Contents

Unit 10
Physical Layer

Structure of the Unit

10.1 Unit Outcomes

After the successful completion of this unit, the student will be able to:

- Define data and signals in the context of communication.
- Differentiate between analog and digital signals.
- Define the data rate and describe the data rate limit.
- Define the different parameters to evaluate the performance of data transmission.
- Comprehend the technique of transmitting digital data between two or more computers.
- Demonstrate the techniques to convert analog data to its digital equivalent and vice-versa.

10.2 Physical Layer – Introduction

The lowest layer in the OSI Reference Model is referred to as the physical layer because it deals with the physical transmission of raw bits between two or more computers. This layer implementation does not deal with the meaning of these bits but is dealt with by the above layers. The physical layer is also responsible for the physical connectivity between two systems such as establishing, maintaining, and deactivating the connections.

To support the above functions, the physical layer has to deal with the configuration of all the hardware equipment in the network, topologies, modes of transmission, cabling and wiring, signaling mechanisms, and frequencies. So, in general, the physical layer is the physical and electrical representation of a communication system.

The different devices operating at the physical layer are repeaters, hubs, and Network Interface Cards (NIC). Repeaters are used to amplify or boost the electrical signals which have lost strength or attenuated after traveling a distance. A hub is a device used to connect multiple computers in a LAN. NIC is a circuit board used to connect a computer to a network. It is also called a Network adapter or LAN adapter.

In the following sections, we study the below-given topics:

- Data and Signal in the context of a communication system.
- Representation of message/information in the form of a Digital Signal.
- Parameters of a digital signal.
- Digital Communication System
- Line Encoding
- Modulation Techniques

10.3 Data and Signals

Any form of data such as text, image, audio, or video sent on the Internet is converted to electromagnetic signals and then transmitted on the medium, because all transmission media can accept and carry only signals. The important role of the physical layer is to transfer all the above-mentioned types of data in the form of signals on different types of transmission media.

Before discussing the different types of Data and Signals, let us understand how communication takes place at the physical layer.

Consider a situation in which a research scientist working at India Research, orders a book online from Navbharat Books.

Fig.10.1 demonstrates the order message (the data) being transferred from the source system to the destination system. Communication between Jay and Ram happens at five different levels following the TCP/IP implementation model.

NOTE: The communication at all the layers above the physical layers is only logical.

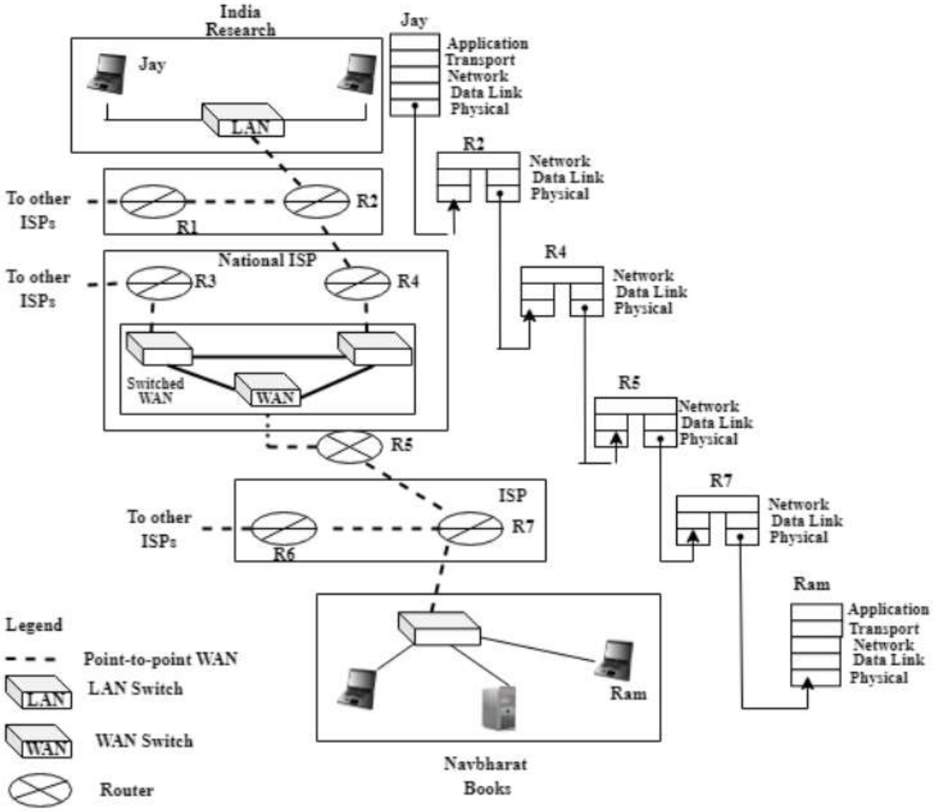


Fig. 10.1: Communication at the physical layer

The smallest unit of the message (data) is represented in the form of bits, which is implemented as a digital signal. This message signal is sent from the source system (User named Jay), which is a part of the LAN of the India Research company. The signal passes through the LAN switch and propagates through different physical media and physical layers of the multiple network devices (routers R2, R4, R5, and R7) and reaches the destination. The message signal is received and processed at the destination by the system (User named Ram) which is a part of the LAN of Navbharat Book Store.

10.3.1 Analog and Digital Data

Data is a raw collection of 0's and 1's (Physical Layer). It gets meaning or becomes information when they are interpreted by software instructions (Application Layer).
Based on its instantaneous value (with reference to time) data can be either analog or digital.

Analog data values vary continuously with time.
Eg: An analog clock provides information in a continuous form. The continuous movements of the hands tell us the time in hours, minutes, and seconds.

