1.1 INTRODUCTION TO COMMUNICATION

The word *communicate* refers to *pass on* and the act of communicating is termed *communication*. In everyday life, we are interested in communicating some information which may include some thought, news, feeling and so on to others. Thus, in a broad sense, the term communication refers to the transmission of information from one place to the other. The information transmission between humans sitting very close (example, across a table) may take place via one or more of the following means: speech, facial expressions and gestures. Among these, the most effective one is via speech mode. However, the speech mode of communication is also limited by how loud a person can produce the speech signal and is effective only over few tens of meters.

For long-distance communication, initially humans employed non-electrical means like drum beats, smoke signals, running messengers, horses and pigeons. The electrical means of communication started with wire telegraphy in the eighteen forties, developing with telephony some decades later in the eighteen seventies and radio at the beginning of the twentieth century. Later, the use of satellites and fibre optics made communication even more widespread with an increasing emphasis on wireless, computer and other data communications.

Presently, in the early period of twenty-first century, we live in a modern society where several electrical modes of communication are at our disposal. Some of these include, landline telephone, television set, fax machine, mobile phone, computer with internet and personal digital assistant. All these different modes bundle the information available in the whole world and provide it to us. At the same time, they also keep us connected to the entire world. Due to miniaturization, most of these communication aids have become gadgets in the hands of the current generation. After enjoying these facilities in our daily routines, we are in such a stage that it is difficult to imagine a modern society without all these modes of communication. By observing all these developments, it may be opt to call the progress in the communication area as *Communication Revolution*.

Several new modes of electrical communication emerge from time to time due to the continuous technological progress. For instance, this progress only brought us from the era of wired telegraphy to the present era of wireless mobile communication. Even though this change occurs, the basic objective of electrical communication remains the same—transmission of information from one place to the other. The different steps involved in the transmission of information may be outlined as follows:

- Origin of information in the mind of the person who wants to communicate
- Generation of message signal carrying the information
- Converting the message signal into electrical form using a suitable transducer
- Processing the message signal such that it will have the capability to travel for a long distance
- Transmission of the processed message signal to the desired destination
- Reception of the processed message signal at the desired destination
- Processing the received message signal in such a way to recreate the original non-electrical form
- Finally delivering the information from the message signal to the intended person

Thus understanding the basic issues involved in the above outlined steps, independent of the type of communication system, is the first step towards making an entry into the electrical communication discipline. Once this is done, several communication systems like telephony, radio broadcasting, television broadcasting, radar communication, satellite communication, fiber optic communication, computer communication and wireless communication can be studied. This book aims at giving qualitative exposure to different concepts in the communication discipline. After this, some of the above–mentioned communication systems will be discussed. Any logical order may be used, but the one adopted here is basic systems, communication processes and circuits, and then more complex systems.

1.2 ELEMENTS OF A COMMUNICATION SYSTEM

Figure 1.1 shows the generic block diagram of a communication system. Any communication system will have five blocks, including the information source and destination blocks. However, from the practical design point of view, we are interested in only the three blocks, namely, *transmitter*, *channel* and *receiver*. This is because, we have little control over the other two blocks. Also, the communication in electrical form takes place mainly in these three blocks. The functions of each of these blocks are described below.

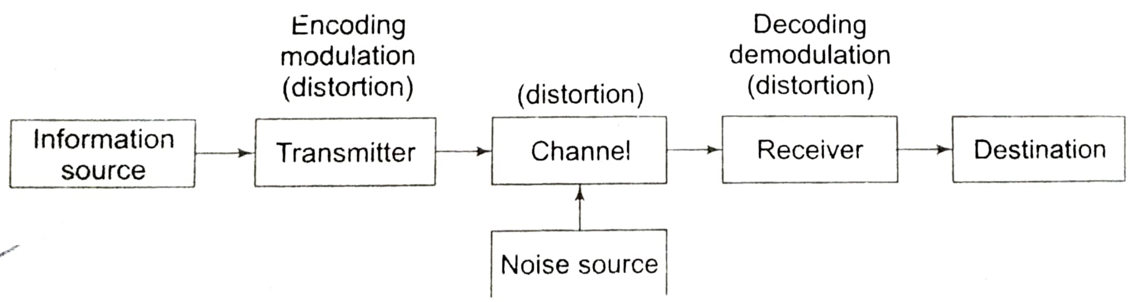


Fig. 1.1 *Block diagram of a communication system.*

1.2.1 Information Source

As mentioned earlier, the objective of any communication system is to convey information from one point to the other. The information comes from the information source, which originates it. *Information* is a very generic word signifying at the abstract level anything intended for communication, which may include some thought, news, feeling, visual scene, and so on. The information source converts this information into a physical quantity. For instance, the thought to be conveyed to our friend may be finally manifested in the form of speech signal, written script or picture. This physical manifestation of the information is termed as *message* signal. Even though we use the words information and message interchangeably, it is better to understand the basic difference between the two.

In the study of electrical communication systems, we are mainly interested in transmitting the information manifested as the message signal to the receiving point, as efficiently as possible. However, the message signal also usually will be in the non-electrical form. For electrical communication purpose, first we need to convert the message signal to the electrical form, which is achieved using a suitable transducer. Transducer is a device which converts energy in one form to the other. For instance, if I choose to convey my thought that *it is raining today at my place* to my friend via speech mode, then the information will be manifested as the speech signal. *It is raining today at my place* is the information and the speech corresponding to it is the message signal. The speech signal is nothing but the acoustic pressure variations plotted as a function of time. These acoustic pressure variations are converted into electrical form using microphone as the transducer. The electrical version of the message signal is the actual input to the transmitter block of the communication system.

1.2.2 Transmitter

The objective of the transmitter block is to collect the incoming message signal and modify it in a suitable fashion (if needed), such that, it can be transmitted via the chosen channel to the receiving point. *Channel* is a physical medium which connects the transmitter block with the receiver block. The functionality of the transmitter block is mainly decided by the type or nature of the channel chosen for communication. For instance, if you are talking to your friend sitting in the next room via intercom service then the speech signal collected from your handset need not go through the sequence of steps needed when your friend is far off and you are reaching him/her over the mobile phone. This is because, in the first case the channel is a simple copper wire connecting your handset with your friend's hand set, whereas in the second case it is the free atmosphere.

The block diagram of typical radio transmitter is shown in Fig. 1.2. This transmitter block involves several operations like amplification, generation of high-frequency carrier signal, modulation and then radiation of the modulated signal. The amplification process essentially involves amplifying the signal amplitude values and also adding required power levels. The high-frequency signal is essential for carrying out an important operation called *modulation*. This high-frequency signal is more commonly termed *carrier* and is generated by a stable oscillator. The carrier signal is characterized by the three parameters amplitude, frequency and phase. The modulation process involves varying one of these three parameters in accordance with the variation of the message signal. Accordingly, we have *amplitude modulation*, *frequency modulation* and *phase modulation*. Even though, modulation is also a generic word indicating the operation of modifying one of the parameters of a given signal, we will still stick to the above context, unless specified otherwise. The modulated signal from the modulator is transmitted or radiated into the atmosphere using an *antenna* as the transducer, which converts the signal energy in guided wave form to free space electromagnetic waves and vice versa.

