Module 5

ANALOG COMMUNICATION SCHEMES

MODEIFN COMMUNICATION SYSTEM SCHEME

We know that communication is the science and practice of transmitting information. Further, communication engineering also deals with the techniques of transmitting information. In brief, communication engineering means electrical communication, in which information is transmitted through electrical signals. In this process, the information or message, c.,q. spoken words, live scenes, photographs, and sounds is first converted into electrical signals and then transmitted through electrical links. Thus, electrical communication is a process by which the information message is transmitted from one point to another, from one person to another, or from place to another in the form of electrical signals, through some communication link.

We may note that a basic communication system provides a link between the information source and its destination. The process of electrical communication involves sending, receiving, and processing information in electrical form. A basic communication system consists of certain units, called constituents, subsystems, or stages. We may also note that the information to be transmitted passes through a number of stages of the communication system prior it reaches its destination. Figure 1.1 shows a block schematic diagram of the most general form of basic communication system.

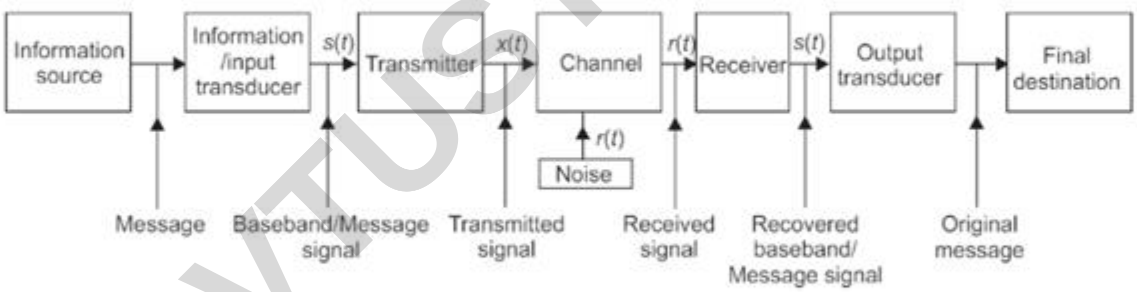


Fig. 5.1 Schematic block diagram of a basic communication system in most general form

We see from Fig. 5.1, the main constituents of basic communication system are:

(i) Information source and input transducer
(ii) Transmitter
(iii) Channel or medium
(iv) Noise
(v) Receiver
(vi) Output transducer and final destination.

We may note that there are many types of communication systems, e.g. analog, digital, radio, and line communication systems. Figure 5.1 shows each type of communication system comprises the constituents. However, different communication systems apply different principles of operation and physical appearance to each constituent, in accordance with its type. Now, we briefly describe each of the constituents or subsystems, explain the correlation between the subsystems, and provide a brief description of the working of a basic communication system.

Information Source and Input Transducer

A communication system transmits information from an information source to a destination and hence the first stage of a communication system is the information source. The physical form of information is represented by a message that is originated by an information source, c.,q. a sentence or paragraph spoken by a person is a message that contains some information. The person, in this case, acts as information source. Few other familiar examples of messages are voice, live scenes, music, written text, and e-mail.

A communication system transmits information in the form of electrical signal or signals. If the information produced by the source is not in an electrical form, one will have to use a device, known as transducer, to convert the information into electrical form.

A transducer is a device that converts a non-electrical energy into its corresponding electrical energy called signal and vice versa, e.g. during a telephone conversation, the words spoken by a person are in the form of sound energy. This has to be converted to its equivalent electrical form prior it is transmitted.

An example of a transducer is a microphone. Microphone converts sound signals into the corresponding electrical signals. Similarly, a television (TV) picture tube converts electrical signals into its corresponding pictures. Some other examples of transducers are movie cameras, Video Cassette, Recorder (VCR) heads, tape recorder heads, and loudspeakers.

The information produced by the information source is applied to the next stage, termed the information or input /transducer. This in turn, produces an electrical signal Corresponding to the information as output. This electrical signal is called the baseband signal It is also called a message signal, an information signal, an intelligent signal, or an envelope. In the communication theory, the baseband signal is usually designated by s(f).

There are two types of signals. (a) analog signal, and (b) digital signal.

(a) Analog Signal

An analog signal is a function of time, and has a continuous range of values. However, there is a definite function value of the analog signal at each point of time. Corresponding to the information as output. An familiar example of analog signal or analog wave form is a pure sink wave form. A practical example of an analog signal is a voice signal When a voice signal is converted to electrical form by a microphone, one get a corresponding electrical analog signal. One can see this electrical signal on an oscilloscope. Obviously, being an analog signal, this wave form has definite values at all points of time. Analog signals are shown in Fig. 1.2.

(b)Digital Signal

A digital signal does not have continuous function values on a time scale. It is discrete in nature, i.e., it has some values at discrete timings. In between two consecutive values, the signal values is either zero, or different value. A familiar example of a digital signal is the sound signal produced by drumbeats.

Figure 1.3 shows a graphical representational of a digital signal.

Digital signals in their true sense correspond to a binary digital signal, where the discrete amplitude of the signal is coded into binary digits represented by ‘0’ and ’1’. The analog signal,

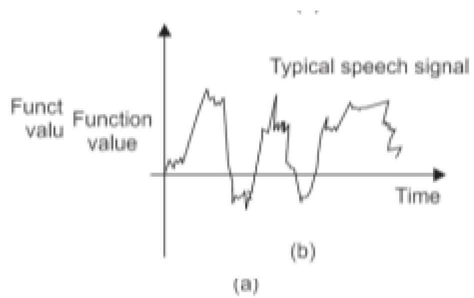


Fig. 5.2 Analog signals: (a) Pure sins wave, (b) Typical speech signal

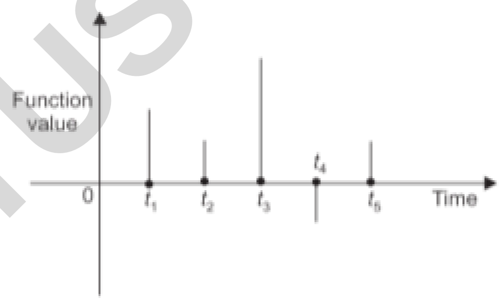


Fig. 5.2 Analog signals:

which is continuous in time, is converted to discrete time, using a procedure calling sampling. The continuous amplitude of the analog signal is converted to discrete amplitude using a process called quantization. Sampling and quantization are together termed as analog-to-digital conversion (ADC) and the circuitry that performs this operation is called an analog to-digital converter.

TRANSMITTER

We can see that the next block in the communication system of Fig. 5.1 is the transmitter. The base band signal, which is the output of an input transducer, is input to the transmitter. This base band signal, s(f), is suitable for transmission in the form in which it is generated by the transducer. The transmitter section processes the signal prior transmission. We may note that the nature of processing depends on the type of communication system. However, the processing carried out for signal transmission in the analog form is different from signal transmission in the digital form.

There are two following options for processing signals prior transmission:

(i) The baseband signal, which lies in the low frequency spectrum, is translated to a higher frequency spectrum.

(ii) The baseband signal is transmitted without translating it to a higher frequency spectrum. In the former case, we call the communication system as a carrier communication system. In this system, the baseband signal is carried by a higher frequency signal, called the carrier signal. In the latter case, we call the system as a baseband communication system, because the baseband signal is transmitted without translating it to a higher frequency spectrum. However, some processing of the signal is required prior its transmission, e.g. a train of pulses that are to be transmitted can be replaced by a series of two sine waves of different frequencies prior to transmission. One of these two frequencies represent a low and the other represents a high value of the digital pulse.

Therefore, the baseband signal is converted into a corresponding series of sine waves of two different frequencies prior to transmission. Figure 5.4 illustrates this processing.

The carrier communication system is based on the principle of translating a low frequency baseband signal to higher frequency spectrum. This process is termed as modulation.

Now, if the baseband signal is a digital signal, the carrier communication system is called a digital communication system. The digital modulation methods are employed for this. If the baseband signal is an analog signal, the carrier communication system is called as an analog communication system and for processing the analog modulation techniques are used.

