**UNIT – 3**

**Data Link Layer**

**Data Encoding: Introduction, Block coding, cyclic codes, checksum, framing, Noiseless channels, noisy channels, Asynchronous and Synchronous transmission, Full and Half duplex**

**Encoding schemes: BCA (NRZ, Bipolar AMI, B8ZS, HDB3, ASK, FSK, PSK, PCM, AM, FM, PM),**

**Data Link Control: Flow control: Stop and Wait, Sliding window**

**Error detection: Parity Check, CRC. Error control: Stop and Wait ARQ, Go back-N ARQ, Selective-Reject ARQ, Brief-idea of HDLC and other Data Link control protocols.**

**PYQ (2023)**

1. What do you mean by a noisy channel?
2. Define a frame.
3. Differentiate between asynchronous and synchronous transmission.
4. Write short note on :-
5. CRC
6. Sliding Window
7. Part**-C**: Draw and explain HDLC and Stop and Wait ARQ.

**PYQ (2022)**

1. How Manchester and Differential Manchester encoding solve the problem of synchronization ?
2. Draw Digital encoding schemes ?
3. List some error detection techniques. How many errors can an "n bit" CRC detect? If a message 11001001 is to be transmitted using the CRC polynomial X³ + 1 to protect it from errors. Calculate the message to be transmitted.

**PYQ (2021)**

1. What is Encoding ?
2. Asynchornous vs Synchronous transmission
3. Go back-N ARQ
4. Sliding Window Protocol
5. Draw Digital encoding schemes ?

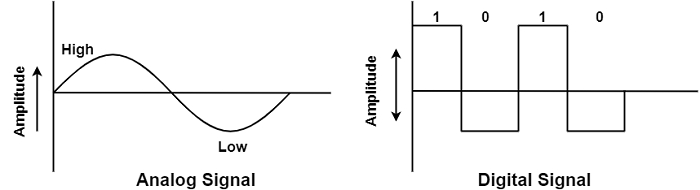
**Data Encoding**

Data encoding is the process of converting data, such as binary sequences, characters, or symbols, into a specific format that is optimized for efficient transmission, storage, or processing. It uses patterns of signals, like electrical or radio waves, to represent the data (like 1s and 0s) so that it can be understood by computers or communication systems. Encoding also helps detect and fix errors during transmission.

**Encoding Techniques-**

The data encoding technique is divided into the following types :-

1. **Analog data to Analog signals** − The modulation techniques such as Amplitude Modulation (AM), Frequency Modulation (FM) and Phase Modulation (PM) of analog signals, fall under this category.
2. **Analog data to Digital signals** − This process can be termed as digitization, which is done by Pulse Code Modulation (PCM). Hence, it is nothing but digital modulation. As we have already discussed, sampling and quantization are the important factors in this. Delta Modulation gives a better output than PCM.
3. **Digital data to Analog signals** − The modulation techniques such as Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), etc., fall under this category.
4. **Digital data to Digital signals** − There are several ways to map digital data to digital signals. e.g. NRZ, Bipolar AMI, Manchester & Differential Manchester encoding, etc.



**Block Coding**

Block coding is a method used to encode data into a specific format. The purpose of block coding is to **add redundant information to the data**, which can be **used to detect and correct errors that may occur during transmission or storage**. Block coding is often used in conjunction with **error correction codes (ECCs)** to provide a more robust way of transmitting and storing data.

