Module -(5)

Analog communication schemes

Modern communication system scheme.

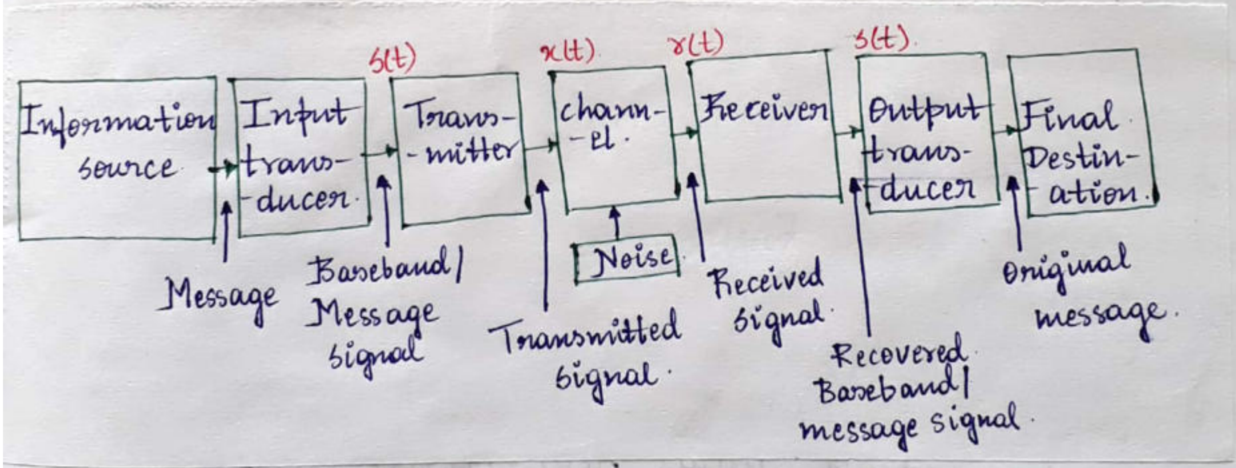
→ Communication is the transfer of information from one point to another..

(or)

exchange of information between 2 points.

→ Electronic communication is a process by which the information/message is transmitted from one point to another. from one person to another in the form of electronic signals through some communication link.

Block diagram



Constituents of modern communication system.

(1) Information source and input transducer.
(2) Transmitter.
(3) Channel or medium
(4) Noise
(5) Receiver.
(6) Output transducer and final destination.

(i) Information Source :-

→ Physical form of information is originated from the information source.

eg:- Sentence spoken by a person, there person acts as information source.

other examples include voice, music, scenes, written text etc.,..

In most of the cases the information source produces a physical quantity.

(ii) Input Transducer :-

→ The physical quantity produced from the information source will be non electrical.

It should be converted to electrical quantity before sending.

→ Transducer is a device which converts a non electrical quantity to corresponding electrical quantity and vice versa.

eg:- Microphone converts speech to corresponding electric signal.

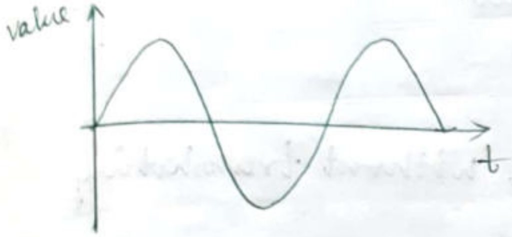
The electrical signal that comes from transducer is called baseband signal / message signal / information signal represented by $s(t)$

→ Two types of signals (1) Analog signal
(2) Digital signal.

Analog signal :-

→ Analog signal is a function of time, and has a continous range of values.

Eg:- Pure sinewave, voice signal generated from microphone.

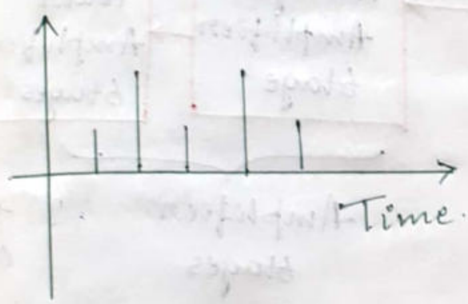


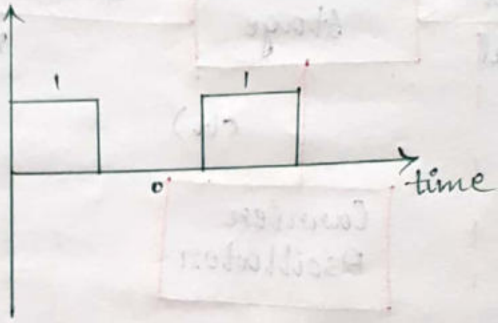
voice signal.
(speech).

