PHYSICAL LAYER

DATA & SIGNALS

Data can be Analog or Digital.

1. Analog data refers to information that is continuous; ex. sounds made by a human voice
2. Digital data refers to information that has discrete states. Digital data take on discrete values.
3. For example, data are stored in computer memory in the form of Os and 1s

Signals can be of two types:

1. **Analog Signal**: They have infinite values in a range.
2. **Digital Signal**: They have limited number of defined values

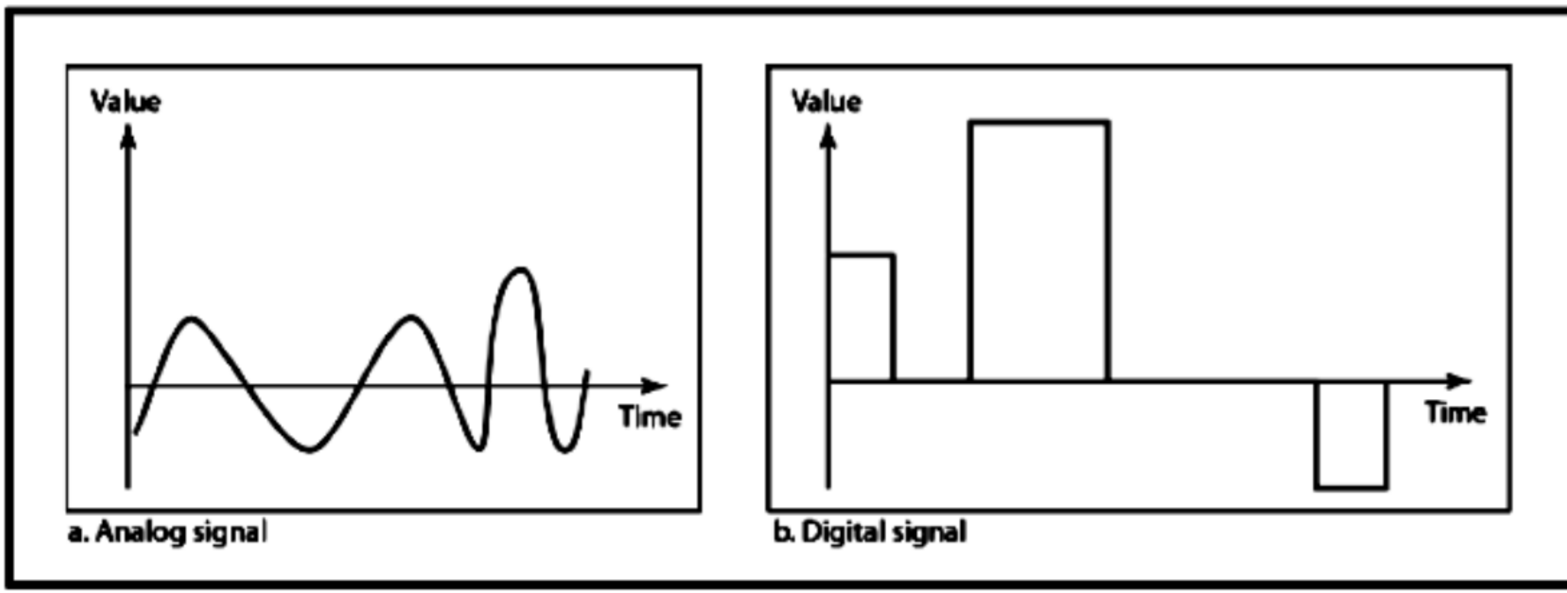


Figure: a. Analog Signal b. Digital Signal*

- Signals which repeat itself after a fixed time period are called Periodic Signals.

- Signals which do not repeat itself after a fixed time period are called Non-Periodic Signals.

- In data communications, we commonly use periodic analog signals and non-periodic digital signals.

ANALOG SIGNAL

- An analog signal has infinitely many levels of intensity over a period of time.

- As the wave moves from value A to value B, it passes through and includes an infinite number of values along its path.

- A simple analog signal is a sine wave that cannot be further decomposed into simpler signals.

- A sine wave is characterized by three parameters:

1. Peak Amplitude
2. Frequency
3. Phase

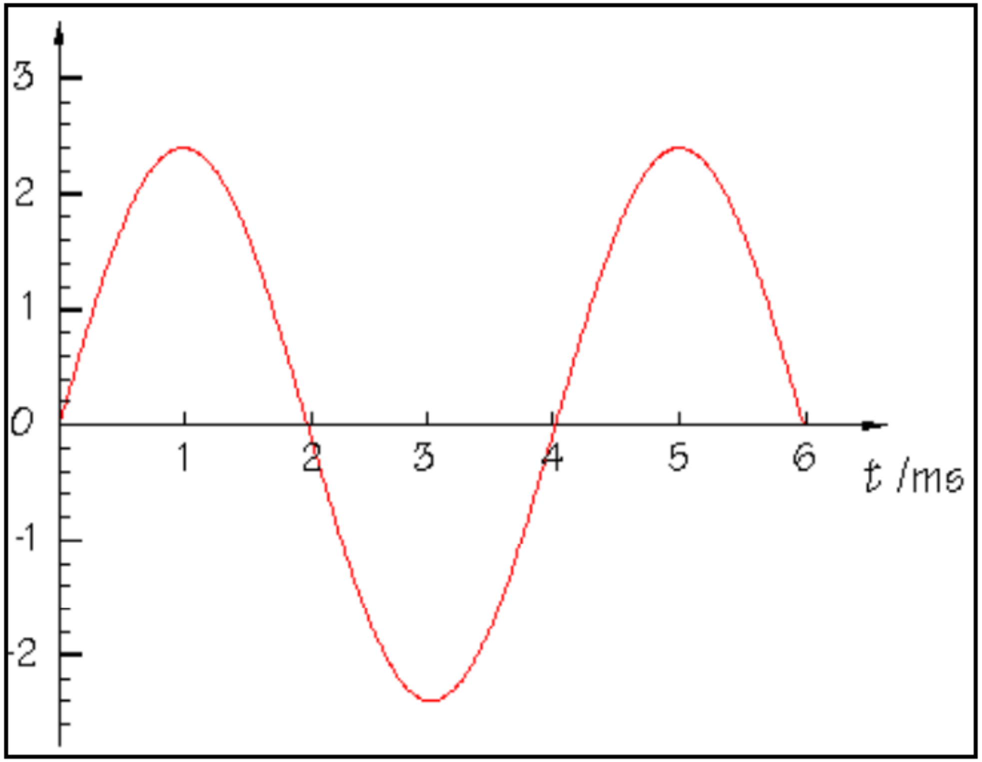


Fig. Sine wave

Characteristics of an Analog Signal

Peak Amplitude

- The amplitude of a signal is the absolute value of its intensity at time t

- The peak amplitude of a signal is the absolute value of the highest intensity.

