Module 5: Analog and Digital Communication

- Modern communication system scheme
- Information source and input transducer.
- Transmitter Channel or Medium – Hardwired and Soft wired Noise Receiver
- Multiplexing Types of communication systems
- Types of modulation AM FM
- Concept of Radio wave propagation.

Digital Modulation Schemes :

- ASK, FSK, PSK Radio signal transmission Multiple access techniques.

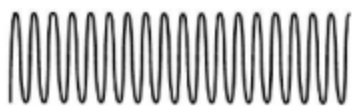
Need for Communication:

- **Speedy transmission**: Requires only few seconds to communicate through electronic media due the technology available for quick transmission.
- **Wide Coverage**: The whole world has become a global village and communication around the globe requires just a second.
- **Low Cost**: Cost of an SMS is cheaper than sending a letter by post
- **Exchange of feedback**: Instant exchange of feedback
- **24/7 accessibility**: Can be accessed anytime.

Message signal: The signal that consists information is called modulating signal. The modulating signal is usually of low-frequency signal. (20 Hz – 20 KHz).

Carrier signal:

The signal which carries the information is called carrier signal. Carrier signal is a high frequency signal which does not contains any information. The purpose of this signal is just to carry the message signal. The range is in terms of Mega Hertz.



4.1.1 Modern Communication System scheme

General form of a basic communication system is shown in the fig.1.

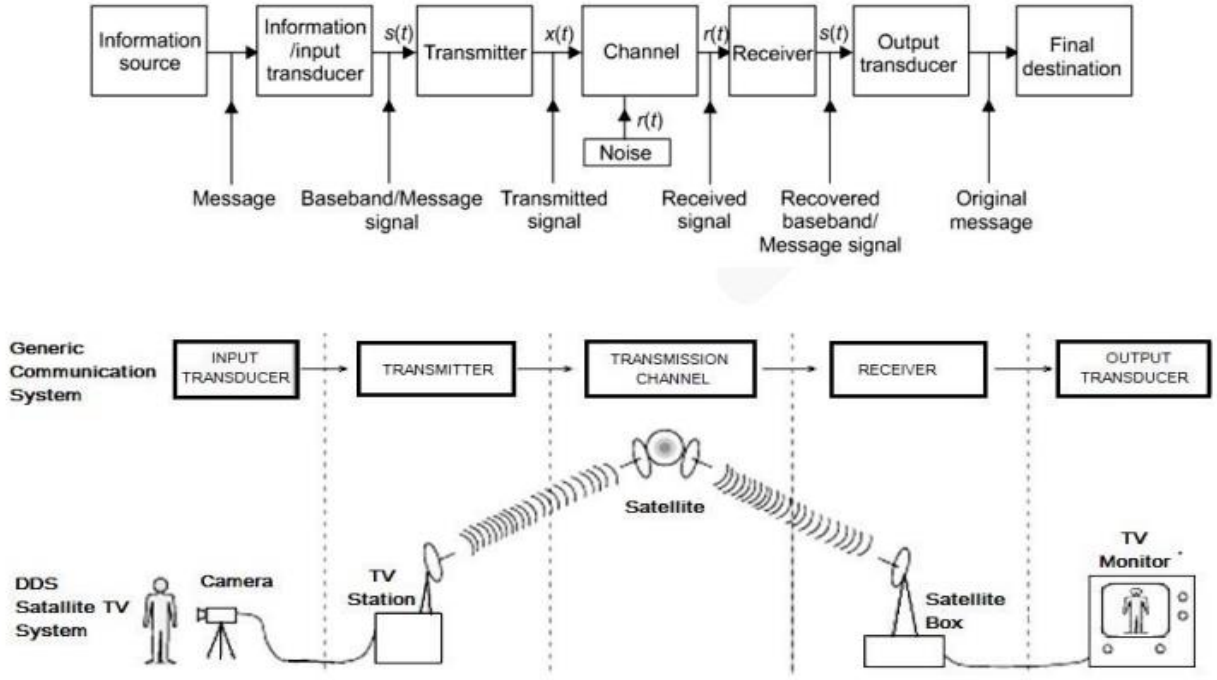


Fig.1 Illustration of Basic Communication System

Elements of Communication System

- Information source and transducer
- Transmitter
- Channel or medium
- Noise
- Receiver
- Output transducer and final destination

A communication system transmits information from an information source (message) to a destination.

Examples: Voice, Live scenes (video), music, written text, and e-mail.

A transducer is a device that converts a physical signal into its corresponding electrical signal and vice versa.

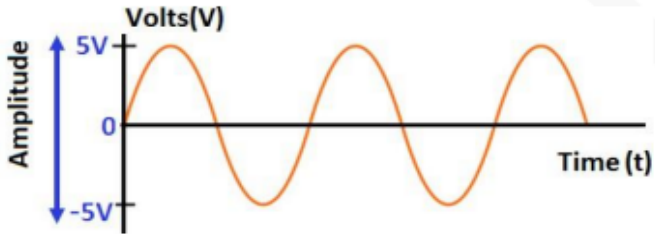
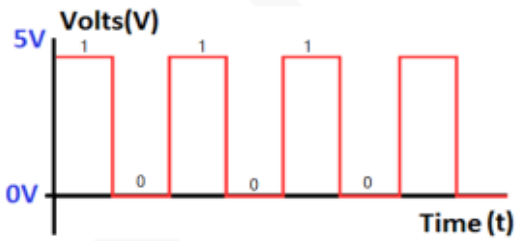
Examples of input transducers: Sound – Microphone, Picture – Camera, Text - Keyboard Temperature/Pressure - Sensor with transducer.