Digital signal.

→ Digital signal does not have continous values on a time scale.

→ It is discrete (either 0 or 1).





(iii) TRANSMITTER :-

→ The baseband signal, i.e., 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 2 options for processing signals prior to transmission.

(1) Carrier communication system :-

→ In this process, modulation is the main function of the transmitter.

→ In this process message signal is superimposes upon a high frequency carrier signal.

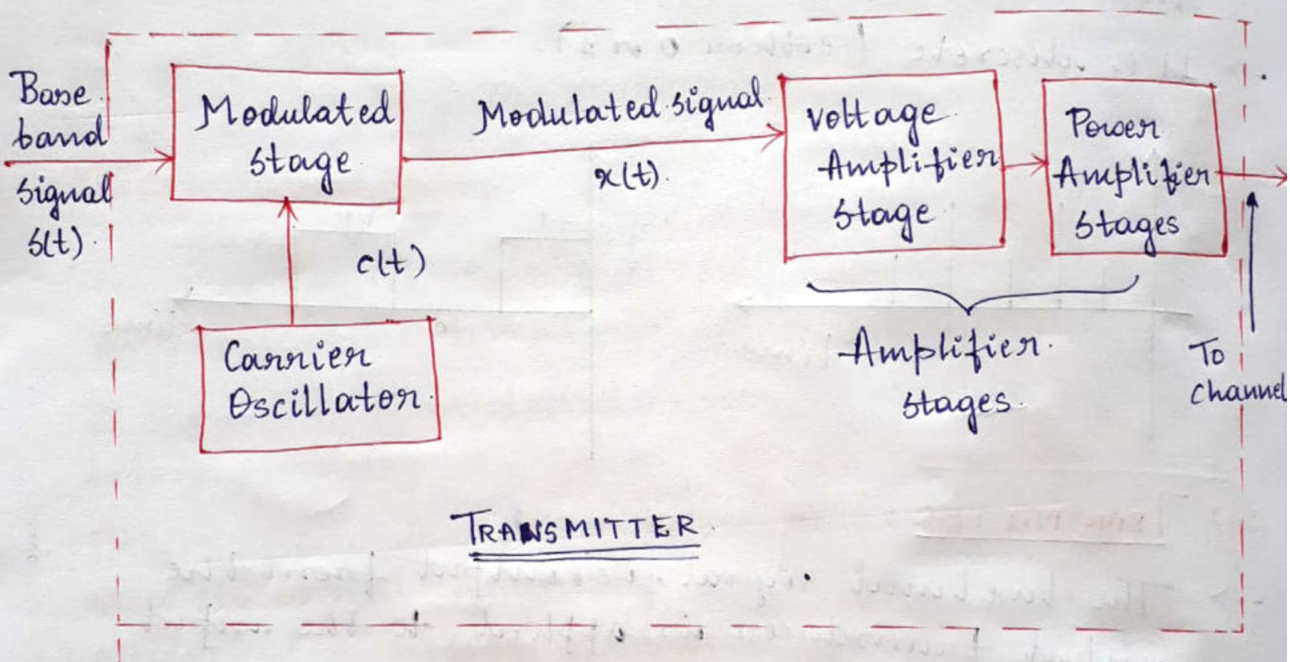
As the original message signal cannot be transmitted over a longer distance because of their low frequency and amplitude they are superimposed.

with high frequency carrier signal.

(2) Baseband communication system :-

Baseband signal is transmitted without translating it to a high frequency spectrum.

TYPICAL ANALOG TRANSMITTER.



→ Let s(t) be the baseband signal applied to the modulated stage to translate (modulate) it from low to high frequency spectrum. i.e., s(t) is superimposed upon a high frequency carrier signal c(t), is generated by a high frequency carrier oscillator.

→ The output of the modulated stage is called modulated signal and is destinated as x(t).

→ This signal is then applied to the amplifier stage.

→ The voltage of modulated signal is amplified and given to power amplifier stage, which amplifies the power of the signal.

→ Finally this signal is passed to information channel.

(iv) Channel or Medium.

→ The term channel means the medium through which the message travels from the transmitter to receiver.

→ The transmitted signal should have adequate power to withstand the channel noise.