- The amplitude of a signal is proportional to the energy carried by the signal

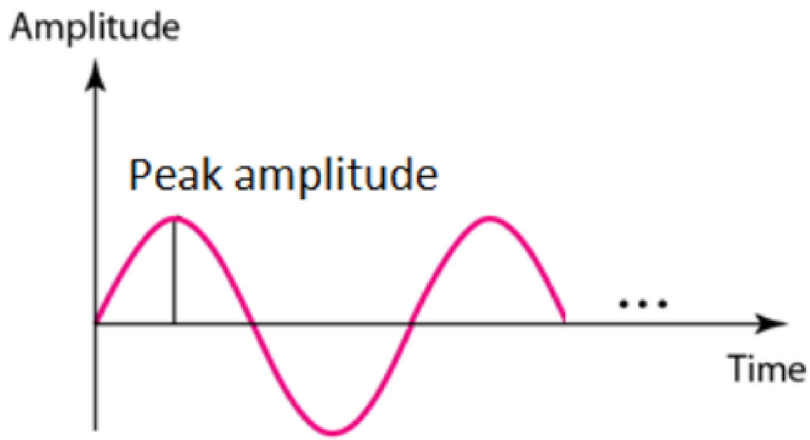
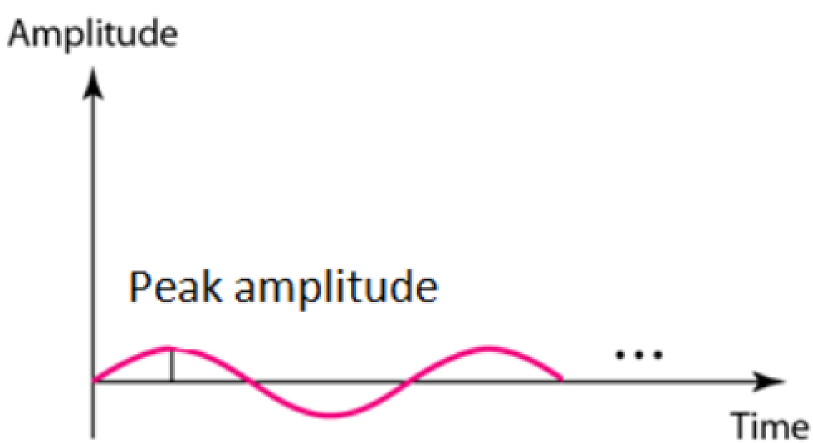
	Fig. Signal with high peak amplitude
	Fig. Signal with low peak amplitude

Fig. Amplitude of a sine wave

Frequency

- Frequency refers to the number of cycles completed by the wave in one second.
- Period refers to the time taken by the wave to complete one second.

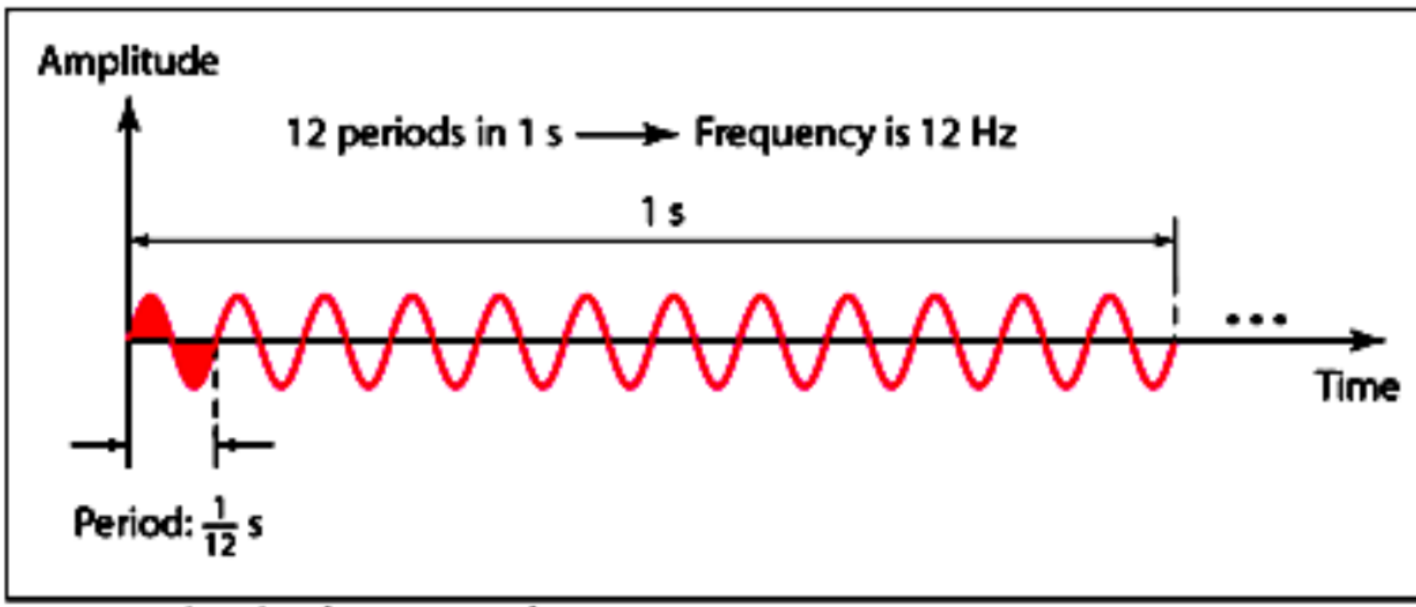


Fig: Frequency & Period of a sine wave

Phase

- Phase describes the position of the waveform with respect to time.

