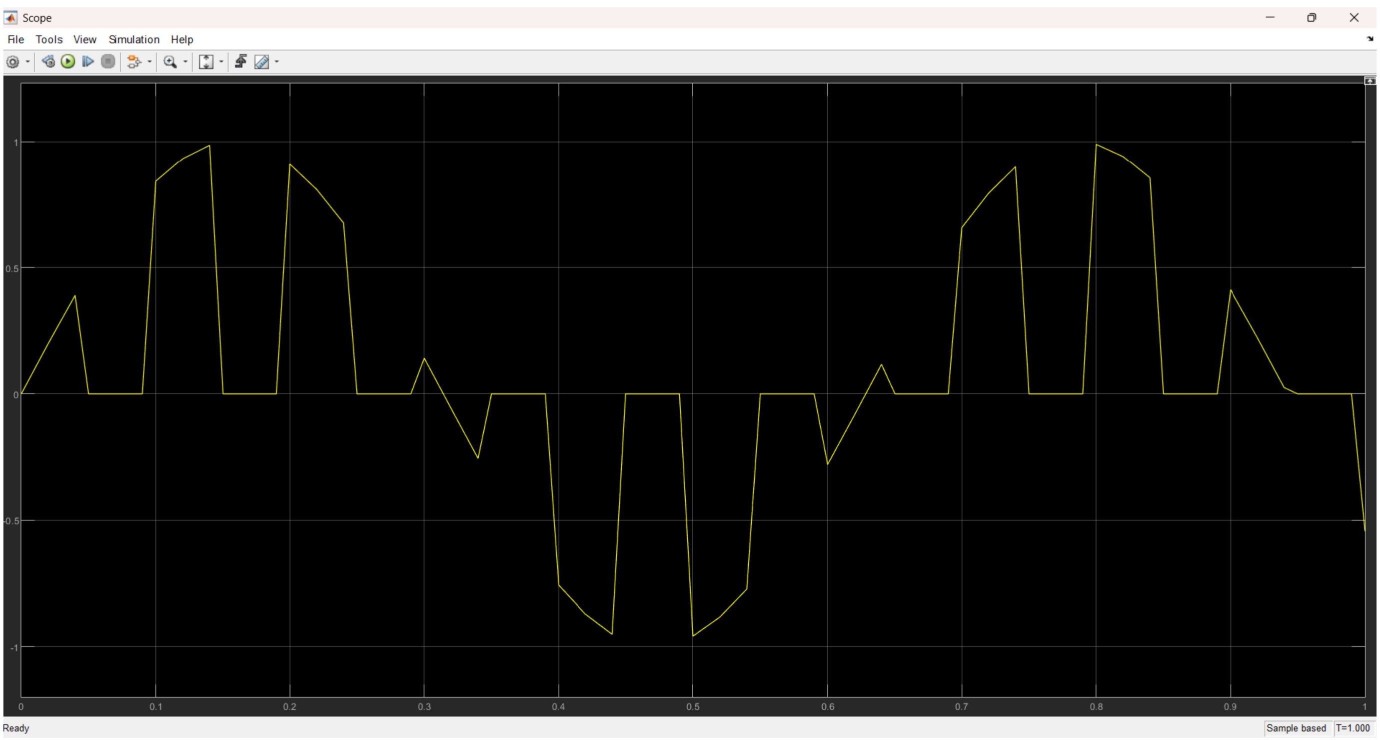




Pulse Width Modulation (PWM)

Introduction

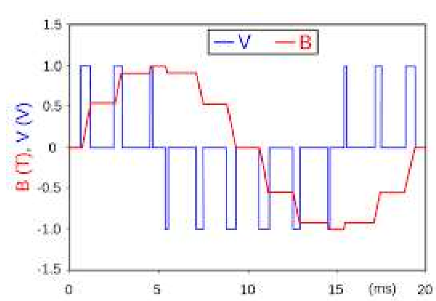
Pulse Width Modulation (PWM) is a modulation technique in which the width of the pulses in a pulse train is varied in direct proportion to the amplitude of an analog input signal. PWM is commonly used for controlling the power supplied to electrical devices, such as motors, LEDs, and other actuators. It is also widely used in communication systems for signal transmission. In modulated signal (PWM), the amplitude and position of pulses are constant while the width (or duration) of pulses varies proportionally with the amplitude of analogical useful signal. Carrier signal is from a clock.