Digital data provides information in discrete steps or states.
Eg: A digital clock shows the hours and the minutes time in discrete steps. The time will change from 8:05 to 8:06, with intermediate values not shown.

10.3.2 Analog and Digital Signals – A comparison

Signals are electric or electromagnetic waves used to encode data and transmit them. So, like data, signals also can be either analog or digital.

If we consider a small time period, an analog signal has infinite levels of intensity. Fig.10.2a shows an analog signal. Between any two points on the x-axis (time axis), the signal amplitude on the y-axis has an infinite number of values. In comparison with this, a digital signal can take only a limited number of defined values as shown in Fig.10.2b.

A digital signal consists of an infinite number of signal components with respect to frequency and so has infinite bandwidth. Therefore it is called a composite signal Although each amplitude value can be any number, it is usually represented as a 1 and 0.

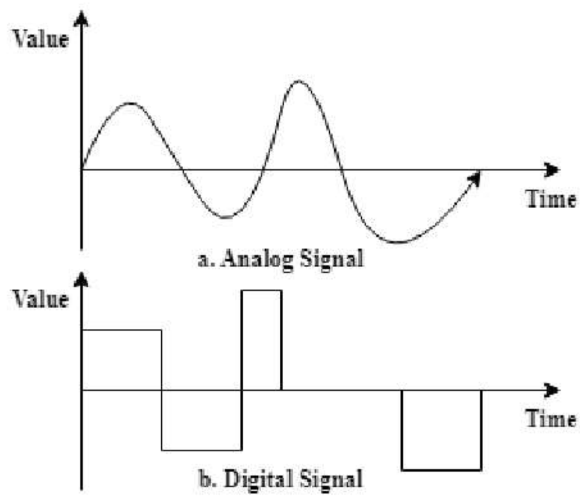


Fig. 10.2 Comparison of Analog and Digital Signals

10.3.3 Periodic and Non-periodic Signals

Both Analog and Digital signals can be Periodic or Non-periodic in nature.

A periodic signal is a signal which follows a specific pattern in a measurable time duration, called a period. This pattern keeps repeating in the subsequent identical periods. When one full pattern completes, it is called a cycle. The reciprocal of the time period value gives the frequency of the signal in cycles/second.

A non-periodic signal keeps changing without showing a pattern or cycle repeating over time.

In Data Communication, data is transmitted by encoding them using either periodic analog signals or non-periodic digital signals.

Periodic analog signals are of two types: Simple and Composite

1. A simple periodic analog signal cannot be divided or decomposed into simpler signals.
2. A composite periodic analog signal consists of sine waves of different frequencies and the difference between the highest and the lowest frequencies contained in that signal is its

bandwidth.

Example 1: Find the bandwidth of a composite signal containing frequencies between 2000 Hz and 4000 Hz.

Solution 1: Bandwidth = Highest frequency - Lowest Frequency

= 4000 – 2000

= 2000 Hz.

10.4 Digital Signal Representation

Digital data at the physical level are represented by voltage levels, so digital signals shown in Fig. 10.3a and Fig.10.3b are voltage signals representing voltage amplitude on the Y-axis with respect to the varying time on the x-axis.

When two-valued data or information is represented by a digital signal, the data value 1 (or high state) can be encoded as a positive voltage and the data value 0 (or low state) with zero voltage. Fig.10.3a shows a digital signal with two levels.

If a digital signal has more than two levels, then it uses more than 1 bit for representing each level. Fig.10.3b shows a digital signal with four levels represented by two bits per level, i.e. 00,01,10,11. These four levels will be encoded with four voltage levels.

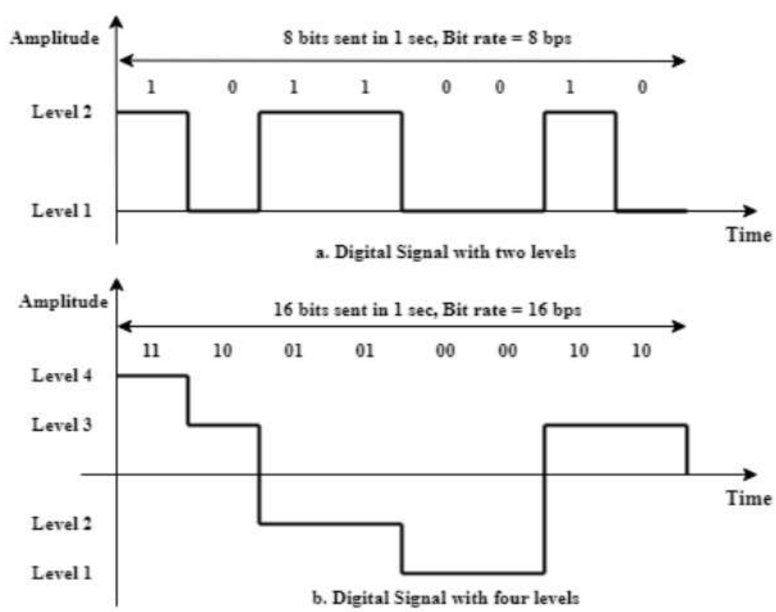


Fig. 10.3 Two Digital Signals with two and four levels

10.5 Digital Signal Parameters

Digital signals used for encoding data in communication systems are mostly nonperiodic, So the parameters, period, and frequency cannot describe them correctly. So, the term, bit rate (frequency), is used to describe them. The other related parameters are Baud rate and Bit length

10.5.1 Bit Rate

It is the number of bits transmitted in 1 second and expressed in bits per second (bps). In Fig.10.3a and b, the bit rates are 8bps and 16bps, as 8 and 16 bits are sent per second respectively.

10.5.2 Baud Rate

It is the number of signal units transmitted per second.