→ Depending on the physical implementations, one can classify the channel in the following 2 groups.

(1) Hardware channels.

(2) Software channels.

Hardware channels (Manmade):-

→ These channels are manmade structures.

→ It is called a line communication system.

Following are the 3 possible implementations of hardware channels.

(1) Transmission lines:-

Twisted pair cables (Landline phones)

Coaxial cables (TV cables).

(2) Wave guides:-

To transmit ultra high frequency (UHF) waveguides are used as medium. wave guides are hollow, circular or rectangular metallic structure.

(3) Optical fiber cables:-

In optical fiber cables signals are transmitted in the form of light energy in optical fiber cables.

Software channels:-

→ The natural resources which can be used as the transmitting medium for signals are called software channels.

Eg:- Air, openspace and seawater.

→ There is no physical link between transmitter and receiver in communication systems if the software channels are used.

(v) Noise.

→ Noise is defined as the 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 deteriorates the waveforms.

Signal to Noise Ratio (SNR) and Noise Figure (F)

→ SNR is defined as the ratio of signal power (S) to the noise power (N), often expressed in dB.

$$SNR = \frac{P_{signal}\ \text{(wanted component)}}{P_{noise}\ \text{(unwanted component)}}$$

Signal to noise ratio is expressed as $\frac{S}{N}$.

$$\therefore \frac{S}{N} = \frac{P_S}{P_N}$$

$$\frac{S}{N} = \frac{P_S}{P_N} = \frac{V_S^2 R}{V_N^2 R}$$

$P = VI$

$P = V \cdot \frac{V}{R} = \frac{V^2}{R}$

$\therefore \boxed{P = \frac{V^2}{R}}$

$$\left(\frac{S}{N}\right)_{dB} = 10 \log_{10}\left(\frac{V_S^2}{V_N^2}\right)$$

$$\left(\frac{S}{N}\right)_{dB} = 20 \log_{10}\left(\frac{V_S}{V_N}\right)$$

→ Noise figure (F) is the measure of the noise introduced by the circuit.

→ It is defined as the ratio of signal to noise power at the input of the circuit and the signal to noise power at the output of the circuit.

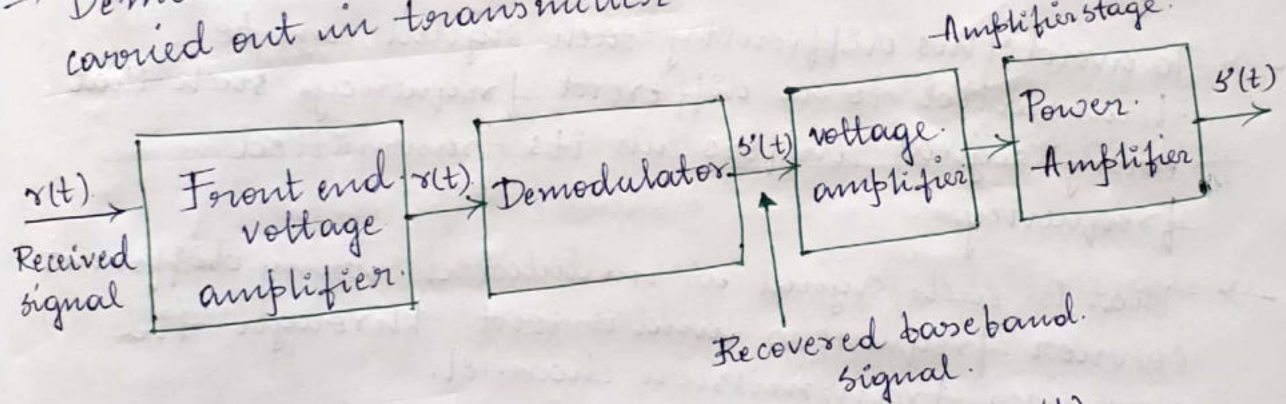
$$F = \frac{\frac{S}{N}\text{ (at the input terminals)}}{\frac{S}{N}\text{ (at the output terminals)}}$$

(vi) Receiver.

→ The main function of the receiver is to reproduce the original message signal.

→ The reproduction of the original signal is accomplished by a process known as demodulation or detection.

→ Demodulation is the reverse process of modulation carried out in transmitter.



→ The signal received by the receiver is r(t). Due to attenuation r(t) is a weak signal.

→ A voltage amplifier amplifies to make the signal strong enough for further processing.

→ Next signal is applied to demodulator. In demodulation the baseband signal is separated from high frequency carrier signal.