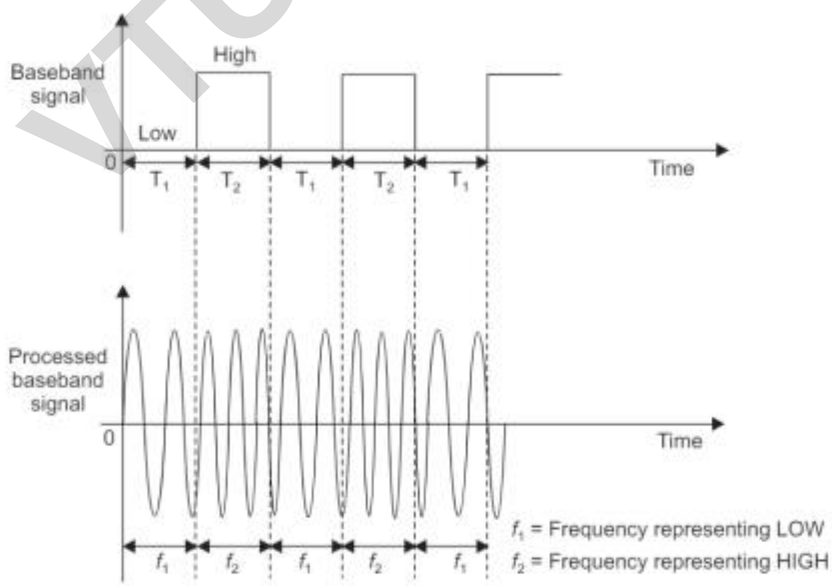


Fig 5.4 The processing of a baseband signal

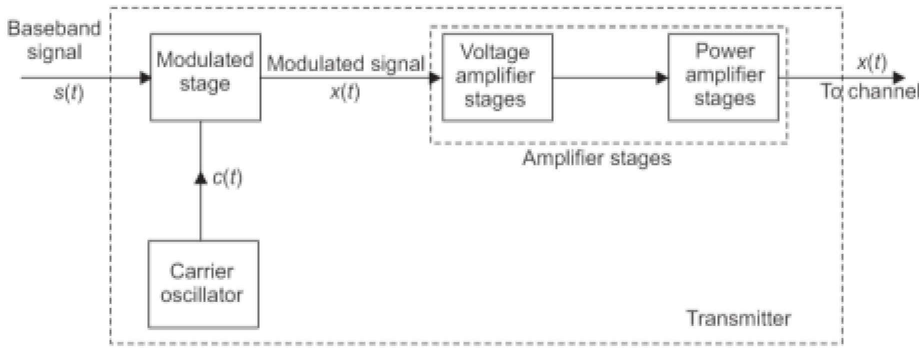


Fig 5.5 Analog Transmitter Section

Figure 5.5 shows the baseband signal, s(i) applied to the modulated stage. This stage translates the baseband signal from its low frequency spectrum to high frequency spectrum. This stage also receives another input called the carrier signal, c(t), which is generated by a high frequency carrier oscillator. Modulation takes place at this stage with the baseband and the carrier signals as two inputs after modulation, the baseband signal is translated to a high frequency spectrum and the carrier signal is said to be modulated by the baseband signal. The output of the modulated stage is called the modulated signal, and is designated as x(t).

The voltage of the modulated signal is then amplified to drive the last stage of the transmitter, called the poker amplifier stage (Fig. 5.5). This stage amplifies the power of the modulated signal and thus it carries enough power to reach the receiver stage of the communication system. Finally, the signal is passed to the transmission medium or channel.

Radio signals are transmitted through electromagnetic (EM) waves, also referred as radio waves, in a radio communication system. The radio waves have a wide frequency range starting from a few ten kilo Hertz (Hz) to several thousand Mega Hertz (MHz). This wide range of frequencies is referred as the radio frequency (If) spectrum.

The RF spectrum is classified according to the applications of the spectrum in different service areas. Table 5.1 shows the classification of the RF spectrum along with the associated applications in communication systems.

Table 5.1: Classification of radio frequency (RF) spectrum along with the associated applications in communication systems.

Radio frequency range	Wavelength (meters)	Class	Applications
10–30 kHz	$3 \times 10^4 - 10^4$	Very Low Frequency (VLF)	Point-to-point communication (long distance)
30–300 kHz	$10^4 - 10^3$	Low Frequency (LF)	Point-to-point communication (long distance) and navigation
300–3000 kHz	$10^3 - 10^2$	Medium Frequency (MF)	Radio broadcasting
3–30 MHz	$10^2 - 10$	High Frequency (HF)	Overseas radio broadcasting, Point-to-point radio telegraphy, and telephony
30–300 MHz	$10 - 1.0$	Very High Frequency (VHF)	FM broadcast, television, and radar
300–3000 MHz	$1.0 - 0.1$	Ultra High Frequency (UHF)	Television and navigation
3000–30,000 MHz	$0.1 - 0.01$	Super High Frequency (SHF)	Radar navigation and radio relays

CHANNEL OR MEDIUM

After the required processing, the transmitter section passes the signal to the transmission medium. The signal propagates through the transmission medium and is received at the other side by the receiver section. The transmission medium between the transmitter and the receiver is called a channel.

We may note that the channel is a very important part of a communication system as its characteristics add many constraints to the design of the communication system, e.g. most of the noise is added to the signal during its transmission through the channel. The transmitted signal should have adequate power to withstand the channel noise. Further, the channel characteristics also impose constraints on the bandwidth. The bandwidth is the frequency range that can be transmitted by a communication system. Moreover, the channel characteristics are also taken into consideration as a design parameter while designing the transmitting and receiving equipment.

In general, we can say that the transmitting power, signal bandwidth, and cost of the communication system are affected by channel characteristics.

Depending on the physical implementations, one can classify the channels in the following two groups:

Hardware Channels

These channels are manmade structure which can be used as transmission medium. There are following three possible implementations of the hardware channels.

- Transmission lines

- Waveguides
- Optical Fiber Cables (OFC)

The examples of transmission lines are twisted-pair cables used in landline telephony and coaxial cables used for cable TV transmission.

However, transmission lines are not suitable for ultrahigh frequency (UHF) transmission. To transmit signals at UHF range, waveguides are employed as medium. Waveguides are hollow, circular, or rectangular metallic structures. The signals enter the waveguide, are reflected at the metallic walls, and propagate towards the other end of the waveguide.

Optical fiber cables are highly sophisticated transmission media, in the form of extremely thin circular pipes. Signals are transmitted in the form of light energy in optical fiber cables. In general, there is always a physical link between the transmitter and receiver in hardware channels. A communication system that makes use of a hardware channel is called as a line

communication system, e.g. landline telephony and cable TV network.

Software Channels

There are certain natural resources which can be used as the transmission medium for signals. Such transmission media are called software channels. The possible natural resources that can be used as software channels are: air or open space and sea water.

We may note that in communication systems that use software channels there is no physical link between the transmitter and the receiver. The transmitter passes the signals in the required form to the software channel. The signals propagate through the natural resource and reach the receiver.

The most widely used software channel is air or open space. The signals are transmitted in the form of electromagnetic (em) muses', also called radio waves. Radio waves travel through open space at a speed equal to that of light pc —— 3 x 10' ms ').

The transmitter section converts the electrical signal into em waves or radiation by using a transmitting antenna. These waves are radiated into the open space by the transmitting antenna. At the receiver side, another antenna, called the receiving antenna, is used to pick up these radio waves and convert them into corresponding electrical signals. Systems that use radio waves to transmit signals through open space are called radio communication systems, c.,q. radio broad cast, television transmission, satellite communication, and cellular mobile communication.

NOISE

In electronics and communication engineering, noise is defined as unwanted electrical energy o/ random and unpredictable nature present in the system date to any cause. Obviously, noise is an electrical disturbance, which does not contain any useful information. Thus, noise is a highly undesirable part of a communication system, and have to be minimized. We may note that noise cannot be eliminated once it is mixed with the signal. When noise is mixed with the transmitted signal, it rides over it and deteriorates it waveform. This results in the alteration of the original information so that wrong information is received.

The receiver processes the signal to cover the original information produced by the information source at the transmitter end. If the amplitude of the noise is comparable with that of the signal, then the noise may render the transmitted signal unintelligible, and the receiver recovers nothing but the noise. In order to avoid this undesirable situation, the system designer can make the signal adequately powerful prior to transmitting it. This enables the signal to withstand the noise. In fact, the system designer increases the power of the signal in comparison with that of the noise. This increases the ratio of the signal power to the noise power, i.c. SWR

The designer provides adequate signal strength at the time of transmission so that a high SNR is available at the receiver.