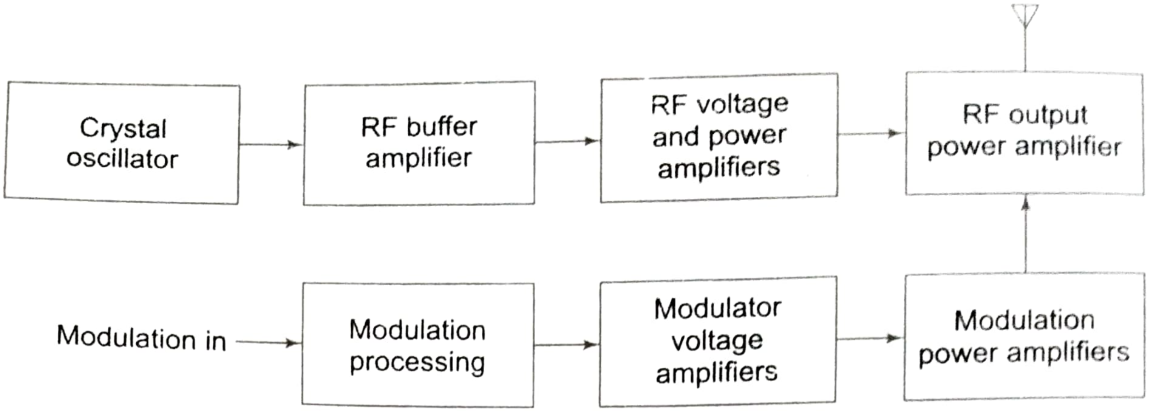


Fig. 1.2 *Block diagram of a typical radio transmitter.*

1.2.3 Channel

Channel is the physical medium which connects the transmitter with that of the receiver. The physical medium includes copper wire, coaxial cable, fibre optic cable, wave guide and free space or atmosphere. The choice of a particular channel depends on the feasibility and also the purpose of communication system. For instance if the objective is to provide connectivity for speech communication among a group of people working in one physically localized place, then copper wire may be the best choice. Alternatively, if the information needs to be sent to millions of people scattered in a geographical area like radio and television broadcasting, then free space or atmosphere is the best choice. The nature of modification of message signal in the transmitter block is based on the choice of the communication channel. This is because the message signal should smoothly travel through the channel with least opposition so that maximum information can be delivered to the receiver. The message signal in the modified form travels through the channel to reach the entry point of the receiver.

The following illustration may help us understand the functionality of channel: Suppose we have two water reservoirs connected through a mechanism (canal) for transferring water from one to the other, when needed. The objective of the canal is just to carry the water from one reservoir to the other and nothing more. In communication also, the objective of the channel is just to carry the message signal from the transmitter to the receiver and nothing more. Of course, the amount of water which finally reaches the other reservoir depends on the condition of the canal. On similar lines, the amount message signal which finally reaches the receiver depends on the characteristics of the channel. Finally, it should be noted that the term channel is often used to refer to the frequency range allocated to a particular service or transmission, such as television channel which refers to the allowable carrier bandwidth with modulation.

1.2.4 Receiver

The *receiver* block receives the incoming modified version of the message signal from the channel and processes it to recreate the original (non-electrical) form of the message signal. There are a great variety of receivers in communication systems, depending on the processing required to recreate the original message signal and also final presentation of the message to the destination. Most of the receivers do conform broadly to the *super heterodyne type*, as does the simple broadcast receiver whose block diagram is shown in Fig. 1.3. The super heterodyne receiver includes processing steps like reception, amplification, mixing, demodulation and recreation of message signal. Among the different processing steps employed, *demodulation* is the most important one which converts the message signal available in the modified form to the original electrical version of the message. Thus demodulation is essentially an inverse operation of modulation.

The purpose of receiver and form of output display influence its construction as much as the type of modulation system used. Accordingly the receiver can be a very simple crystal receiver, with headphones, to a far more complex radar receiver, with its involved antenna arrangements and visual display system. The output of a receiver may be fed to a loud speaker, video display unit, teletypewriter, various radar displays, television picture tube, pen recorder or computer. In each instance different arrangements must be made, each affecting the receiver design. Note that the transmitter and receiver must be in agreement with modulation methods used.

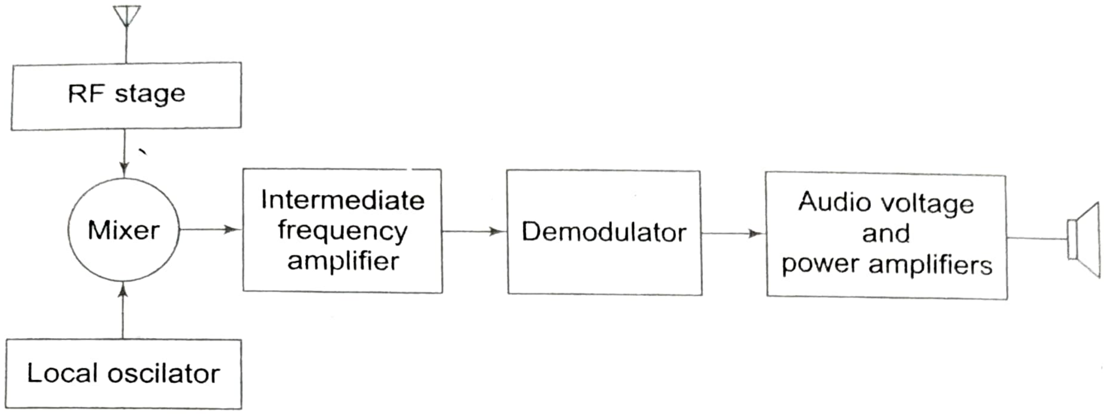


Fig. 1.3 *Block diagram of an AM superheterodyne receiver.*

1.2.5 Destination

The *destination* is the final block in the communication system which receives the message signal and processes it to comprehend the information present in it. Usually, humans will be the destination block. The incoming message signal via speech mode is processed by the speech perception system to comprehend the information. Similarly, the message signal via video or visual scene and written script is processed by the visual perception system to comprehend the information. Even though there are several theories put forward about the comprehension of the information from the message signal, the robustness exhibited by the human system in extracting information even under very noisy condition infers that, the entire sequence is less understood as of now. This may also be due the fact that human brain is the least understood part of human body in terms of its functional ability.

1.3 NEED FOR MODULATION

The term *modulate* means *regulate*. The process of regulating is modulation. Thus, for regulation we need one physical quantity which is to be regulated and another physical quantity which dictates regulation. In electrical communication, the signal to be regulated is termed as *carrier*. The signal which dictates regulation is termed as *modulating signal*. Message acts as modulating signal. The modulation process is the most important operation in the modern communication systems. Hence before studying the modulation and its types, it is essential to know the need for modulation.

The following example may help to better understand the need for modulation. Assume that there is a special and rare cultural event from a reputed artist organized at a far distant place (destination city) from your geographical location (source city). It is too far to reach the destination city by walking. However, you have decided to attend the event and enjoy the live performance. Then what will you do? The obvious choice is you will take the help of transportation vehicle to carry you from the source city to the destination city. Thus there are two important aspects to be observed in this example. The first one is you because you are the message part. The second one is the transportation vehicle which is the carrier. Once you reach the destination city, the purpose of the carrier is served. Exactly similar situation is present in an electrical communication. The message signal which is to be transmitted to the receiver is like you and cannot travel for long distance by itself. Hence it should take the help of a carrier which has the capacity to take the message to the receiver. This is the basic reason why we need to do modulation, so that message can sit on the carrier and reach the receiver.