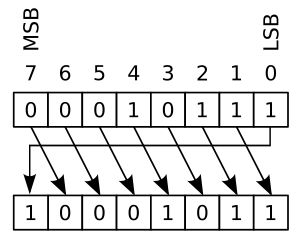
*Types of Block Codes* *:-*

1. **Parity Check Codes** - In this technique, an extra parity bit is included with each block of data. The calculation of the parity bit is done as per the number of 1s in the block of data. However, the parity check codes can detect only 1-bit errors, also they cannot correct them.
2. **Hamming Codes** - Hamming codes are relatively advanced codes than parity check codes used for block coding. These codes are able to detect as well as correct 1-bit errors. This method adds additional redundant bits to each data block to create a specific code-word. The positions of the redundant bits in the code-word allow for detection and correction of errors in the data.
3. **Reed-Solomon Codes** - Reed-Solomon codes are highly advanced codes used for block coding where robust error detection and correction is desired. These codes have ability to detect and correct multi-bit errors in a data block. The operation of Reed-Solomon Codes is based on the combination of parity checks and polynomial mathematics, where parity check detects errors in the data block, while the error locator polynomials correct them.
4. **BCH (Bose-Chaudhuri-Hocquenghem) Codes** - BCH codes are a type of block code that can correct a specific number of errors. They are commonly used in digital communication systems to ensure the accuracy of transmitted data. BCH codes are mainly used where error correction is required multiple times.

**Cyclic Codes**

A cyclic code is a block code, where the **circular shifts of each codeword gives another word that belongs to the code**. They are **error-correcting codes** that have **algebraic properties** that are convenient for efficient error detection and correction.

**Some examples of cyclic codes include**: BCH codes, Hamming codes, Golay codes, RS codes, and LDPC codes.

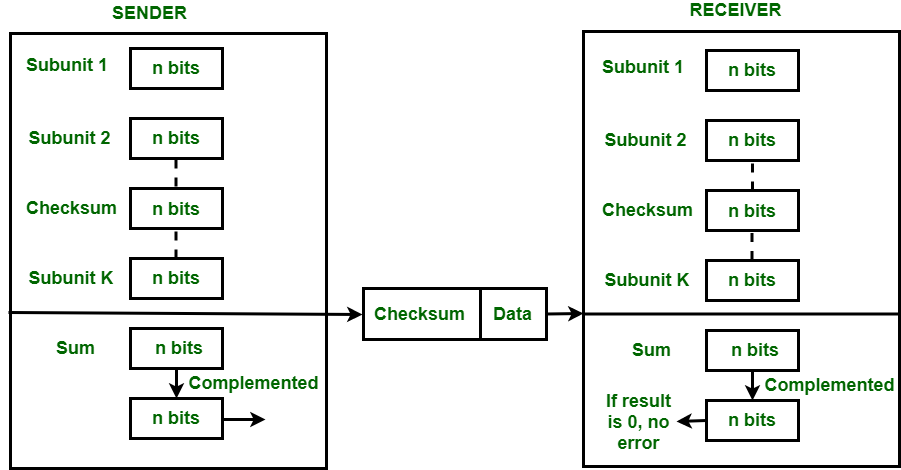


**Checksum**

**Checksum** is the **error detection method** used by upper layer protocols and is considered to be more reliable than LRC, VRC and CRC. This method makes the use of **Checksum Generator** on Sender side and **Checksum Checker**on Receiver side.

At the Sender side, the data is divided into equal subunits of n bit length by the checksum generator. This bit is generally of 16-bit length. These subunits are then added together using one’s complement method. The resultant bit is then **complemented**. This **complemented sum** which is called **checksum** is appended to the end of original data unit and is then transmitted to receiver.

The Receiver after receiving data + checksum passes it to checksum checker. Checksum checker divides this data unit into various subunits of equal length and adds all these subunits. These subunits also contain checksum as one of the subunits. The resultant bit is then complemented. **If the complemented result is zero, it means the data is error-free. If the result is non-zero it means the data contains an error and Receiver rejects it.**

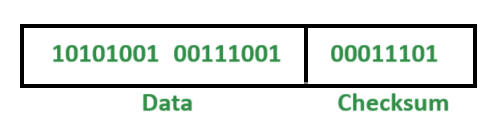


**Example –**If the data unit to be transmitted is 10101001 00111001, the following procedure is used at Sender side and Receiver side.

**Sender Side:**

10101001 subunit 1   
00111001 subunit 2   
11100010 sum (using 1s complement)   
**00011101**  checksum (complement of sum)

**Data transmitted to Receiver is:**



**Receiver Side :**

10101001 subunit 1   
00111001 subunit 2   
00011101 checksum   
11111111 sum  
**00000000** sum's complement

**Result is zero, it means no error.**

**Advantages -** The checksum detects all the errors involving an odd number of bits as well as the error involving an even number of bits.