- Phase indicates the forward or backward shift of the waveform from the axis

- It is measured in degrees or radian

- The figure shows the sine waves with same amplitude and frequency but different phases

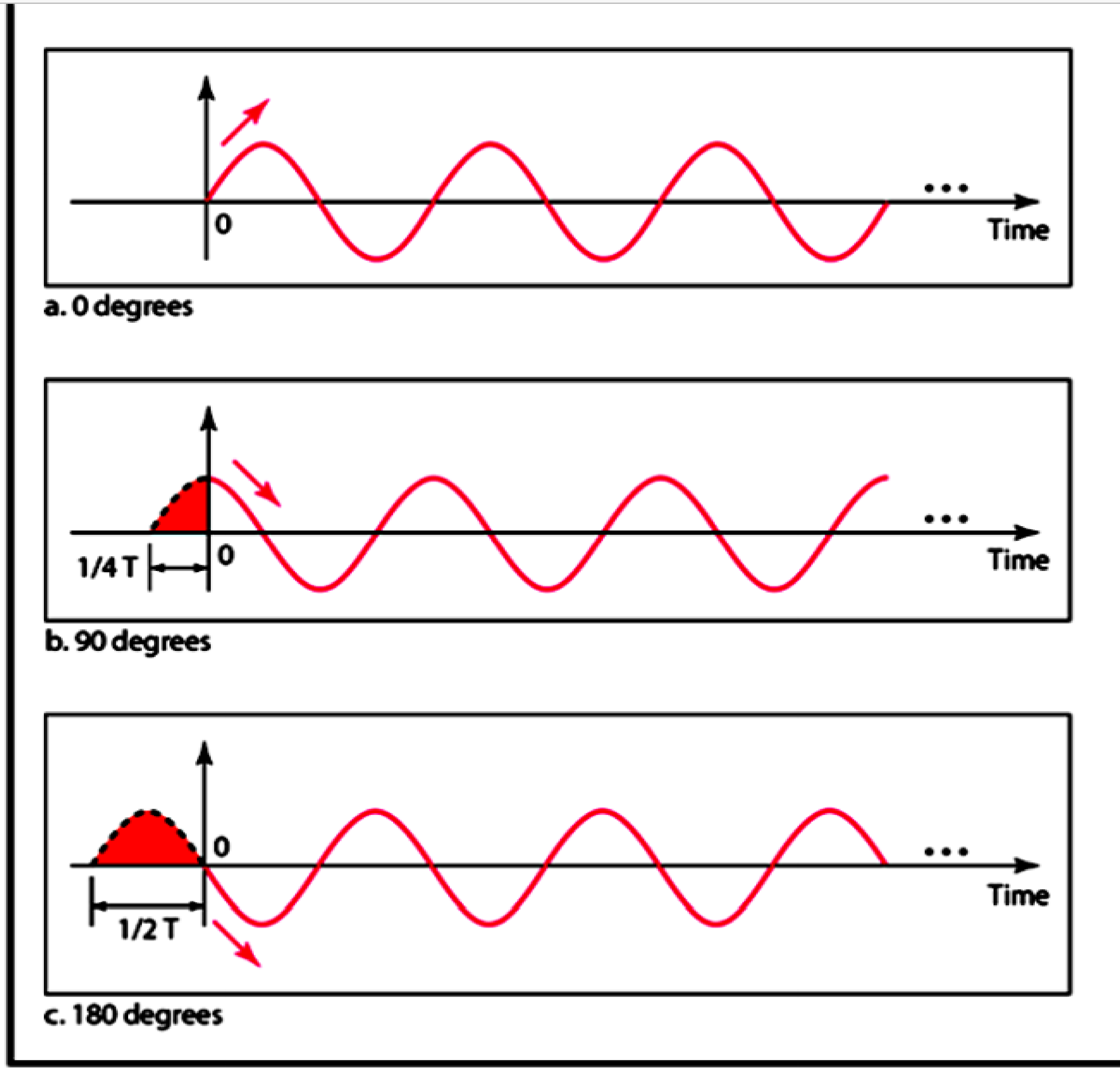


Fig: Phase of a sine wave*

Relation between Frequency & Period

- Frequency & Period are inverse of each other.

- It is indicated by the following formula:

$$\boxed{\begin{array}{c} T = 1/f \\ \text{Or} \\ f = 1/T \end{array}}$$

Example1. A wave has a frequency of 100hz. Its period(T) is given by

$$T = 1/F = 1/100 = 0.01 \text{ sec}$$

Wavelength

- The wavelength of a signal refers to the relationship between frequency (or period) and propagation speed of the wave through a medium.
- The wavelength is the distance a signal travels in one period.
- It is given by

$$\text{Wavelength} = \text{Propagation Speed} \times \text{Period}$$

OR

$$\text{Wavelength} = \text{Propagation Speed} \times \frac{1}{\text{Frequency}}$$

- It is represented by the symbol : λ (pronounced as lamda)
- It is measured in micrometers It varies from one medium to another.

Time Domain and Frequency domain representation of signals

- A sine wave can be represented either in the time domain or frequency domain.

- The **time-domain** plot shows changes in signal amplitude with respect to time.

- It indicates time and amplitude relation of a signal.

- The **frequency-domain** plot shows signal frequency and peak amplitude.

