Transmission Media: Guided Transmission Media, Wireless Transmission, Data Encoding-Digital Data, Digital Signals, Analog Signals, Analog Data.

Learning Outcomes: At the end of this unit Students will be able to

1. Describe the characteristics of guided and unguided media with representation.
2. Analyse the signals with encoding techniques to present the target data.

{REFER TEXTBOOK AND CLASS NOTES FOR PROBLEMS AND IN-DEPTH QUESTIONS}

Guided Transmission Media

- Transmission media can be twisted pair wire such as that used for telephone installation, wire media are referred to as bounded media and wireless media are sometimes referred to as unbounded media.
- Different types of transmission media is used for different data transfer rates and long distances. Bandwidth, noise, radiation and attenuation are considered while using the different transmission media.
- Higher bandwidth transmission media support higher data rates. Attenuation limits the usable distance that data can travel on the media. Noise is related to electrical signal noise that can cause distortion of the data signal and data errors.
- Radiation is the leakage of signal from the media caused by undesirable electrical characteristics of the transmission media.
- Classification of transmission media:
- The transmission medium mainly classified into two types.
- Bounded or guided media
- Unbounded or unguided media

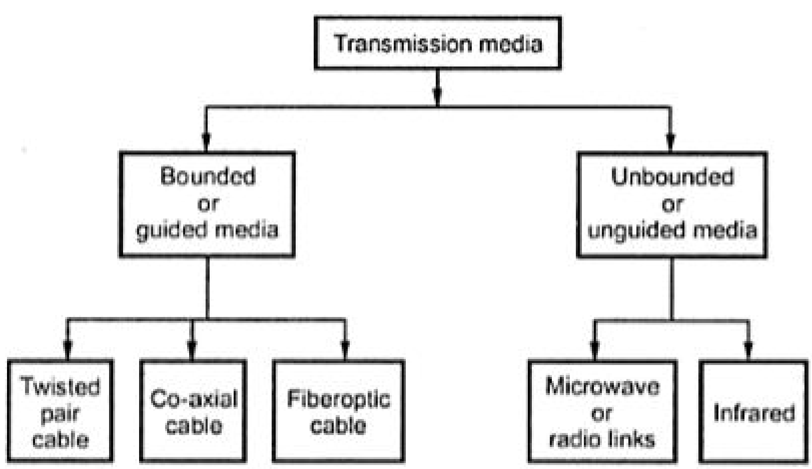


Fig1: Classification of Transmission Media

- **Bounded or guided media**: Depending on the type of transmission medium used the bounded media can be further classified into three types.

  Twisted pair cable

  Co-axial cable

Fiber optic cable

- The bounded media is also called as **wired media**.
- **Unbounded or unguided media:** Depending on the method of transmission the unbounded media can be further classified into two types.

Microwave links

Radio links

Infrared

1) Twisted Pair (TP):

- Twisted pair is least expensive and most widely used.
- A Twisted pair (TP) consists of two insulated copper wires arranged in a regular spiral pattern.
- A wire pair acts as a single communication link. TP may be used to transmit both analog and digital signals. For analog signals amplifiers are required about every 5 to 6 km. For digital signals, repeaters are required every 2 or 3 km.
- TP is most commonly used medium for in the telephone network. Compared to other commonly used transmission media, TP is limited in distance, bandwidth and data rate when two copper wires conduct electric signal in close proximity, a certain amount of electromagnetic interface occurs (EMI).
- This type of interference is called crosstalk. Twisting the copper wire reduces crosstalk. Twisted pair comes in two varieties.
- 1) Unshielded Twisted Pair (UTP)
  2) Shielded Twisted Pair (STP)
- Unshielded Twisted Pair (UTP):
- UTP is a set of twisted pairs of cable within a plastic sheath. UTP is ordinary telephone wire. This is the least expensive of all the transmission media commonly used for LAN, and is easy to work with and simple to install. UTP is subject to external electromagnetic interference. Fig1 shows Unshielded four pair cable.