The relationship between the Baud rate and Bit rate is given as,

Baud rate = Bit rate / Number of bits per symbol (baud).

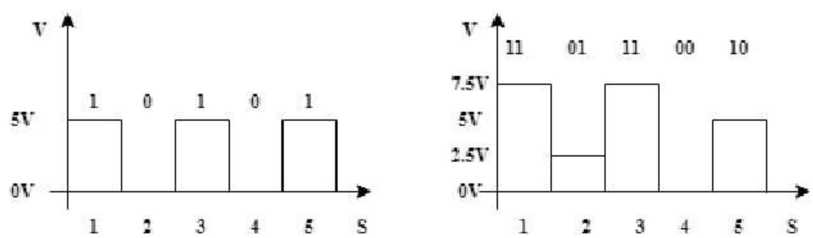
As the number of bits per symbol will be one or more than one, the baud rate is always less than or equal to the bit rate.

Baud rate <= Bit rate

It is demonstrated in Fig. 10.4.

In Fig.10.4a there are only two voltage levels 0 volts and 5 volts with each level encoded with 1-bit (0 or 1). The number of signal units sent per second is 1. So the bit rate is equal to the baud rate or 1-bit is sent per second.

In Fig.10.4b, there are four two voltage levels 0 volts, 2.5 volts, 5 volts, and 7.5 volts with each level encoded with 2- bits each (00, 01, 10, and 11). The number of signal units sent per second is 1. So the bit rate is two times the baud rate or 2-bits are sent per second.



a. Bit Rate = Baud Rate

b. Bit Rate = 2 times Baud Rate

Fig. 10.4: Bit Rate Vs Baud Rate

10.5.3 Bit length

For a digital signal, its bit length is the distance occupied by one bit on the transmission medium. It is expressed as,

Bit length (mtrs) = propagation speed × bit duration,

where propagation speed is the speed at which a bit or the signal moves through a medium lying in the range of 2×10^8 m/s and 3×10^8 m/s (speed of light) and bit interval or duration is the time required (in seconds) to send one single bit.

10.6 Digital Communication System

Real-world signals such as the ones generated by a microphone or a camera are analog in nature, so if voice or video signals are to be transmitted over a digital system such as the computer network, then there is a need for the analog data to be converted to digital format, as a computer network is built for sharing digital data between two computing devices. But, the transmission media or channel in a network can carry only signals, so, the digital data has to be again converted to an analog signal or a digital signal before transmission. At the receiver, the reverse processes help in extracting the input signal.

There are many **advantages** of using data in digital format. The first one is that the digital signals are not much affected by noise, distortion, and interference compared to analog signals. Secondly, digital data are very convenient to save and retrieve than analog data. Also, compared to analog circuits, digital circuits are easier to design, more reliable, and cheaper to construct.

10.6.1 Transmission of Digital Signals

As we know that a digital signal is a composite analog signal consisting of frequencies ranging from zero to infinity, the channel needed to transmit it should be a low pass channel with infinite bandwidth. As it is difficult to have such a channel in real life, usually a digital signal is converted to an analog signal and then transmitted after using a suitable modulation technique.

Based on whether a digital signal is converted to an analog signal or not, for transmission on a medium, there are two ways: Baseband and Broadband.

10.6.1.1 Baseband Transmission

In this technology, a single data signal is transmitted at a time, and the single data signal occupies the complete bandwidth of the channel. As the whole bandwidth is available, here data in the form digital signal is sent over the medium without changing or converting it to an analog signal. In this transmission, digital signals can be transmitted in both directions but in one direction at a time. This transmission technology uses a multiplexing technique known as Time Division Multiplexing (TDM) discussed in Section 2.5.1.1, where each signal is allocated a time slot for transmission. Used for short-distance communication and the medium used can be wires, twisted pair cables, and coaxial cables.
Eg: Ethernet LAN.

10.6.1.2 Broadband Transmission

In this technology, multiple data signals or channels are transmitted simultaneously. This is done by dividing the channel's bandwidth into different frequency ranges to transmit the signals also called Frequency Division Multiplexing (FDM) discussed in Section 2.5.1.1. Also, here the digital signal is modulated or converted to an analog signal for transmission. At the receiver, the analog signal is demodulated or converted back to a digital signal. The signals can move in both directions simultaneously. Used for long-distance transmission and medium used are co-axial cables, Fibre-optic cables, and Radio Waves.
Eg: Telephone and Cable networks.

Fig.10.5a shows that each signal occupies a time slot for transmission and during this time slot, the signal uses the whole bandwidth.

Fig.10.5b shows that all three signals are transmitted simultaneously using different frequency ranges and the channel bandwidth is shared.

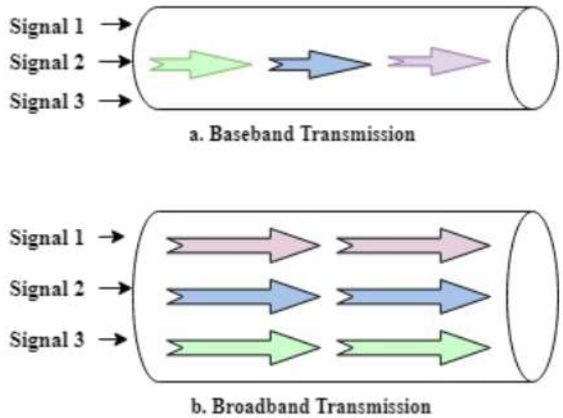


Fig.10.5: Baseband and Broadband Transmission

10.6.2 Block Diagram of a Digital Communication System

Fig.10.6 shows the basic block diagram of digital communication system. The upper three blocks are at the transmitter and the lower ones are at the receiver. This system uses Broadband transmission, as the digital data is converted to an analog signal before being transmitted on the medium. The analog information signal, is converted back to a digital signal at the receiver for processing.