- The figure below show time and frequency domain plots of three sine waves

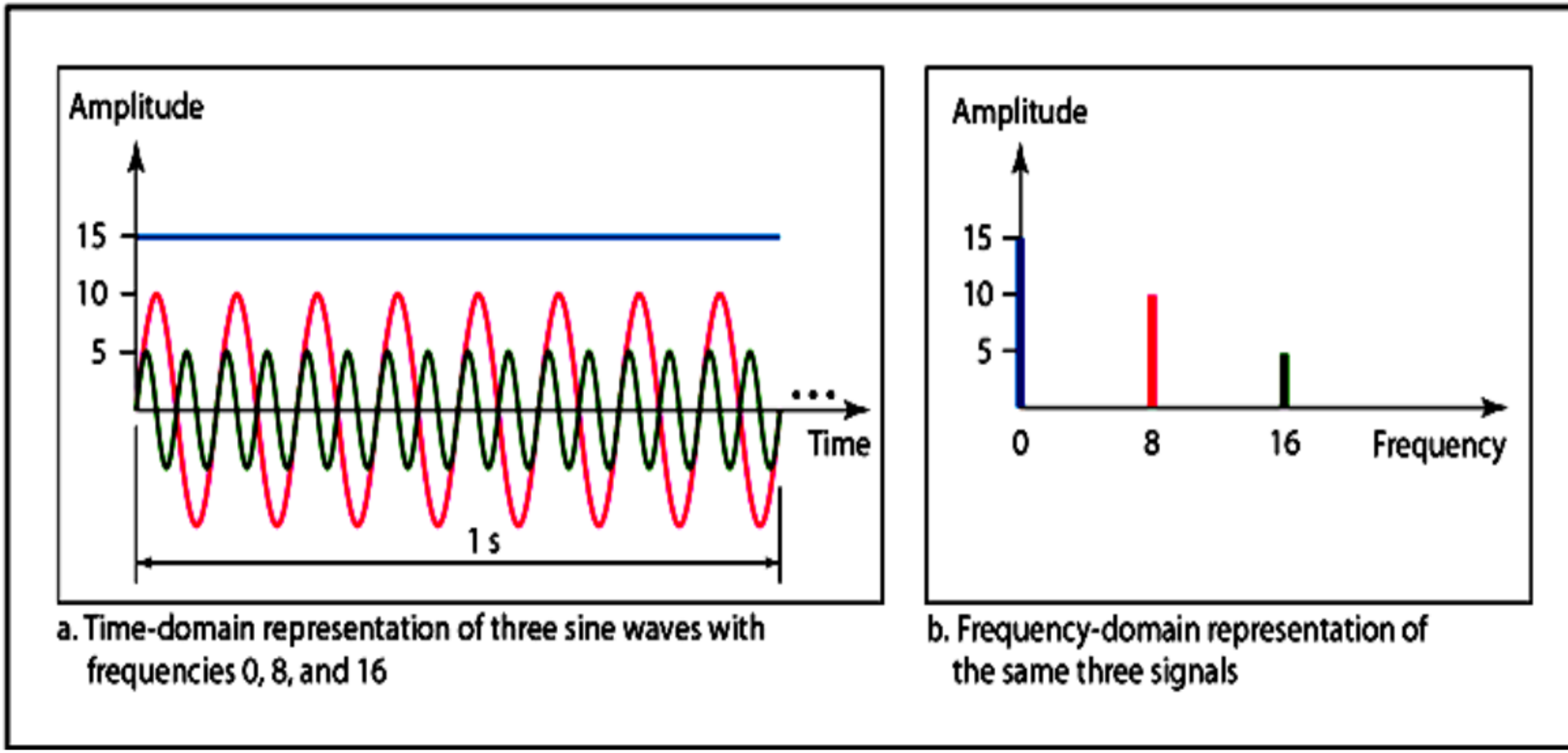


Fig: Time domain and frequency domain plots of three sine waves*

Composite Signal

- A composite signal is a combination of two or more simple sine waves with different frequency, phase and amplitude.
- If the composite signal is periodic, the decomposition gives a series of signals with discrete frequencies; if the composite signal is non-periodic, the decomposition gives a combination of sine waves with continuous frequencies.
- For data communication a simple sine wave is not useful, what is used is a composite signal which is a combination of many simple sine waves.
- Composite signal is a combination of simple sine waves with different amplitudes and frequencies and phases.
- Composite signals can be periodic or non periodic. A periodic composite signal can be decomposed into a series of signals with discrete frequencies.
- A non-periodic signal when decomposed gives a combination of sine waves with continuous frequencies.

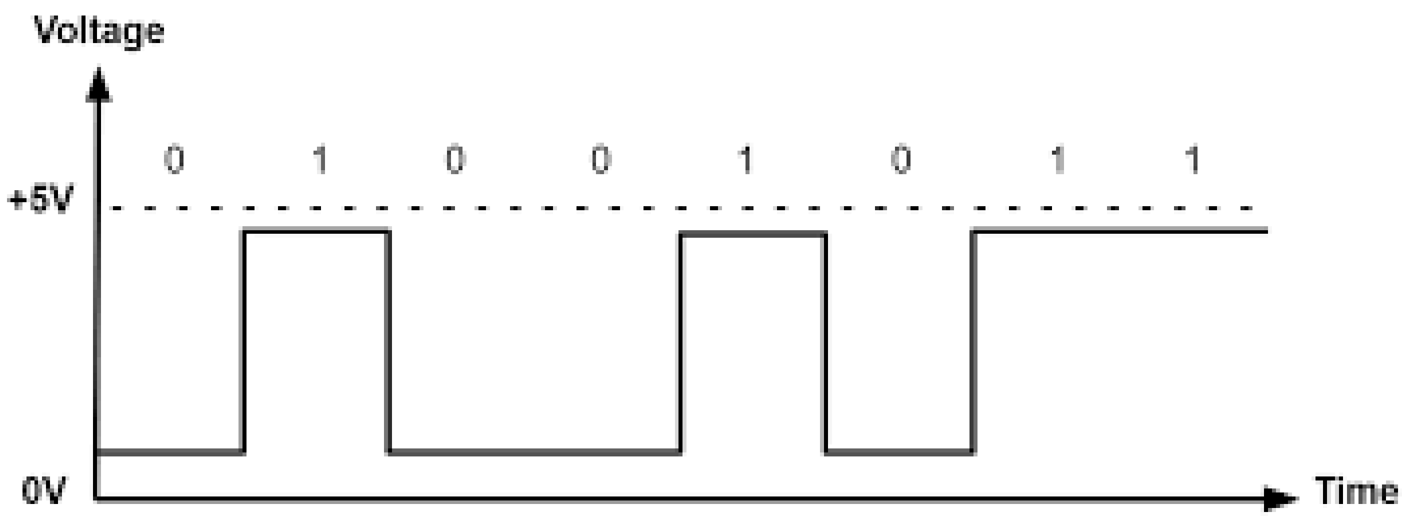
Digital Signal

- Information can also be explained in the form of a digital signal.