→ After recovering the original baseband signal s'(t) its voltage and power is amplified before sent to final destination.

(vii) Destination.

→ Destination is the final stage which is used to convert an electrical message signal into its original form.

For eg:- in radio broadcasting, the destination is a ~~too~~ loud speaker that converts the electrical signal to original sound signal.

Multiplexing.

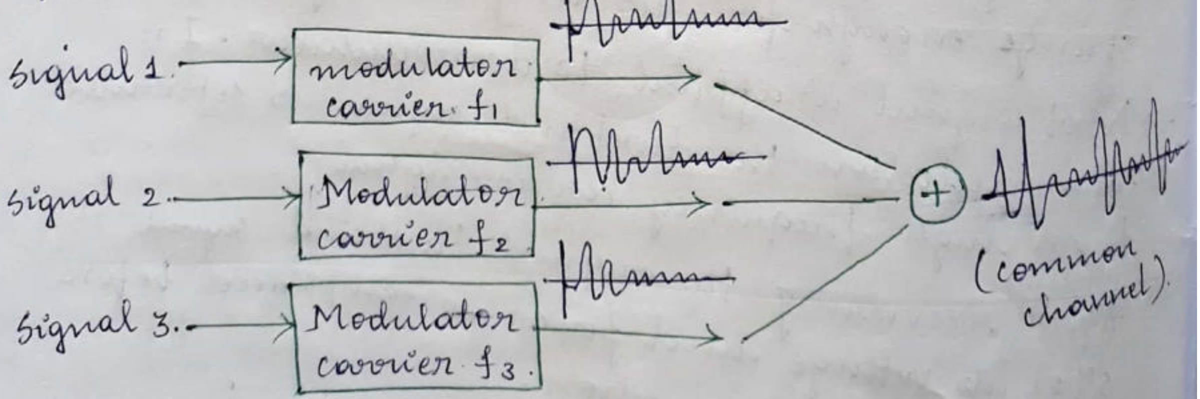
→ Multiplexing is the process which allows more than one signal to transmit through a signal channel.

→ If all the signals have the same frequency and are transmitted together they will be mixed together.

→ To avoid this difficulty each signal can be translated to a different frequency, such that every signal differs in its transmitted frequency.

→ That is each signal is modulated using different carrier frequencies and is sent through the common transmission channel.

→ At the receiver, different signals can be easily separated because they are ~~are~~ at different frequencies.



Types of Communication Systems:-

Communication based on physical Infrastructure.

Based on physical infrastructure there are two types of communication systems.

(i) Line communication systems.

(2) Communication system based on signal Specifications → Nature of base band; → Nature of transmitted signal.

(1) 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 transmitter and receiver in line communication systems.

example :- landline telephony, cable TV.

(2) Communication systems based on signal specifications:-

(A) Based on nature of baseband or information signal

(i) Analog communication system:-

Exchange of information between 2 points through analog signals.

eg:- Audio, video.

(ii) Digital communication systems:-

Exchange of information through digital signals.

eg:- HDTV.

(B) Based on Nature of transmitted signal :-

(i) Baseband communication system:-

Baseband signals are transmitted without translating to higher frequencies.

eg:- Landline, fax.

(ii) Carrier communication system:-

The base band signal is mixed with high frequency carrier signal

eg:- Radio, voice messages. cables.