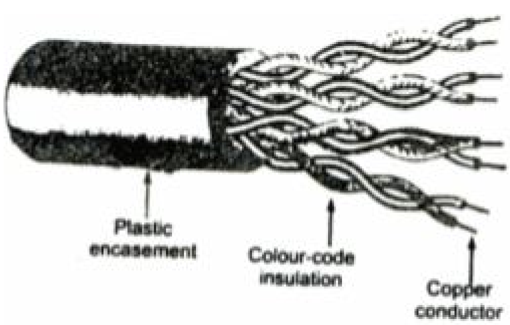


Fig1: Unshielded four pair cable

Shielded Twisted Pair (STP) :

- STP offers a protective sheathing around the copper wire. STP provides better performance at lower data rates. They are not commonly used in networks. Installation is easy. Special connectors are required for installation. Cost is moderately expensive. Distance is limited to 100 M for 500 Mbps. STP will still suffer from outside interference but not as much UTP. Fig. 2 shows the STP cable.

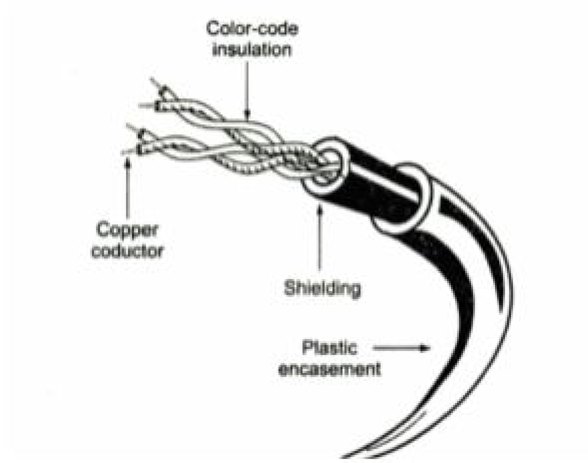


Fig2: Shielded Twisted Pair (STP) Cable

2) Coaxial Cable:

- It is made up of two conductors that share the common axis. It consists of a hollow outer cylindrical conductor that surrounds a single inner wire conductor.
- Coaxial cable is used to transmit both analog and digital signals. Data transfer rate of co-axial cable is in between TP and fiber optic cable. Coaxial cable must be grounded and terminated.
- Coaxial cable transmits information in two modes: Baseband mode or Broadband mode.
- In baseband mode, the cable bandwidth is devoted to a single stream of data. The high bandwidth capability allows high data rates over a cable.
- Mostly used in local area networks. In LAN, only one data stream is present at any time. In Broadband the bandwidth is divided into ranges.
- Each range typically carries separate coded information, which allows the transmission of multiple data streams over the same cable simultaneously. Cable television is an example of multiple signals.

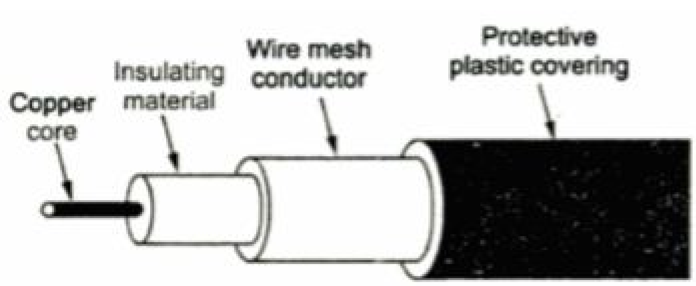


Fig3: Coaxial Cable

3) Fiber Optic Cable (FOC):

- A fiber optic cable is a light pipe which is used to carry a light beam from one place to another. Light is an electromagnetic signal and can be modulated by information.

- Since the frequency of light is extremely high hence it can accommodate wide bandwidths of information, also higher data rate can be achieved with excellent reliability.
- The modulated light travel along the fiber and at the far end, are converted to an electrical signal by means of a photo electric cell. Thus the original input signal is recovered at the far end.
- FOC transmits light signals rather than electrical signals. Each fiber has a inner core of glass or plastic that conducts light. The inner core is surrounded by cladding, a layer of glass that reflects the light back into core.
- A cable may contain a single fiber, but often fibers are bundled together in the centre of the cable. FOC may be multimode or signal mode.
- Multimode fibers use multiple light paths whereas signal mode fibers allow a single light path and are typically used with laser signaling. It is more expansive and greater bandwidth.

Wireless Transmission:

1) Radio Transmission:

- Radio waves have frequencies between 10 kilohertz (kHz) and 1 gigahertz (GHz). Radio waves include the following types:
- a) Short wave b) Very high frequency (VHF) television and FM radio. c) Ultra high frequency (UHF) radio and television.