- A digital signal can be explained with the help of following points:

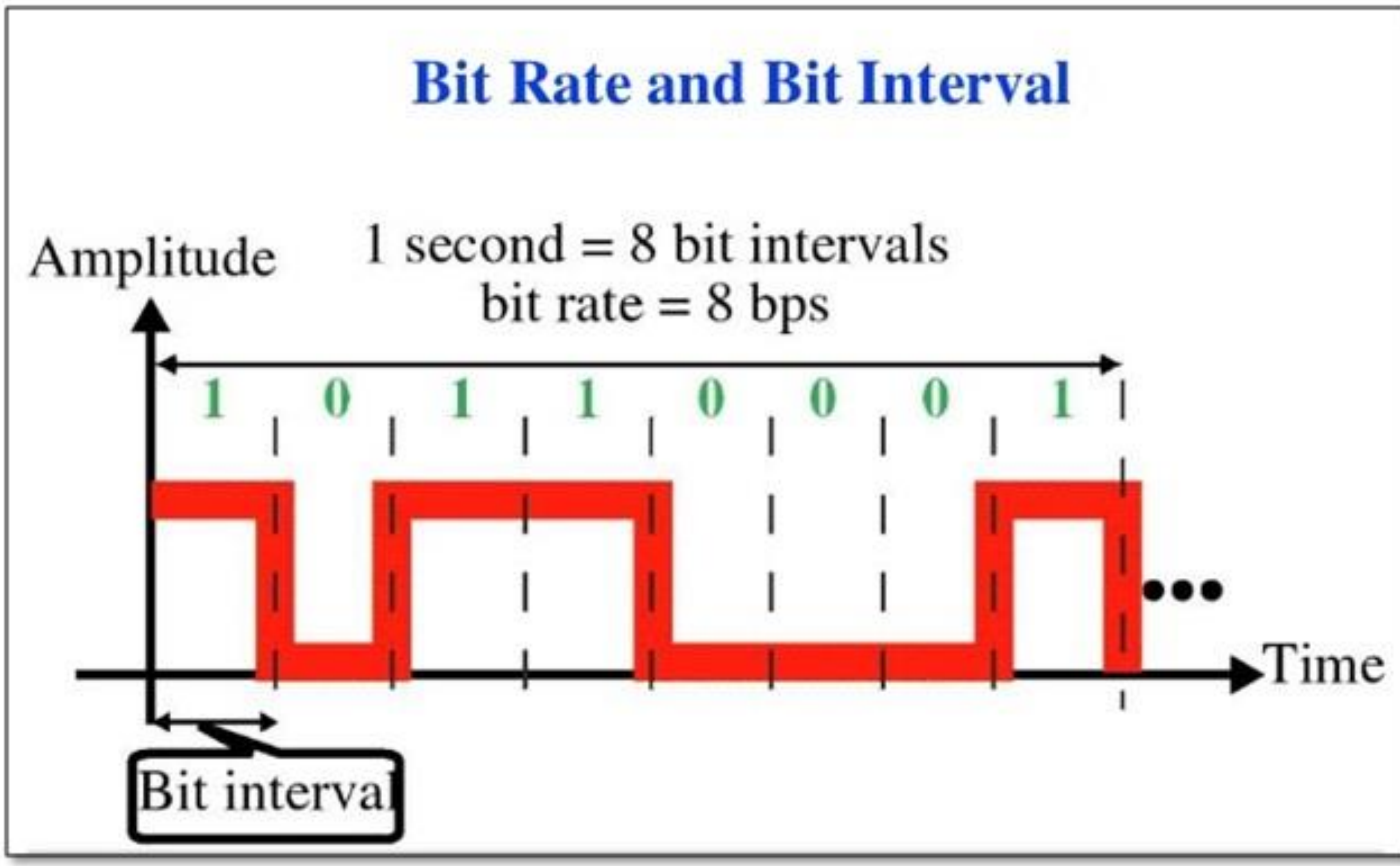
➢ Definition:- A digital is a signal that has discrete values.

➢ The signal will have value that is not continuous.



BIT LENGTH or Bit Interval (Tb)

- It is the time required to send one bit.
- It is measured in seconds.



BIT RATE

- It is the number of bits transmitted in one second.

- It is expressed as bits per second (bps).

- Relation between bit rate and bit interval can be as follows

  Bit rate = 1 / Bit interval

- Bit rate is also called as signalling rate and is defined as the number of bits which can be transmitted in a second.

- With increase in bit rate the bandwidth of transmission medium must be increased, in order to ensure that the signal is received without any distortion

Baud Rate

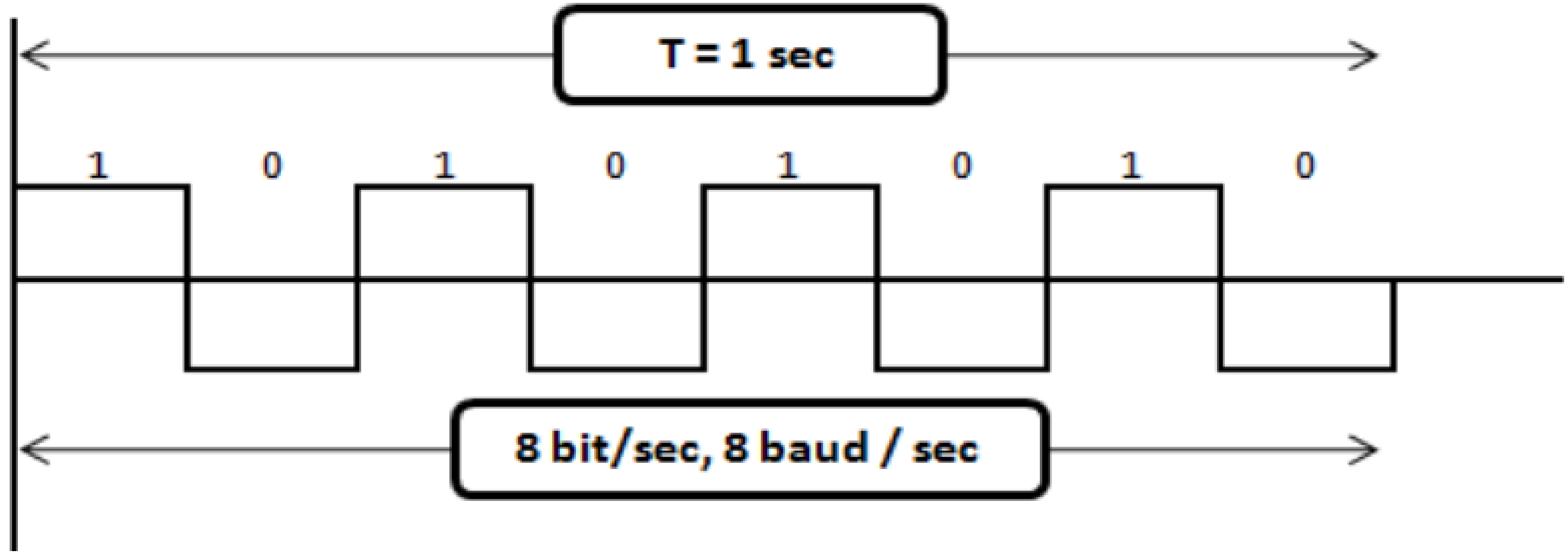
- It is the rate of Signal Speed, i.e the rate at which the signal changes.