In a more formal way, the need for modulation can be explained as follows. The distance that can be travelled by a signal in an open atmosphere is directly (inversely) proportional to its frequency (wavelength). Most of the message signals like speech and music are in the audio frquency range (20 Hz–20 kHz) and hence they can hardly travel for few meters on their own. Further, for efficient radiation and reception, the transmitting and receiving antennas would have to have lengths comparable to a quarter-wavelength of the frequency used. For a message at 1 MHz, its wavelength is 300 m ($3 \times 10^8 / 1 \times 10^6$) and hence antenna length should be about 75 m. Alternatively, for a signal at 15 kHz, the antenna length will be about 5000 m. A vertical antenna of this size is impracticable.

There is an even more important argument against transmitting signal frequencies directly; all message is concentrated within the same range (20 Hz–20 kHz for speech and music, few MHz for video), so that all signals from the different sources would be hopelessly and inseparably mixed up. In any city, only one broadcasting station can operate at a given time. In order to separate the various signals, it is necessary to convert them all to different portions of the electromagnetic spectrum. Each must be given its own carrier frequency location. This also overcomes the difficulties of poor radiation at low frequencies and reduces interference. Once signals have been translated, a tuned circuit is employed in the front end of the receiver to make sure that the desired section of the spectrum is admitted and all unwanted ones are rejected. The tuning of such a circuit is normally made variable and connected to the tuning control, so that the receiver can select any desired transmission within a predetermined range.

The use of modulation process helps in shifting the given message signal frequencies to a very high frequency range where it can occupy only negligible percentage of the spectrum. For instance, at 1000 kHz, the 10 kHz wide message signal represents 1% of spectrum. But at 1 GHz, the same 10 kHz represents 0.001% of spectrum. This means that more number of message signals can be accommodated at higher frequencies.

Although this separation of signals has removed a number of the difficulties encountered in the absence of modulation, the fact still remains that unmodulated carriers of various frequencies cannot, by themselves, be used to transmit information. An unmodulated carrier has a constant amplitude, a constant frequency and a constant phase relationship with respect to some reference. A message consists of ever-varying quantities. Speech, for instance, is made up of rapid and unpredictable variations in amplitude (volume) and frequency (pitch and resonances). Since it is impossible to represent these two variables by a set of three constant parameters, an unmodulated carrier cannot be used to convey information. In a continuous wave modulation (amplitude or frequency modulation, but not pulse modulation) one of the parameters of the carrier is varied by the message. Therefore, at any instant its deviation from the unmodulated value (resting frequency) is proportional to the instantaneous amplitude of the modulating voltage, and the rate at which this deviation takes place is equal to the frequency of this signal. In this fashion, enough information about the instantaneous amplitude and frequency is transmitted to enable the receiver to recreate the original message.

1.4 ELECTROMAGNETIC SPECTRUM AND TYPICAL APPLICATIONS

As the name indicates, an electromagnetic (EM) wave is a signal made of oscillating electric and magnetic fields. That is, the signal information is manifested as changing electric and magnetic field intensities at specified number of times per second. The ocsillations are sinusoidal in nature and measured as cycles per second or hertz (Hz). The oscillations can be as low as 1 Hz and can extend up to a very large value. The entire range of frequencies that the EM wave can produce oscillations is termed as *Electromagnetic Spectrum*.

Table 1.1 *EM spectrum classified in terms different frequency ranges and corresponding wavelength ranges, nomenclature and typical application. The abbreviations in the table have the following values: 1 kHz = 1 × 10³ Hz, 1 MHz = 1 × 10⁶ Hz. 1 GHz = 1 × 10⁹ Hz, 1THz = 1 × 10¹² Hz, 1μm = 1 × 10⁻³ m and 1 μm = 1 × 10⁻⁶m.*

Frequency (f) range	Wavelength (λ) range	EM Spectrum Nomenclature	Typical Application
30 – 300 Hz	$10^7 - 10^6$ m	Extremely low frequency (ELF)	Power line communication
0.3 – 3 kHz	$10^6 - 10^5$ m	Voice frequency (VF)	Face to face speech communication Intercom
3 – 30 kHz	$10^5 - 10^4$ m	Very low frequency (VLF)	Submarine communication
30 – 300 kHz	$10^4 - 10^3$ m	Low frequency (LF)	Marine communication
0.3 – 3 MHz	$10^3 - 10^2$ m	Medium frequency (MF)	AM Broadcasting
3 – 30 MHz	$10^2 - 10^1$ m	High frequency (HF)	Landline Telephony
30 – 300 MHz	$10^1 - 10^0$ m	Very high frequency (VHF)	FM Broadcasting, TV
0.3 – 3 GHz	$10^0 - 10^{-1}$ m	Ultra high frequency (UHF)	TV, Cellular telephony
3 – 30 GHz	$10^{-1} - 10^{-2}$ m	Super high frequency (SHF)	Microwave oven, radar
30 – 300 GHz	$10^{-2} - 10^{-3}$ m	Extremely high frequency (EHF)	Satellite communication, radar
0.3 – 3 THz	0.1 – 1 mm	Experimental	For all new explorations
43 – 430 THz	7 – 0.7 μm	Infrared	LED, Laser, TV Remote
430 – 750 THz	0.7 – 0.4 μm	Visible light	Optical communication
750 – 3000 THz	0.4 – 0.1 μm	Ultravoilet	Medical application
> 3000 THz	< 0.1 μm	X-rays, gamma rays, cosmic rays	Medical application

1.5 TERMINOLOGIES IN COMMUNICATION SYSTEMS

Time Time (t) is a fundamental quantity with reference to which all communications happen. It is typically measured in seconds (*sec*). For instance, the duration of a conversation with your friend using a mobile phone is charged in *sec* based on the time duration for which you used the service of the communication system.

Frequency Frequency (f) is another fundamental quantity with reference to which all signals in a communication system are more commonly distinguished. Frequency is defined as the number of oscillations per second and is measured in hertz (Hz). For instance, the message in a communication system is usually measured in terms of the range of frequencies and the carrier is one frequency value.

Wavelength Wavelength (λ) is yet another fundamental quantity used as an alternative to frequency for distinguishing communication signals. Wavelength is defined as the distance travelled by an EM wave during the time of one cycle. EM waves travel at the speed of light in atmosphere or vacuum, that is, 3×10^8 m/s. The wavelength of a signal can then be found by using the relation $\lambda = c/f = 3 \times 10^8 / f$. For instance, if the frequency of a given signal is 30 MHz, then its wavelength is $\lambda = 10$ m.

Spectrum The frequency domain representation of the given signal.

Bandwidth Bandwidth (B_W) is that portion of the EM spectrum occupied by a signal. More specifically it is the range of frequencies over which the information is present in the original signal and hence it may also be termed as *signal bandwidth.*

Channel Bandwidth The range of frequencies required for the transmission of modulated signal.

Modulation In terms of signal and channel bandwidths, modulation is a process of transforming signal from signal bandwidth to channel bandwidth.

Demodulation On the similar lines, demodulation is the reverse process of modulation, that is, transforming signal from channel bandwidth to signal bandwidth.

Baseband Signal Message signal in its original frequency range.

Baseband Transmission Transmission of message signal in its original frequency range.

Broadband Signal Message signal in its modulated frequency range.

Broadband Transmission Transmission of message signal in the modulated frequency range.

1.6 BASICS OF SIGNAL REPRESENTATION AND ANALYSIS

It is reasonable to expect that the frequency range (i.e., bandwidth) required for a given transmission should depend on the bandwidth occupied by the modulating signals themselves. A high-fidelity audio signal requires a range of 50 to 15000 Hz, but a bandwidth of 300 to 3300 Hz is adequate for a telephone conversation and is termed as narrowband speech. For wideband speech the frequency range is from 0 to 8000 Hz. When a carrier has been similarly modulated with each, a greater bandwidth will be required for the high-fidelity (hi-fi) transmission. At this point, it is worth noting that the transmitted bandwidth need not be exactly the same as the bandwidth of the original signal, for reasons connected with the properties of the modulating systems. This will be made clear in Chapters 3 and 4.