1.Information Source and Transducer: Message or information originates in the information source may be in the form of sound (human speech), picture (image source), words (text). However, out of these messages, only the desired message is selected and communicated.

A transducer is a device which converts one form of energy into another form. Generally, the input transducer converts the non-electrical signal (Ex: sound signal or light signal) into an electrical signal. For example, in case of radio-broadcasting, a microphone converts the information or massage which is in the form of sound waves into corresponding electrical signal.

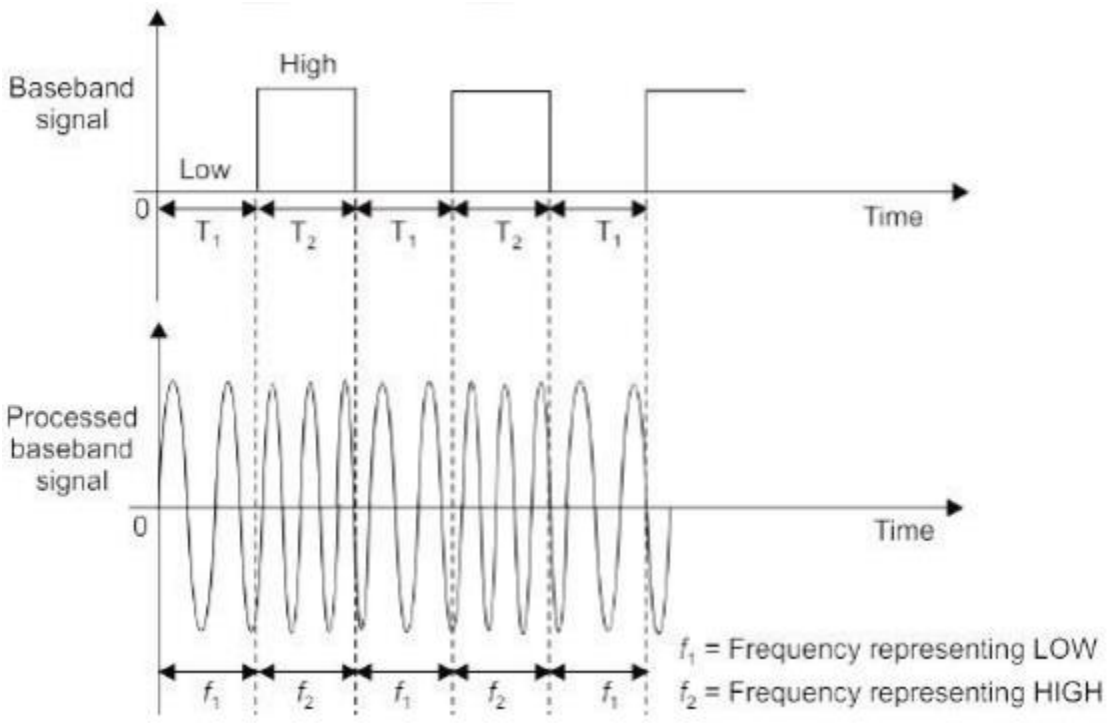
Type of Signals

Signals are functions that carry information. We use signals to convey information from place to place. In electronics, signals are mainly in the form of varying voltages. There are two types of signals.

Analog Signals	Digital Signals
	
Analog signal is continuous and time varying	Digital signal have two or more states (binary form)
Troubleshooting is difficult.	Troubleshooting is easy.
Easily affected by the noise.	These are stable and less prone to noise.
Analog signals use continuous values to represent the data, usually in the form of sine wave.	Digital signals use discrete values to represent the data, usually in the form of square wave.
Accuracy may be affected by noise.	Accuracy is immune from the noise.
Analog signals may be corrupted during data transmission.	Digital signals are not corrupted during data transmission.
Analog signals use more power.	Digital signals use less power.
Examples: Temperature, Pressure, Flow measurements, etc.	Examples: Motor Start, Trip, etc.
Components like resistors, Capacitors, Inductors, Diodes are used in analog circuits.	Components like transistors, logic gates, and micro-controllers are used in digital circuits.

2.Transmitter: The base band signal (electrical form), output from the input transducer is applied to the input of the transmitter. The transmitter section processes the signal prior to transmission. The nature of processing depends on the type of communication system. There are

two options for processing signals prior transmission (i) The baseband signal, which lies in the low frequency spectrum, is translated to a higher frequency spectrum --- carrier communication system In this process, modulation is the main function of the transmitter. In modulation, the message signal is superimposed upon the high-frequency carrier signal. As the original message signal cannot be transmitted over a longer distance because of their low frequency and amplitude, they are superimposed with high frequency carrier signal. (ii) The baseband signal is transmitted without translating it to a higher frequency spectrum --- baseband communication system.



If the signal is to be transmitted through the space, then the transmitter will convert the electrical signals into radio waves. If the signal is to be transmitted through the fiber optic cable then the transmitter will convert the electrical signal into light or optical signal.