**Disadvantages -** The main problem is that the error goes undetected if one or more bits of a subunit is damaged and the corresponding bit or bits of a subunit are damaged and the corresponding bit or bits of opposite value in second subunit are also damaged. This is because the sum of those columns remains unchanged.

**Example –** If the data transmitted along with checksum is 10101001 00111001 00011101. But the data received at destination is **0**0101001 **1**0111001 00011101.

**Receiver Side:**

**0**0101001 1st bit of subunit 1 is damaged  
**1**0111001 1st bit of subunit 2 is damaged  
00011101 checksum  
11111111 sum  
00000000 Ok 1's complement

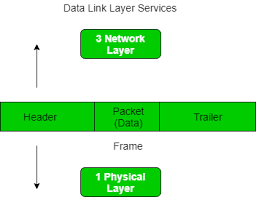
**Although data is corrupted, the error is undetected.**

**Framing**A frame can be defined as the **digital data transmission unit** in telecommunication and computer networking.

At the data link layer, it extracts the message from the sender and provides it to the receiver by providing the sender’s and receiver’s addresses. The advantage of using frames is that data is broken up into recoverable chunks that can easily be checked for corruption.

The process of dividing the data into frames and reassembling it is transparent to the user and is handled by the **data link layer**.

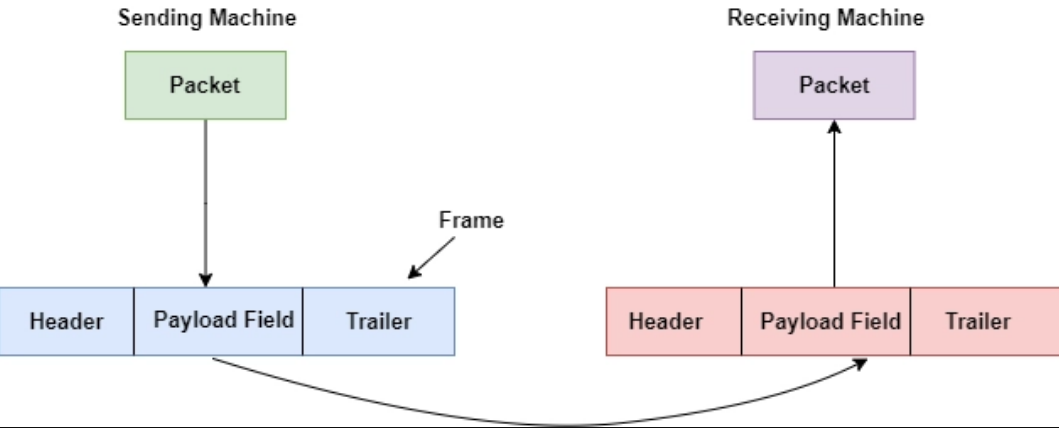
Framing is an important aspect of data link layer protocol design because it allows the transmission of data to be organized and controlled, ensuring that the data is delivered accurately and efficiently.

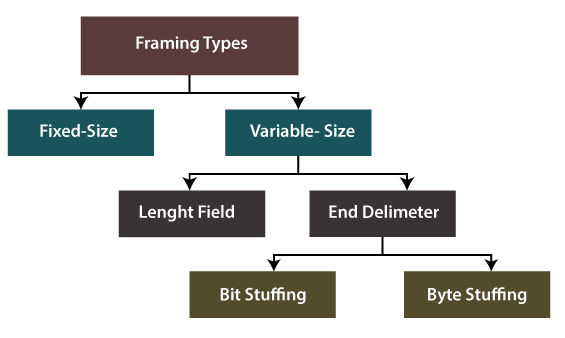


**Frame Structure**:

* **Header**: Contains control information like the source and destination address, frame type, and synchronization details.
* **Payload**: The actual data being transmitted.
* **Trailer**: Includes error detection codes (e.g., CRC) to help detect transmission errors.
* **Flags**: It marks the beginning and end of the frame.







