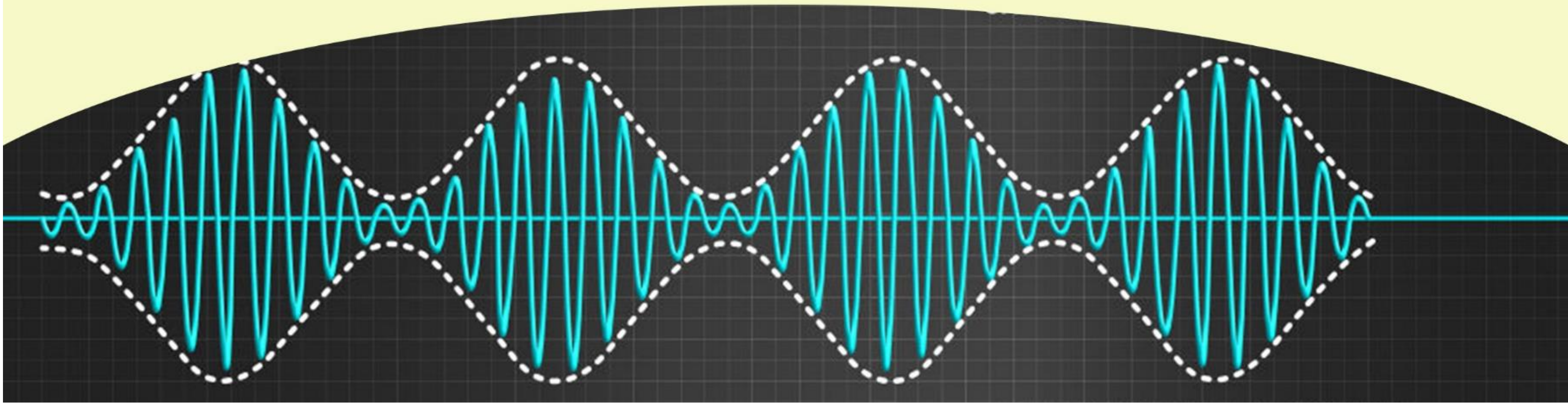
PHYSICS

XI

COMMUNICATION

PROF:IMRAN HASHMI



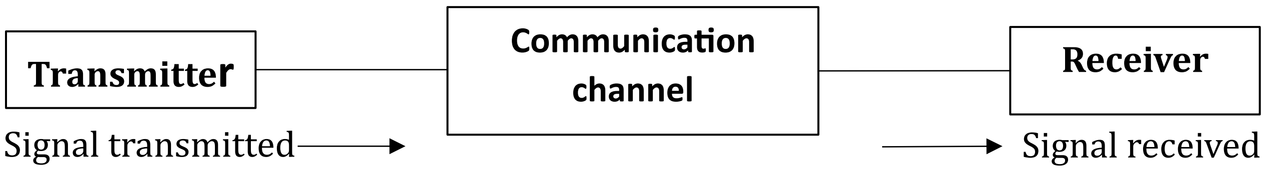
Chapter 14
Communication

COMMUNICATION

The transfer of information from one point to another is called communication. Communication may take place between people and machines or systems through communication technologies. Social Media platforms, Blogs, Vlogs, Live Video Conferencing Technology, Podcasts, Web Chat, Email, and Text messaging are some examples of communication technologies.

COMMUNICATION SYSTEM

A communication system is a setup that is used to transmit information from one place to another. It consists of a transmitter, a communication channel, and a receiver.



➢ Transmitter

A transmitter is a device that converts the information or message into an equivalent electrical signal and modifies it into a suitable form for communication.

➢ Communication channel

The communication channel is the medium between the transmitter and receiver through which the signals are transmitted. The medium could be free space, air, or transmission cable.

➢ Receiver

A receiver is a device that receives the transmitted signal and then converts it into a form that is intelligible to a person or equipment that receives it.

Information carried by communication channels

The communication channel can be classified into two categories, Cable and Broadcast. These categories are further divided into the following main components.