3. Channel or medium: The term channel means the medium through which the message travels from the transmitter to the receiver. The transmitted signal should have adequate power to withstand the channel noise. The channel characteristics also impose constraints on the bandwidth.

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

Hardwired channels (Manmade structure):

Transmission lines: It is a conductive medium consisting of two or more conductors through which electrical signal are transmitted from transmitting point to receiver point.

Example:

i) Twisted pair cables used in telephony, in which two conductors are twisted together for the purposes of improving electromagnetic compatibility.

ii) Coaxial cable used in TV transmission, to carry high-frequency electrical signals with low losses.

Waveguide: consisting of a hollow, metal tube of uniform cross-section used for transmitting electromagnetic waves. When signals entered the waveguides are reflected at the metallic walls and propagate at the other end. The energy is in the form of electric field and magnetic field which are perpendicular to each other.

Optical Fiber: consist of very thin hollow glass fiber through which signal is transmitted in the form of light energy.

Soft-wired channels:

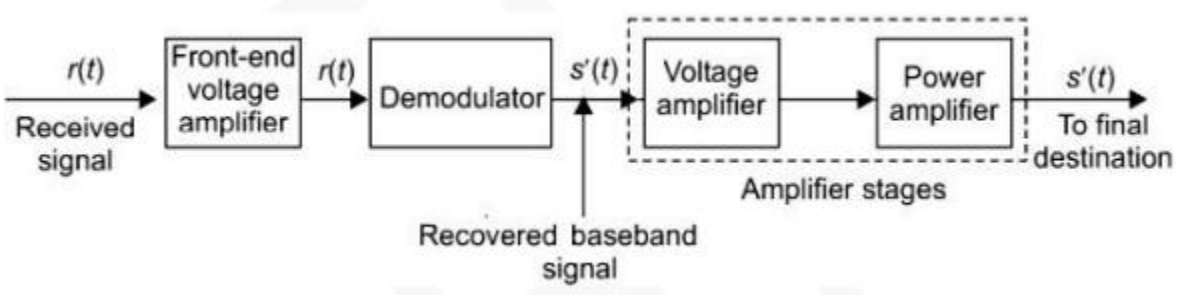
No physical link between transmitter and receiver. Natural resources which can be used as the transmission medium for signals.

Example: Air or Open space and Sea water. The signals are transmitted in the form of electromagnetic (EM) waves also called radio waves. Radio waves travel through open space at a speed equal to that of light ($c = 3 \times 10^8$ m/s).

4.Noise: Noise is defined as unwanted electrical signal which do not have any useful information. Noise is a highly undesirable part of a communication system, and has to be minimized. When noise is mixed with the transmitted signal, it rides over it and deteriorates its waveform.

5. Receiver: The main function of the receiver is to reproduce the original message signal. This reproduction of the original signal is accomplished by a process known as the demodulation or detection. Demodulation is the reverse process of modulation carried out in transmitter

Typical analog receiver section is shown in the figure below. The signal received by the receiver is r(t). Due to attenuation this received signal r(t) is a weak signal. A voltage amplifier amplifies to make strong enough for further processing.



Next, this signal is applied to the demodulator. In demodulation, the baseband signal is separated from the high-frequency carrier signal. After recovering the original baseband signal s'(t), its voltage and power is amplified before send to the final destination block.

6. Destination: Destination is the final stage which is used to convert an electrical message signal into its original form. For example in radio broadcasting, the destination is a loudspeaker which works as a transducer that converts the electrical signal to original sound signal.

Types of Communication Systems

Communication Systems based on Physical Infrastructure: Based on physical infrastructure there are two types of communication systems:

Line communication systems: Uses power lines to transfer data from one point to another point. There is a physical link, called a hardwire channel between the transmitter and the receiver inline communication systems. Ex: Land line telephony, Cable TV.

Communication systems based on Signal specifications

A. Based on Nature of baseband or information signal:

i) Analog communication systems: Exchange of information between two points through analog signals. Ex: Audio, video and pictures between two points using the analog signals.

ii) Digital communication systems: Exchange of information between two points through digital signals. Ex: Audio, HDTV