The noise block in Fig. 5.1 represents the total noise present in the system, contributed by all the sources. The noise signal not), is applied to the channel block. However, this does not mean that the noise is intermingled with the signal only during its propagation through the channel. In fact, the channel contributes the major part of the noise. However, other noise sources along the communication chain can also add noise to the signal. We may note that the noise may also be mixed with the signal from within the transmitting and receiving equipment. Since it is not possible to show all the individual sources of noise along the communication chain, we have shown only one noise block in Fig. 5.1, beneath the channel block, as the channel in the main source of noise.

The noise introduced by the transmission medium is called extraneous or external noise. The main cause of the internal noise is the thermal agitation of atoms and electrons of electronic components used in the equipment.

RECEIVER

The task of the receiver is to provide the original information to the user. This information is altered due to the processing at the transmitter side. The signal received by the receiver, thus, does not contain information in its original form. The receiver system receives the transmitted signal and performs some processing on it to recover the original baseband signal.

We have marked the signal received by the receiver by rat) in Fig. 1.1. This signal contains both the transmitted signal, x(/), and the noise, n(f), added to it during transmission. The function of the receiver section is to separate the noise from the received signal, and then recover the original baseband signal by performing some processing on it. The receiver receives a weak signal because the transmitted signal losses its strength during its propagation through the channel. This occurs due to the attenuation of the signal.

A voltage amplifier first amplifies the received signal so that it becomes strong enough for further processing, and then recovers the original information. The original baseband signal is recovered by performing an operation opposite to the one performed by the transmitter section. The transmitter performs modulation on the baseband signal to translate it to a higher spectrum from its low frequency spectrum. The receiver, in turn, performs an operation known as demodulation, which brings the baseband signal from the higher frequency spectrum to its original low-frequency spectrum. The demodulation process removes the high frequency carrier from the received signal and retrieves the original baseband. This occurs in a carrier communication system. The baseband communication systems, assume that the transmitter replaces the digital baseband signal with a series of two sinusoidal wave forms of different frequencies as shown in Fig. 5.4. When the receiver receives this signal, it recovers the original baseband pulse by replacing the two sinusoidal waveforms with the corresponding original levels.

The recovered baseband signal is then handed over to the final destination, which uses a transducer to convert this electrical signal to its original form. It is essential that enough signal power is given to the transducer so that it satisfactorily reproduces the message. Therefore, prior to handing over the recovered baseband signal to its final destination, the voltage and power are amplified by the amplifier stages.

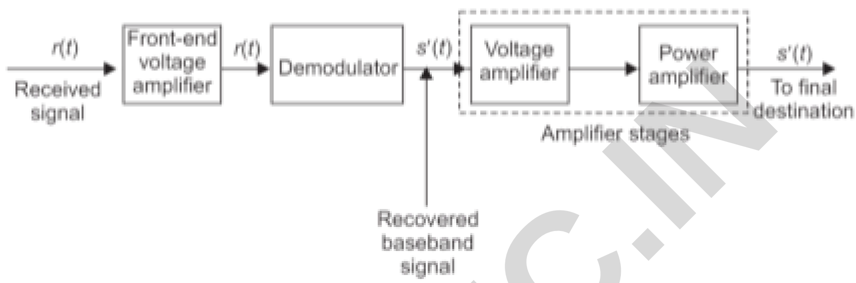


Fig 5.6 Receiver section

From Fig. 5.7 it is evident that the received signal, rat), is first amplified by the front-end voltage amplifier. This is done to strengthen the received signal, which is weak and to facilitate easy processing. Next, this signal is given to the demodulator, which in turn, demodulates the received signal to recover the original baseband signal. Interestingly, the type of demodulation is based on the type of modulation employed at the transmitter. After recovering the original baseband signal, its voltage and power is amplified prior it to final destination block.

1.14 MULTIPLEXING

This is a technique that is most widely used in nearly all types of communication systems, radio and line communication systems. Basically, multiplexing is a process which allows more one signal to transmit through a single channel. Clearly, multiplexing facilitates the

simultaneous transmission of multiple messages over a single transmission channel.

Multiplexing allows the maximum possible utilization of the available bandwidth of the system. Bandwidth is an important entity in any communication system. The use of multiplexing also makes the communication system economical because more than one signal can be transmitted through a single channel. Multiplexing is possible in communication system only through modulation.

To consider multiplexing, let us consider the following example. If many people speak loudly and simultaneously, then it becomes nearly impossible to understand their conversion because the overall result is noise. This noise is the result of mixing of all the speeches. The human ear is not capable of separating these intermingled speeches and therefore no intelligent words are communicated to brain.

The same situation is now applied to the transmission of audio signals. These audio signals may come from, say ten different persons. While the speech frequency of different persons will be different, all the ten signals will lie in the same audio range of 20 Hz to 20 kHz. If all these baseband audio signals are simultaneously transmitted through a single channel, then they will be mixed together. The transmitter will transmit these mixed signals, and the receiver will receive them. The purpose of the receiver is to deliver the audio signals in their original form. However, all the received signals lie the same audio range, and the receiver is not capable of separating them into individual signals, similar to the case with human ears.

In order to avoid this difficulty, each signal can be translated to a different frequency spectrum, such that every signal differs in its transmitted frequency. This is done through modulation. Therefore, if all the baseband signals are modulated, i.e., translated to higher frequencies by using different carrier frequencies, then each signal is easily distinguishable from the other although they all lie within the same audio band. At the transmitter they can be mixed and transmitted.

At the receiver, the different signals can be easily separated because they are at different frequencies, and these can be delivered to the next stages of the receiver for further processing. Obviously, multiplexing becomes possible only because of modulation.

TYPES OF COMMUNICATION SYSTEMS

One may categorize communication systems based on their physical infrastructure and the specifications of the signals they transmit. The physical infrastructure pertains to the type of the channel used and the hardware design of the transmitting and receiving equipment. The signal specifications signify the nature and type of the transmitted signal.

Communication Systems based on Physical Infrastructure

There are two types of communication systems based on the physical infrastructure:

(i) Line Communication Systems

There is a physical link, called the hardware channel, between the transmitter and the receiver in the line communication systems. In a radio communication system, there is no such link and natural resources, such as space and water are used as softwire channels. A particular communication system can be one of these two types, e.g. radio broad cast is a purely radio communication system and cannot be categorized as a line communication system. on the other hand, landline telephony is purely a line communication system and cannot be typed as a radio communication system.

Let us consider a TV system in which a user can only receive the signals and view available channels. A television receiver cannot transmit the signals. In another example, we consider telephony. In this case, one can simultaneously send and receive signals. TV transmission is a one-way transmission. This is called as simplex, while a two-way transmission is called duplex. A derivative of duplex is ml/ duplex, in which two-way transmission is carried out, but not simultaneously. In this system, the signal can either be sent or received at a time.

The one-way or two-way transmission feature of a communication system depends on the design of the equipment used on the two sides of the communication system, and is therefore included in the physical structure specifications of the system. As a rule, a communication system can be simplex or a duplex, but not both.

Obviously, based on the physical structure of a communication system, one can define two groups, and only one specification from each group is required to decide the type of communication system. These groups are:

- Line/radio communication
- Simplex/duplex communication

For example, a TV communication system is a combination of the radio and simplex communication system and landline telephony is a combination of the line and duplex communication systems. A particular communication system can be implemented as both line and radio communication system, e.g. landline telephony is a line communication system. However, overseas or long-distance telephony is carried out through satellites and the system is called radio telephony as it makes use of radio waves for transmission and reception. This system is then categorized as radio communication system.

(ii) Classification Systems Based on Signal Specifications

The signal specifications used to decide the type of communication include:

- Nature of baseband or informal signal
- Nature of the transmitted signal.

Based on the nature of the baseband signal, there are two types of communication systems:

- Analog communication systems
- Digital communication systems.

Based on the nature of the transmitted signal, the baseband signal can either be transmitted as it is, without modulation, or through a carrier signal with modulation. The two systems can then be put under following categories:

- Baseband communication system
- Carrier communication system

Thus, there are Your types of communication system categories based on signal specification.