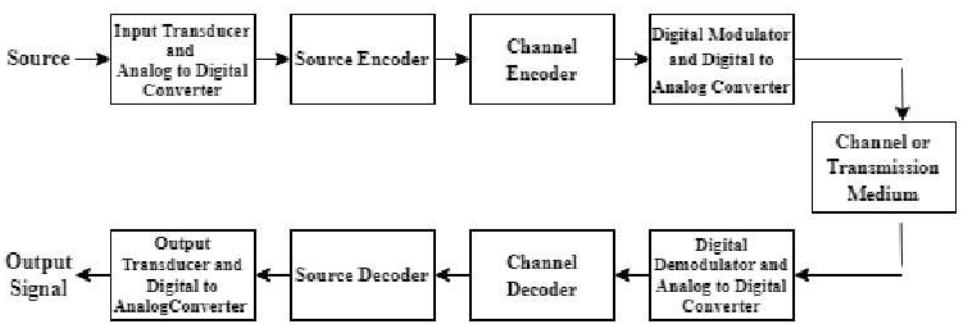


Fig. 10.6: Basic Elements of a Digital Communication System

Source: Can be an analog audio or video signal

Input Transducer: A transducer such as a microphone converts sound signals into electrical signals.

Analog to Digital Converter: Helps in converting an analog input signal into a digital data or binary digits.

Source Encoder: This block compresses the data for effective utilization of the bandwidth of the channel.

Channel Encoder: Imperfections in the channel or medium noise to the signal and corrupts the data. The encoder adds extra bits for error detection and correction at the receiver.

Digital Modulator: The message signal gets modified by a carrier signal and transmitted. This process is called modulation. It is discussed in detail in the next sections. Also, another circuit converts the digital signal into an analog signal for being transmitted over the medium.

Channel or medium: The signal travels through different types of medium based on the distance between the transmitter and the receiver. Eg: Coaxial cable, Fiber Optic Cable, etc in case of wired transmission or Air in case of wireless transmission

Digital Demodulator: First block at the receiver and helps in reconstruction the message signal. Also, in another block the analog signal is converted into a digital signal.

Channel Decoder: This block helps in detecting and correcting errors if any in the message signal.

Source Decoder: This block demodulates the signal into the original signal.

Digital to Analog converter: The digital message signal is converted to its analog form.

Output Transducer: This device converts the analog electrical signal to a physical form. Eg: a loud speaker converts electrical signal back into sound signal.

In the next two sections we discuss some of the blocks of the digital communication systems such as the Source encoder, Modulation process, and its techniques.

10.7 Encoding or Digital Data Conversion

Source encoding is also known as digital-to-digital conversion or digital baseband transmission, as this process is used to convert digital data to digital signals. The encoding process incorporates three techniques: Line coding, Block coding and Scrambling. Out of the three, Line coding is a mandatory process whereas Block coding and Scrambling may be used as required. In this section, Line coding is discussed in detail.

10.7.1 Line Coding

This process takes bit sequence as input and generate digital signals from them. So, here we assume that all the forms of data such as textual, numeric, image, audio and video files are already converted into a sequence of bits and are stored in memory devices. At the transmitter, digital data are encoded into digital signals and at the receiver, digital data are recreated from the digital signals by a reverse process called as decoding.

Fig.10.7 shows the Line coding and Decoding process.

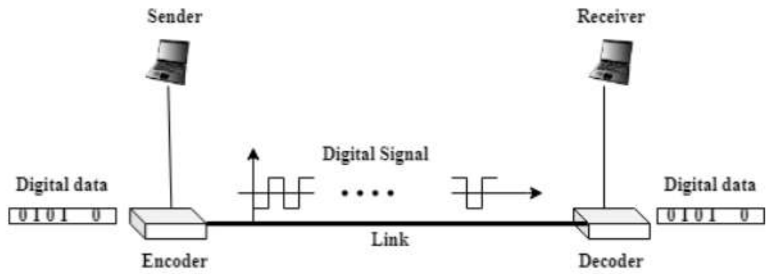


Fig. 10.7: Line Coding and Decoding

10.7.1.1 Line Coding Methods

As Line coding results in a digital signal, the line coding methods are classified according to the rules used to assign voltage levels in the signal which represent the input binary data.

According there are five basic categories:

- Unipolar
- Polar
- Bipolar
- Multilevel
- Multitransition

Fig.10.8 shows the Line Encoding schemes and the sub schemes in each category.

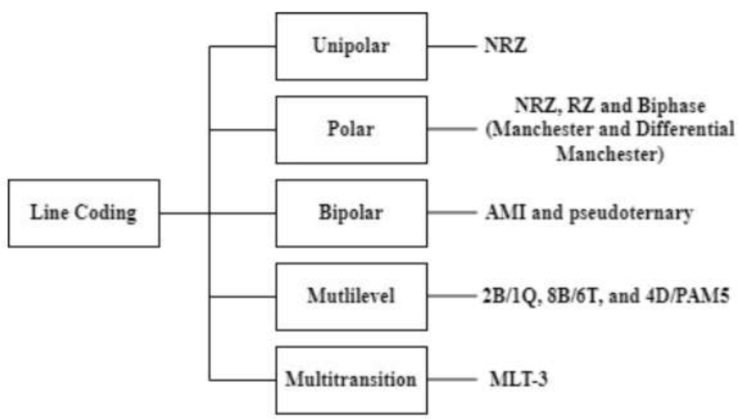


Fig. 10.8: Line Coding Schemes

In the following subsections, we briefly discuss Unipolar, Polar and Bipolar encoding methods.