Before trying to estimate the bandwidth of a modulated transmission, it is essential know the bandwidth occupied by the modulating signal itself. If this consists of sinusoidal signals, then there is no problem, and the occupied bandwidth will simply be the frequency range between the lowest and the highest sine wave signal. However, if the modulating signals are nonsinusoidal, a much more complex situation results. Since such nonsinusoidal waves occur very frequently as modulating signals in communications, their frequency requirements will be discussed in Section 1.6.2.

1.6.1 Sine Wave and Fourier Series Review

It is very important in communications to have a basic understanding of a sine wave signal. Described mathematically in the time domain and in the frequency domain, this signal may be represented as follows:

$$v(t) = E_m \sin(2\pi f t + \phi) = E_m \sin(wt + \phi)$$

where $v(t)$ = voltage as a function of time

E_m = peak voltage

sin = trigonometric sine function

f = frequency in hertz

w = radian frequency ($w = 2\pi f$)

t = time

ϕ = phase angle

The electronic communication systems may be classified into various categories as shown in figure 1.15. It shows that the electronic communication system may be basically categorised into three groups based on:

(i) Whether the system is unidirectional or bidirectional.

(ii) Whether it uses an analog or digital information signal.

(iii) Whether the system uses baseband transmission or uses some kind of modulation.

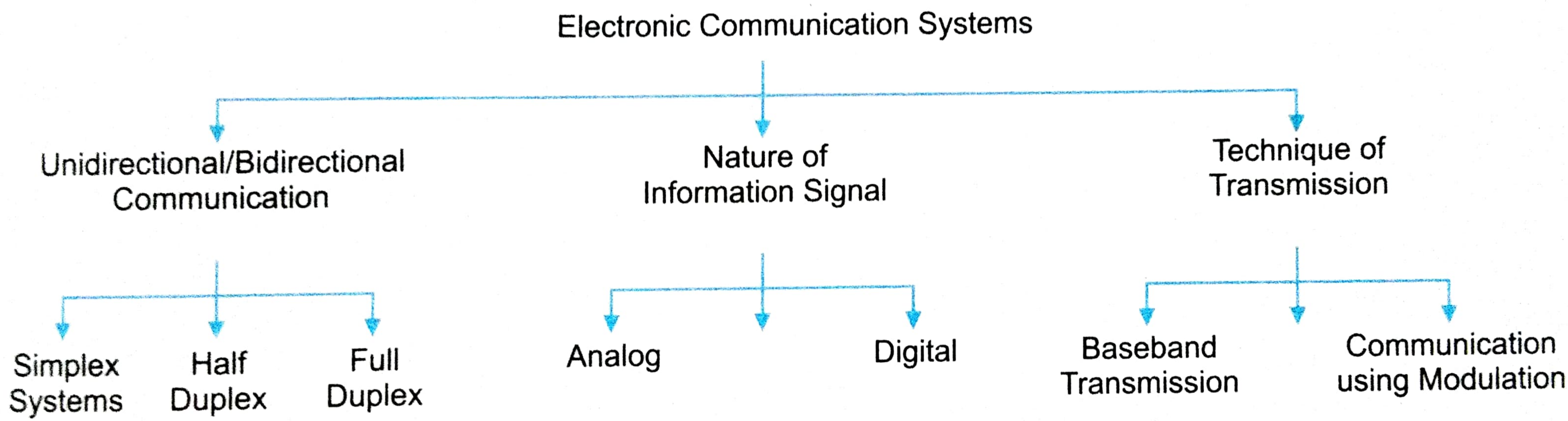


Fig. 1.15. Classification of electronic communication system

1.7 CLASSIFICATION BASED ON DIRECTION OF COMMUNICATION

Based on whether the system communicates only in one direction or otherwise, the communication systems are classified as under:

1. Simplex system
2. Half duplex system

3. Full duplex system

Figure 1.16. shows this classification.

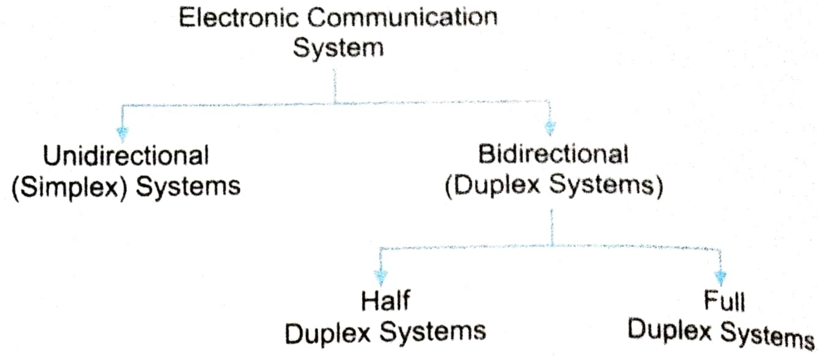


Fig. 1.16. Types of electronic communications

1. Simplex System

In these systems, the information is communicated in only one direction. For example, the radio or TV broadcasting system can only transmit. They cannot receive. Another example of simplex communications is the information transmitted by the telemetry system of a satellite to earth. The telemetry system transmits information about the physical status of the satellite such as its position of temperature. The simplex systems have been demonstrated in figure 1.17.

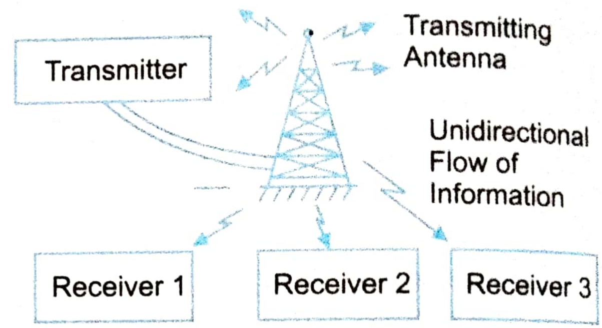


Fig. 1.17. Simplex system

2. Half Duplex Systems

These systems are bidirectional, i.e. they can transmit as well as receive but not simultaneously. At a time, these systems can either transmit or receive, for example, a transreceiver or walky talky set. The direction of communication alternates. The radio communications such as those used in military, fire fighting, citizen band (CB) and amateur radio are half duplex system.

3. Full Duplex Systems

These are truly bidirectional systems as they allow the communication to take place in both the directions simultaneously. These system can transmit as well as receive simultaneously, for example, the telephone systems. However, the bulk of electronic communications is two-way. The best example of full duplex communication system is the telephone system. Figure 1.18. illustrates the concept of duplex communication.

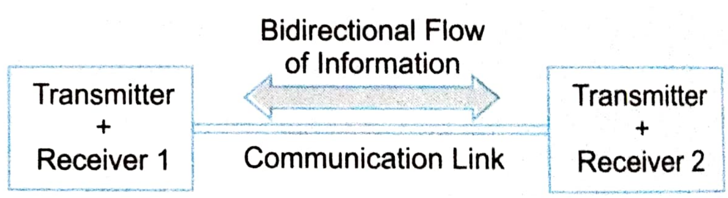


Fig. 1.18. Duplex communication

1.7.1. Comparison of Half Duplex and Full Duplex Systems

S. No.	Parameter	Half Duplex	Full Duplex
1.	Definition	Communication is two way but one at a time	Communication is two way.
2.	Examples	Walky Talky	Telephone

1.7.2. Comparison Between Simplex and Duplex Systems

S.No.	Parameter	Half Duplex	Full Duplex
1.	Definition	Communication is one way	Communication is two way.
2.	Examples	Radio/TV broadcast	Telephone

1.8 CLASSIFICATION BASED ON THE NATURE OF INFORMATION SIGNAL

Figure 1.19. shows another way of classifying the electronic communication system. They are classified into two categories namely:

(i) Analog communication systems.
(ii) Digital communication systems.