Cable:

- Twisted pair cable
- Coaxial pair cable
- Optical fiber cable

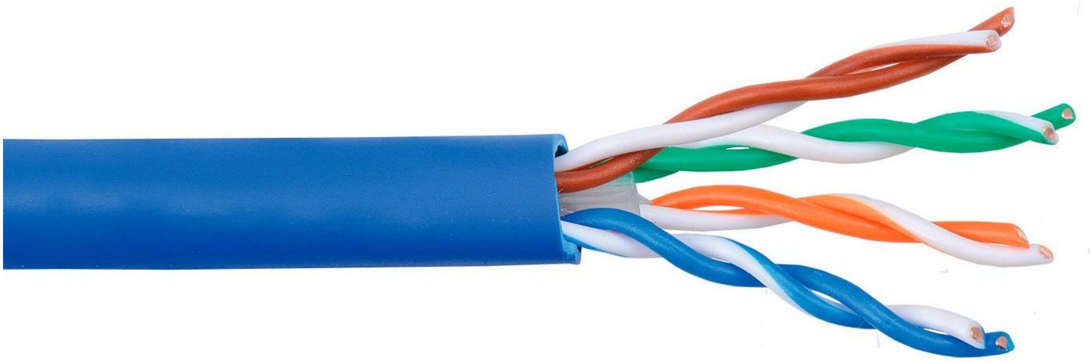
Broadcast:

- Radio or infrared link
- Microwave link
- Satellite link

Twisted pair cable

Twisted pair cable is the ordinary copper wire which is widely used in telephone communication and computer networks. To reduce cross-talk or electromagnetic induction between pairs of wires, two insulated copper wires are twisted around each other. Each signal on a twisted pair requires both wires. It was invented by Alexander Graham Bell in 1881. There are two types of twisted pair cable, Shielded twisted pair cable (STP) and Unshielded twisted pair cable (UTP).

Shielded twisted pair (STP) is a special kind of copper telephone and local area network (LAN) wiring used in some business installations. Unlike unshielded twisted pair (UTP), shielded twisted pair also encloses these wires in a shield and ground them to further reduce electromagnetic and radio frequency interference. STP cables are more expensive and harder to install than UTP wiring.



Merits of twisted pair cable:

1. It's relatively easy to implement and terminate.
2. If a portion of a twisted pair cable is broken it doesn't affect the whole network.
3. Less vulnerable to electrical interference caused by nearby equipment or wires.
4. Low cost and best performance in short distances.
5. Twisted Pair cable is easy to connect.

Coaxial pair cable

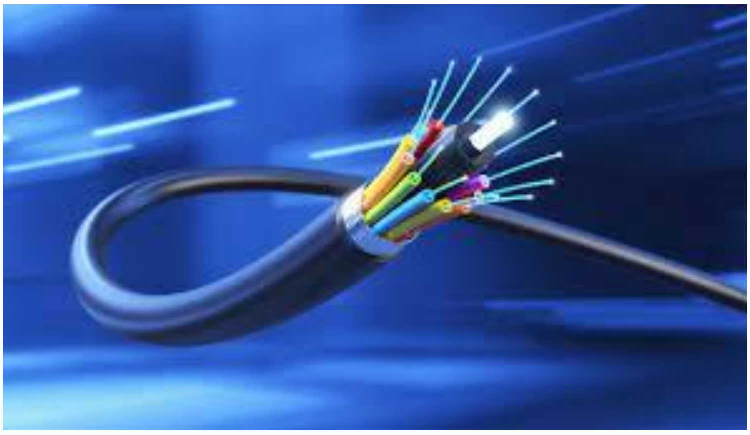
Coaxial Cable is a category of guided media that is used to perform the transmission of large-frequency signals. Coaxial cable constitutes a solid conductor, three coats of insulation, and a grounding conductor. In coaxial cables, the inner solid conductor helps in transmitting the signals in the form of electrical signals. Coaxial cables are commonly used in internet connections, television signal distribution, and radio transmissions.

Merits of Coaxial pair cable:

1. It is small in diameter.
2. It is less susceptible to noise interference compared to twisted pair.
3. It is easy to wire and easy to expand to flexibility.
4. It supports high bandwidth signal transmission compared to twisted pair.
5. It requires fewer repeaters than a twisted pair.