1) Unipolar Signaling:

Unipolar Signaling is also known as NRZ (Non-return-to-zero) scheme as the voltage levels do not return to zero value in the middle of a bit. This signaling method uses either Positive-logic or Negative-logic. In the positive–logic unipolar signaling, a high voltage level (+V volts) represents a bit 1 and zero voltage (0 Volts) represents bit 0 as shown in Fig.10.9.

Unipolar signaling is also known on–off keying.

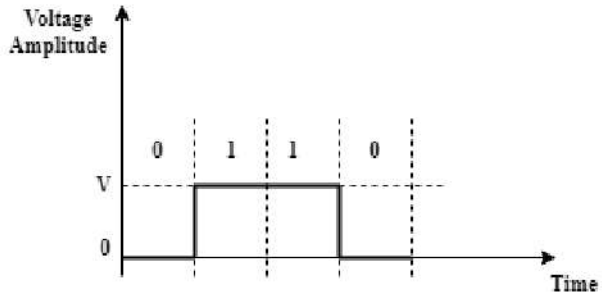


Fig. 10.9: Unipolar Line Encoding

2) Polar Signaling:

In this scheme, the binary values are represented by equal positive and negative voltage values on both sides of the time axis. The scheme uses either NRZ or Return-to-zero (RZ) signaling.

There are two sub schemes in NRZ method: NRZ-Level or NRZ-L and NRZ-Invert or NRZ-I. The signals are shown in Fig.10.10.

In NRZ-L, bit 0 is represented by a positive voltage level and bit 1 is represented by a negative voltage level.

In NRZ-I, bit 1 is represented by a changing voltage level and bit 1 is represented by no change in voltage levels.

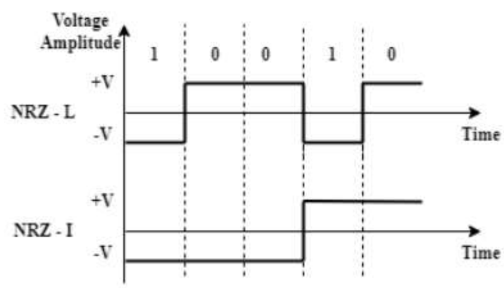


Fig. 10.10: Polar NRZ Encoding

Fig.10.11 shows the RZ coding where, three voltage values : positive, negative and zero are used for signaling. The signal voltage value returns to zero during the bit duration.

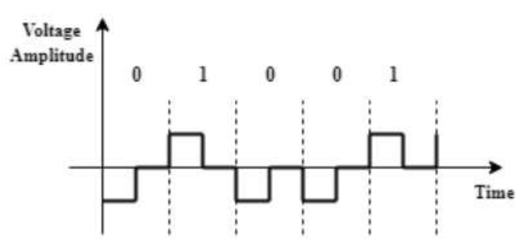


Fig. 10.11: Polar RZ coding

3) Bipolar (Pseudoternary) Signaling:

In this scheme, there are three voltage levels +ve,-ve and 0 used for signaling. There are two types of schemes in this signaling method: Pseudoternary and Alternate Mark Inversion (AMI).

In Pseudoternary method, the voltage level for one data element is at 0 while the voltage level of other elements alternate between +ve and –ve.

The term "Mark" is derived from telegraphy where mark means a 1. So, in AMI a binary 1 is represented by alternating +ve and –ve voltages and a binary 0 is represented by a zero voltage level.

Fig.10.12 shows both the Bipolar Encoding schemes.

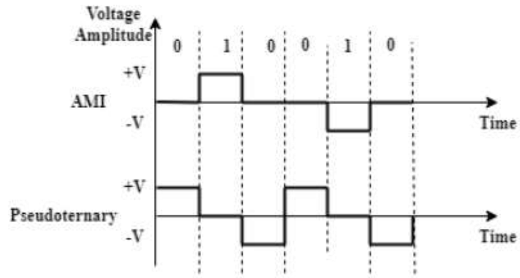


Fig. 10.12: Bipolar Encoding

10.8 Modulation

In communications, **modulation** is the process where one or more properties or parameters of a periodic waveform, also called the carrier signal, are varied according to the information signal (also called the modulation signal) that is to be transmitted. In other words, the information signal is superimposed on a high frequency carrier signal and transmitted. Modulating a message or information signal has many advantages:

- Signals can be transmitted for longer distances due to the high frequency carrier which also reduces the size of the antenna.
- Multiplexing of signals over different frequency ranges helps in using a single channel for transmitting signals from different sources simultaneously
- Also more channels can be allocated for users within a frequency band with a guard band between the channels to improve noise immunity.

Examples of modulation signals:

- An audio signal from a microphone representing sound.
- A video signal from a camera representing moving images.
- A digital signal from a computer bit-stream representing a sequence of binary digits.

Based on the application used, the carrier signal can be a direct current or alternating signal or a chain of pulses which in turn gives the two basic categories of modulation techniques:

- Analog Modulation
- Digital Modulation

10.8.1 Analog Modulation or Analog to Analog Conversion

Here a high frequency sinusoidal carrier wave is used to modulate a low frequency message signal such as an audio signal, picture signal for a TV or a data signal. It is nothing but converting a low-pass analog signal to a band-pass analog signal with a smaller bandwidth.

Based on the three parameters: amplitude, frequency, or phase of the carrier signal altered, there are three types of analog modulation techniques:

- Amplitude Modulation (AM)
- Frequency Modulation (FM)
- Phase Modulation (PM)

10.8.1.1 Amplitude Modulation (AM)

This technique was the oldest modulation techniques and is still used today in computer modems, portable and aircraft radios. Here, the amplitude of the career signal is varied in accordance with the information signal while its frequency and phase components remain constant.