MODULATION :-

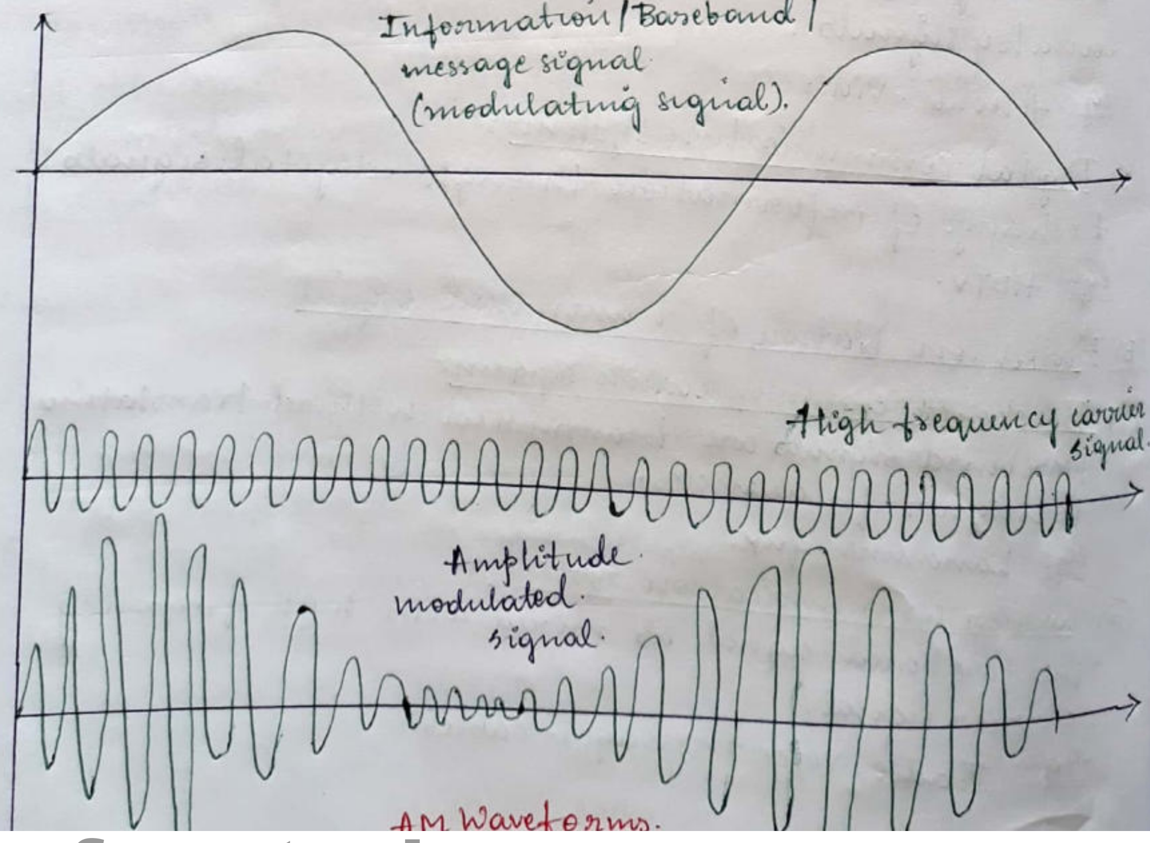
→ Modulation is the process in which any one of the parameters (amplitude, frequency, phase) of high frequency carrier signal is varied according to the instantaneous values of the low frequency message signal, keeping other parameters constant.

TYPES OF MODULATION.

- Modulation.
  - Analog.
    - Amplitude modulation
    - Frequency modulation
    - Phase modulation
  - Digital.
    - Amplitude shift keying
    - frequency shift keying
    - Phase shift keying

Amplitude Modulation (AM)

→ Process by which amplitude of the carrier signal is varied in accordance with the values of message signal, whereas frequency and phase are kept constant.