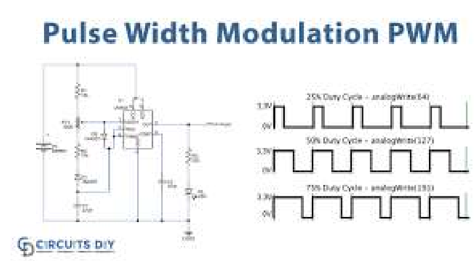
Principle of Operation

In PWM, the message signal modulates the duty cycle of a square wave signal. The duty cycle is the ratio of the pulse width to the period of the signal. By varying the duty cycle, the average power delivered to a load can be controlled.

The basic steps in generating a PWM signal are:

1. **Sampling the Message Signal:** The analog message signal is sampled at a high rate.
2. **Comparison with a Carrier Signal:** The sampled message signal is compared with a high-frequency triangular or sawtooth carrier signal.
3. **Generation of PWM Signal:** The output is a pulse whose width varies in proportion to the sampled message signal.





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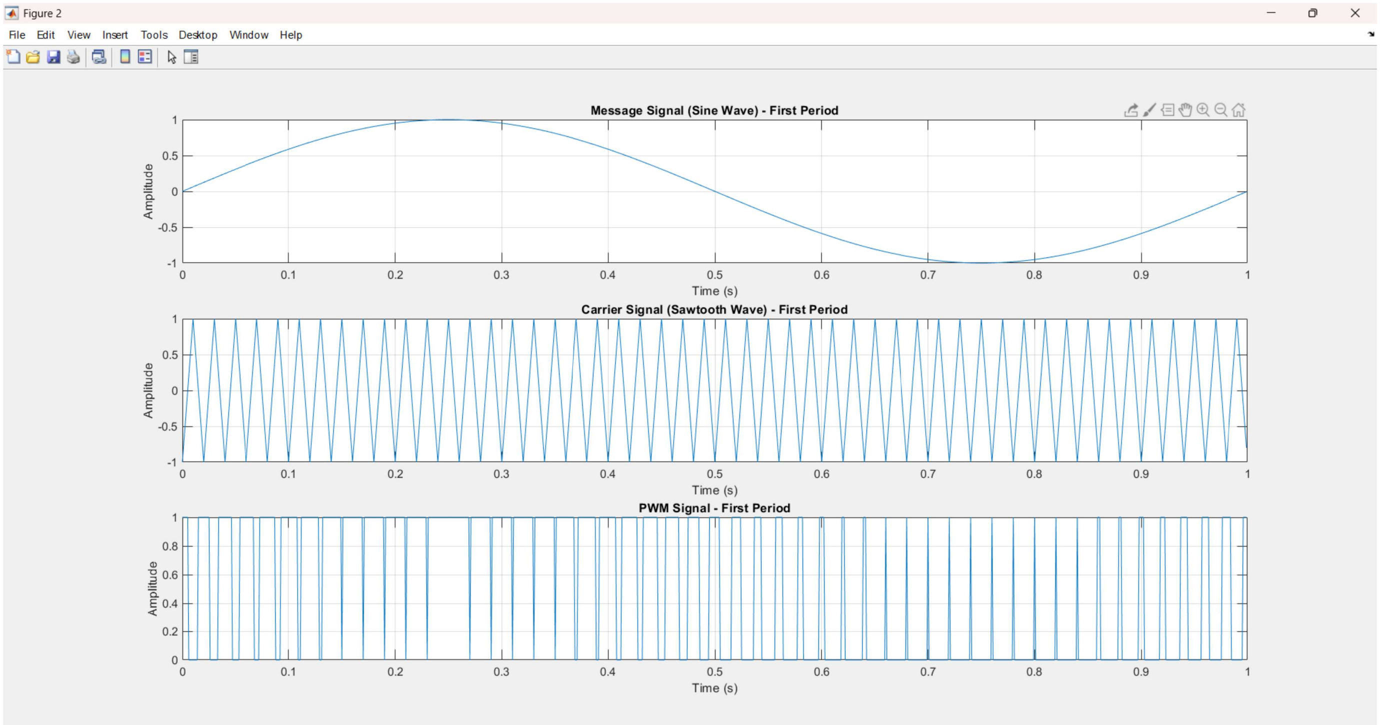