2) Microwave Transmission:

- Above 100 MHz, the waves travel in straight lines and can therefore be narrowly focused. Concentrating all the energy into a small beam using a parabolic antenna (like the satellite TV dish) gives a much higher signal to noise ratio, but the transmitting and receiving antennas must be accurately aligned with each other.
- In its simplest form the microwave link can be one hop, consisting of one pair of antennas spaced as little as one or two kilometers apart or can be a backbone, including multiple hops, spanning several thousand kilometers.
- A single hop is typically 30 to 60 km in relatively flat regions for frequencies in the 2 to 8 GHz bands. When antennas are placed between mountain peaks, a very long hop length can be achieved.

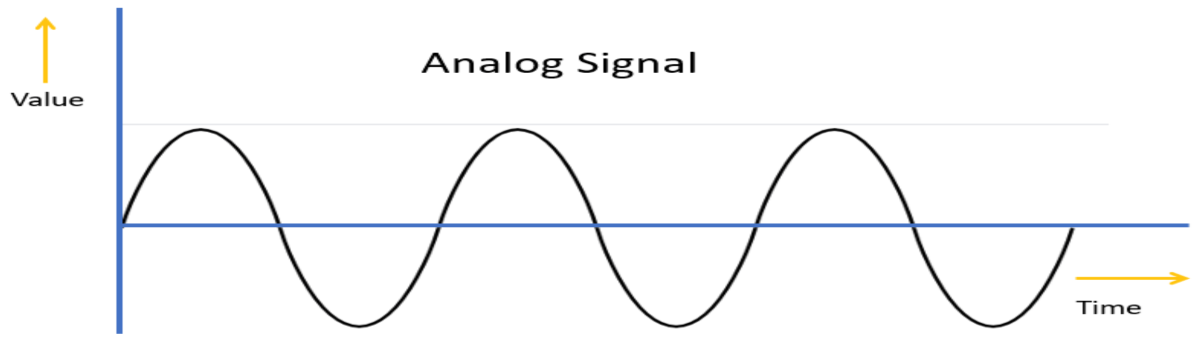
3) Infrared Light Wave Transmission:

- Unguided infrared light (wave) is widely used for short range communication. The remote control used in TV, VCR and stereos all use infrared communication.
- They are relatively directional, cheap, and easy to build, but have a major drawback: they do not pass-through solid objects. On the other hand, the fact that infrared waves do not pass-through solid walls well is also a plus.
- It means that an infrared system in one room of a building will not interfere with a similar system in adjacent rooms. Security of infrared system against eavesdropping is better than that of radio system precisely for this reason; infrared light is suitable for indoor wireless LAN.

What is Signal?

- A signal is an electromagnetic or electrical current that is used for carrying data from one system or network to another.
- In electronics and telecommunications, it refers to any time-varying voltage that is an electromagnetic wave which carries information.
- A signal can also be defined as an observable change in quality such as quantity. There are two main types of signals: Analog signal and Digital signal.

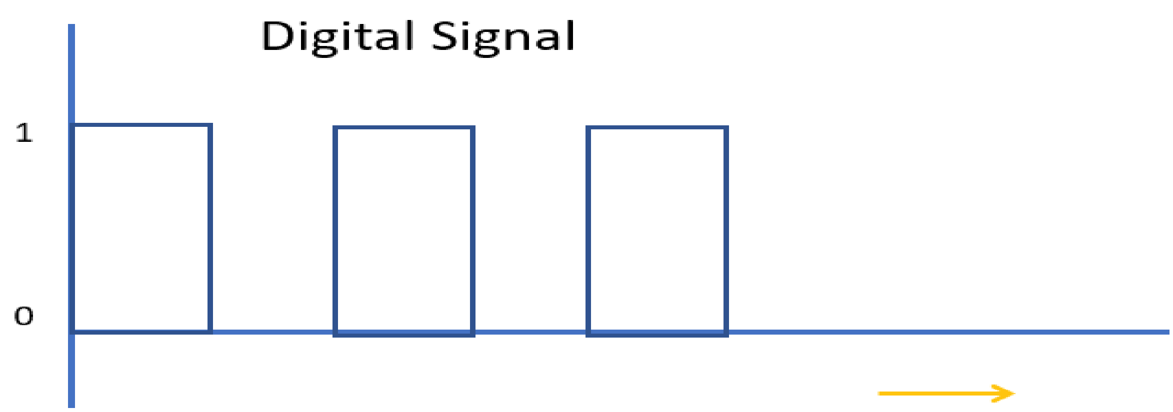
What is an Analog Signal?



Analog Signal

- Analog signal is a continuous signal in which one time-varying quantity represents another time-based variable.
- These kind of signals works with physical values and natural phenomena such as earthquake, frequency, volcano, speed of wind, weight, lighting, etc.