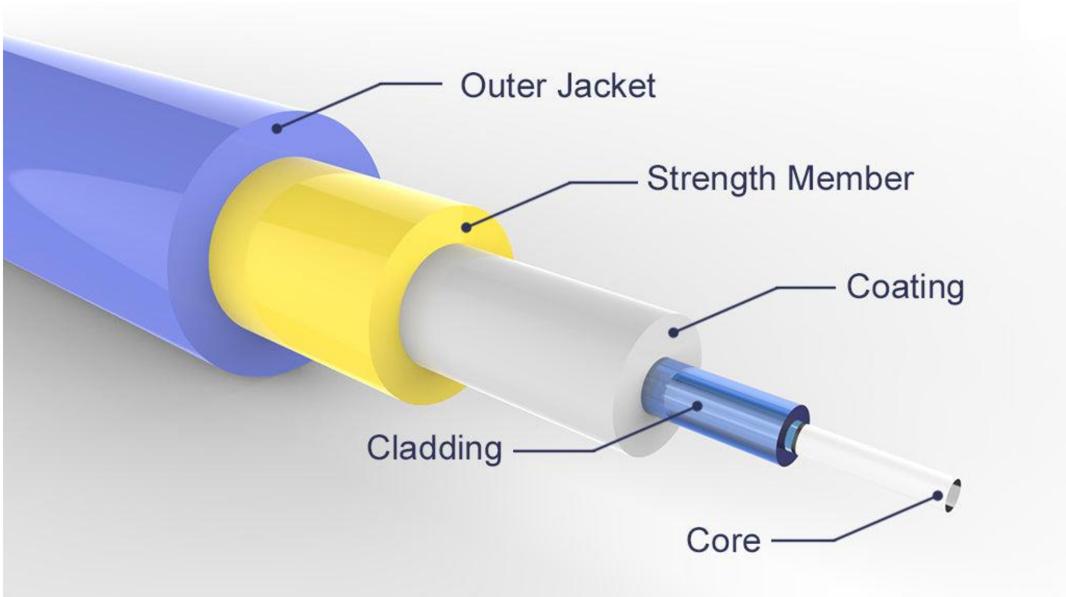
Optical fiber cable

Fiber optics, or optical fiber, refers to the technology that transmits information as light pulses along a glass or plastic fiber.



A fiber optic cable consists of one or more strands of glass, each only slightly thicker than a human hair. The center of each strand is called the core, which provides the pathway for light to travel. The core is surrounded by a layer of glass called cladding that reflects light inward (total internal reflection) to avoid loss of signal and allow the light to pass through bends in the cable.

Fiber optic cable is composed of two layers of glass: The core, which carries the actual light signal, and the cladding, which is a layer of glass surrounding the core. The cladding has a lower refractive index than the core. This causes Total Internal Reflection within the core.

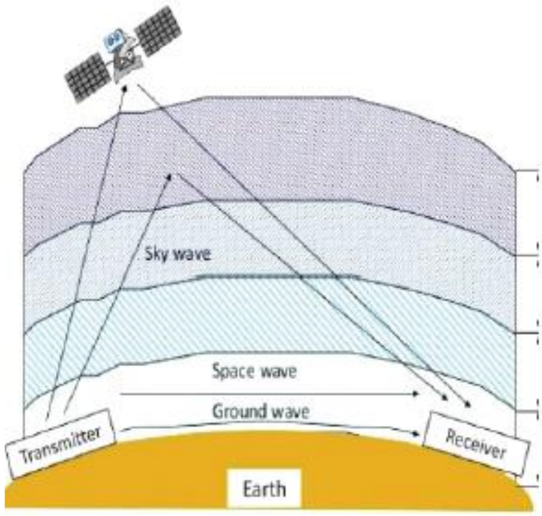


Merits of fiber optic cable:

1. Fiber optic cables provide more bandwidth for carrying more data than copper cables of the same diameter.
2. This allows fiber optic cables to carry signals at speeds that are only about 31 percent slower than the speed of light.
3. Compared to copper cables, fiber optic cables are thinner and lighter in weight.
4. Cost-effective for long-distance transmission.
5. Minimal signal loss compared to copper cable. (<0.2dB/km, 1dB/km microwave, 10db/km twisted copper pair)

Radio waves communication

Radio waves are electromagnetic waves having the longest wavelengths in the electromagnetic spectrum, typically with frequencies of 300 gigahertz (GHz) and below.



Propagation of radio waves

There are three modes of propagation of radio waves.

1. Ground or surface wave propagation.
2. Sky wave propagation.
3. Space wave propagation

1) Ground or surface wave propagation.

The radio waves which travel along the surface of the earth from the transmitter to the receiver are called ground or surface waves and transmission of data through these waves is called ground or surface wave propagation. Ground wave transmission is not suitable for long-distance communication because signals become weak due to absorption by the ground. Ground wave propagation is effective for frequencies in the range of 500kHz to 1500kHz.