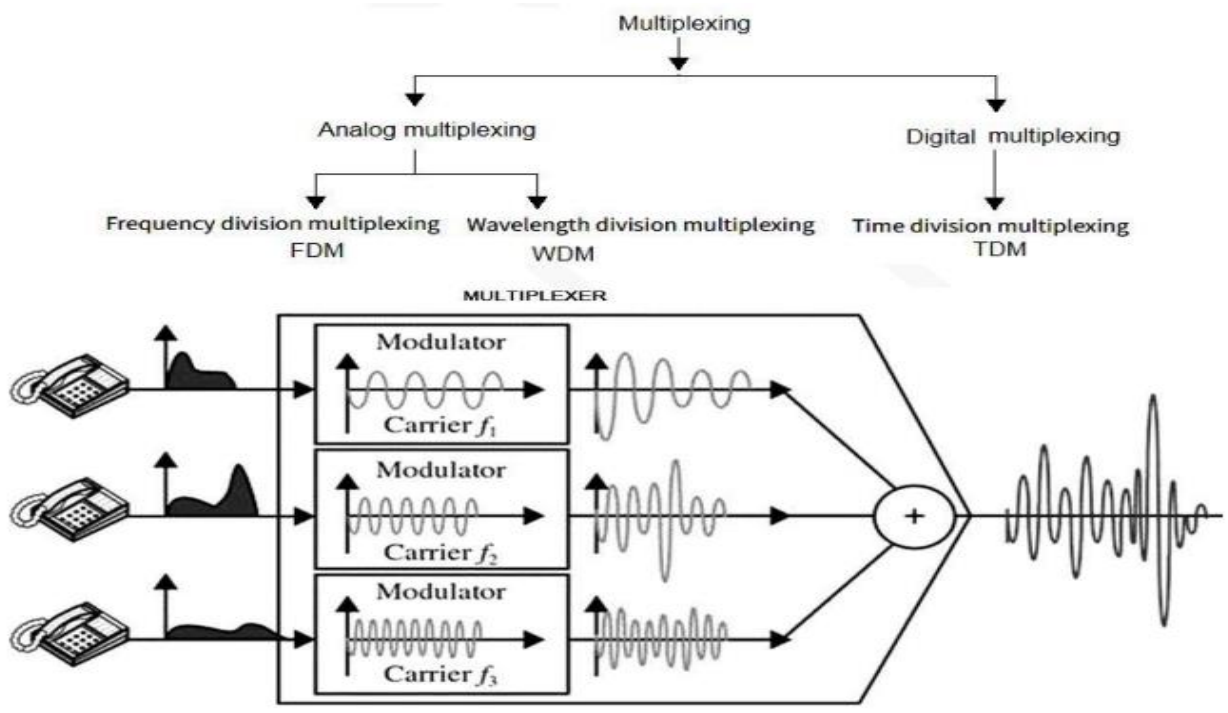
B. ***Based on Nature of the transmitted signal.***

i) **Baseband communication system**: Baseband signals are transmitted without translating (or amplified) to higher frequencies. Ex: Land line, fax, etc

ii) Carrier communication system: The baseband signal (low frequency) is mixed with high frequency carrier signal. Ex: Radio, voice messages and calls.

Multiplexing

Multiplexing is a process which allows more than one signal to be transmitted through a single channel.

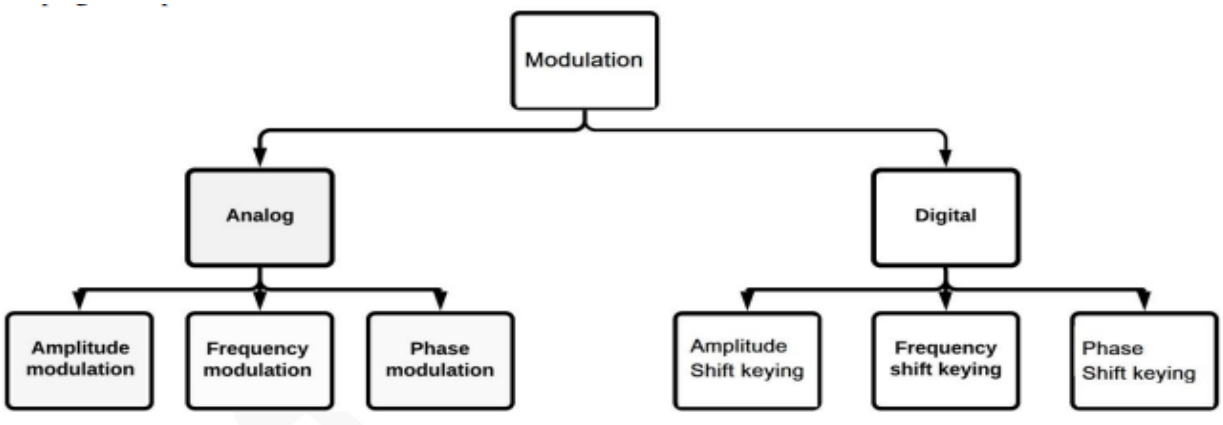


In multiplexing, each baseband signals are modulated with different carrier frequencies. At the transmitter they can be mixes and transmitted. At the receiver end, all different transmitted signals can be easily separated by the known carrier frequencies.

Due to multiplexing it is possible to increase the number of communication channels so that more information can be transmitted where it makes the communication system economical. The typical applications of multiplexing are telephone, satellite communication etc.

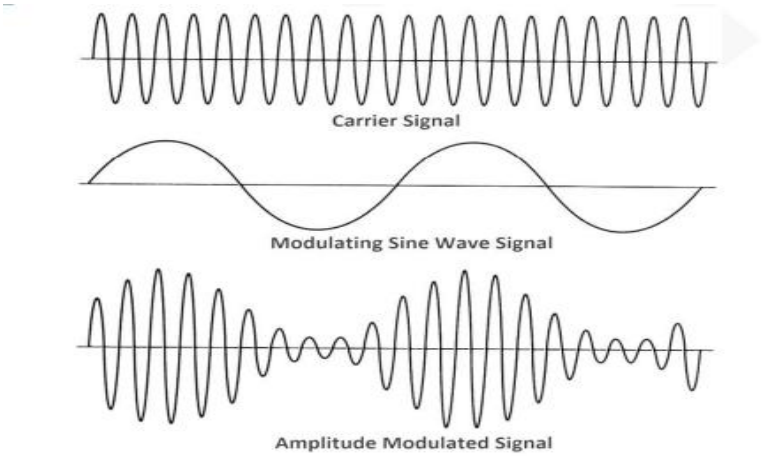
Types of Modulation

Modulation is the process in which any one of the parameters (amplitude, frequency or phase) of the high frequency carrier signal is varied according to the instantaneous values of the low frequency message signal, keeping other parameters constant.