What is a Digital Signal?



- A digital signal is a signal that is used to represent data as a sequence of separate values at any point in time.
- It can only take on one of a fixed number of values.
- This type of signal represents a real number within a constant range of values.

KEY DIFFERENCES:

- An analog signal is a **continuous signal** whereas Digital signals **are time separated signals**.
- Analog signal is denoted by sine waves while It is denoted by **square waves**.
- Analog signal uses a continuous range of values that help you to **represent information on the other hand digital signal uses discrete 0 and 1 to represent information**.
- Comparing Digital vs Analog signals, The analog signal **bandwidth is low** while the bandwidth of the digital signal is high.
- Analog instruments give considerable **observational errors** whereas Digital instruments never cause any kind of observational errors.
- Analog hardware never offers flexible implementation, but Digital hardware offers flexibility in implementation.
- Comparing Analog vs Digital signal, Analog signals are suited for audio and video transmission while Digital signals are suited for Computing and digital electronics.

Analog	Digital
✓ An analog signal is a continuous signal that represents physical measurements.	✓ Digital signals are time separated signals which are generated using digital modulation.
✓ It is denoted by sine waves	✓ It is denoted by square waves
✓ It uses a continuous range of values that help you to represent information.	✓ Digital signal uses discrete 0 and 1 to represent information.
✓ Temperature sensors, FM radio signals, Photocells, Light sensor, Resistive touch screen are examples of Analog signals.	✓ Computers, CDs, DVDs are some examples of Digital signal.
✓ The analog signal bandwidth is low	✓ The digital signal bandwidth is high.
✓ Analog signals are deteriorated by noise throughout transmission as well as write/read cycle.	✓ Relatively a noise-immune system without deterioration during the transmission process and write/read cycle.
✓ Analog hardware never offers flexible implementation.	✓ Digital hardware offers flexibility in implementation.
✓ It is suited for audio and video transmission.	✓ It is suited for Computing and digital electronics.
✓ Processing can be done in real-time and consumes lesser bandwidth compared to a digital signal.	✓ It never gives a guarantee that digital signal processing can be performed in real time.
✓ Analog instruments usually have s scale which is cramped at lower end and gives considerable observational errors.	✓ Digital instruments never cause any kind of observational errors.
✓ Analog signal doesn’t offer any fixed range.	✓ Digital signal has a finite number, i.e., 0 and 1.

Characteristics OF Analog Signal

- Minimum and maximum values which is either positive or negative.
- It can be either periodic or non-periodic.
- Analog Signal works on continuous data.
- The accuracy of the analog signal is not high when compared to the digital signal.
- It helps you to measure natural or physical values.
- Analog signal output form is like Curve, Line, or Graph, so it may not be meaningful to all.

Characteristics of Digital Signals

- Here, are essential characteristics of Digital signals
- Digital signal are continuous signals
- This type of electronic l signals can be processed and transmitted better compared to analog signal.
- Digital signals are versatile, so it is widely used.
- The accuracy of the digital signal is better than that of the analog signal.

Advantages of Analog Signals

- Easier in processing
- Best suited for audio and video transmission.
- It has a low cost and is portable.
- It has a much higher density so that it can present more refined information.
- Not necessary to buy a new graphics board.
- Uses less bandwidth than digital sounds
- Provide more accurate representation of a sound
- It is the natural form of a sound.

Advantages of Digital Signals

- Digital data can be easily compressed.
- Any information in the digital form can be encrypted.
- Equipment that uses digital signals is more common and less expensive.
- Digital signal makes running instruments free from observation errors like parallax and approximation errors.
- A lot of editing tools are available
- You can edit the sound without altering the original copy
- Easy to transmit the data over networks

Disadvantages of Analog Signals

- Here are cons/drawback of Analog Signals:
- Analog tends to have a lower quality signal than digital.
- The cables are sensitive to external influences.
- The cost of the Analog wire is high and not easily portable.
- Low availability of models with digital interfaces.
- Recording analog sound on tape is quite expensive if the tape is damaged

- It offers limitations in editing
- Tape is becoming hard to find
- It is quite difficult to synchronize analog sound
- Quality is easily lost
- Data can become corrupted
- Plenty of recording devices and formats which can become confusing to store a digital signal
- Digital sounds can cut an analog sound wave which means that you can't get a perfect reproduction of a sound
- Offers poor multi-user interfaces

Disadvantages of Digital Signals

- Sampling may cause loss of information.
- A/D and D/A demands mixed-signal hardware
- Processor speed is limited
- Develop quantization and round-off errors
- It requires greater bandwidth
- Systems and processing is more complex.