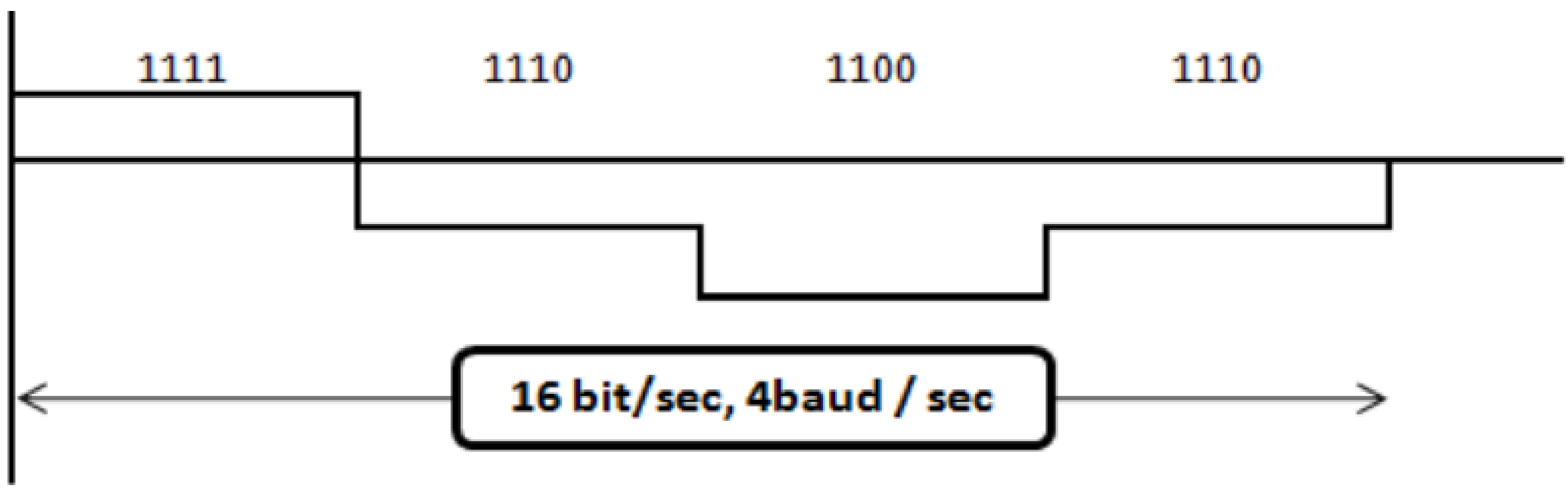
- A digital signal with two levels '0' & '1' will have the same baud rate and bit rate.

- The diagram below shows three signal of period (T) 1 second

a) Signal with a bit rate of 8 bits/ sec and baud rate of 8 baud/sec

b) Signal with a bit rate of 16 bits/ sec and baud rate of 4 baud/sec


T = 1 sec
1
0
1
0
1
0
1
0
8 bit/sec, 8 baud / sec


1111
1110
1100
1110
16 bit/sec, 4baud / sec

TYPES OF CHANNELS

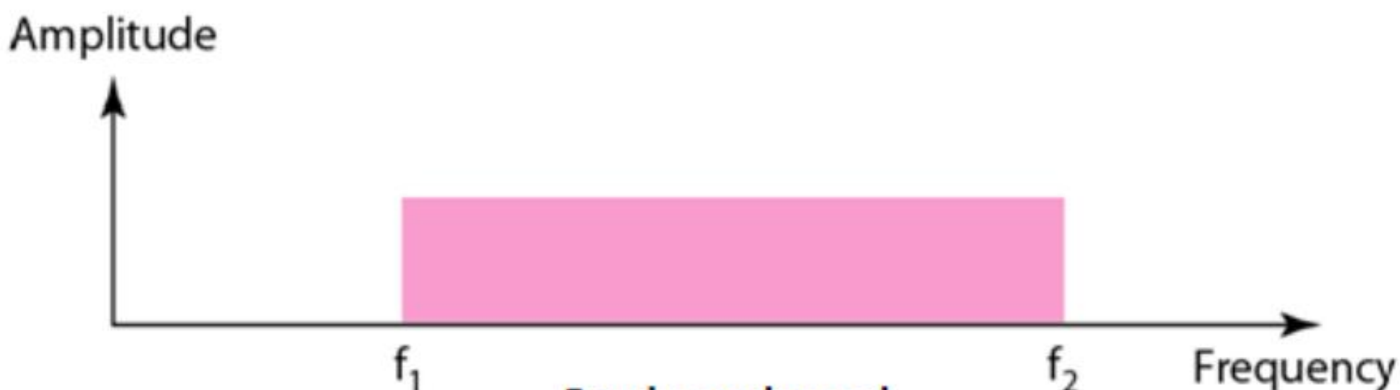
- Each composite signal has a lowest possible(minimum) frequency and a highest possible (maximum) frequency.

- From the point of view of transmission, there are two types of channels:

- **Low pass Channel** : This channel has the lowest frequency as '0' and highest frequency as some non-zero frequency 'f1'. This channel can pass all the frequencies in the range 0 to f1.

- **Band pass channel** : This channel has the lowest frequency as some non-zero frequency 'f1' and highest frequency as some non-zero frequency 'f2'. This channel can pass all the frequencies in the range f1 to f2.