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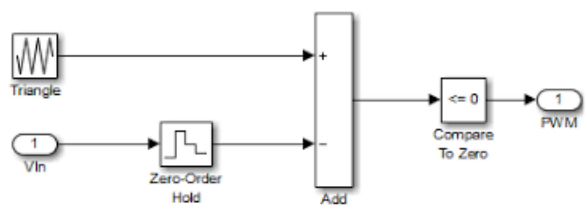
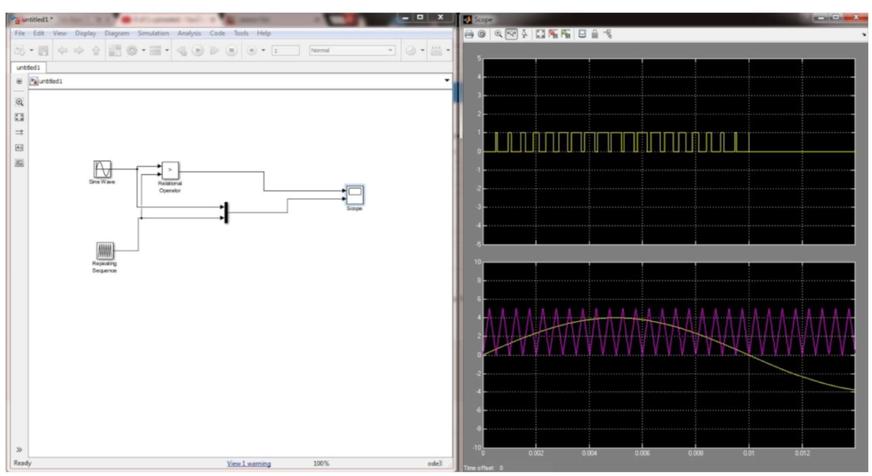




Pulse Position Modulation (PPM)

Pulse Position Modulation (PPM) is a type of modulation where the position of the pulse in a pulse train is varied according to the amplitude of the message signal. It is used in various communication systems to encode information into the timing of the pulses rather than their amplitude or width. In modulated signal (PPM), the amplitude and width of pulses are constant while the position of pulses varies proportionally with the amplitude of analogical useful signal. Carrier signal is from a clock. 6.1. Principle The analogical signal e(t) is converted into a succession of rectangular signals. The decalage of these rectangular pulses compared to the period of sampling varies proportionally with the amplitude of the useful signal.

Pulse Position Modulation (PPM)

Pulse Position Modulation (PPM) is a type of modulation where the position of the pulse in a pulse train is varied according to the amplitude of the message signal. It is used in various communication systems to encode information into the timing of the pulses rather than their amplitude or width.

Key Concepts

1. **Pulse Position Modulation (PPM):**
    - In PPM, the position of each pulse within a fixed time slot is determined by the amplitude of the message signal.
    - The time slot duration is constant, and within this time slot, the position of the pulse varies according to the instantaneous value of the message signal.
2. **Advantages of PPM:**
    - **Resistance to Amplitude Noise:** Since the information is carried in the position of the pulse rather than its amplitude, PPM is less affected by amplitude noise.
    - **Simple Demodulation:** The demodulation process is straightforward as it primarily involves detecting the pulse positions.
3. **Disadvantages of PPM:**
    - **Bandwidth Requirements:** PPM can require a wider bandwidth compared to other modulation techniques like Pulse Amplitude Modulation (PAM) or Pulse Width Modulation (PWM).
    - **Timing Synchronization:** Accurate timing synchronization is crucial for PPM, as the information is encoded in the position of the pulse.