Fig.10.13 shows the modulating or information signal on the top, the high frequency carrier signal and the Amplitude modulated signal at the bottom.

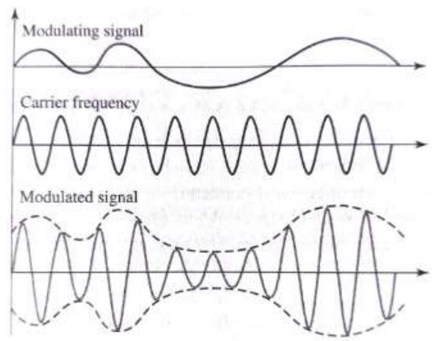


Fig.10.13: Amplitude Modulation

The modulated signal consist of a three components a lower-frequency band, upper-frequency band and carrier frequency. This technique requires more power and greater bandwidth, but simple to implement, have better noise immunity and use less expensive receivers.

10.8.1.2 Frequency Modulation (FM)

In this technique, the frequency of the carrier signal is varied in accordance with the message signal, while its amplitude and phase components remain constant. As this modulation techniques incorporates frequency variations, the receivers can be tuned to the required frequency of sufficient bandwidth and hence noise cancellation is possible. FM is used in applications like radar, FM radio, etc.

Fig.10.14 shows the modulating or information signal on the top, the high frequency carrier signal and the Frequency modulated signal at the bottom.

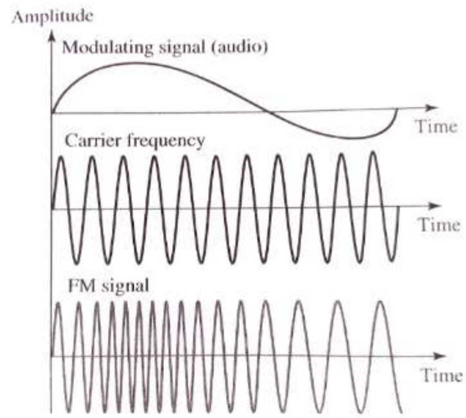


Fig.10.14: Frequency Modulation

Narrowband FM is used radio broadcasting as in AM radio stations, whereas wideband FM can modulate a wider range of frequencies and is used for applications like TV audio and FM stereo broadcasting.

The advantages of FM are: FM systems are less susceptible to noise and static, they generate higher fidelity audio and due to wider bandwidth usage they allow more channels.

10.8.1.3 Phase Modulation (PM)

In this technique the phase of the carrier signal is changed in accordance with the message signal, and its amplitude and frequency components remain constant. It is used in coding systems, used to generate signals in all synthesizers, in Wi-Fi systems, in satellite communication systems etc.

Fig.10.15 shows the modulating or information signal on the top, the high frequency carrier signal and the Phase modulated signal at the bottom.

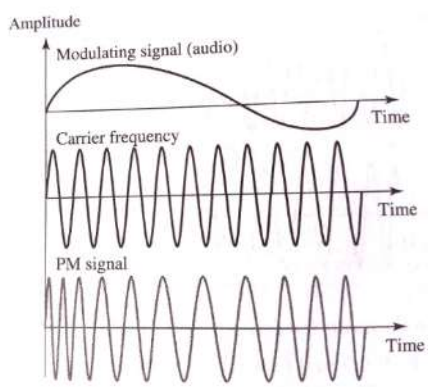


Fig.10.15: Phase Modulation

10.8.2 Digital Modulation or Digital to Analog Conversion

This process basically converts digital data to a bandpass analog signal. The transmitting device produces a high carrier signal. The digital data modifies the carrier signal by changing one of the characteristics such as amplitude, frequency or phase, giving rise to three modulation techniques:

Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) or Phase Shift Keying (PSK).

Digital modulation has many advantages and the most important one is high noise immunity.

Digital Modulation techniques are used Wireless communication, Radio communication, Cordless phones, Telemetry, Modems and wireless LANs.

10.8.2.1 Amplitude Shift Keying (ASK)

In this process, based on the digital signal, the amplitude of the carrier wave is changed, without changing its frequency and phase. Fig. 10.16 shows the Binary ASK signal implemented with two amplitude levels to represent the binary 0 and 1. The data value 1 is represented using the same amplitude as of the carrier signal and the data value 0 is represented with the zero amplitude value.

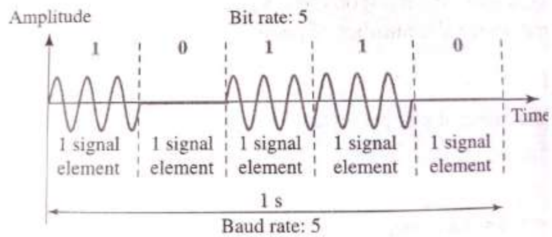


Fig.10.16: Binary Amplitude Shift Keying

10.8.2.2 Frequency Shift Keying (FSK)

In this process, based on the digital signal, the frequecy of the carrier wave is changed, without changing its amplitude and phase. Fig. 10.17 shows the Binary FSK signal implemented with two frequency values to represent the binary 0 and 1. The data value 1 is represented using one carrier signal frequency and the data value 0 is represented with another frequency value.

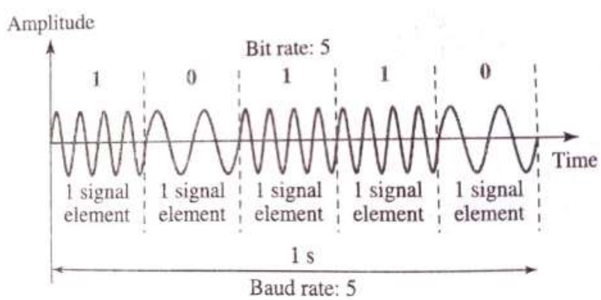


Fig.10.17: Binary Frequency Shift Keying

10.8.2.3 Phase Shift Keying (PSK)

In this process, based on the digital signal, the phase of the carrier wave is changed, without changing its amplitude and frequency. Fig. 10.18 shows the Binary PSK signal implemented with two different phase values to represent the binary 0 and 1. The data value 1 is represented using one carrier signal phase and the data value 0 is represented with another phase value.