These are:

- Analog communication system
- Digital communication system

- Baseband communication system
- Carrier communication system

Of the four, at least two types are required to specify a particular communication system. Thus, one can form two groups consisting each of two types such that at least one of the types from each group is necessarily required to specify a communication system. These groups can be put as:

- Analog /digital communication system
- Baseband /carrier communication system

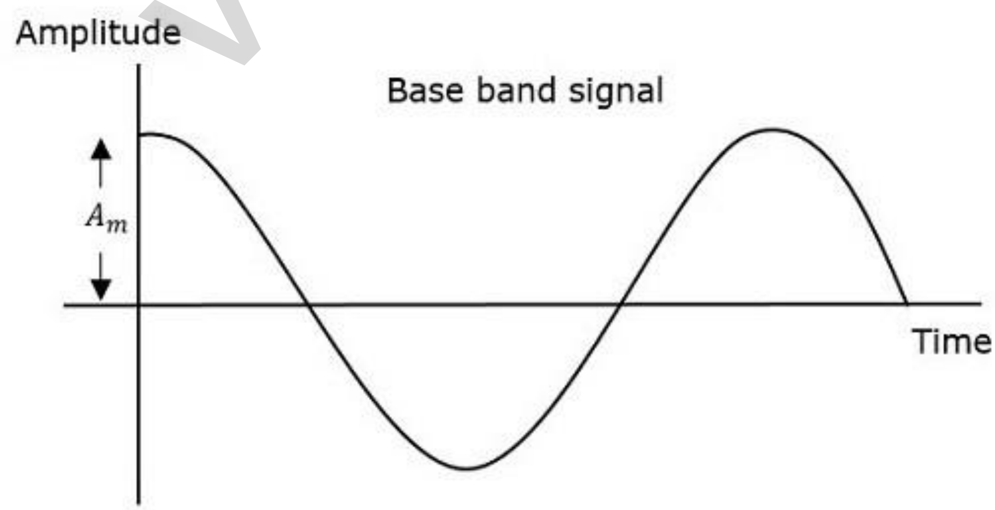
We may note that a particular communication system is either an analog communication system or a digital communication system at a time. For example, TV transmission is an analog communication system while high-definition television (HDTV) is a digital communication system. Another example of a digital communication system is Internet.

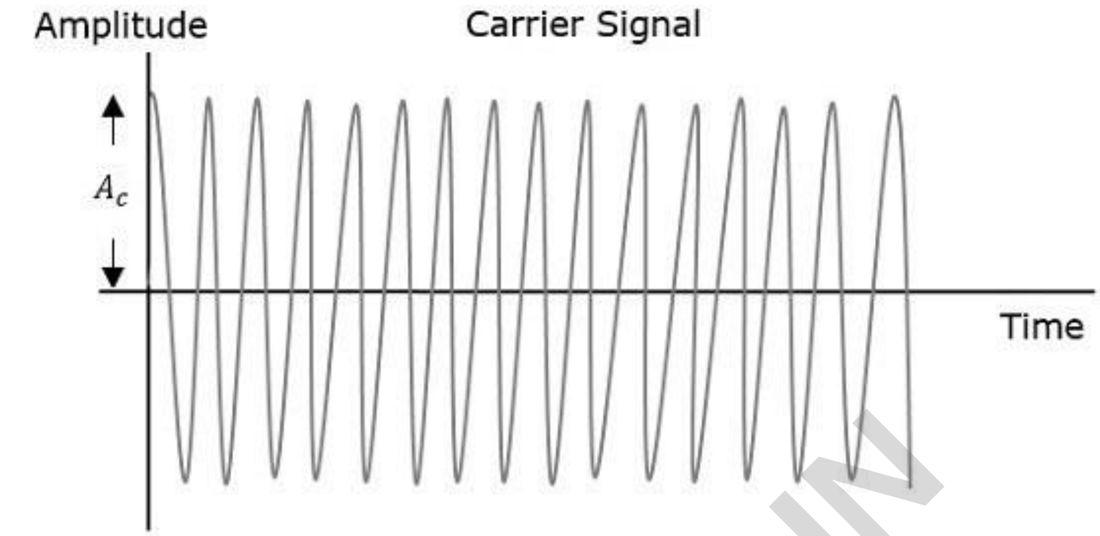
Similarly, a particular communication system is either a baseband communication system or a carrier communication system. Examples of baseband communication systems are landline telephony and Fax. Examples of carrier communication systems are TV transmission, radio broadcast, and cable TV.

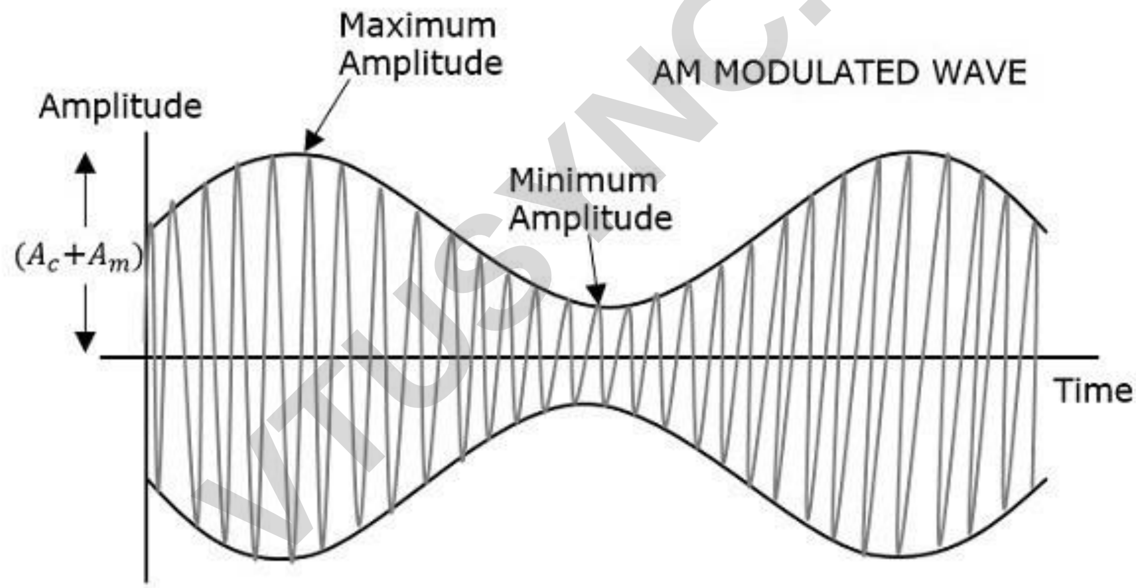
Amplitude Modulation:

A continuous-wave goes on continuously without any intervals and it is the baseband message signal, which contains the information. This wave has to be modulated.

According to the standard definition, "The amplitude of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal." Which means, the amplitude of the carrier signal containing no information varies as per the amplitude of the signal containing information, at each instant. This can be well explained by the following figures.







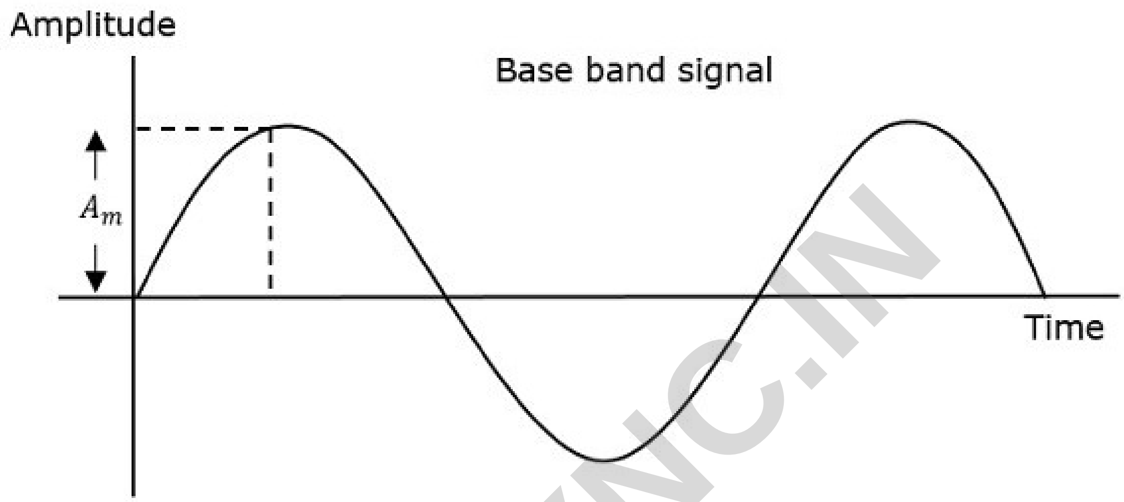
The first figure shows the modulating wave, which is the message signal. The next one is the carrier wave, which is a high frequency signal and contains no information. While, the last one is the resultant modulated wave.