PPM Signal Generation and Demodulation

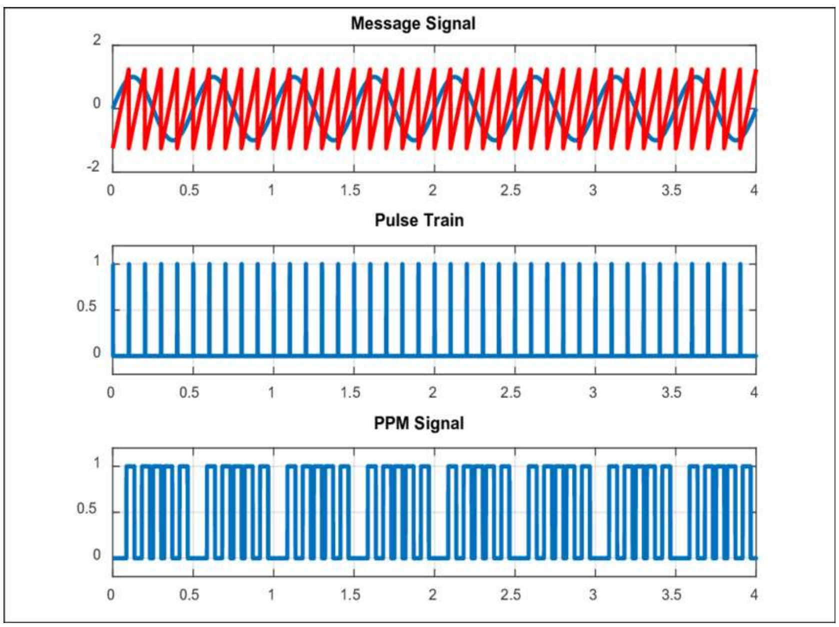
1. **Generation:**

- The message signal modulates the position of pulses within a fixed time interval.
- A reference clock generates a regular pulse train.
- The position of each pulse in the pulse train is varied according to the instantaneous value of the message signal.

2. **Demodulation:**

- The demodulator measures the position of each pulse and reconstructs the original message signal based on these measurements.
- This typically involves detecting the timing of pulses and comparing them with reference time slots.

MATLAB IMPLEMENTATION:



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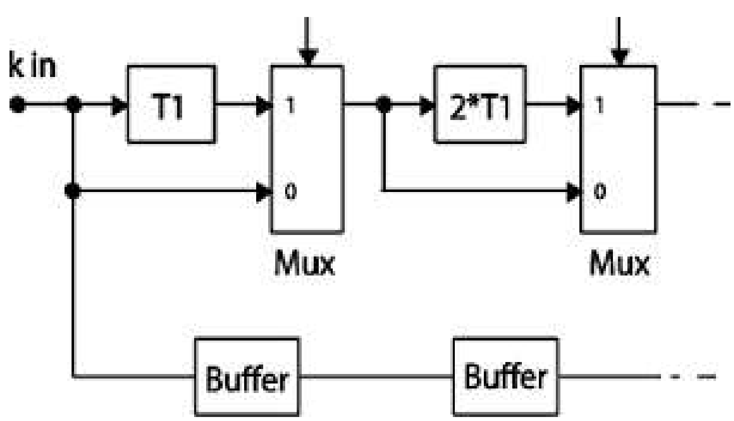

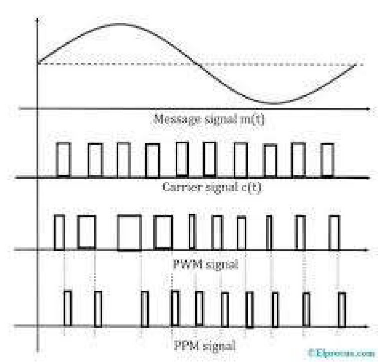

APPLICATIONS:

Amplitude Modulation (AM), Frequency Modulation (FM), and Phase Modulation (PM) are key techniques in communication systems, each with unique applications. Here's a detailed look at their applications:

Amplitude Modulation (AM)

1. **AM Radio Broadcasting:**
    - **Description:** AM is widely used for AM radio broadcasting, where audio signals are modulated to vary the amplitude of the carrier wave.
    - **Application:** Radio stations use AM for transmitting news, music, and talk shows. The long-range capability of AM signals makes it suitable for regional and international broadcasting.
2. **Television Transmissions:**
    - **Description:** Early analog TV systems used AM for video signals and Frequency Modulation (FM) for audio signals.
    - **Application:** Although largely replaced by digital TV, AM was used in standard-definition television (SDTV) broadcasting.
3. **Aircraft Communication:**
    - **Description:** AM is used in aviation communication for transmitting voice communication between aircraft and ground stations.
    - **Application:** AM provides reliable communication over long distances, essential for air traffic control and pilot communications.
4. **Two-Way Radios:**
    - **Description:** Many two-way radios (walkie-talkies) use AM for communication.
    - **Application:** Used in various sectors, including emergency services, military, and personal communication.
5. **Signal Detection and Processing:**
    - **Description:** AM techniques are utilized in demodulating and detecting signals in various electronic devices.
    - **Application:** Devices such as AM radios and communication receivers employ AM for signal processing.

Frequency Modulation (FM)

1. **FM Radio Broadcasting:**

- **Description:** FM is widely used for FM radio broadcasting due to its high fidelity and resistance to noise and interference.
- **Application:** FM radio provides high-quality audio for music and talk shows, and its use is prevalent in commercial and public radio.

2. **Television Audio Transmission:**

- **Description:** FM is used for transmitting audio signals in television broadcasts.
- **Application:** Provides clear and high-fidelity audio for TV broadcasts, enhancing the viewing experience.