1.8.1. Analog Communication

1. Basic Aspects

The modulation systems or techniques in which one of the characteristics of the carrier is varied in proportion with the instantaneous value of modulating signal is called as analog modulation system. If the carrier is sinusoidal, then it's amplitude, frequency or phase is changed in accordance with the modulating signal to obtain AM, FM or PM respectively. These are continuous wave modulation systems.

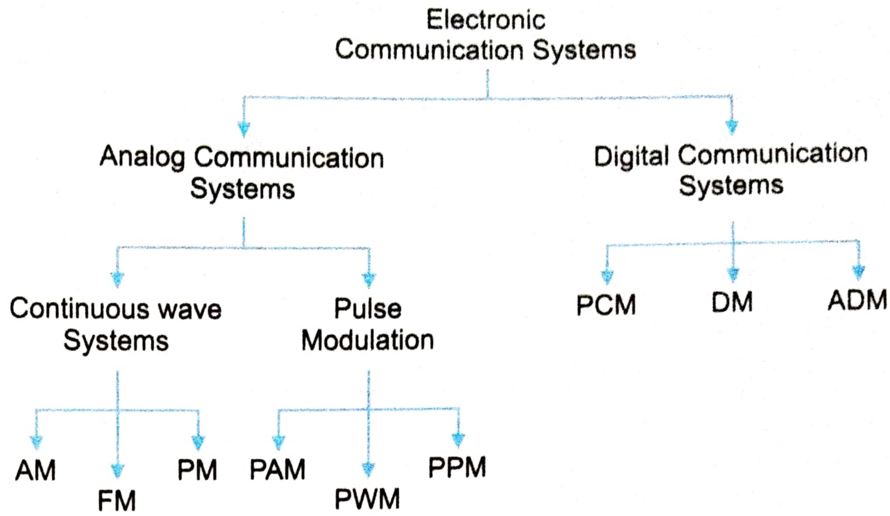


Fig. 1.19. Classification based on analog or digital communication

Analog modulation can be pulsed modulation as well. Here, the carrier is in the form of rectangular pulses. The amplitude, width (duration) or position of the carrier pulses is varied in accordance with the modulating signal to obtain the PAM, PWM or PPM outputs.

2. Examples of analog modulation

Following are the examples of analog modulation systems:

(i) Amplitude Modulation (AM)
(ii) Frequency Modulation (FM)
(iii) Phase Modulation (P.M.)
(iv) Pulse Amplitude Modulation (PAM)
(v) Pulse Width Modulation (PWM)
(vi) Pulse Position Modulation (PPM)

3. Advantages of analog communication

Some of the advantages of analog communication are as under:

(i) Transmitters and receivers are simple.
(ii) Low bandwidth requirement
(iii) FDM (frequency division multiplexing) can be used.

4. Drawbacks of analog communication

Some of the drawbacks are as under :

(i) Noise affects the signal quality
(ii) It is not possible to separate noise and signal.
(iii) Repeaters cannot be used between transmitters and receivers.
(iv) Coding is not possible.
(v) It is not suitable for the transmission ofsecret information.

5. Applications

(i) Radio broadcasting (AM and FM).
(ii) TV broadcasting
(iii) Telephones

1.8.2. Digital communication

1. Basic Aspects

The modulation system or technique in which the transmitted signal is in the form of digital pulses of constant amplitude, constant frequency and phase is called as digitral modulation system.

2. Examples

Pulse code modulation (PCM) and delta modulation (DM) are the examples of digital modulation.

(i) In the PCM and DM, a train of digital pulses is transmitted by the transmitter.

(ii) All the pulses are of constant amplitude, width and position. The information is contained in the combination of the transmitted pulses.

3. Advantages of digital communication

Some of the advantages of digital communication are as under:

(i) Due to the digital nature of the transmitted signal, the interference of additive noise does not introduce many errors. Hence, digital communication has a better noise immunity.

(ii) Due to the channel coding techniques used in digital communication, it is possible to detect and correct the errors introduced during the data transmission.

(iii) Repeaters can be used between transmitter and receiver to regenerate the digital signal. This improves the noise immunity further.

(iv) Due to the digital nature of the signal, it is possible to use the advanced data processing techniques such as digital signal processing, image processing data compression etc.

(v) TDM (Time Division Multiplexing) technique can be used to transmit many voice channels over a single common transmission channel.

(vi) Digital communication is useful in military applications where only a few permitted receivers can receive the transmitted signal.

(vii) Digital communication is becoming simpler and cheaper as compared to the analog communication due to the invention of high speed computers and integrated circuits (ICs).

4. Drawbacks of digital communication

Some of the important drawbacks of digital communication are as under :

(i) The bit rates of digital systems are high. Therefore, they require a larger channel bandwidth as compared to analog systems.

(ii) Digital modulation needs synchronization in case of synchronous modulation.

5. Applications of digital communications

(i) Long distance communication between earth and space ships.

(ii) Satellite communication.

(iii) Military communications which needs coding.

(iv) Telephone systems.

(v) Data and computer communications.

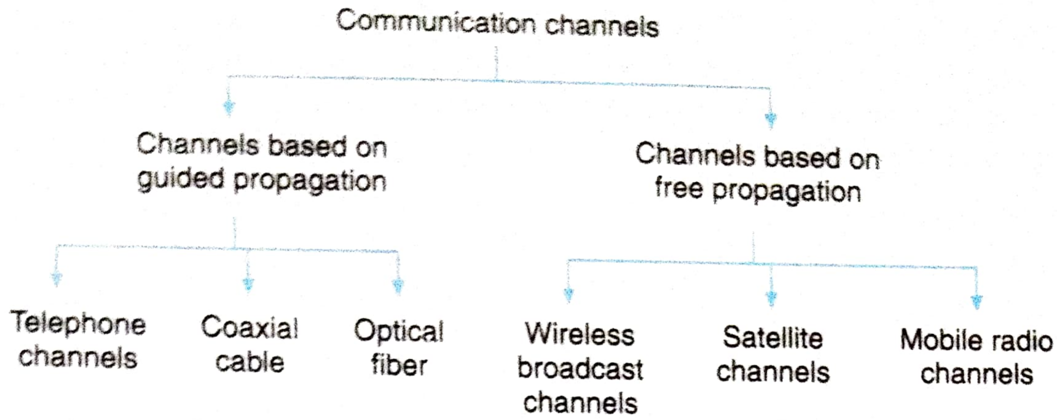


Fig. 1.6. Classification of communication channels

1.5.1. Telephone Channels

It is designed for providing service to voice signals such as telephones. The telephone channels are also used for the worldwide Internet connection. Therefore, telephone channel is the best possible option for the data communication over long distances.*

DO YOU KNOW?

Cellular phones transmitting above 3 W, such as some portable and mobile cellular phones, should be held at least 12 inch away from a pacemaker, or they could interfere with its function. Even some high-power stereo speakers could be dangerous to pacemaker users, because they contain large magnets.