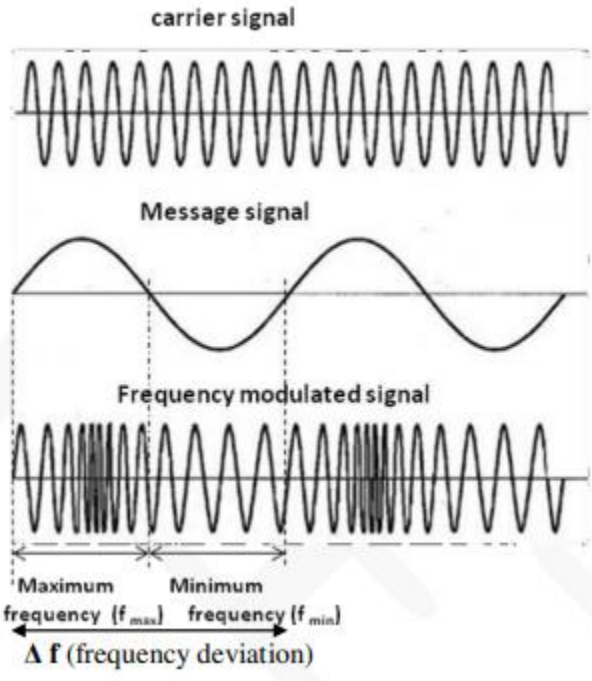
Analog modulation is typically used for AM, FM radio, and short-wave broadcasting. Digital modulation involves transmission of binary signals (0 and 1).

Amplitude Modulation (AM) is the process in which the amplitude of the carrier signal is varied according to the instantaneous values of the message signal, where as the frequency and phase are kept constant. It is as shown in the fig



In AM, most of the transmitted power is wasted in carrier, but used for longer distance communication.

Frequency Modulation(FM) is defined as a process in which the frequency of the carrier is varied in accordance with the instantaneous values of the message signal, where as the amplitude and phase are kept constant.



In FM, all the transmitted power is useful, but used for short distance communication.

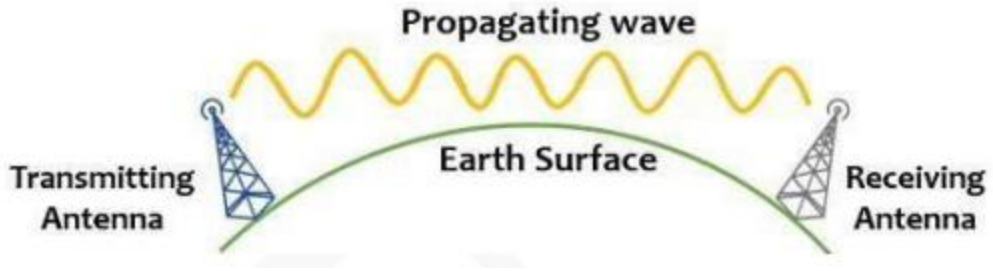
Radio Wave Propagation:

Radio waves exhibit the properties of light with the velocity $3x10^8$ m/s. These are electromagnetic (EM) waves that consist of electric and magnetic field components. It is traversed in nature. Radio signals can travel from one end to another over vast distances. Since these are EM waves, they exhibit properties (like light waves) such as reflection, refraction, diffraction, absorption, polarization and scattering.

Radio propagation is the way of transmitting radio signals in different ways:

Ground or surface wave:

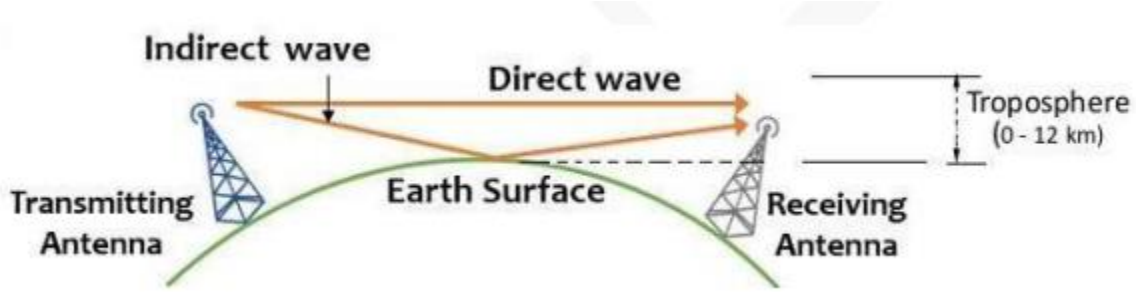
Ground waves can be used for radio communication. Ground wave transmission is very reliable irrespective of the atmospheric conditions.



Frequency range: 30 kHz to 3 MHz Transmission distance: 100 to 1000 km Example: AM radio broadcast in the medium frequency band cover local areas.