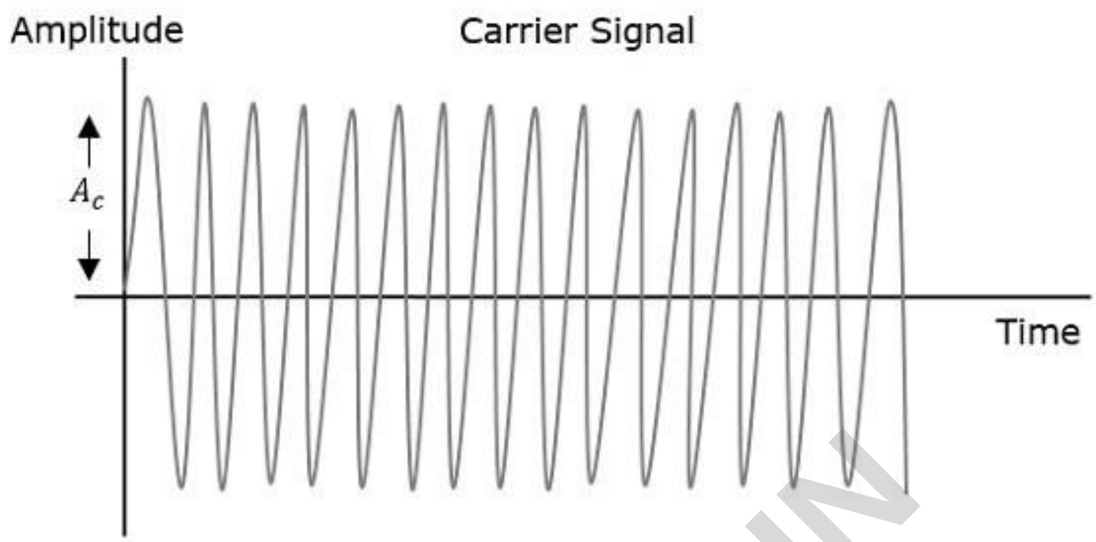
It can be observed that the positive and negative peaks of the carrier wave, are interconnected with an imaginary line. This line helps recreating the exact shape of the modulating signal. This imaginary line on the carrier wave is called as **Envelope**. It is the same as that of the message signal.

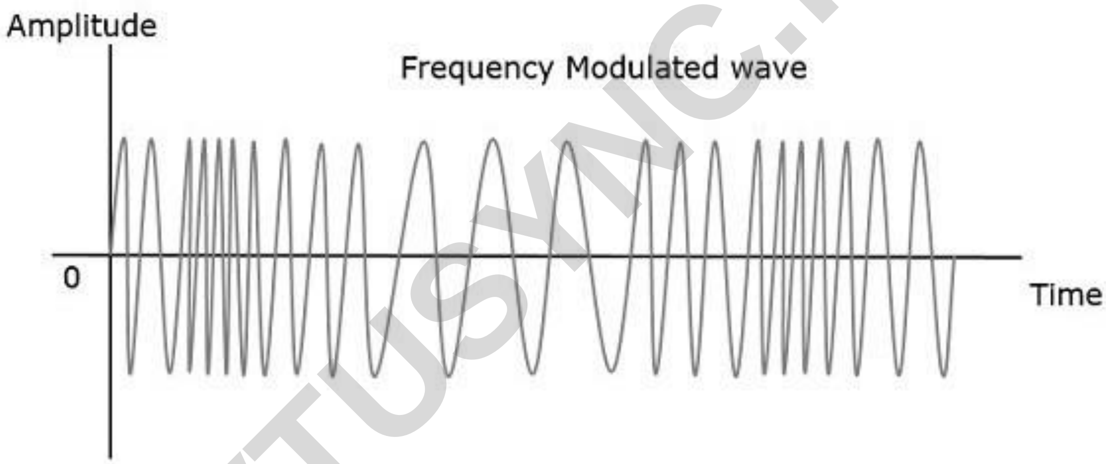
Frequency Modulation

In amplitude modulation, the amplitude of the carrier signal varies. Whereas, in **Frequency Modulation (FM)**, the frequency of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal.

Hence, in frequency modulation, the amplitude and the phase of the carrier signal remains constant. This can be better understood by observing the following figures.







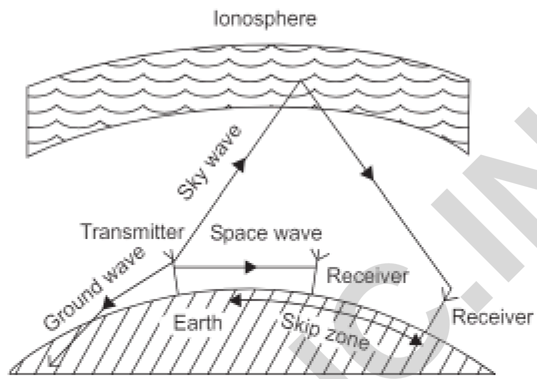
The frequency of the modulated wave increases, when the amplitude of the modulating or message signal increases. Similarly, the frequency of the modulated wave decreases, when the amplitude of the modulating signal decreases. Note that, the frequency of the modulated wave remains constant and it is equal to the frequency of the carrier signal, when the amplitude of the modulating signal is zero.

Concept of Radio Wave propagation

Depending primarily on the frequency a radio wave travels from the transmitting to the receiving antenna in several ways. On the basis of the mode of propagation, radio waves can be broadly classified as:

(i) ground or surface wave (ii) space or tropospheric wave, and (*iii)* sky way. Accordingly, we have three types of propagation:

(i) Ground wave propagation: In ground wave propagation, radio waves are guided by the earth and move along its curved surface from the transmitter to the receiver. As the waves moves over the ground, they are strongly influenced by the electrical properties of the ground. As high frequency waves are strongly absorbed by ground, ground wave propagation is useful only at low frequencies. Below 500 kHz, ground waves can be used for communication within distances of about 1500 km from the transmitter. AM radio broadcast in the medium frequency band cover local areas and take place primarily by the ground wave. The ground waves at higher frequencies employed by frequency modulation (FM) and television (TV) are increasing absorbed and therefore become very weak beyond a distance of several kilometers from the transmitter. Ground wave transmission is very reliable whatever the atmospheric conditions be.



(*ii*) Space or tropospheric wave propagation: When a radio wave transmitted from an antenna, travelling in a straight line directly reaches the receiving antenna, it is termed as space or tropospheric wave. In space wave or line of sight propagation, radio waves move in the earth's troposphere within about 15 km over the surface of the earth. The space wave is made up of two components: (c) n *direct or line-of- sight MGVE* form the transmitting *to* the receiving antenna and *b)* the *ground-reflected* urine traversing form the transmitting antenna to ground and reflected to the receiving antenna. Television frequencies in the range 100-220 MHz are transmitted through this mode.

(*iii*) Sky wave propagation: In this mode of propagation, radio waves transmitted from the transmitting antenna reach the receiving antenna after reflection form the ionosphere, i.e. the ionized layers lying in the earth's upper atmosphere. Short wave transmission around the globe is possible through sky wave via successive reflections at the ionosphere and the earth's surface.

- The ionized *region* of the earth's upper atmosphere extending from about 40 km to the height of a few earth radii above the earth, is referred to as the ionosphere. The ionosphere is made up of electrons, and positive and negative ions in the background of neutral particles of the atmosphere.
- *The propagation of radio wave through the ionosphere* is affected by the electrons and ions in the ionosphere. The effect of the electrons on the propagation is much greater than that of the ions since the electronic mass is much less than the ionic mass.

Amplifier. This strengthens the detected signal which is not strong enough to be made use of directly.