There are two types of framing:

**1. Fixed-size:**The frame is of fixed size and there is no need to provide boundaries to the frame, the length of the frame itself acts as a delimiter.

* **Drawback:**It suffers from internal fragmentation if the data size is less than the frame size
* **Solution:**Padding

**2. Variable size:** In this, there is a need to define the end of the frame as well as the beginning of the next frame to distinguish. This can be done in two ways:

1. **Length field –** We can introduce a length field in the frame to indicate the length of the frame. Used in **Ethernet(802.3)**. The problem with this is that sometimes the length field might get corrupted.
2. **End Delimiter (ED) –** We can introduce an ED(pattern) to indicate the end of the frame. Used in **Token Ring**. The problem with this is that ED can occur in the data. This can be solved by:

**1. Byte Stuffing:**Used when frames consist of characters. If data contains ED then, a byte is stuffed into data to differentiate it from ED.

Let ED = “$” –> if data contains ‘$’ anywhere, it can be escaped using ‘\O’ character.   
–> if data contains ‘\O$’ then, use ‘\O\O\O$'($ is escaped using \O and \O is escaped using \O).

**Disadvantage –** It is very costly and obsolete method.

**2. Bit Stuffing:**Let ED = 01111 and if data = 01111   
**–>** Sender stuffs a bit to break the pattern i.e. here appends a 0 in data = 0111**0**1.   
**–>** Receiver receives the frame.   
**–>** If data contains 011101, receiver removes the 0 and reads the data.

**Examples:**

* If Data –> 011100011110 and ED –> 0111 then, find data after bit stuffing.

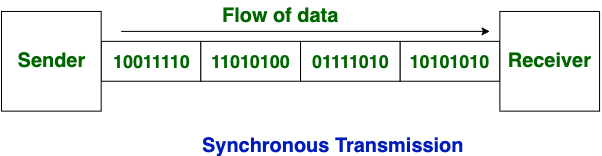
--> 011**0**100011**0**11**0**0

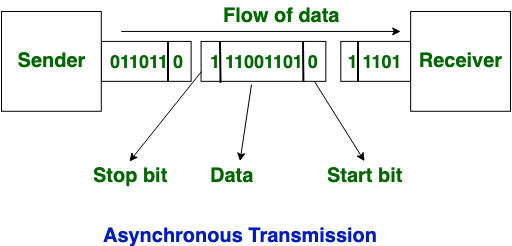
* If Data –> 110001001 and ED –> 1000 then, find data after bit stuffing?