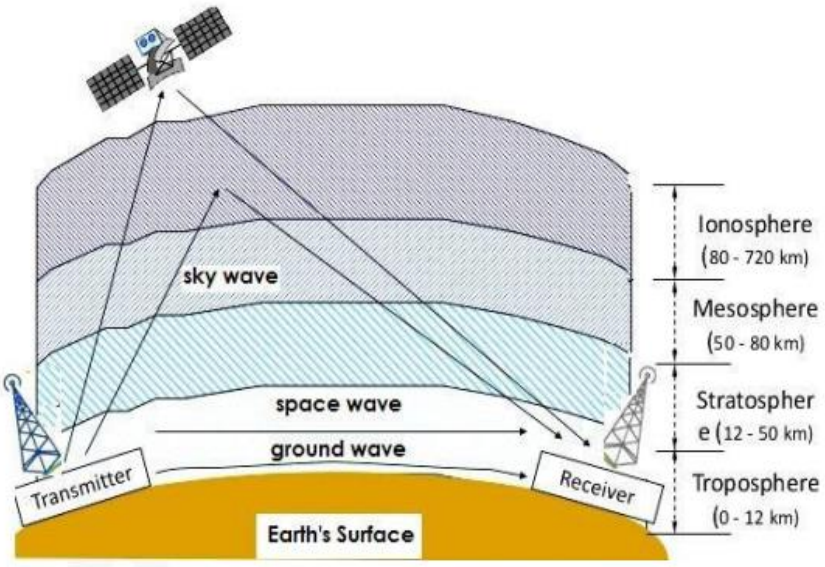
Space or tropo-spheric wave:

In space wave (or line of sight propagation), radio waves move in the earth's troposphere within about 12 KM over the surface of the earth. Frequency range: 3MHz to 30 MHz. Example, TV Transmission. The space wave is made up of two components: (a) a direct or line-of- sight wave from the transmitting to the receiving antenna and (b) an indirect or ground-reflected wave traversing form the transmitting antenna to ground and reflected to the receiving antenna.



Sky wave:

Radio waves transmitted from the transmitting antenna reach the receiving antenna after reflection from the ionosphere (the earth's upper atmosphere). Sky wave is responsible for short wave transmission around the globe via successive reflections at the ionosphere and the earth's surface. Ionosphere - The ionized region extending about 80 KM above the earth's surface. In ionosphere radiation from the sun ionizes atoms and molecules that liberate electrons and ions from molecules. The propagation of radio wave through the ionosphere is affected by the electrons and ions. 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.



Advantages of sky wave propagation:

1. It supports large distance propagation.

2. The frequency range of operation is considerably high.

3. Attenuation due to atmospheric conditions is less.

Disadvantages of sky wave propagation

1. Long-distance propagation requires large-sized antennas.

2. Due to the presence of the ionosphere near and far during night and day respectively there exist variation in signal transmission in day and night. Applications Sky wave propagation is widely used in mobile and satellite communications.

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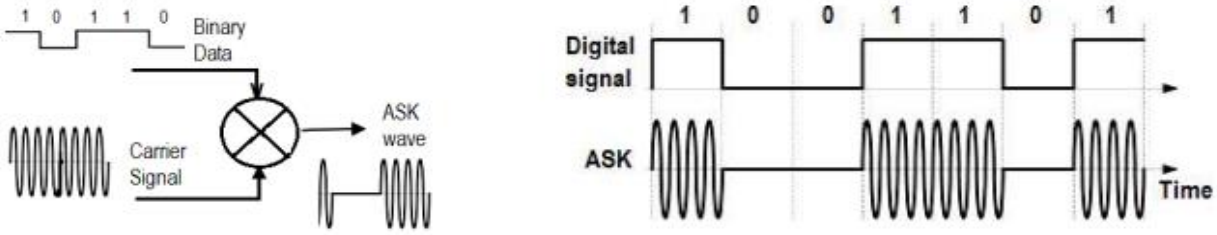
Digital Modulation Schemes

In digital communications, the modulating signal consists of binary data. When it is required to transmit digital signals, the amplitude, frequency or phase of the sinusoidal carrier is varied in accordance with the incoming digital data.

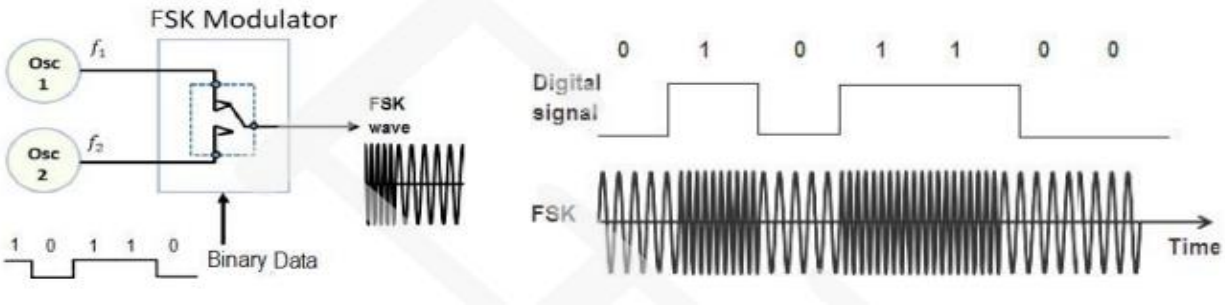
Digital modulation schemes are classified as

i) Amplitude Shift Keying (ASK)
ii) Frequency Shift Keying (FSK)
iii) Phase Shift Keying (PSK)