Data Encoding

- Encoding is the process of converting the data or a given sequence of characters, symbols, alphabets etc., into a specified format, for the secured transmission of data.
- Decoding is the reverse process of encoding which is to extract the information from the converted format.

Data Encoding

- Encoding is the process of using various patterns of voltage or current levels to represent 1s and 0s of the digital signals on the transmission link.
- The common types of line encoding are Unipolar, Polar, Bipolar, and Manchester.

Encoding Techniques

The data encoding technique is divided into the following types, depending upon the type of data conversion.

- **Analog data to Analog signals** − The modulation techniques such as Amplitude Modulation, Frequency Modulation and Phase Modulation of analog signals, fall under this category.
- **Analog data to Digital signals** − This process can be termed as digitization, which is done by Pulse Code Modulation PCMPCM.
- 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.

- **Digital data to Analog signals** − The modulation techniques such as Amplitude Shift Keying ASKASK, Frequency Shift Keying FSK, Phase Shift Keying PSK, etc., fall under this category.

Digital data to Digital signals –
There are several ways to map digital data to digital signals.
Non Return to Zero NRZ

- NRZ Codes has 1 for High voltage level and 0 for Low voltage level. The main behavior of NRZ codes is that the voltage level remains constant during bit interval.
- The end or start of a bit will not be indicated and it will maintain the same voltage state, if the value of the previous bit and the value of the present bit are same.

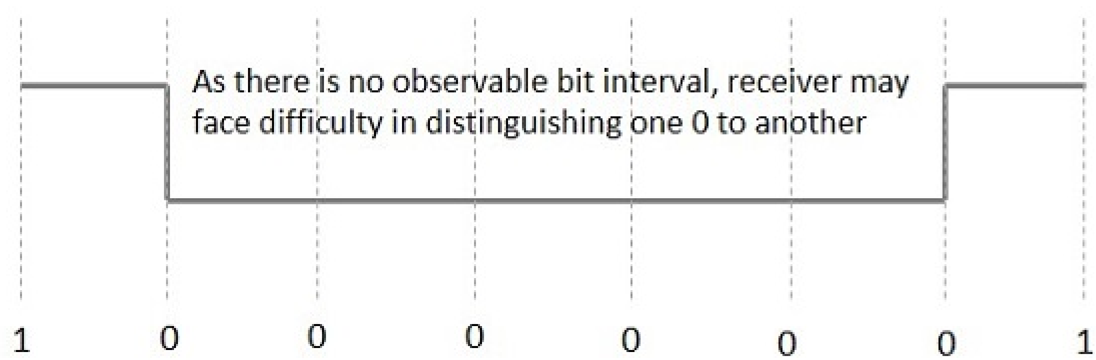
Line Coding

A line code is the code used for data transmission of a digital signal over a transmission line. This process of coding is chosen so as to avoid overlap and distortion of signal such as inter-symbol interference.

Properties of Line Coding

- As the coding is done to make more bits transmit on a single signal, the bandwidth used is much reduced.
- For a given bandwidth, the power is efficiently used.
- The probability of error is much reduced.
- Error detection is done and the bipolar too has a correction capability.
- Power density is much favourable.
- The timing content is adequate.
- Long strings of 1s and 0s is avoided to maintain transparency.

The following figure explains the concept of NRZ coding.



NRZ Coding

If the above example is considered, as there is a long sequence of constant voltage level and the clock synchronization may be lost due to the absence of bit interval, it becomes difficult for the receiver to differentiate between 0 and 1.

There are two variations in NRZ namely −

NRZ - L
NRZ–LEVEL

- There is a change in the polarity of the signal, only when the incoming signal changes from 1 to 0 or from 0 to 1.
- It is the same as NRZ, however, the first bit of the input signal should have a change of polarity.

NRZ - I
NRZ–INVERTED

- If a 1 occurs at the incoming signal, then there occurs a transition at the beginning of the bit interval. For a 0 at the incoming signal, there is no transition at the beginning of the bit interval.
- NRZ codes has a disadvantage that the synchronization of the transmitter clock with the receiver clock gets completely disturbed, when there is a string of 1s and 0s. Hence, a separate clock line needs to be provided.