--> 1100**1**0100**1**1

**Asynchronous VS Synchronous Transmission**

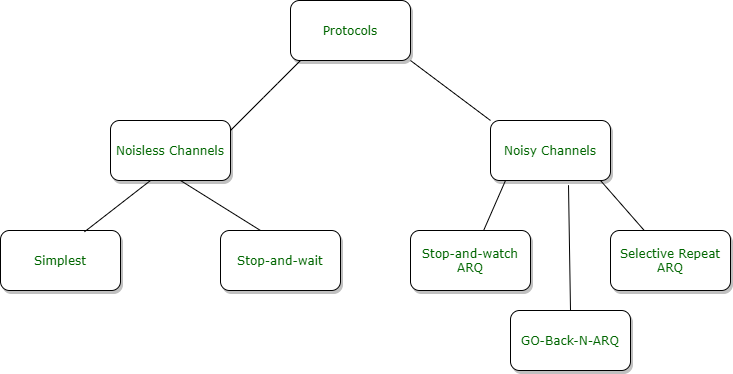
| **Basis** | **Synchronous Transmission** | **Asynchronous Transmission** |
| --- | --- | --- |
| **Data Format** | Data is sent in blocks or frames, making it more efficient for large data transfers. | Data is sent in bytes or characters, ideal for smaller data transmissions. |
| **Speed** | Faster due to continuous data flow, suitable for real-time communication like video calls. | Slower as each byte requires additional start and stop bits, making it less efficient for real-time uses. |
| **Cost** | More expensive due to the need for precise clock synchronization and advanced hardware. | More economical, as it requires simpler hardware without the need for synchronization. |
| **Time Interval** | Constant time interval for data transmission, ensuring a steady flow of information. | Irregular and random time intervals between bytes, making it less predictable. |
| **User Response** | Users must wait until the entire transmission is complete before getting a response. | Users receive responses without waiting for the whole transmission, improving responsiveness. |
| **Gap Between Data** | No gap between data blocks, ensuring a smooth and continuous data flow. | Gaps between transmitted bytes create pauses in the communication flow. |
| **Transmission Line Usage** | Efficient use of transmission lines, minimizing idle time during communication. | Inefficient use, as the line remains idle during gaps between character transmissions. |
| **Start and Stop Bits** | No start and stop bits are used, which reduces overhead and increases efficiency. | Start and stop bits are required for each byte, adding extra overhead. |
| **Clock Synchronization** | Requires precise clock synchronization, making sure both sender and receiver are in sync. | No need for synchronized clocks, as the parity bit handles byte information. |
| **Error Detection and Correction** | Errors are detected and corrected in real-time, improving accuracy during transmission. | Errors are only detected and corrected after the data has been completely received. |
| **Latency** | Low latency because data is transmitted in real-time with no gaps. | Higher latency due to the gaps between bytes and processing delays. |
| **Examples** | Telephonic conversations, Video conferencing, Online gaming where real-time data transfer is needed. | Email, File transfer, and online forms where instant response is not crucial. |
| **Transmission Mode** | Often used in Full-Duplex, where data is sent and received at the same time. | Usually used in Half-Duplex, where data is sent one way at a time with pauses. |