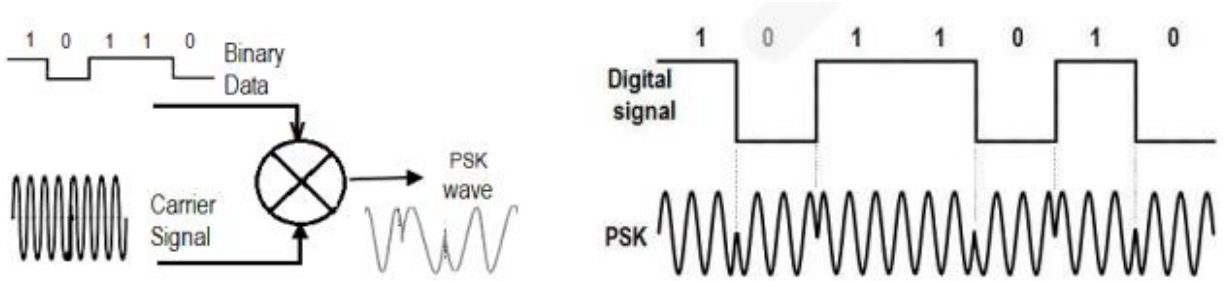
ASK (Amplitude Shift Keying): ASK represents digital data as variations in the amplitude of a carrier wave. ASK signal can generated when the incoming binary data and the sinusoidal carrier are applied a product modulator as inputs.



FSK (Frequency Shift Keying): In this technique digital signal is transmitted by switching between low frequency and high frequency in order to represent 0's and 1's. The simplest FSK is Binary FSK (BFSK). It uses a pair of discrete frequencies to transmit binary (0s and 1s) information.



Phase Shift Keying (PSK) The simplest form of PSK is binary phase shift keying (BPSK). In this case, the carrier phase is shifted between two different phases (typically 0° and 180°) depending on whether 0-bit or 1-bit is being transmitted. For example: 0-bit: the symbol transmitted is Vc cos (2πfc t) 1-bit: the symbol transmitted is Vc cos (2πfc t +180°) = − Vc cos(2πfc t)



Radio signal Transmission

From the fig.5 the wireless transmitter accepts four different binary streams of bits (00, 10, 11 and 01) from the application software. Further, these bits encoded on to a radio wave, known as a carrier by adjusting its amplitude or phase. Transmitter operates in two stages. In the first stage, quadrature phase shift keying (QPSK) modulator accepts the incoming binary bits and convert it to symbols that represents the amplitude and the phase. Then, the symbols are passed over the analog transmitter, which generates the radio wave.

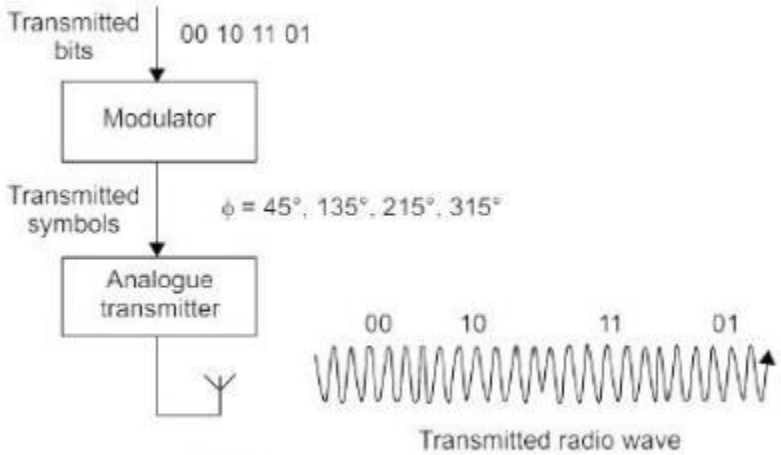


Fig.5 Wireless communication transmitter

QPSK modulator takes two bits at a time and transmits them using a radio wave. Four different binary states have phases of 45^o , 135^o , 225^o , and 315^o as shown in the fig

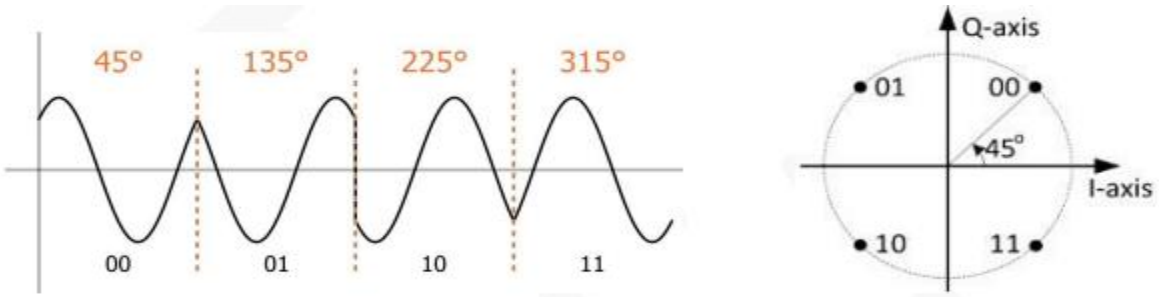


Fig.6 (a) QPSK representation **(b) QPSK constellation diagram**

The distance of each state from the origin represents the amplitude of the transmitted wave, while angle measured anti-clockwise from x-axis represents the phase. Each symbol is conveniently represented by two components: in-phase (I) and quadrature (Q). I = a cos Φ (real part) and Q = a sin Φ (imaginary part).