Digital Modulation Schemes:

Advantages of digital communication over analog communication:

As the signals are digitized, there are many advantages of digital communication over analog communication, such as −

- The effect of distortion, noise, and interference is much less in digital signals as they are less affected.
- Digital circuits are more reliable.
- Digital circuits are easy to design and cheaper than analog circuits.
- The hardware implementation in digital circuits, is more flexible than analog.
- The occurrence of cross-talk is very rare in digital communication.
- The signal is un-altered as the pulse needs a high disturbance to alter its properties, which is very difficult.
- Signal processing functions such as encryption and compression are employed in digital circuits to maintain the secrecy of the information.
- The probability of error occurrence is reduced by employing error detecting and error correcting codes.
- Spread spectrum technique is used to avoid signal jamming.
- Combining digital signals using Time Division Multiplexing (TDM) is easier than combining analog signals using Frequency Division Multiplexing (FDM).
- The configuring process of digital signals is easier than analog signals.
- Digital signals can be saved and retrieved more conveniently than analog signals.
- Many of the digital circuits have almost common encoding techniques and hence similar devices can be used for a number of purposes.
- The capacity of the channel is effectively utilized by digital 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 ones.

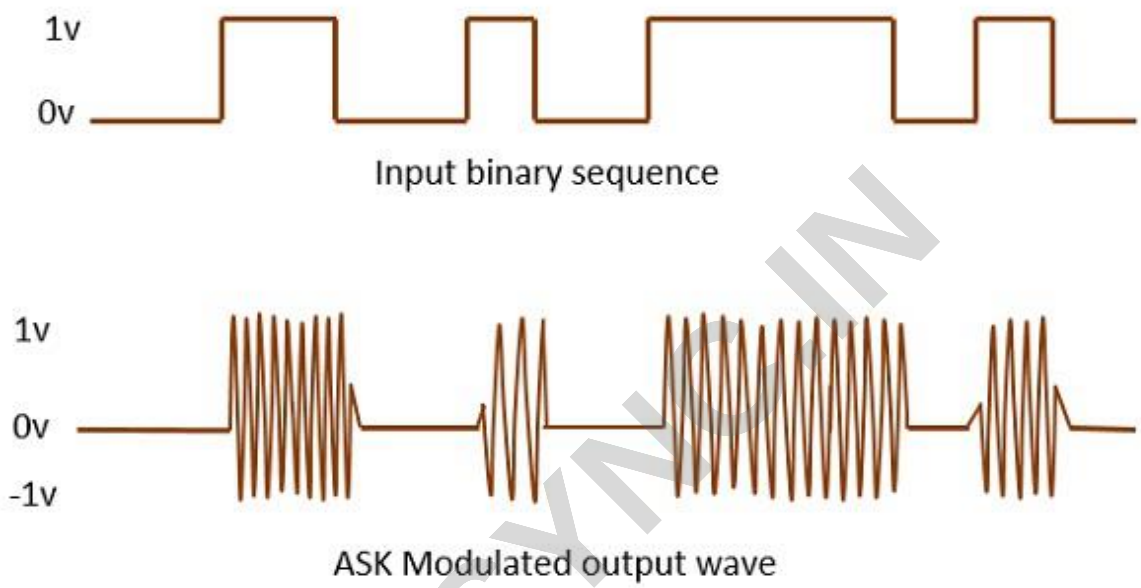
There are many types of digital modulation techniques and we can even use a combination of these techniques as well. In this chapter, we will be discussing the most prominent digital modulation techniques.

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.

Amplitude Shift Keying (ASK) is a type of Amplitude Modulation which represents the binary data in the form of variations in the amplitude of a signal.

Following is the diagram for ASK modulated waveform along with its input.



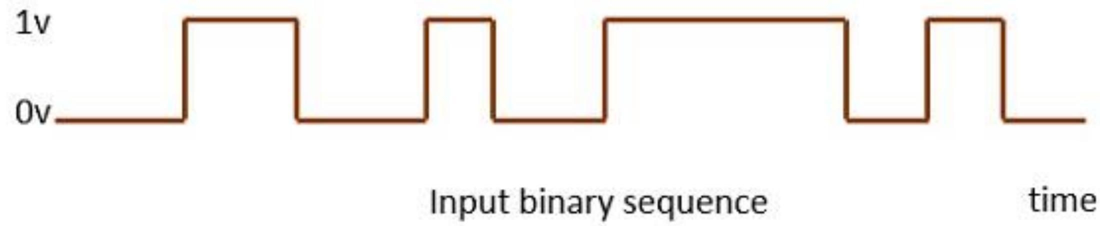
Any modulated signal has a high frequency carrier. The binary signal when ASK is modulated, gives a zero value for LOW input and gives the carrier output for HIGH input.

Frequency Shift Keying

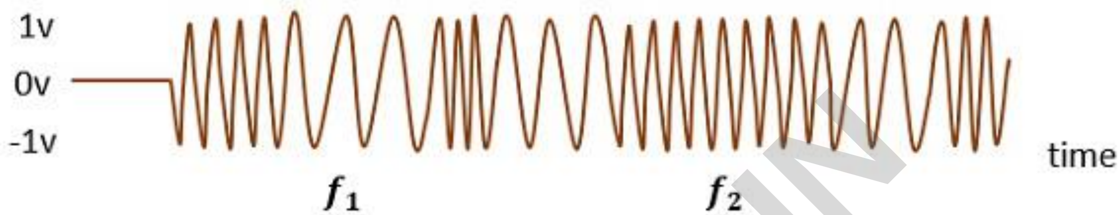
The frequency of the output signal will be either high or low, depending upon the input data applied.

Frequency Shift Keying (FSK) is the digital modulation technique in which the frequency of the carrier signal varies according to the discrete digital changes. FSK is a scheme of frequency modulation.

Following is the diagram for FSK modulated waveform along with its input.



Input binary sequence



FSK Modulated output wave

The output of a FSK modulated wave is high in frequency for a binary HIGH input and is low in frequency for a binary LOW input. The binary 1s and 0s are called **Mark** and **Space frequencies**.

Phase Shift Keying

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

Phase Shift Keying (PSK) is the digital modulation technique in which the phase of the carrier signal is changed by varying the sine and cosine inputs at a particular time. PSK technique is widely used for wireless LANs, bio-metric, contactless operations, along with RFID and Bluetooth communications.

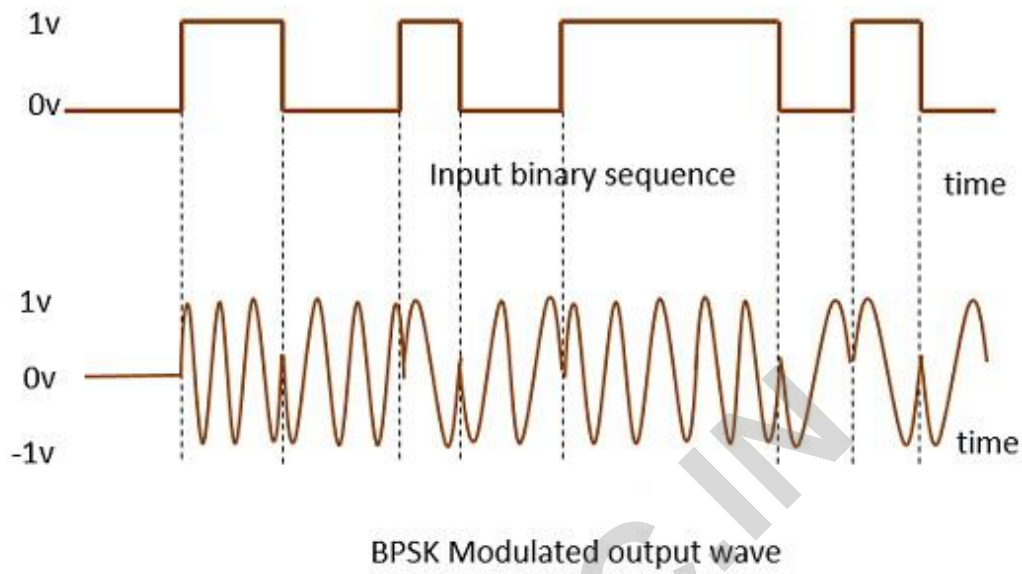
PSK is of two types, depending upon the phases the signal gets shifted. They are −

Binary Phase Shift Keying (BPSK)

This is also called as **2-phase PSK** (or) **Phase Reversal Keying**. In this technique, the sine wave carrier takes two phase reversals such as 0° and 180°.