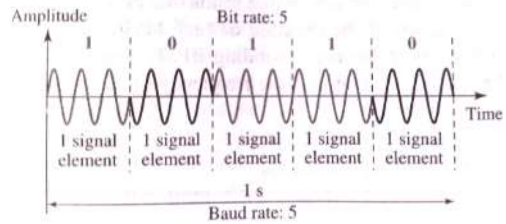


Fig.10.18: Binary Phase Shift Keying

10.9 Analog to Data Conversion

For digital transmission, the analog signals produced by a microphone or a camera need to be converted to their digital equivalent for processing. There two important digitization techniques: Pulse Code Modulation (PCM) and Delta Modulation (DM). The PCM is discussed in detail in the next subsection.

10.9.1 Pulse Code Modulation (PCM)

This technique involves three processes: Sampling of the Analog Signal, Quantization, and Encoding. Fig.10.19 shows the components of the PCM encoder.

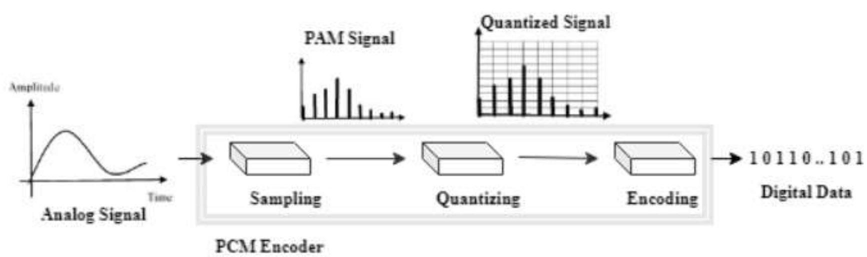


Fig. 10.19: Components of PCM Encoder

Sampling:

It is a process of measuring the instantaneous values of the (continuous-time) input signal at a regular time interval (in a discrete form). Sampling is a process where a piece of data is selected from the whole data which is continuous with respect to time. The sampling rate or sampling frequency f_s (in Hz)=$1/T_s$, where T_s is referred to as the sampling interval in secs. Sampling gives rise to a series of pulses whose amplitude values vary between two limits: a minimum and a maximum. This process is also known as pulse amplitude modulation (PAM) and the output is a signal with real values.

NOTE: The Nyquist theorem or Sampling theorem says that, in order to reproduce a given signal faithfully, the sampling rate must be at least twice the highest frequency contained in the signal.

Quantization:

There are infinite non-integral amplitude values of the PAM between the two limits and cannot be used for encoding. So these infinite real values are limited to a discrete set (such as the integers) by the

Quantization process.

With the assumption that the original signal has instantaneous amplitudes between V_{max} and V_{min}, let us discuss the steps of quantization below.

1. Divide the range between V_{max} and V_{min} into L zones (levels) each with height $\Delta = (V_{max} - V_{min}) / L$
2. To the midpoint of each zone, assign quantized values of 0 to L-1.
3. Approximate the sample amplitude values to the quantized values.

NOTE: The value of L should be chosen based on the analog signal amplitude range and the accuracy with which the signal has to be recovered.

Encoding:

This process is used to assign codes to each zone or encoding. The steps of encoding are given below:

1. After the quantization process, the number of bits/samples is decided. Then each quantized sample will be encoded to an n - bit binary code.
2. This binary code is assigned to each zone.
3. The number of bits per sample or number of bits required to encode the zones is given by,

$$n = \log_2 L$$

Example 1: Encode an analog signal with instantaneous amplitudes ranging between 0 and +20 volts

Solution 1: As the signal values are positive, the sampled values can be coded using unsigned binary representation, where all the bits in the code represent the magnitude of the instantaneous signal amplitude

We have $V_{max} = +20$ volts and $V_{min} = 0$ Volts.

If $n = 3$, then $L = 2^3 = 8$, the 8 zones (or level) codes are therefore: 000, 001, 010, 011, 100, 101, 110, and 111

Assigning codes to zones:

000 will refer to zone 0V to 2.5V, 001 to zone 2.5V to 5V, 010 to 5V to 7.5V, ……. 111 to 17.5V to 20V.

Example 2: Encode an analog signal with instantaneous amplitudes ranging between -10 Volts and +10 Volts

Solution 2: As the signal values are both positive and negative, the sampled values can be coded using signed binary representation, where the Most significant bit of the code (MSB) represents the sign of the signal value and the remaining bits in the code represents the magnitude of the instantaneous signal amplitude.

We have, $V_{max} = +10$ Volts and $V_{min} = -10$ Volts.

If $n = 3$, then $L = 2^3 = 8$,

If we use a 1 in the MSB to represent a positive value and 0 for a negative value, then the 8 zones (or level) codes 000, 001, 010, 011, 100, 101, 110, and 111 refer to -10V to –7.5V, -7.5V to -5V, -5V to -2.5V, -2.5V to 0V, 0V to +2.5V, +2.5V to +5V, +5V to +7.5V and +7.5V to +10V ranges respectively.

PCM Decoder / Demodulator

Fig. 10.20 shows the components of a PCM Decoder Circuit.