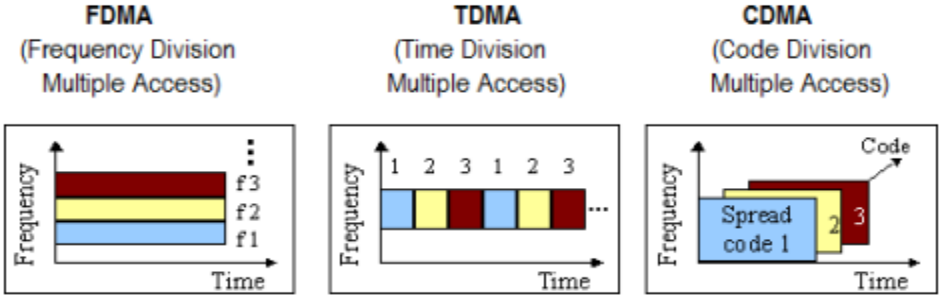
Multiple Access Techniques

Multiple access is a technique to provide communication service to multiple users over a single channel. It allows multiple mobile users share the allotted spectrum in the most effective manner.

Frequency Division Multiple Access (FDMA) Available frequency band is split into smaller frequency channels, and different channels are assigned to different users. The carriers are separated by guard bands, which avoid the interference between the users.

Time Division Multiple Access (TDMA) Various users can transmit at the same frequency band at different times. Every user is permitted to transmit only in specific time slots using a common frequency band. GSM uses a combination of both TDMA and FDMA techniques. LTE uses orthogonal FDMA techniques.

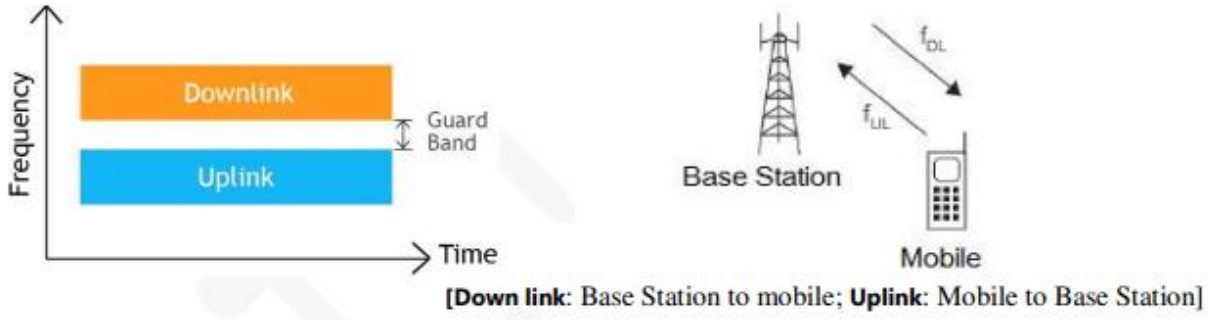
Code Division Multiple Access (CDMA) Mobiles receive signals on the same carrier frequency and at the same time. But the signals are labeled by the use of codes, which allows a mobile to separate its own signal from the others. CDMA is the common platform on which 3G technologies are built.



Duplexing:

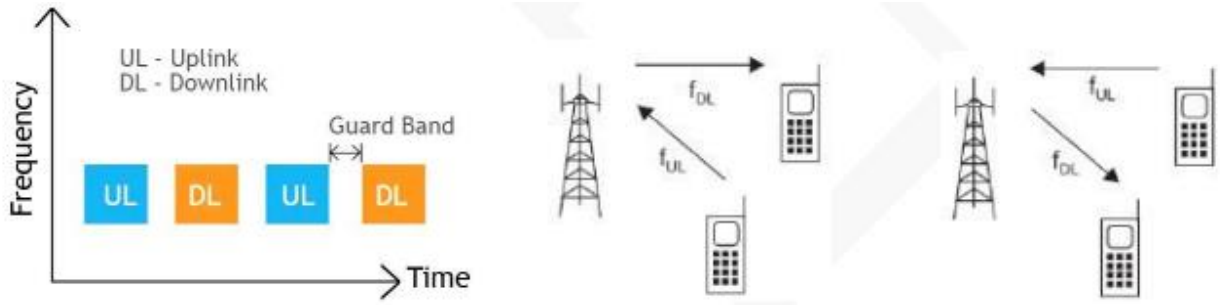
Allows users to send information simultaneously to the base station, while receiving information from the base station. The wireless telephony applies duplexing technique where talking and listening is enabled at a time.

Frequency Division Duplexing (FDD): Base station and mobile will transmit and receive at the same time, but using different carrier frequencies. FDD uses two separate frequency bands for every user. A sufficient guard band needs to separate the transmitting and receiving channels, so they do not interfere with one another. FDD is suitable for radio communication systems. It uses frequency for uplink and down link.



[Down link: Base Station to mobile; **Uplink**: Mobile to Base Station]

Time Division Duplexing (TDD)- Base station and mobile will transmit and receive on the same carrier frequency but at different times. Time slots could be dynamically allocated separated by a guard band. A guard period ensures that UL and DL transmissions do not collide. TDD is more suitable for fixed wireless systems. It uses time for uplink and down link.



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