Bi-phase Encoding

- The signal level is checked twice for every bit time, both initially and in the middle.
- Hence, the clock rate is double the data transfer rate and thus the modulation rate is also doubled. The clock is taken from the signal itself. The bandwidth required for this coding is greater.
- There are two types of Bi-phase Encoding.

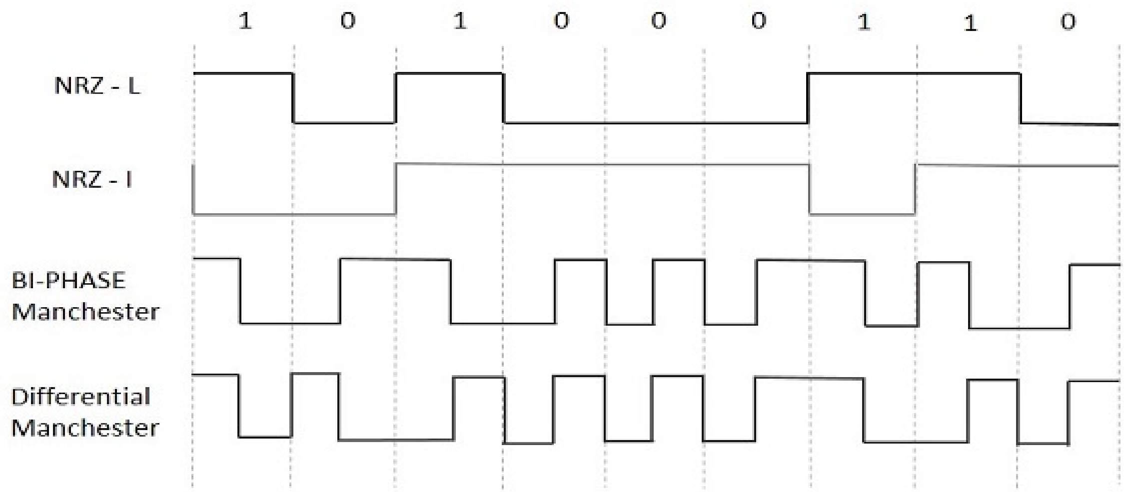
- Bi-phase Manchester
- Differential Manchester

Bi-phase Manchester

- In this type of coding, the transition is done at the middle of the bit-interval.
- The transition for the resultant pulse is from High to Low in the middle of the interval, for the input bit 1.
- While the transition is from Low to High for the input bit 0.

Differential Manchester

- In this type of coding, there always occurs a transition in the middle of the bit interval.
- If there occurs a transition at the beginning of the bit interval, then the input bit is 0. If no transition occurs at the beginning of the bit interval, then the input bit is 1.



Digital to Analog Signals:

- Digital Modulation provides more information capacity, high data security, quicker system availability with great quality communication.
- Hence, digital modulation techniques have a greater demand, for their capacity to convey larger amounts of data than analog modulation techniques.
- There are many types of digital modulation techniques and also their combinations, depending upon the need.

ASK – Amplitude Shift Keying

The amplitude of the resultant output depends upon the input data whether it should be a zero level or a variation of positive and negative, depending upon the carrier frequency.

FSK – Frequency Shift Keying

The frequency of the output signal will be either high or low, depending upon the input data applied.

PSK – Phase Shift Keying

The phase of the output signal gets shifted depending upon the input. These are mainly of two types, namely Binary Phase Shift Keying BPSK and Quadrature Phase Shift Keying QPSK, according to the number of phase shifts. The other one is Differential Phase Shift Keying DPSK which changes the phase according to the previous value.

M-ary Encoding

M-ary Encoding techniques are the methods where more than two bits are made to transmit simultaneously on a single signal. This helps in the reduction of bandwidth.

The types of M-ary techniques are −

- M-ary ASK
- M-ary FSK
- M-ary PSK

Analog to Digital Signals

Digital Signal: A digital signal is a signal that represents data as a sequence of discrete values; at any given time it can only take on one of a finite number of values.
Analog Signal: An analog signal is any continuous signal for which the time varying feature of the signal is a representation of some other time varying quantity i.e., analogous to another time varying signal.
The following techniques can be used for Analog to Digital Conversion:

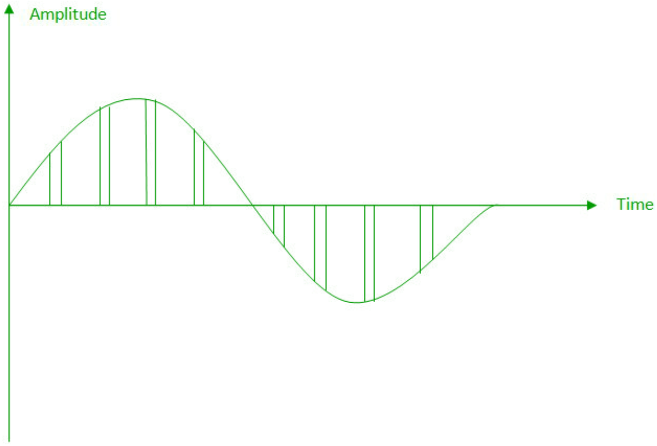
a. PULSE CODE MODULATION:

The most common technique to change an analog signal to digital data is called pulse code modulation (PCM). A PCM encoder has the following three processes:

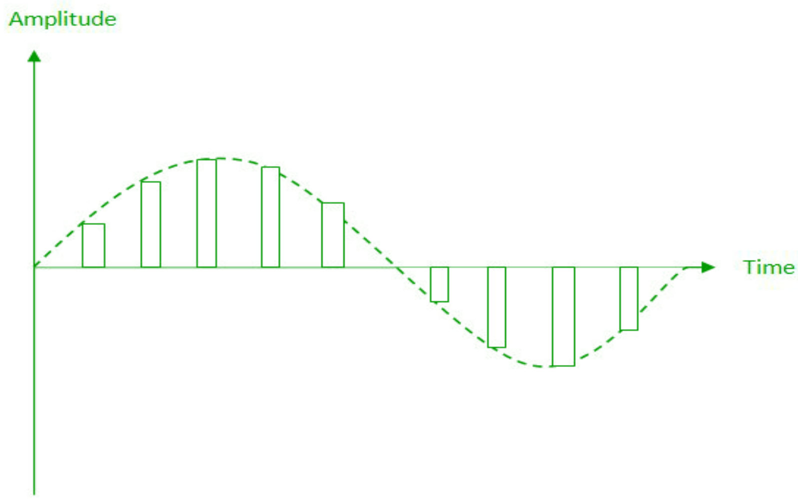
1. Sampling
2. Quantization
3. Encoding

1. **Sampling –** The first step in PCM is sampling. Sampling is a process of measuring the amplitude of a continuous-time signal at discrete instants, converting the continuous signal into a discrete signal. There are three sampling methods:
   (i) **Ideal Sampling**: In ideal Sampling also known as Instantaneous sampling pulses from the analog signal are sampled. This is an ideal sampling method and cannot be

   easily implemented.
   (ii) **Natural Sampling**: Natural Sampling is a practical method of sampling in which pulse have finite width equal to T.The result is a sequence of samples that retain the shape of the analog signal.



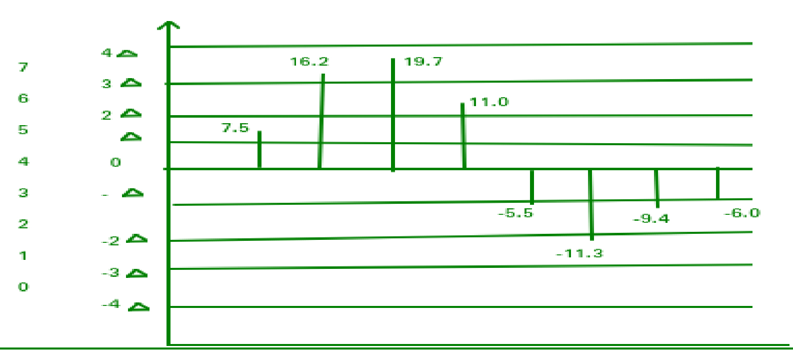
   (iii) **Flat top sampling**: In comparison to natural sampling flat top sampling can be easily obtained. In this sampling technique, the top of the samples remains constant by using a circuit. This is the most common sampling method used.