Salient Features

Features of telephone channel are as follows :

(i) Bandpass characteristics over 300 to 3400 Hz as shown in figure 1.7.

(ii) High signal to noise ratio of about 30 dB.

(iii) Approximately linear response.

The amplitude response is flat over the entire passband as shown in Figure 1.7.

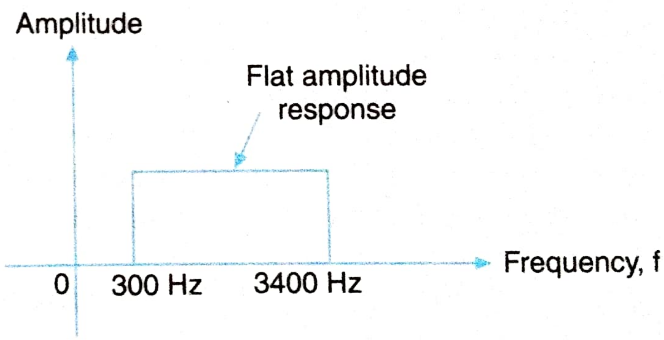
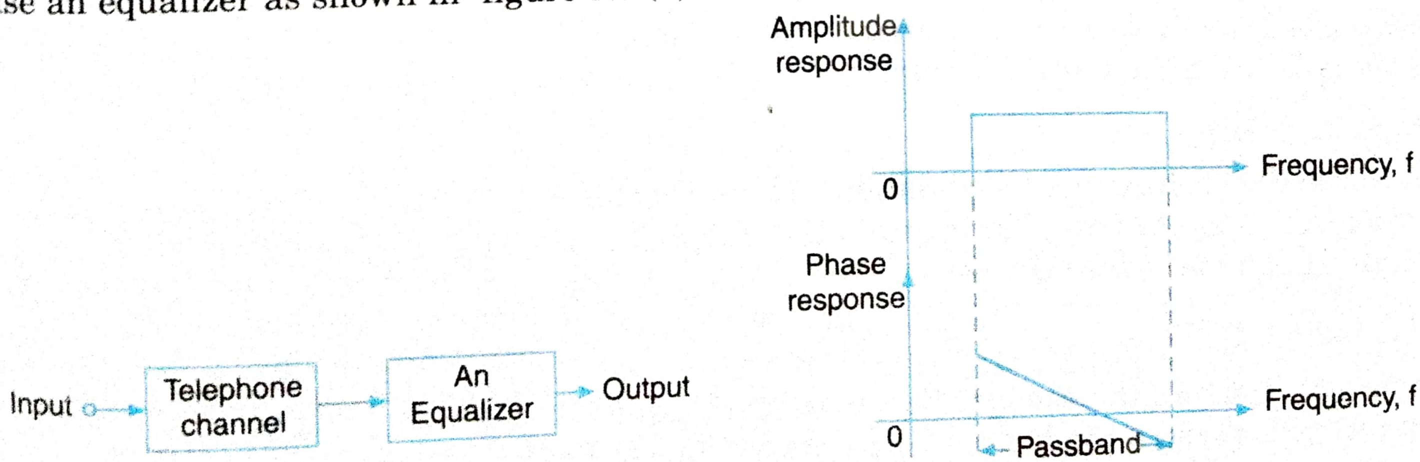


Fig. 1.7. Characteristics of telephone channel

However, no particular attention is given to the phase response because human ears are not very sensitive to the phase delay variations. But the data and images (i.e., pictures) are strongly affected by the phase delay variations. Therefore, for digital transmission over the telephone channels, it is essential to use an equalizer as shown in figure 1.8 (a).



(a) Use of equalizer

(b) Amplitude and phase response of the telephone channel with equalizer

As depicted in Figure 1.8 (b), the equalizer maintains a flat amplitude response and linear phase response over the passband. Also the telephone channel is a bandwidth limited channel. Figure 1.9 (a) depicts the variation of insertion loss with frequency and figure 1.9 (b) illustrates the variation of envelope delay with frequency, for a telephone channel.*

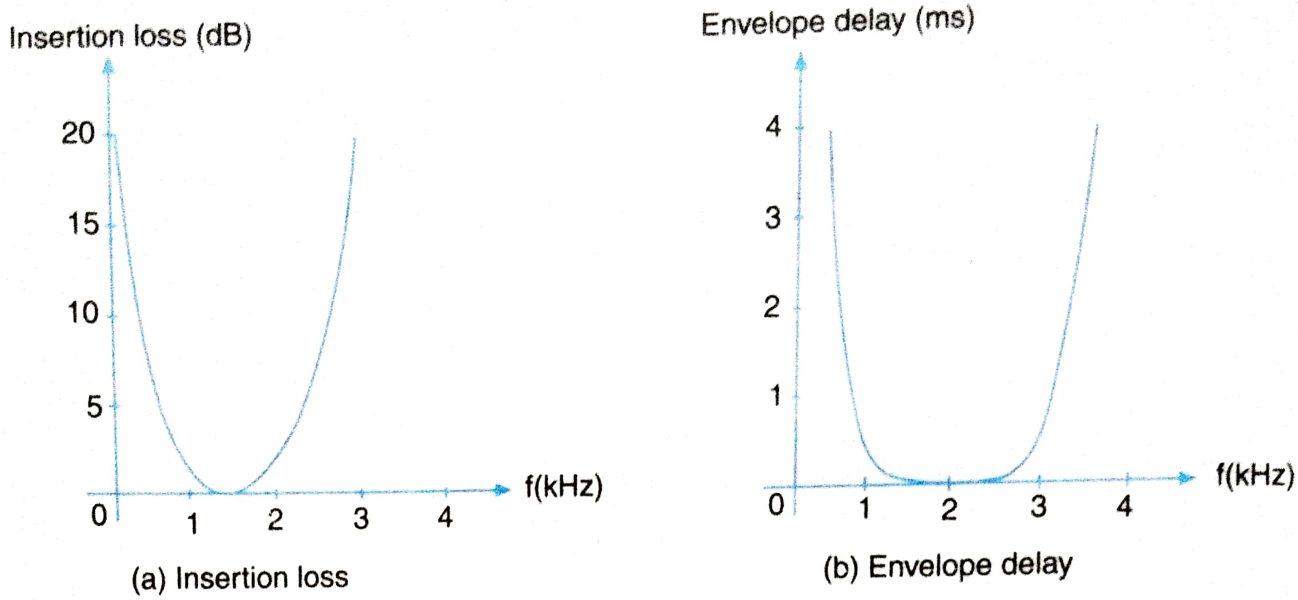


Fig. 1.9. Characteristics of a typical telephone channel

Insertion loss may be defined as under:

$$\text{Insertion loss} = 10 \log_{10} (P_o | P_L)$$

where P_L = load power from a source to load via channel

P_o = load power when the load is connected directly to source

An envelope delay is defined as the negative of the phase response with respect to $\omega = 2\pi f$. The telephone channels are built using the twisted pair of wires. The construction of twisted pair cables has been shown in figure 1.10. This is also commonly used medium and it is quite cheaper than the co-axial cable. A twisted pair consists of two insulated conductor twisted together in the spiral form as shown in figure 1.10. It can be shielded or unshielded. The unshielded twisted pair cables are very cheap and easy to install. However, they are badly affected by the noise interference.