3. **Two-Way Radios:**

- **Description:** Many two-way radios and walkie-talkies use FM for communication.
- **Application:** FM radios are used for reliable voice communication in various sectors, including emergency services and personal use.

4. **Wireless Microphones:**

- **Description:** FM is commonly used in wireless microphone systems for live performances and broadcasting.
- **Application:** Provides reliable audio transmission with minimal interference and high sound quality.

5. **Telemetry Systems:**

- **Description:** FM is used in telemetry systems to transmit data over a distance.
- **Application:** Used in applications like remote sensing, weather monitoring, and data acquisition systems.

6. **Satellite Communication:**

- **Description:** FM is employed in satellite communication for transmitting signals over long distances.
- **Application:** Used for transmitting data, television signals, and internet services via satellites.

Phase Modulation (PM)

1. **Digital Communication Systems:**

- **Description:** PM is used in various digital communication schemes, including Phase Shift Keying (PSK).
- **Application:** PSK is used in digital data transmission systems, including Wi-Fi, Bluetooth, and cellular networks.

2. **Satellite Communication:**

- **Description:** PM is used in satellite communication for transmitting data and voice signals.

- **Application:** Provides efficient use of bandwidth and robust signal integrity for satellite-based communication systems.

3. **Telemetry and Tracking Systems:**
    - **Description:** PM is used in telemetry and tracking systems to transmit data and control signals.
    - **Application:** Used in space missions, remote sensing, and scientific experiments for reliable data transmission.
4. **Analog Modulation Techniques:**
    - **Description:** PM is utilized in some analog modulation systems and applications.
    - **Application:** In specific contexts, PM can be used alongside other modulation techniques to achieve desired signal characteristics.
5. **Cable Modems:**
    - **Description:** PM is used in cable modems for high-speed data transmission over cable networks.
    - **Application:** Provides efficient and high-speed internet access through cable television infrastructure

For Broadcasting and Audio Quality: FM is generally preferred due to its superior audio quality and resistance to noise. It's the standard for FM radio and television audio transmission.

- **For Long-Range Communication: AM** is useful for long-distance broadcasting and simple two-way communication where noise is less of a concern.
- **For Digital Data Transmission: PM** and its variants (like PSK) are widely used in digital communication systems where efficient data transmission is critical.

Choosing the best modulation technique depends on the specific requirements of the application, such as the importance of audio quality, resistance to noise, bandwidth availability, and system complexity. Each technique excels in different areas, so the best choice will vary based on the communication goals and constraints.

CONCLUSION

In this report, we have thoroughly explored and simulated various data modulation techniques—Amplitude Modulation (AM), Frequency Modulation (FM), Phase Modulation (PM), Pulse Amplitude Modulation (PAM), Pulse Width Modulation (PWM), and Pulse Position Modulation (PPM)—using MATLAB and Simulink. Each modulation technique was analyzed for its principles, simulation methodology, and practical applications, providing a comprehensive understanding of their functionality and use cases.

Key Findings:

1. **Amplitude Modulation (AM):**
    - AM varies the amplitude of the carrier signal according to the message signal. While AM is simple and efficient for long-range broadcasting, it is susceptible to noise, which affects signal quality. Its applications include AM radio broadcasting and communication systems where simplicity and range are critical.
2. **Frequency Modulation (FM):**
    - FM modulates the frequency of the carrier signal in accordance with the message signal. It offers superior noise immunity and better audio quality compared to AM. FM is widely used in FM radio broadcasting, television audio transmission, and wireless communication systems where high fidelity is essential.
3. **Phase Modulation (PM):**
    - PM alters the phase of the carrier signal based on the message signal. It is less sensitive to amplitude variations and is utilized in digital communication systems. PM is instrumental in modern communication technologies, including satellite communications and digital data transmission.
4. **Pulse Amplitude Modulation (PAM):**
    - PAM modulates the amplitude of pulses in a pulse train according to the message signal. While simple to implement, PAM is less robust to noise and interference. It is used in digital signal processing and analog-to-digital conversion systems.
5. **Pulse Width Modulation (PWM):**
    - PWM varies the width of pulses in a pulse train to represent the message signal. It is widely used in power control applications, motor speed regulation, and signal processing. PWM's advantages include efficient power conversion and simple implementation.
6. **Pulse Position Modulation (PPM):**
    - PPM encodes information by varying the position of pulses within a fixed time interval. It is effective in resisting amplitude noise and is used in systems requiring precise timing and synchronization, such as telemetry and tracking systems.

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