Lowpass channel

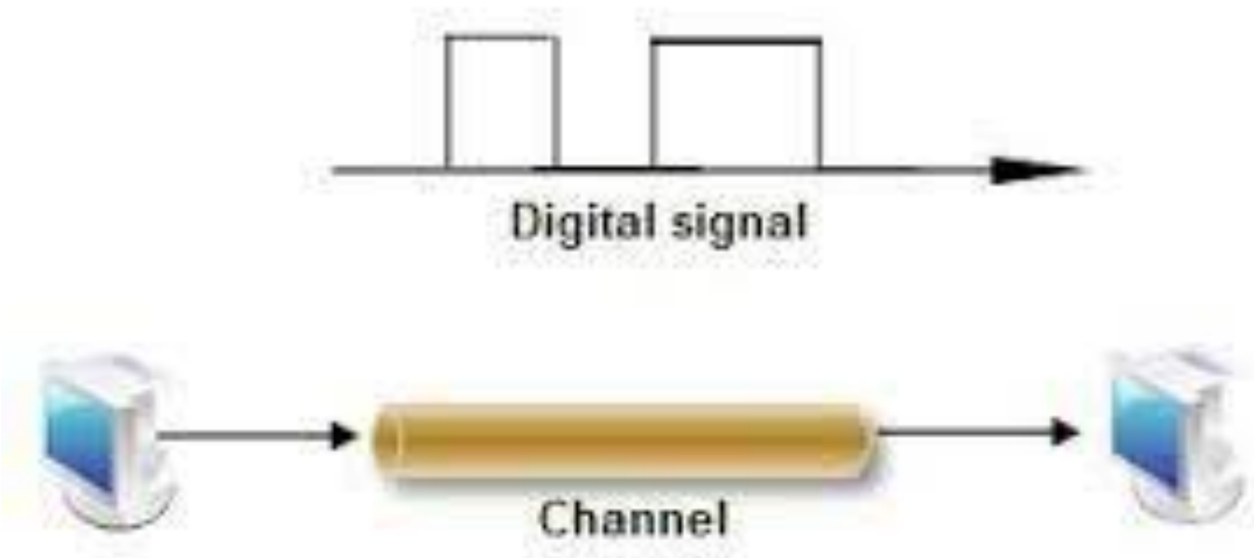


Bandpass channel

Transmission of Digital signal

Baseband Transmission

- The signal is transmitted without making any change to it (ie. Without modulation).
- In baseband transmission, the bandwidth of the signal to be transmitted has to be less than the bandwidth of the channel.
- Ex. Consider a Baseband channel with lower frequency 0Hz and higher frequency 100Hz, hence its bandwidth is 100 (Bandwidth is calculated by getting the difference between the highest and lowest frequency).
- We can easily transmit a signal with frequency below 100Hz, such a channel whose bandwidth is more than the bandwidth of the signal is called Wideband channel.
- Logically a signal with frequency say 120Hz will be blocked resulting in loss of information, such a channel whose bandwidth is less than the bandwidth of the signal is called Narrowband channel



Baseband Transmission

Broad band Transmission

- Given a bandpass channel, a digital signal cannot be transmitted directly through it In broadband transmission we use modulation, i.e we change the signal to analog signal before transmitting it.
- The digital signal is first converted to an analog signal, since we have a bandpass channel we cannot directly send this signal through the available channel.
- Ex. Consider the bandpass channel with lower frequency 50Hz and higher frequency 80Hz, and the signal to be transmitted has frequency 10Hz.
- To pass the analog signal through the bandpass channel, the signal is modulated using a carrier frequency.
- Ex. The analog signal (10Hz) is modulated by a carrier frequency of 50Hz resulting in an signal of frequency 60Hz which can pass through our bandpass channel.
- The signal is demodulated and again converted into an digital signal at the other end as shown in the figure below

Transmission Impairment

- In the data communication system, analog and digital signals go through the transmission medium.
- Transmission media are not ideal. There are some imperfections in transmission mediums.
- So, the signals sent through the transmission medium are also not perfect. This imperfection cause **signal impairment**.
- It means that signals that are transmitted at the beginning of the medium are not the same as the signals that are received at the end of the medium that is what is sent is not what is received.
- These impairments tend to deteriorate the quality of analog and digital signals.

Consequences

- For a digital signal, there may occur bit errors.

- For analog signals, these impairments degrade the quality of the signals.