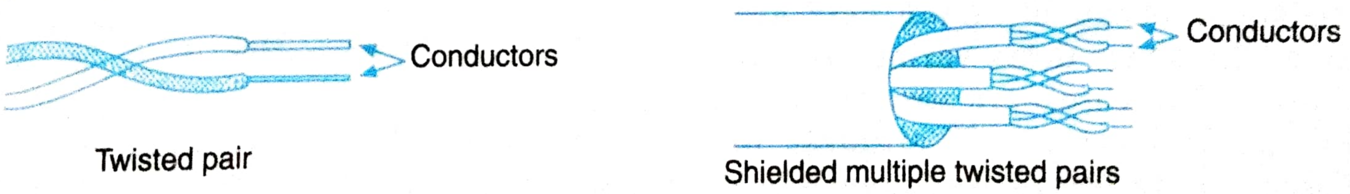


Fig. 1.10. Twisted pair cables

The noise immunity can be improved by using a shielded twisted pair cable. As shown in figure 1.10, a metallic braid can be used around the twisted pair. Protective plastic coating is then provided.

Transmission rates

If we use the sophisticated modulation techniques along with equalizer, then it is possible to attain the transmission rates upto 16.8 kilobits/sec (kb/s).

DO YOU KNOW?

The ionosphere refracts radio waves, making long-distance communications possible for some frequencies at certain times.

1.5.2. Co-axial Cables

Figure 1.11 shows the construction of co-axial cable. It consists of two concentric conductors separated by a dielectric material. The external conductor is metallic braid and used for the purpose of shielding. The co-axial cable may contain one or more co-axial pairs.

The co-axial cable was initially developed as the backbone of analog telephone networks where a single telephone cable would be used to carry more than 10,000 voice channels at a time. The digital transmission systems using the co-axial cable were developed in 1970s. These systems operated in the range of 8.5 Mb/s to 274 Mb/s. Another important application is cable modem, with the cable modem termination system (CMTS). One more application is Ethernet LAN using the co-axial cable. The co-axial cable is used for its large bandwidth and high noise immunity.

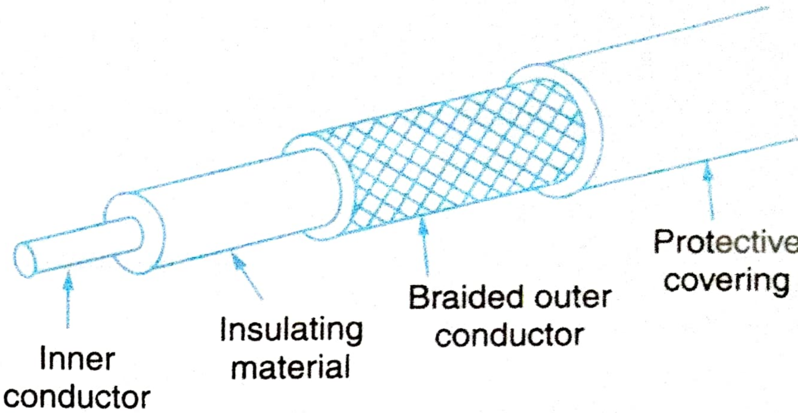


Fig. 1.11. Construction of a co-axial cable

Salient Features

The important characteristics of a co-axial cable may be listed as under :

(i) Two types of cables having 75 Ω and 50 Ω impedance are available.

(ii) Because of the shield provided, this cable has excellent noise immunity.

(iii) It has a large bandwidth and low losses.

(iv) This cable is suitable for point to point or point to multipoint applications. Actually, this is the most widely used medium for local area networks (LANs).

(v) These cables are costlier than twisted pair cables, however, they are cheaper than the optical fiber cables.

(vi) It is essential to use closely spaced (after every 1 km) repeaters to achieve the data rates of 8.5 Mb/s to 274 Mb/s.

Important Point: As compared to the twisted pair of wires, the coaxial cable provides a higher immunity to electromagnetic interference (EMI). Because of their higher bandwidths, the coaxial cables are more suitable for the digital signal transmission.

1.5.3. Optical Fiber Cables

1. Definition and Construction

The construction of an optical fiber cable has been shown in Figure 1.12. It consists of an inner glass core surrounded by a glass cladding which has a lower refractive index. Digital signals are transmitted in the form of intensity-modulated light signal which is trapped in the glass core.

Light is launched into the fiber using a light source such as a light Emitting Diode (LED) or Laser. It is detected on the other side using a photo detector such as a phototransistor. The optical fiber cables are costlier than the other two types but they have several advantages over the other two types.*

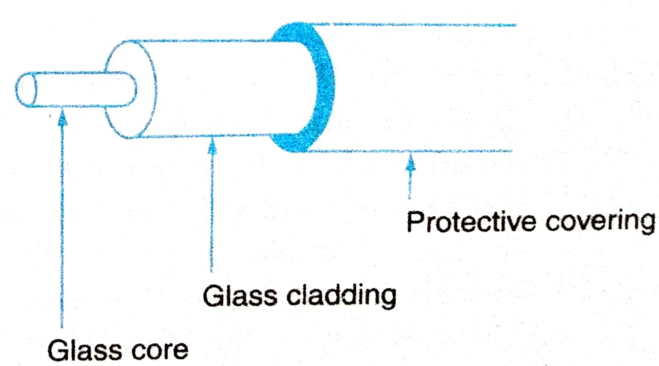


Fig. 1.12. Construction of optical fiber cable

2. Special Characteristics

The characteristics of optical fiber cables may be listed as under :

(i) Higher bandwidth therefore can operate at higher data rates
(ii) Reduced losses as the signal attenuation is low
(iii) Distortion is reduced hence better quality is assured.
(iv) They are immune to electromagnetic interferences.
(v) Small size and light weight
(vi) Used for point to point communication

3. Applications

(i) Optical fiber transmission systems are widely used in the backbone of networks. Current optical fiber systems provide transmission rates from 45 Mb/s to 9.6 Gb/s using the single wavelength transmission.
(ii) The installation cost of optical fibers is higher than that for the co-axial or twisted wire cables.
(iii) Optical fibers are now used in the telephone systems.
(iv) In the local area networks (LANs).

4. Advantages of Optical Fibers

Some of the advantages of fiber optic communication over the conventional means of communication may be listed as under:

(i) Small Size and Light Weight: The size (diameter) of the optical fibers is very small (it is comparable to the diameter of human hair). Therefore, a large number of optical fibers can fit into a cable of small diameter.

DO YOU KNOW?

The SHF and EHF bands are used primarily for satellite communications and radar.

(ii) Easy availability and low cost: The material used for the manufacturing of optical fibers is silica glass. This material is easily available. Hence, the optical fibers cost lower than the cables with metallic conductors.

(iii) No electrical or Electromagnetic interference: Since the transmission takes place in the form of light rays the signal is not affected due to any electrical or electromagnetic interference.

(iv) Large bandwidth: As the light rays have a very high frequency in the GHz range, the bandwidth of the optical fiber extremely large. This allows transmission of more number of channels. Therefore, the information carrying capacity of an optical fiber is much higher than that of a co-axial cable.

(v) Other advantages: In addition to the advantages discussed earlier, the optical fiber communication has the following other advantages:

(i) No crosstalk inside the optical fiber cable
(ii) Signal can be transmitted upto 100 times faster
(iii) Intermediate amplifier are not required as the transmission losses in the fiber are low
(iv) Ground loops are absent
(v) Installation is easy as the fiber optic cables are flexible
(vi) These cables are not affected by the drastic environmental conditions

Because of all these advantages the optical fiber cable is replacing the conventional metallic conductor cable rapidly in many areas.