2) Sky wave propagation.

The radio waves, which are directed towards the sky from a transmitter at a certain location on the earth and are reflected from the ionosphere towards another location on the earth are called sky waves, and transmission of data through these waves is called sky wave propagation.

Skywave transmission is suitable for frequencies in the range 2MHz to about 20MHz. Above 30MHz, the ionosphere does not reflect the waves.

(The ionosphere is the layer of the earth's atmosphere that contains a high concentration of ions and free electrons and can reflect radio waves. It lies above the mesosphere and extends from about 50 to 600 miles (80 to 1,000 km) above the earth's surface)

3) Space wave propagation

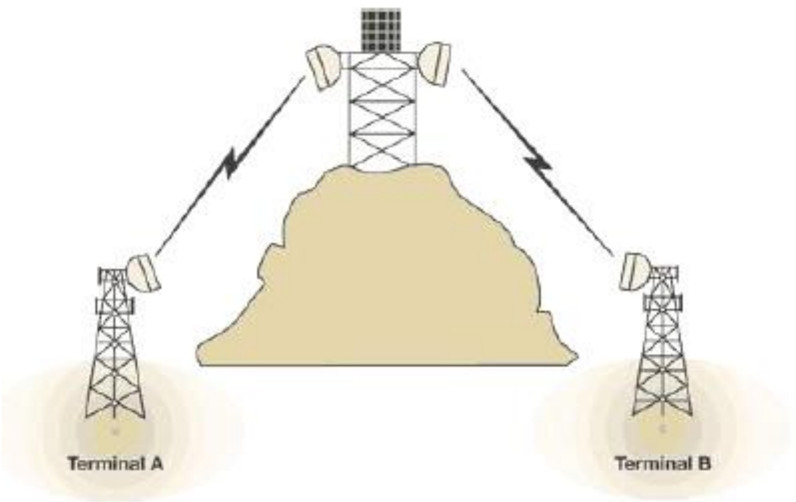
Radio waves that travel in the earth’s atmosphere from a transmitting antenna to a receiving antenna are called space waves. They have frequencies higher than 30MHz. The transmission of data through space waves is called space wave propagation.

The maximum distance up to which signal from an antenna of height at a TV station can reach directly is given by

$$d_{max} = \sqrt{2Rh_t} + \sqrt{2Rh_r}$$

Where $h_t =$ The height of the transmitting tower, $h_r =$ the height of the receiving tower and R is the earth's radius.

Microwaves communication



The electromagnetic waves having frequencies between 1 and 300 GHz are known as a microwave. Microwave systems use very high-frequency radio or television signals to transmit data through space. Therefore, the transmitter and receiver of a microwave system, which is mounted on very high towers, should be invisible to each other, i.e., they both should be in a line of sight. Moreover, the signals become weak after traveling a certain distance and require power amplification which is obtained by repeaters.

Microwave systems can carry large quantities of data at high rates of speed. The data transmission rate is about 16 Gb/s (Gigabits per second). A microwave system can take 250,000 voice channels at an equivalent time. They are used for the transmission of Radio, TV, and telephone signals.

Merits of microwave communication.

1. High data transmission rates.
2. High capacity to carry huge quantities of data.
3. Lower error rates, thus making it more reliable as compared to cable.
4. Microwaves offer communication over very long distances.
5. They implement better in bad weather conditions than radio waves.

Satellite communication

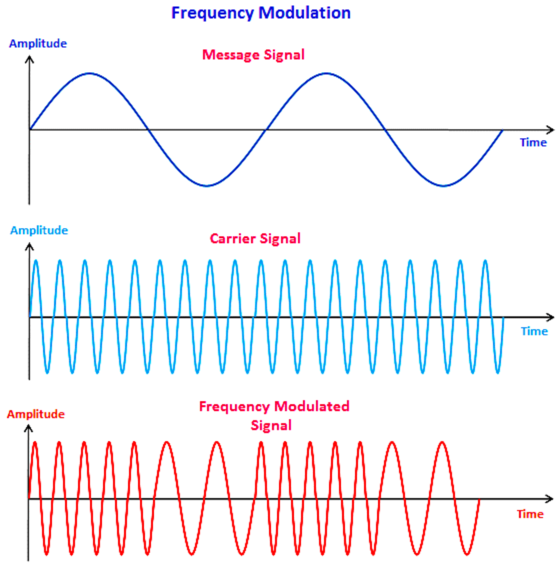
Satellite communication is the mode of communication in which microwave signals propagate from a transmitter to a receiver via a satellite. The satellite used is geostationary.