BPSK is basically a DSB-SC (Double Sideband Suppressed Carrier) modulation scheme, for message being the digital information.

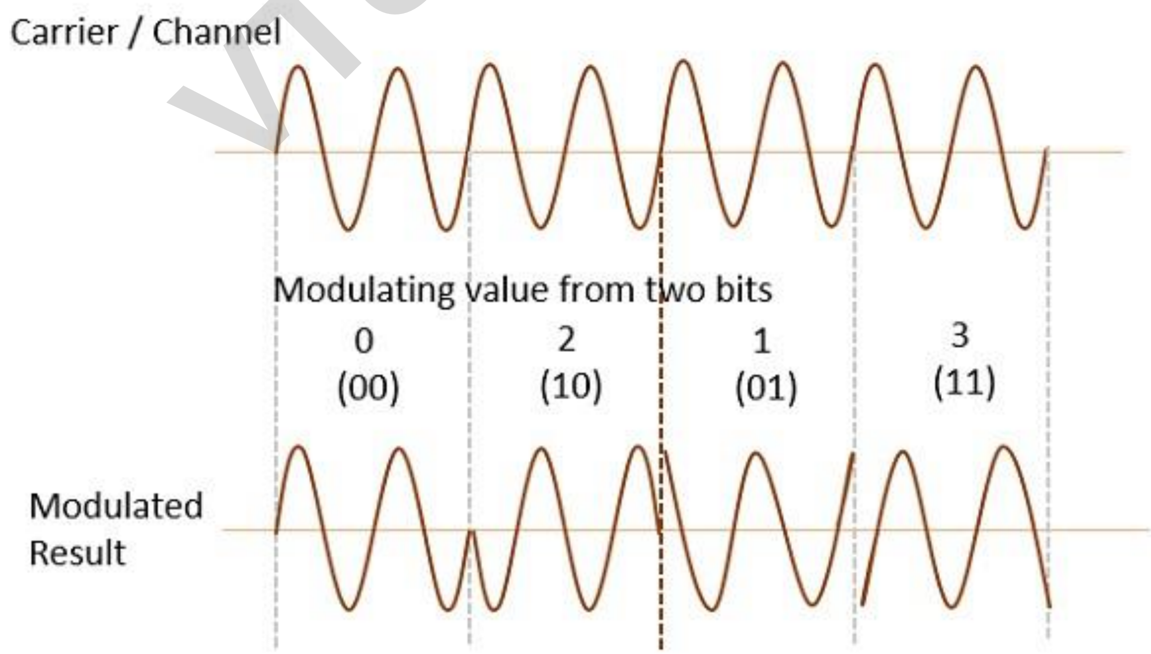
Following is the image of BPSK Modulated output wave along with its input.



Quadrature Phase Shift Keying (QPSK)

This is the phase shift keying technique, in which the sine wave carrier takes four phase reversals such as 0°, 90°, 180°, and 270°.

If this kind of techniques are further extended, PSK can be done by eight or sixteen values also, depending upon the requirement. The following figure represents the QPSK waveform for two bits input, which shows the modulated result for different instances of binary inputs.



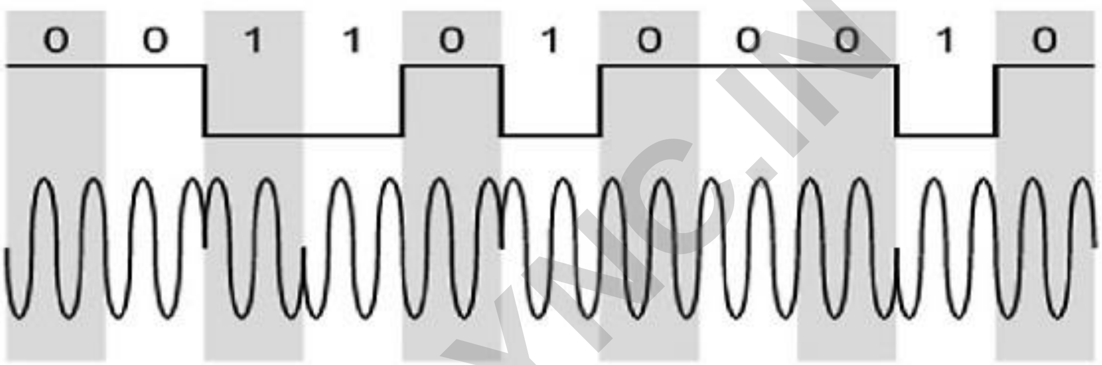
QPSK is a variation of BPSK, and it is also a DSB-SC (Double Sideband Suppressed Carrier) modulation scheme, which send two bits of digital information at a time, called as **digits**.

Instead of the conversion of digital bits into a series of digital stream, it converts them into bit-pairs. This decreases the data bit rate to half, which allows space for the other users.

Differential Phase Shift Keying (DPSK)

In DPSK (Differential Phase Shift Keying) the phase of the modulated signal is shifted relative to the previous signal element. No reference signal is considered here. The signal phase follows the high or low state of the previous element. This DPSK technique doesn't need a reference oscillator.

The following figure represents the model waveform of DPSK.



It is seen from the above figure that, if the data bit is LOW i.e., 0, then the phase of the signal is not reversed, but is continued as it was. If the data is HIGH i.e., 1, then the phase of the signal is reversed, as with NRZI, invert on 1 (a form of differential encoding).

If we observe the above waveform, we can say that the HIGH state represents an **M** in the modulating signal and the LOW state represents a **W** in the modulating signal.

RADIO TRANSMISSION AND RECEPTION

Signal Transmission

Figure shows the most important components of a wireless transmission system. In the figure, the transmitter accepts a stream of bits from the application software. It then encodes these bits onto a radio wave, known as a *carrier*, by adjusting parameters of the wave such as its amplitude or phase.

As shown in the figure, the transmitter usually processes the information in two stages. In the first stage, a *modulator* accepts the incoming bits, and computes symbols that represent the amplitude and phase of the outgoing wave. It then passes these to the analogue transmitter, which generates the radio wave itself.

The modulation scheme used in Fig. is known as *quadrature phase* shift *keying* (QPSK). A QPSK modulator takes the incoming bits two at a time and transmits them using a radio wave that can have four different states. These have phases of 45^o, 135^o, 225^o and 315^o

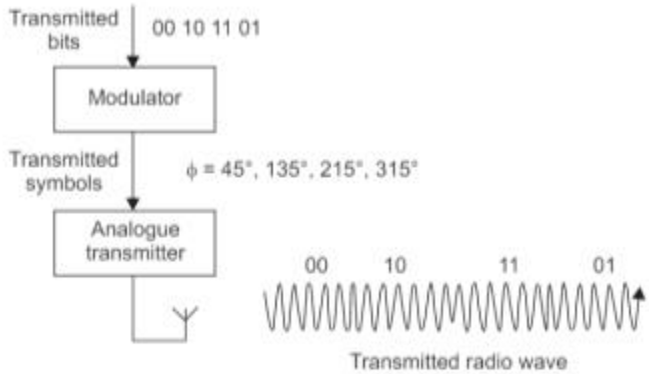


Fig : Architecture of a wireless communication transmitter

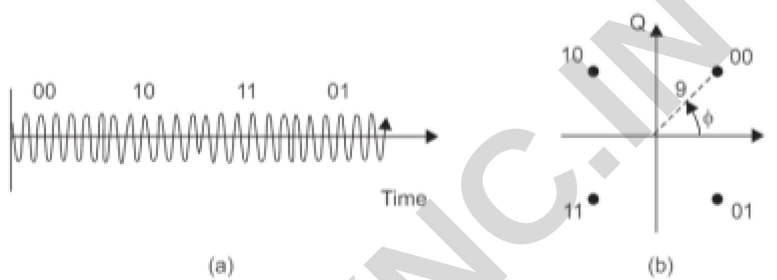


Fig: Quadrature Shift keying a) QPSK waveform b) QPSK Constellation diagram

(Fig. a which correspond to bit combinations of 00, 10, 11 and 01 respectively. We can represent the four states of QPSK using the constellation diagram shown in Fig.b.