Nyquist Theorem:
One important consideration is the sampling rate or frequency. According to the Nyquist theorem, the sampling rate must be at least 2 times the highest frequency contained in the signal. It is also known as the minimum sampling rate and given by:
Fs =2*fh

2. **Quantization –**
   The result of sampling is a series of pulses with amplitude values between the maximum and minimum amplitudes of the signal. The set of amplitudes can be infinite with non-integral values between two limits.
   The following are the steps in Quantization:

   1. We assume that the signal has amplitudes between Vmax and Vmin
   2. We divide it into L zones each of height d where,
      d= (Vmax- Vmin)/ L



Normalised PAM value :	1.50	3.24	3.94	2.20	-1.10	2.26	-1.88	-1.20
Quantized Value :	1.50	3.50	3.50	2.50	-1.50	-2.50	-1.50	-1.50
Normalized Error :	0	0.26	-0.44	0.30	-0.40	-0.24	0.38	-0.30
Quantization Code :	5	7	7	6	2	1	2	2
Encoded Words :	101	111	111	110	010	001	010	010

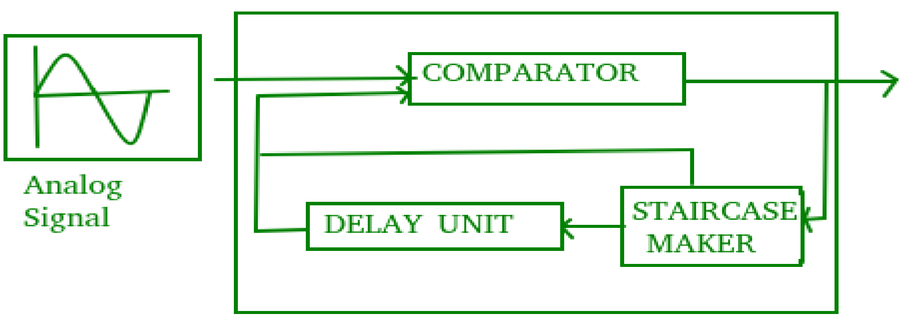
3. The value at the top of each sample in the graph shows the actual amplitude.
4. The normalized pulse amplitude modulation(PAM) value is calculated using the formula amplitude/d.
5. After this we calculate the quantized value which the process selects from the middle of each zone.

6. The Quantized error is given by the difference between quantised value and normalised PAM value.
7. The Quantization code for each sample based on quantization levels at the left of the graph.

3. **Encoding –**
   The digitization of the analog signal is done by the encoder. After each sample is quantized and the number of bits per sample is decided, each sample can be changed to an n bit code.
   Encoding also minimizes the bandwidth used.

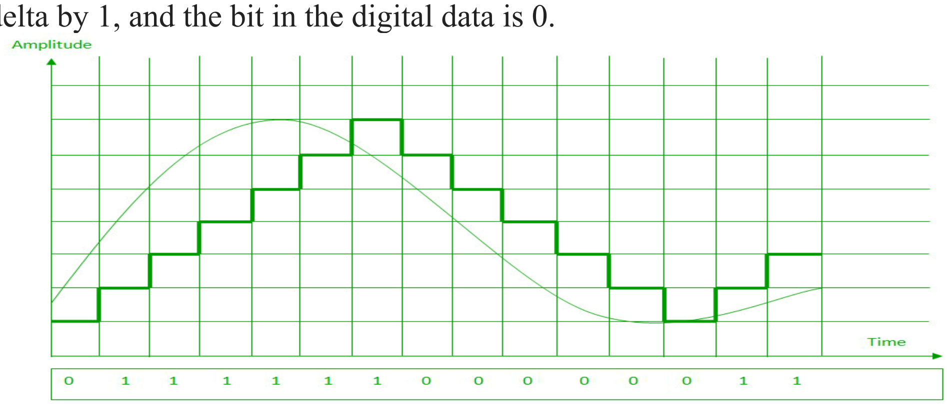
b. DELTA MODULATION :

- Since PCM is a very complex technique, other techniques have been developed to reduce the complexity of PCM. The simplest is delta Modulation.
- Delta Modulation finds the change from the previous value.
- Modulator – The modulator is used at the sender site to create a stream of bits from an analog signal. The process records a small positive change called delta. If the delta is positive, the process records a 1 else the process records a 0. The modulator builds a second signal that resembles a staircase. The input signal is then compared with this gradually made staircase signal.



We have the following rules for output:

1. If the input analog signal is higher than the last value of the staircase signal, increase delta by 1, and the bit in the digital data is 1.
2. If the input analog signal is lower than the last value of the staircase signal, decrease delta by 1, and the bit in the digital data is 0.



C. ADAPTIVE DELTA MODULATION:

- ✓ The performance of a delta modulator can be improved significantly by making the step size of the modulator assume a time-varying form.
- ✓ A larger step-size is needed where the message has a steep slope of modulating signal and a smaller step-size is needed where the message has a small slope.
- ✓ The size is adapted according to the level of the input signal. This method is known as adaptive delta modulation (ADM).