Merits of satellite communication

1. Through satellite transmission, coverage over geographical areas is quite large mainly for sparsely populated areas.
2. High bandwidth and broadcast possibilities.
3. Wireless and mobile communication applications can be easily established by satellite communication independent of location.
4. It is used in a wide variety of applications such as global mobile communication, private business networks, Long-distance telephone transmission, weather forecasting, radio/TV signal broadcasting, gathering intelligence in the military, navigation of ships and aircraft, connecting remote areas, television distribution, etc.

MODULATION

Modulation is the process of transmitting a message signal with a carrier signal to cover longer distances. Two signals are involved in the modulation process. Message signals are also known as baseband signals or modulating signals. Baseband signals are the band of frequencies representing the original signal which is to be transmitted. The frequency of such a signal is usually low. The other signal involved in modulation is a high-frequency sinusoidal wave. This signal is called the carrier signal. The carrier wave is represented by a sinusoidal waveform. Mathematically we can write



$$V_c(t) = A\sin(2\pi f_c t + \phi)$$

Where $A =$ Amplitude of the carrier wave

$f_c =$ frequency of the carrier wave

$\phi =$ Phase angle

The modulating signal having a single tone (i.e. single frequency) is given by

$$V_m(t) = B\sin 2\pi f_m t$$

Where B and f_m represents the amplitude and frequency of the modulating signal.

Types of modulation

There are three types of modulation depending upon the change in characteristics (amplitude, frequency, or phase) of high-frequency carrier waves in accordance with the modulating signal (intelligence).

Amplitude modulation

The process in which the amplitude of the high-frequency carrier wave is changed in accordance with the amplitude of the input audio signal is called amplitude modulation. The TV broadcast is an example of AM

Modulation Index

It is the ratio of the amplitude of the modulating signal to the amplitude of the carrier wave.

$$\mu = \frac{\text{Amplitude of modulating signal}}{\text{Amplitude of carrier wave}}$$

$$\mu = \frac{A_m}{A_c}$$

Expression for Amplitude Modulated Wave

The amplitude and frequency of a carrier wave remain constant. Generally, it will be high frequency, and it will be a sine or cosine wave of electronic signal; it can be represented as

$$C(t) = A_c \sin\omega_c t$$

The modulating signal is nothing but the input signal (electronic signal), which has to be transmitted. It is also a sine or cosine wave; it can be represented as

$$m(t) = A_m \sin\omega_m t$$

Where A_c and A_m = Amplitude of the carrier wave and the modulating signal

$\sin\omega_c t$ = Phase of the carrier wave

$\sin\omega_m t$ = Phase of the modulating

We are superimposing the modulating signal into a carrier wave and also varying the amplitude of the carrier wave in accordance with the amplitude of the modulating signal, and the amplitude-modulated wave Cm(t) will be

$$C_m(t) = (A_c + A_m\sin\omega_m t)\sin\omega_c t. \qquad (1)$$

This is the general form of an amplitude-modulated wave.

Where,

$A = A_c + A_m\sin\omega_m t$ = Amplitude of the modulated wave

$\sin \omega_m t$ = Phase of the modulated wave

$$C_m(t) = A_c\left(1 + \frac{A_m}{A_c}\sin \omega_m t\right)\sin \omega_c t$$
$$C_m(t) = A_c(1 + \mu \sin \omega_m t)\sin \omega_c t$$
$$C_m(t) = A_c \sin \omega_m t + A_c\mu \sin \omega_m t \sin \omega_c t. \qquad (2)$$

Where,

$\mu = \frac{A_m}{A_c}$ =modulation index

From equation 2, we can see amplitude modulated wave is the sum of three sine or cosine waves.

Frequency modulation

The process in which the amplitude of the high-frequency carrier waves remains constant but its frequency is modified in accordance in accordance with the amplitude of the input audio signal is called frequency modulation.

1. It is used in radio signal broadcasting.
2. During satellite and microwave communication, frequency modulation is widely used.
3. It has extensive applications in cellular radio communication and TV sound transmission.