Causes of impairment

There are three main causes of impairment are,

- Attenuation
- Distortion
- Noise

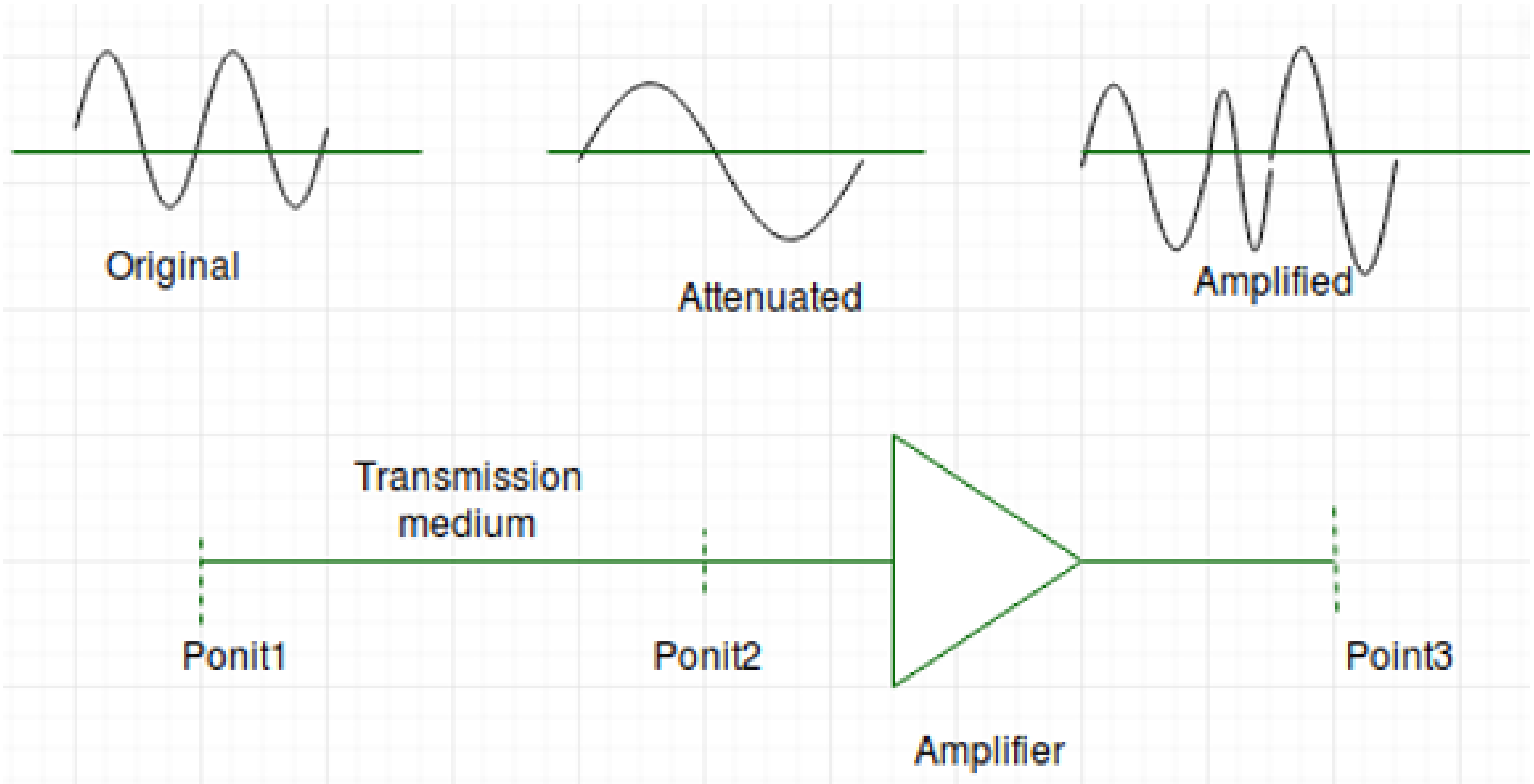
➢ Attenuation

- Attenuation Means loss of energy that is the weaker signal.

- Whenever a signal transmitted through a medium it loses its energy, so that it can overcome by the resistance of the medium.

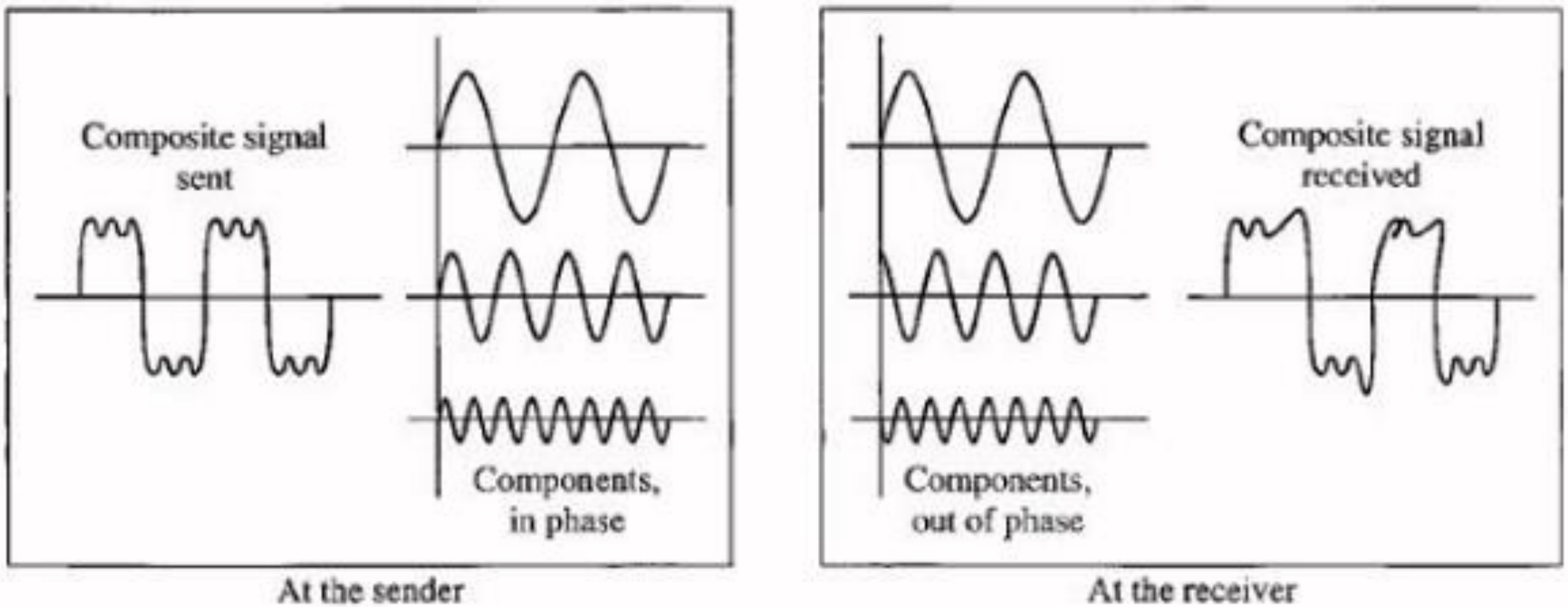
- That is why a wire carrying electrical signals gets warm, if not hot, after a while. Some of the electrical energy is converted to heat in the signal.

- Amplifiers are used to amplify the signals to compensate for this loss.


Original
Attenuated
Amplified
Transmission
medium
Ponit1
Ponit2
Point3
Amplifier

Distortion

- If a signal changes its form or shape, it is referred to as **distortion**.
- Signals made up of different frequencies are composite signals. Distortion occurs in these composite signals.
- Each component of frequency has its propagation speed traveling through a medium and therefore, different components have different delay in arriving at the final destination.
- It means that signals have different phases at the receiver than they did at the source.


Composite signal sent
Components, in phase
At the sender
Composite signal received
Components, out of phase
At the receiver

Distortion

➢ Noise

- Noise is another problem. There are some random or unwanted signals mix up with the original signal is called noise.

- Noises can corrupt the signals in many ways along with the distortion introduced by the transmission media.

Different types of noises are:

- Thermal noise
- Intermodulation noise
- Crosstalk
- Impulse noise

a) **Thermal noise**

- The thermal noise is random motion of electrons in a conductor that creates an extra signal not originally sent by the transmitter.
- It is also known as white noise because it is distributed across the entire spectrum (as the frequency encompass over a broad range of frequencies).

b) **Intermodulation noise**

- More than one signal share a single transmission channel, intermodulation noise is generated.
- For instance, two signals S1 and S2 will generate signals of frequencies (S1 + S2) and (s1 - S2), which may interfere with the signals of the same frequencies sent by the sender. due to If nonlinearity present in any part of the communication system, intermodulation noise is introduced.

c) Cross talk

- Cross talk is an effect a wire on the another. One wire acts as a sending antenna and the transmission medium acts as the receiving antenna.
- Just like in telephone system, it is a common experience to hear conversation of other people in the background. This is known as cross talk.

d) Impulse noise

- Impulse noise is irregular pulses or spikes(a signal with high energy in a very short period) generated by phenomena like that comes from power lines, lightning, spark due to loose contact in electric circuits and so on.
- It is a primary source of bit-errors in digital data communication that kind of noise introduces burst errors.