**Full Duplex VS Half Duplex**

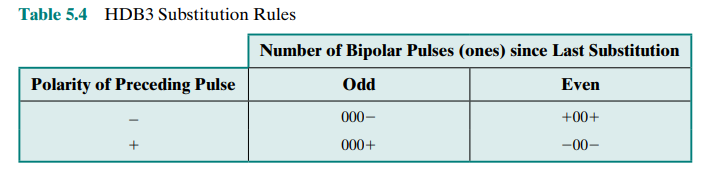
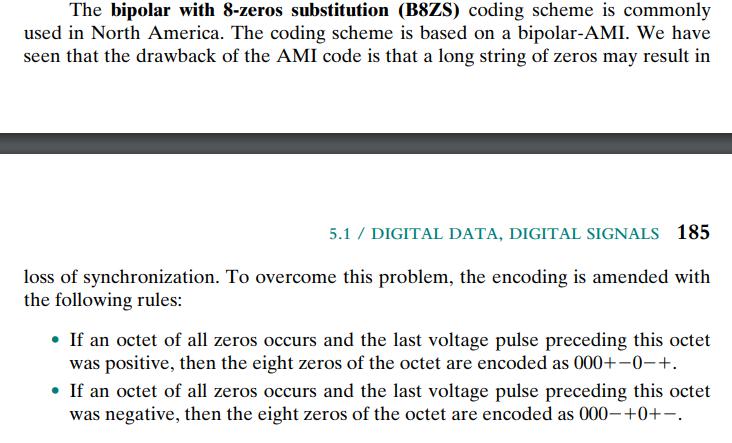
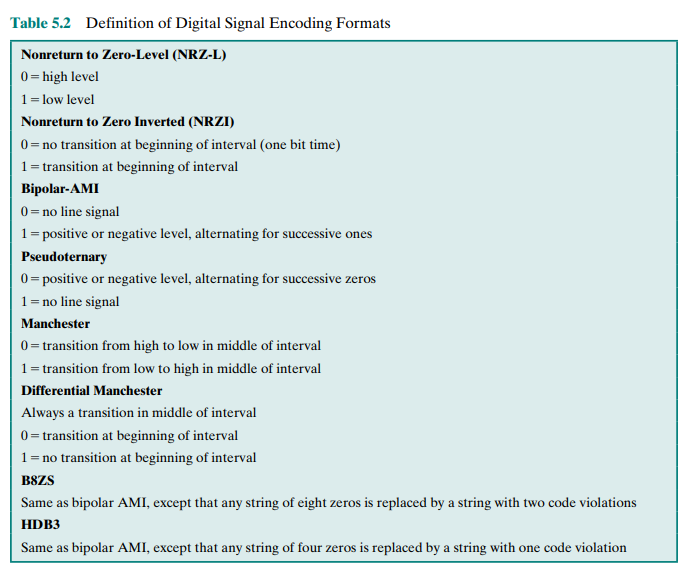
| **Parameters** | **Simplex** | **Half Duplex** | **Full Duplex** |
| --- | --- | --- | --- |
| **The direction of communication** | Simplex mode is a uni-directional communication. | Half Duplex mode is a two-way directional communication but one at a time. | Full Duplex mode is a two-way directional communication simultaneously. |
| **Sender and Receiver** | In simplex mode, Sender can send the data but that sender can’t receive the data. | In Half Duplex mode, Sender can send the data and also can receive the data but one at a time. | In Full Duplex mode, Sender can send the data and also can receive the data simultaneously. |
| **Channel usage** | Usage of one channel for the transmission of data. | Usage of one channel for the transmission of data. | Usage of two channels for the transmission of data. |
| **Performance** | The simplex mode provides less performance than half duplex and full duplex. | The Half Duplex mode provides less performance than full duplex. | Full Duplex provides better performance than simplex and half duplex mode. |
| **Bandwidth Utilization** | Simplex utilizes the maximum of a single bandwidth. | The Half-Duplex involves lesser utilization of single bandwidth at the time of transmission. | The Full-Duplex doubles the utilization of transmission bandwidth. |
| **Suitable for** | It is suitable for those transmissions when there is requirement of full bandwidth for delivering data. | It is suitable for those transmissions when there is requirement of sending data in both directions, but not at the same time. | It is suitable for those transmissions when there is requirement of sending and receiving data simultaneously in both directions. |
| **Examples** | Example of simplex mode are: Keyboard and monitor. | Example of half duplex mode is: Walkie-Talkies. | Example of full duplex mode is: Telephone. |

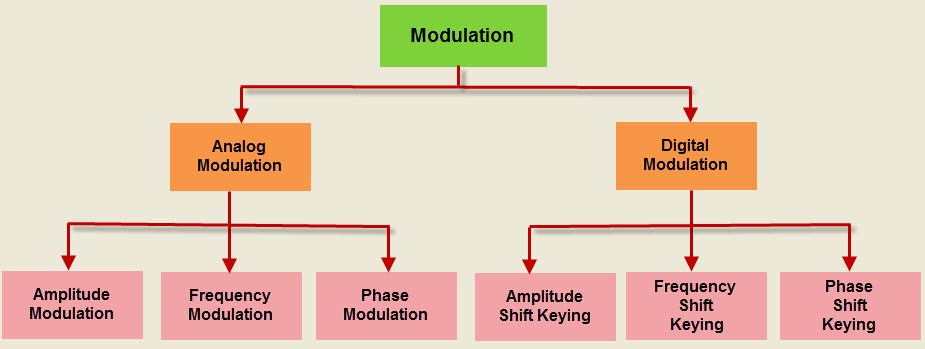


**Noisy channels**

**Noiseless channels**

**Digital Signal Encoding Format**



**Modulation Techniques**

Modulation is a fundamental process in communication systems, where a carrier signal (usually a high-frequency wave) is varied to carry information. The information can either be in **analog form** (continuous signals like sound and video) or in **digital form** (binary data like 0s and 1s). Modulation is essential for efficient transmission of data over long distances, through various media such as air (wireless), copper cables, or fiber optics.