Expression for Frequency Modulated Wave

We know that we need two waves for modulation, the high-frequency carrier wave and the modulating wave

$$C(t) = A_c \cos \omega_c t$$
$$C(t) = A_c \cos 2\pi f_c t$$
$$m(t) = A_m \cos \omega_m t$$
$$m(t) = A_m \cos 2\pi f_m t$$

Where A_c and A_m = Amplitude of the carrier wave and the modulating signal

The frequency of modulated wave will be

$$f_m(t) = f_c + kA_m \cos 2\pi f_m t$$
$$f_m(t) = f_c + km(t)$$

Where,

$f_m(t)$ = frequency modulated wave

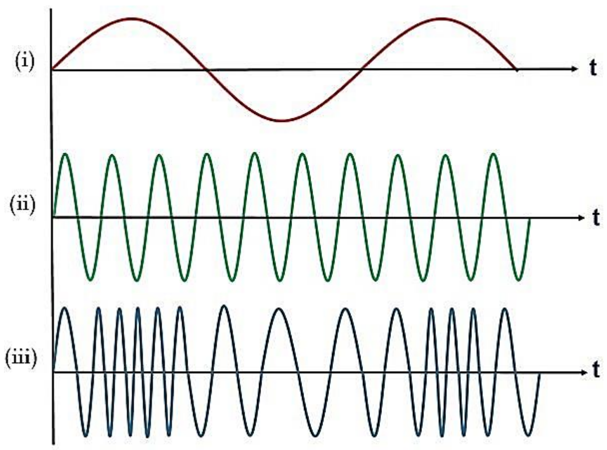
f_c = frequency of the carrier wave

$m(t)$ =modulating signal

k = proportionality constant

Advantages of amplitude modulation (AM)

1. The amplitude modulation is simple to implement and therefore the cost of amplitude modulation is low.
2. It requires a simple and cheaper transmitter and receiver.
3. Amplitude modulation is used to transmit the signal over long distances because amplitude-modulated signals are reflected by the earth from the ionosphere layer.
4. AM waves have low bandwidth suitable for long-range communication.



(i) Modulating signal
(ii) Carrier waveform
(iii) Frequency modulated signal

Advantages of frequency modulation (FM)

1. FM provides better sound quality due to higher bandwidth (ideal for broadcasting music and high-fidelity sound).
2. FM is less susceptible to noise, resulting in clear and more consistent reception.
3. FM has a wider frequency range, allowing more channels and better transmission of stereo signals.
4. A higher signal-to-noise ratio enhances overall signal quality and reduces the impact of background noise.

Amplitude modulation vs. Frequency modulation

Amplitude modulation	Frequency modulation
Frequency and phase remain constant	Amplitude and phase remain constant
The frequency range varies between 535kHz and 1705kHz	The frequency range varies between 88MHz and 108NMHz
Easily susceptible to noise	Less susceptible to noise
The modulation index varies from 0 to 1	The modulation index is always greater than 1
It can be transmitted over a long distance but has poor sound quality	It has better sound quality due to higher bandwidth
Power consumption is high	Power consumption is low