In this diagram, the distance of each state from the origin represents the amplitude of the transmitted wave, while the angle (measured anti-clockwise from the x-axis) represents its phase.

Usually, it is more convenient to represent each symbol using two other numbers, which are known as the in-phase (I) and quadrature (Q) components. These are computed as follows:

I = c cos $

Q = o sin $,

where a is the amplitude of the transmitted wave and Q is its phase. Mathematicians will recognize the in-phase and quadrature components as the real and imaginary parts of a complex number.

As shown in Fig below, LTE uses four modulation schemes altogether. Binary phase shift keying (BPSK) sends bits one at a time, using two states that can be interpreted as starting phases of 00 and 180°, or as signal amplitudes of +1 and —1. LTE uses this scheme for a limited number of control streams, but does not use it for normal data transmissions. 16-bit quadrature amplitude modulation (16-QAM) sends bits four at a time, using 16 states that have different amplitudes and phases. Similarly, 64-QAM sends bits six at a time using 64 different states, so it has a data rate six times greater than that of BPSK.

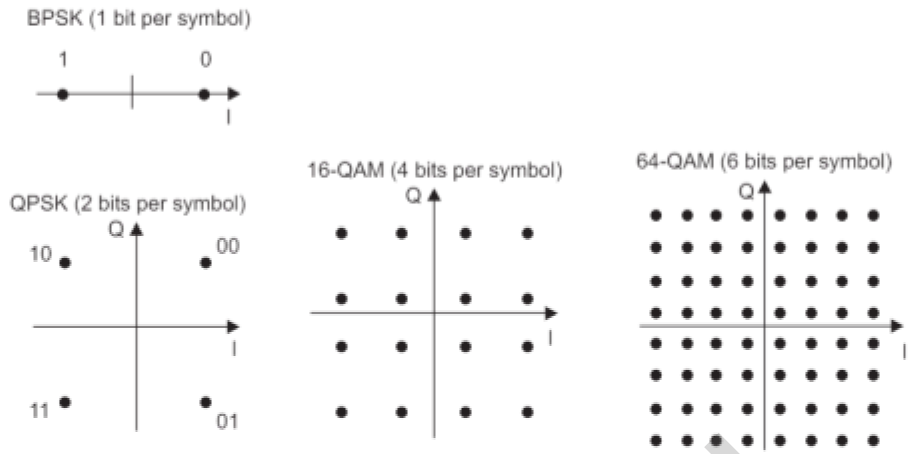


Fig: Modulation schemes used by LTE

Multiple Access Techniques

The techniques described so far work well for one-to-one communications. In a cellular network, however, a base station has to transmit to many different mobiles at once.

It does this by sharing the resources of the air interface, in a technique known as multiple access mobile communication systems use a New different multiple access techniques, two of which are shown in Fig. 6A.6. frequency division multiple access (FDMA) was used by the first-generation analogue systems. In this technique, each mobile receives on its own carrier frequency, which it distinguishes from the others by the use of analogue filters. The carriers are separated by unused guard bands, which minimizes the interference between them. In time division multiple access (TDMA), mobiles receive information on the same carrier frequency but at different times.

GSM uses a mix of frequency and time division multiple access, in which every cell has several carrier frequencies that are each shared amongst eight different mobiles. LTE uses another mixed technique known as orthogonal frequency division multiple access (OFDMA).

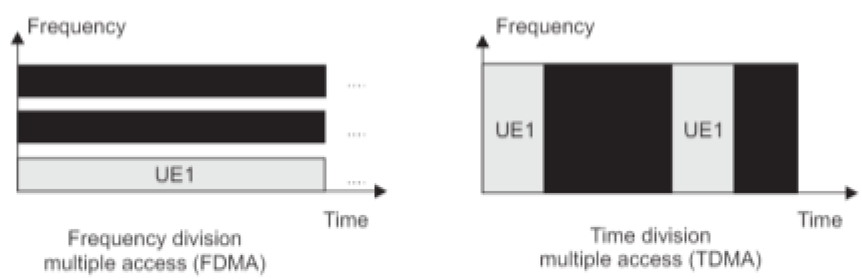


Fig. Example multiple access techniques

Third generation communication systems used a different technique altogether, known as code division multiple access (CDMA). In this technique, mobiles receive on the same carrier frequency and at the same time, but the signals are labelled by the use of codes, which allow a mobile to separate its own signal from those of the others. LTE uses a few of the concepts from CDMA for some of its control signals, but does not implement the technique otherwise. Multiple access is actually a generalization of a simpler technique known as multiplexing.

The difference between the two is that a multiple access system can dynamically change the allocation of resources to different mobiles, while in a multiplexing system the resource allocation is fixed.

FDD arid TDD Modes

By using the multiple access techniques described above, a base station can distinguish the transmissions to and from the individual mobiles in the cell. However, we still need a way to distinguish the mobiles' transmissions from those of the base stations themselves.

To do this, a mobile communication system can operate in the transmission modes that we introduced in Fig. 6A.7. When using frequency division duplex (FDD), the base station and mobile transmit and receive at the same time, but using different carrier frequencies. Using time division duplex (TDD), they transmit and receive on the same carrier frequency but at different times.

FDD and TDD modes have different advantages and disadvantages. In FDD mode, the bandwidths of the uplink and downlink are fixed and are usually the same. This makes it suitable for voice communications, in which the uplink and downlink data rates are very similar. In TDD mode, the system can adjust how much time is allocated to the uplink and downlink. This makes it suitable for applications such as web browsing, in which the downlink data rate can be much greater than the rate on the uplink.

TDD mode can be badly affected by interference if, for example, one base station is transmitting while a nearby base station is receiving. To avoid this, nearby base stations must be carefully time synchronized and must use the same allocations for the uplink and downlink, so that they all transmit and receive at the same time. This makes TDD suitable for networks that are made from isolated hotspots, because each hotspot can have a different timing and resource allocation. In contrast, FDD is often preferred for wide-area networks that have no isolated regions.

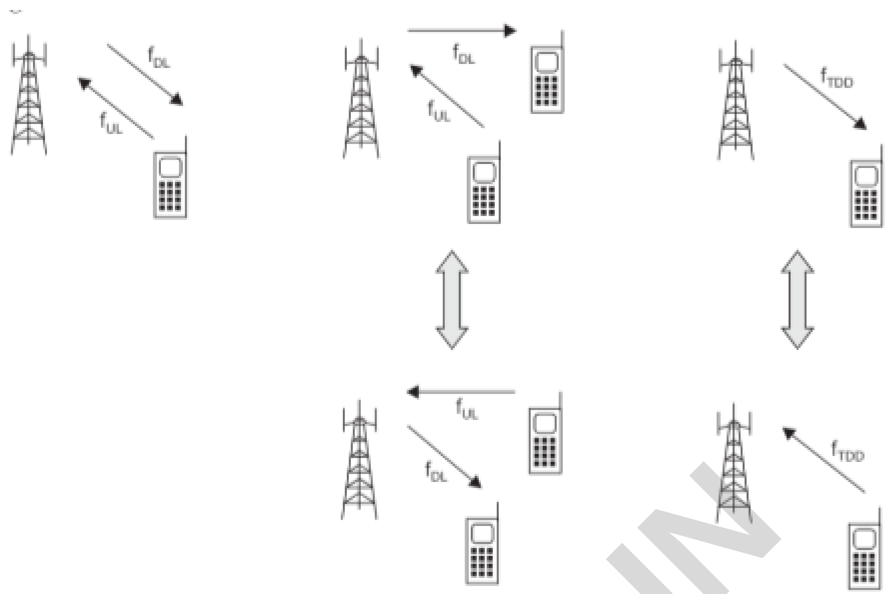


Fig. Operation of FDD and TDD modes

When operating in FDD mode, the mobile usually has to contain a high attenuation duplex filter that isolates the uplink transmitter from the downlink receiver. In a variation known as half duplex FDD mode, a base station can still transmit and receive at the same time, but a mobile can only do one or the other. This means that the mobile does not have to isolate the transmitter and receiver to the same extent, which eases the design of its radio hardware.

LTE supports each of the modes described above. A cell can use either FDD or TDD mode. A mobile can support any combination of full duplex FDD, half duplex FDD and TDD, although it will only use one of these at a time.