The process of modulation not only improves the **signal strength** but also enables **multiplexing**, where multiple signals are combined into one, allowing efficient use of bandwidth. The key types of modulation can be broadly classified into **Analog Modulation** and **Digital Modulation**. Each has its own set of techniques that are suited for different types of communication.

**1. Analog Modulation**

Analog modulation is employed when the information to be transmitted is continuous, like audio signals or TV broadcasts. The carrier wave, which is typically a high-frequency sine wave, is varied in different ways to encode this analog information.

**Types of Analog Modulation:**

1. **Amplitude Modulation (AM):**
   * In **Amplitude Modulation**, the **amplitude** (or height) of the carrier wave is varied according to the information signal. For example, in AM radio broadcasting, the audio signal modulates the carrier wave by altering its amplitude. Louder sounds are represented by higher amplitudes, while softer sounds correspond to smaller amplitudes.
   * **Applications:** AM is primarily used in AM radio broadcasting and some forms of early analog TV transmissions.
   * **Advantages:** Simple to implement and cost-effective.
   * **Disadvantages:** AM is more susceptible to noise and interference because noise tends to affect the amplitude of a signal.
2. **Frequency Modulation (FM):**
   * In **Frequency Modulation**, the **frequency** of the carrier wave is varied based on the input signal. The amplitude remains constant, but the wave's frequency shifts higher or lower depending on the information.
   * **Applications:** FM is widely used in **FM radio broadcasting**, as well as in television sound transmission and radar systems.
   * **Advantages:** FM offers better noise immunity than AM, providing clearer sound quality.
   * **Disadvantages:** FM requires more bandwidth compared to AM.
3. **Phase Modulation (PM):**
   * In **Phase Modulation**, the **phase** of the carrier wave is shifted in proportion to the input signal. Unlike AM or FM, PM alters the **timing** or **phase** of the wave to carry information.
   * **Applications:** PM is often used in digital communication, radar systems, and as a component of **Phase Shift Keying (PSK)**, a key digital modulation technique.
   * **Advantages:** PM is less susceptible to amplitude-based noise but is harder to implement than AM or FM.
   * **Disadvantages:** Phase distortion can cause significant signal loss or errors in transmission.

**2. Digital Modulation**

As digital communication systems have evolved, the need to transmit **binary data (0s and 1s)** efficiently and reliably over networks has become essential. Digital modulation is used to encode data into a form that can be easily transmitted and decoded over a communication channel.

**Types of Digital Modulation:**

1. **Amplitude Shift Keying (ASK):**
   * In **Amplitude Shift Keying**, the **amplitude** of the carrier wave is shifted between two values—typically one amplitude for a binary "1" and a different (often zero) amplitude for a binary "0". This method is straightforward and low-cost, but it's more prone to errors in noisy environments.
   * **Applications:** ASK is used in low-speed **modems**, RFID systems, and optical communication systems.
   * **Advantages:** Easy to implement and cost-efficient.
   * **Disadvantages:** Highly susceptible to noise, since noise impacts the amplitude of the signal.
2. **Frequency Shift Keying (FSK):**
   * In **Frequency Shift Keying**, the **frequency** of the carrier signal is varied to represent the binary data. One frequency is used for a binary "1", and another frequency is used for a binary "0".
   * **Applications:** FSK is used in **wireless communication**, early modems, Bluetooth communication, and RFID systems.
   * **Advantages:** More resistant to noise than ASK.
   * **Disadvantages:** FSK requires more bandwidth and is more complex to implement than ASK.
3. **Phase Shift Keying (PSK):**
   * In **Phase Shift Keying**, the **phase** of the carrier wave is changed to represent binary data. For instance, a 180-degree phase shift may represent a "1", and no shift may represent a "0".
   * **Applications:** PSK is widely used in modern communication systems, including **Wi-Fi**, **satellite communication**, and **cellular networks**.
   * **Advantages:** PSK is highly efficient and resistant to noise, especially in its more advanced forms such as **Quadrature Phase Shift Keying (QPSK)** and **8-PSK**.
   * **Disadvantages:** PSK requires complex receivers for accurate demodulation.

**HDLC**