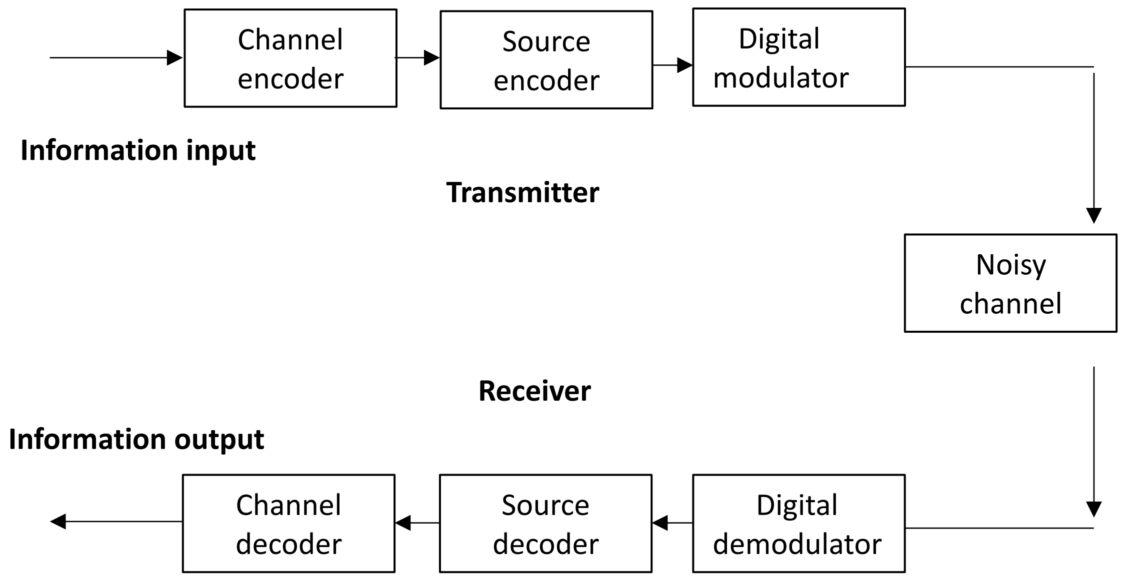
Bandwidth

Network bandwidth is a measurement indicating the maximum capacity of a wired or wireless communications link to transmit data over a network connection in a given amount of time. For example, if the bandwidth of a network is 40 Mbps, it implies that the network cannot transmit data faster than 40 Mbps in any given case.

Digital communication system

Digital communication refers to the exchange of digital information between the sender and receiver using different devices and methods. In a digital communication system, the messages in analog form are converted into digital format before transmission. The digital data is converted back into analog form at the receiver end.

Digital communication consists of six basic blocks. The functional blocks at the transmitter are responsible for processing the input signal, encoding, modulating, and transmitting over the communication channel. The functional blocks at the receiver process the digital data to retrieve the original message.



Advantages of digital communication system

1. **Performance**: In digital signals, the impact of noise interference, and distortion is less.
2. **Compression and security**: To maintain the secrecy of information, signal processing functions like compression and encryption are employed in digital circuits. As compared to analog signals, it is easy to save and retrieve digital signals.
3. **Multiplexing**: It is the process in which multiple signals coming from multiple sources are combined and transmitted over a single communication/physical line. In a digital communication system, it is easily done by using Time Division Multiplexing (TDM).
4. **Storage**: Digital signals can be stored and retrieved more accurately and inexpensively by the use of transistor and error control codes.
5. **Signal processing**: Signal processing functions such as encryption and compression are employed in digital circuits to maintain the secrecy of the information.
6. **Reconstruction:** Digital signals can be faultlessly carried over larger distances by using repeaters. However, analog has become gradually weaker due to noise and distortion.
7. **Cost:** Digital communication is cheaper and simpler compared to analog signals because of the advancement of IC technologies.
8. **Secrecy:** The probability of cross-talk is very low in digital communication due to encryption and compression.
9. **Quality of copies**: The quality of copies in analog transmission is not good as compared to its original while in digital transmission, copies can be made definitely.

Digital transmission of speech or music

In the real world, every real quantity such as voice, temperature, weight, etc. exists in the analog state and it cannot be processed by any digital device such as a computer or a cell phone.
Analog signal refers to the information (e.g., speech or music) expressed by continuously changing physical quantities, such as current, voltage, etc. We usually call them analog signals or continuous signals, which can have infinitely many different values in a certain time range. The digital signal is discrete and discontinuous in terms of values.

The method of translating analog signals into digital format is called Analog-to-Digital (A/D) conversion and the device used to perform this translation is called Analog-to-Digital converter (ADC).

Steps for A/D conversion:

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:

Sampling is the process of taking amplitude values of the continuous analog signal at discrete time intervals. The time between two samples is called the sample period T and the number of samples taken per second is referred to as the sample frequency f_s.
To recover the original analog signal from the discrete values of sampling, the sampling rate f_s must be greater than twice of the signal's highest frequency f_{max} (i.e., $f_s > 2f_{max}$). This is called Nyquist sampling theorem. The Nyquist sampling rate is $f_N = 2f_{max}$