5. Drawback of Optical Fiber

Some of the drawbacks of optical communication system may be listed as under:

(i) Sophisticated plants are required for manufacturing optical fibers
(ii) The initial cost incurred is high
(iii) Joining the optical fibers is a difficult job.

1.5.4. Wireless Broadcast Channels

These channels are used for the transmission of radio and TV signals. The information signal or message signal which represents the speech, music etc. modulates a carrier frequency. The carrier frequency is different for every transmitting station. A transmitting antenna radiates the modulated signal in the form of electromagnetic radiator into the free space. These waves are radiated in all the directions or in some specific directions. The transmitting antenna is mounted on a tower or a hall in order to reach the farther receiver. The ground wave, sky wave and space wave are the three types of propagation techniques used for the propagation of EM waves. At the receiving end, the receiving antenna is used for picking up the transmitted signal. The receivers are superheterodyne type.

1.5.5. RF Link (Microwave Link)

Long form of RF link is radio frequency link.* This is actually a type of point to point wireless communication. The radio frequencies used for RF links are in microwave range, therefore, RF links are also called as microwave links. This has been shown in figure 1.13.

Although many wire communication systems use copper wires or optical fiber, some just send the signal into the air. This happens when infrared, lasers, microwaves and radio are used for the transmission of data, as they do not need any physical medium. For long distance communication, microwave radio transmission is widely used as an alternative to coaxial cable. The signal transmission takes place in the form of electromagnetic waves which have wavelengths of few centimeters. Parabolic antennas can be mounted on the towers to send a beam of waves to another antenna, tens of kilometers away. The transmitting and receiving antennas are highly directional to enable a point to point communication. This system is widely used for both telephone and television transmission. The higher this tower which holds the antenna, the greater is the range. With a 100 meter high tower, the distances of 100 km can be easily covered.

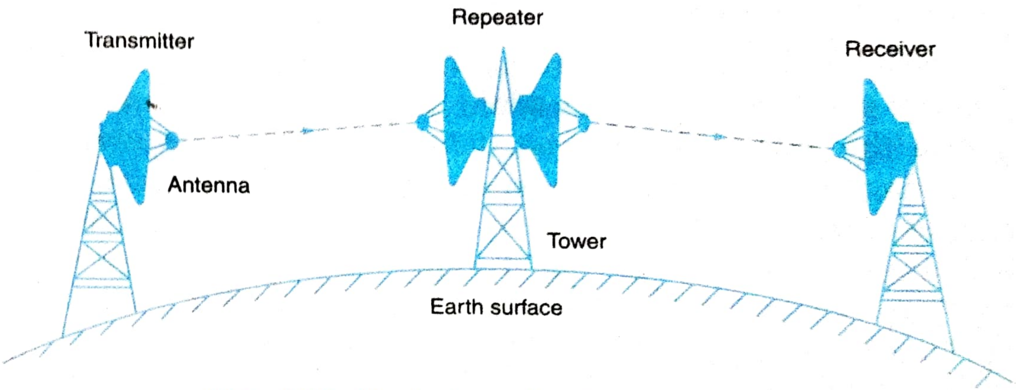


Fig. 1.13. Illustration of microwave link

Salient Features of microwave link

Some of the important features may be listed as under:

(i) Installation of towers and associated equipments is cheaper than laying down a cable of 100 km length.

(ii) Less maintenance as compared to cables.

(iii) Repeaters can be used. Therefore, effect of noise is reduced.

(iv) No adverse effects such as cable breakage etc.

(v) Because of the use of highly directional antenna, these links do not make any interference with other communication systems.

(vi) Size of transmitter and receiver reduces because of the use of high frequency.

Drawbacks

(i) Signal strength at the receiving antenna reduces due to multipath reception.

(iii) The transmission will be affected by the thunderstorms, and other atmospheric phenomenons.

Range of Frequencies

Generally, the microwave transmission takes place at frequencies between 2 and 40 GHz. This will correspond to a wavelength of 15 cm to 0.75 cm.

1.5.6. A Mobile Radio Channel

In mobile communication, the sender and the receiver both are allowed to move with respect to each other. The radio propagation takes place due to scattering of EM waves from the surfaces of the surrounding buildings and diffraction over and around them. Hence, the transmitted energy reaches the receiver via multiple paths. This is called as multipath communication. The signals taking different paths will have to travel different path lengths. So, they have different phase shifts when they reach the receiver. The total signal strength at the receiver is equal to the vector sum of all the signals. Therefore it keeps changing continuously. Hence, mobile channels are called as the linear time varying channels and it is statistical in nature.

1.5.7. Satellite Channel

Satellite microwave systems transmits signals between directional parabolic antennas. They use low gigahertz frequencies and line of sight communication. These systems use satellites which are in the geostationary orbit (36000 km above the earth). The satellites act as repeaters with receiving antenna, transponder and transmitting antenna. Satellite microwave systems can reach the most remote places on earth and communicate with mobile devices. This systems works in the following way: signal is sent through cable media to an antenna which beams the signal to the satellite. The satellite then transmits the signal back to another location on earth as shown in Figure 1.14.

Satellite microwave systems experience delays between the transmission of a signal and its reception back to the earth (540 ms).

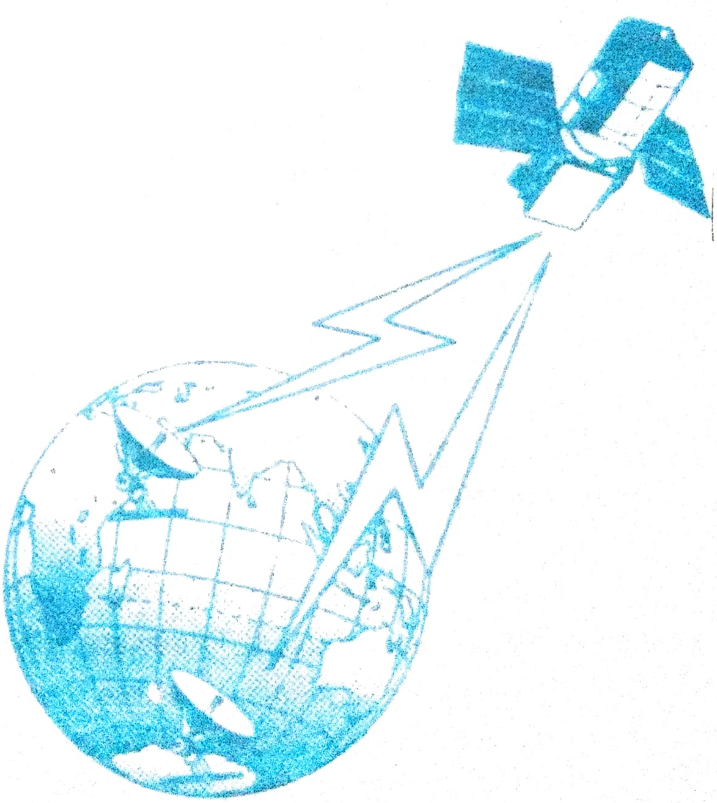


Fig. 1.14. Illustration of satellite system

Characteristics

Satellite microwave systems have the following characteristics:

1. It uses frequency range between 11 GHz and 14 GHz.
2. Attenuation depends on frequency, power, antenna size and atmospheric condition.
3. The signals are affected by EMI effect, jamming and eavesdropping.
4. The installation of satellites is extremely difficult and the alignment of earth station antennas must be perfectly aligned.
5. The cost of building and launching is very high.
6. The satellites can provide point to point or broadcast services.
7. The message signal transmitted by the earth station to the satellite is called as an uplink signal