An analog signal can be recovered from a digitized signal with the following steps:

1. A hold circuit is used to fix and hold the amplitude value of a pulse until the arrival of the next pulse.
2. This signal then passes through a low-pass filter whose cutoff frequency is equal to the highest frequency in the sampled signal.
3. With higher values of L, there is less distortion in the recovered signal.

NOTE: A low pass filter is a circuit, which allows the frequencies from 0 Hz up to the cut-off frequency.

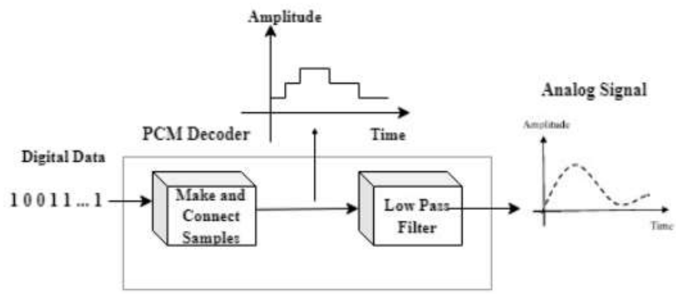


Fig.10.20: Components of a PCM Decoder

10.10 Self-Assessment Questions

Q1. What are the two important functions of the Physical Layer? (2 marks, L2)

Q2. Discuss Data and Signals in the context of Data Communication Networks (4 marks, L3)

Q3. Compare an Analog Signal with a Digital Signal (4 marks, L4)

Q4. Define Bit rate and Baud rate. Compare them. (5 marks, L4)

Q5. With the help of a diagram compare Baseband and Broadband transmission technologies. (8 marks, L4)

Q6. What are the advantages of digital transmission? (2 marks, L2)

Q7. With the help of a block diagram, explain the working of a digital communication system. (8 marks, L4)

Q8. What is Modulation? Explain its need in communication systems (4 marks, L3)

Q9. Explain Line Coding and its methods. (8 marks, L4)

Q10. Explain the different digital modulation techniques (8 marks, L4)

Q11. Explain the Pulse Code Modulation technique (8 marks, L3)

Q12. Describe a PCM decoder with a block diagram (8 marks, L3)

10.11 Self-Assessment Activities

Q1. If a periodic signal is decomposed into five sine wave signals of frequencies of 100, 200, 300, 400, and 500 Hz, what is its bandwidth? Draw the spectrum, assuming all components have a maximum amplitude of 8 V.

10.12 Multiple-Choice Questions

Q1. Before transmission, data will be converted to, [1 mark, L1]

A. Low-frequency sine waves

B. Periodic signals

C. Aperiodic signals

D. Electromagnetic Signals

Q2. Data can be ____ [1 mark, L1]

A. Analog

B. Digital

C. Either A or B

D. None of the above

Q3. _______ data are continuous and take continuous values. [1 mark, L1]

A. Analog

B. Digital

C. Either A or B

D. None of the above

Q4. _______ data have states and take discrete values [1 mark, L1]

A. Analog

B. Digital

C. Both A or B

D. None of the above

Q5. ______ rate is the number of data elements in 1 sec and _____ rate defines the number of signal elements in 1 sec. [1 mark, L1]

A. Data, Signal

B. Baud, Bit

C. Signal, Data

D. None of the above

Q6. ____ rate is another name for signal rate. [1 mark, L1]

A. Bit

B. Baud

C. Either A or B

D. None of the above

Q7. The process of converting the analog sample into discrete form is called, [1 mark, L1]

A. Multiplexing

B. Modulation

C. Sampling

D. Quantization

Q8. The sequence of operations in which PCM is done is, [1 mark, L1]

A. Sampling, Quantizing, Encoding

B. Quantizing, Sampling, Encoding

C. Encoding, Sampling, Quantizing

D. None of the above

10.13 Keys to Multiple-Choice Questions

Q1. Electromagnetic Signals (D)

Q2. Data can be Either analog or digital (C)

Q3. Analog data varies continuously with time (A).

Q4. Digital Data can take only discrete values with time (B).

Q5. Data, Signal (A)

Q6. Baud (B)

Q7. Quantization (D)

Q8. Sampling, Quantizing, Encoding (A).

10.14 Summary of the Unit

This unit covered important topics related to the physical layer such as data and its transmission. Data can be analog or digital in nature. Data has to be converted to a form or energy that can be carried by the transmission medium and this form is known as a signal. Signals also can be analog and digital. Digital signals have infinite bandwidth, so if a channel bandwidth is less, these signals cannot be transmitted without loss. Hence they are converted to analog signals before transmission.

In data communication, periodic analog signals and non periodic digital signals are used. There are two types of transmission techniques used: Baseband and Broadband. In baseband, only one signal is used for transmission, and in broadband, multiple signals are used.

This unit covered another important topic related to the physical layer which is the utilization of the available bandwidth of the transmission link. There are two important goals to be met which are: usage efficiency and privacy of the data. The first one is achieved through multiplexing techniques and the second one through spreading the bandwidth.

10.15 Recommended Learning Resources

[1] James F Kurose and Keith W Ross, Computer Networking, A Top-Down Approach, Sixth Edition, Pearson,2017.

[2] Behrouz A Forouzan, Data Communications and Networking, Fifth Edition, McGraw Hill, Indian Edition

10.16 References

[1] https://beginnersbook.com/2020/10/computer-network-data-and-signals-in-physical-layer/
[2] http://zai.lecturer.pens.ac.id/Kuliah/Komunikasi%20Data/2nd-Week-Data-Communications-Data-and-Signals.pdf

MCQs:

[1] https://examradar.com/data-communication-networking-data-signals-mcq-set-behrouz-forouzan/
[2] https://electronicspost.com/multiple-choice-questions-and-answers-on-digital-communication/