2. Quantization:

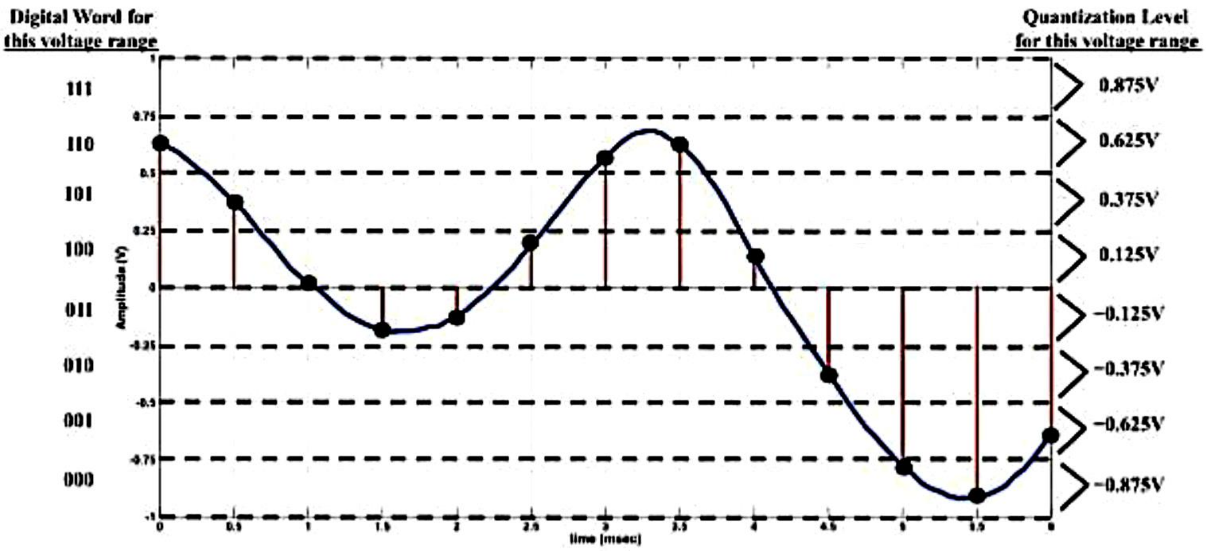
Quantization is the process of mapping the sampled analog voltage values to discrete voltage levels, which are then represented by binary numbers (bits).
Quantization is the process of mapping continuous infinite values to a smaller set of discrete finite values. These values are called quantization levels.
An N-bit A/D converter has 2^N quantization level and output binary words of length N. For example, a 3-bit A/D converter system has $2^3 = 8$ quantization levels, all samples of 1volt signal will be quantized into one of only 8 possible quantization levels and each sample will be represented by a 3-bit digit

3. Encoding

After quantization the samples are converted to N-bit binary code words. For the first sample point at time 0, the voltage is 0.613 V, which means that sample is assigned a binary value of 110.
The A/D then creates a voltage signal that represents these bits. The binary representation of the above signal is: 110 101 100 011 011 100 110 110 100 010 000 000 001.
In this example, every sample produces 3 bits (3 bits/sample). The sample rate was 2000 samples/sec. The bit rate (**R_b**) produced from this:

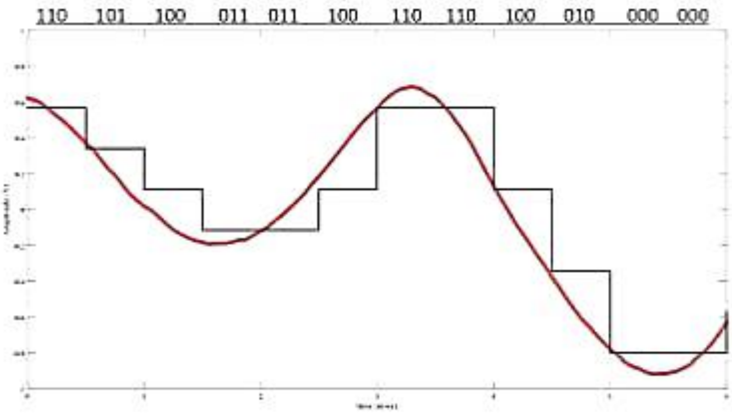
$$R_b = \frac{3\text{bits}}{\text{sample}} \times \frac{2000\text{sampes}}{\text{second}} = 6000\,\frac{\text{bits}}{\text{secoond}}$$

Bit rate is the speed of transfer of data given in number of bits per second.



Conversion from digital to analog (D/A):

The receiver converts these N-bit digital words back into an analog signal. This process is called digital-to-analog (D/A) conversion. The analog signal is reconstructed by converting the N-bit digital words into the appropriate quantization levels, and this voltage is "held" for one sample period, creating a stair-step type signal shown below



The reconstructed analog signal is shown in a thick black line in Figure 14.19, along with the 3-bit digital word that represents each sample. The original analog signal is also shown in the continuous line. Even if we perform filtering to smooth out the reconstructed signal to remove its staircase appearance it will still not quite be the same as the original signal. It is called quantization error. Quantization error can be reduced by increasing the number of bits N for each sample. This will make the quantization intervals smaller.