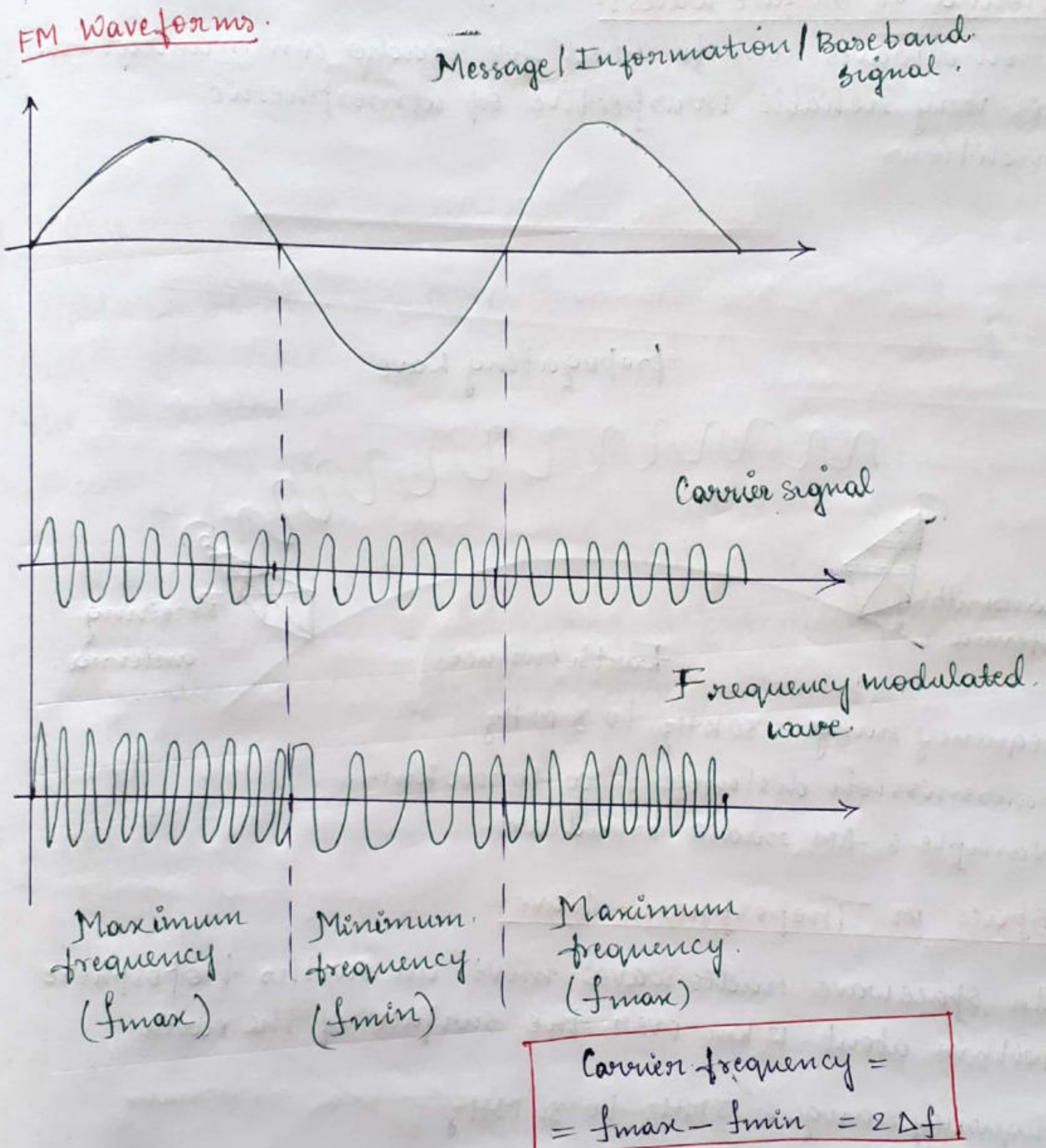


AM Waveforms.

Frequency Modulation (FM).

→ Frequency modulation is defined as a process in which frequency of the carrier is varied in accordance with the values of the message signal, whereas amplitude and phase are kept constant.

FM Waveforms.



Carrier frequency = $= f_{max} - f_{min} = 2\Delta f$

Concept of Radio Wave propagation :-

→ Radiowaves exhibit the properties of light with the velocity of 3×10^8 m/s.

→ These are electromagnetic waves that consists of electric and magnetic field components.

→ It is traversed in nature.

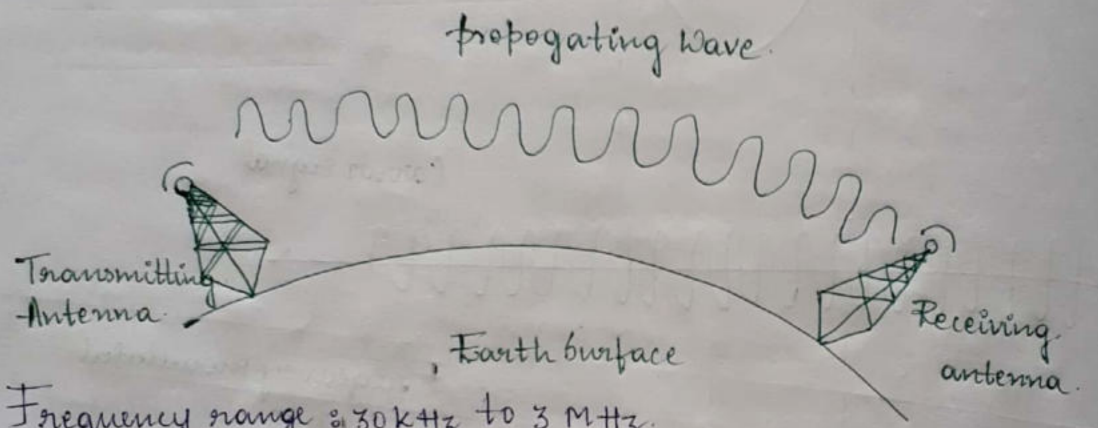
→ Radio signals can travel from one end to another over vast distances.

→ Since, these are EM waves, they exhibit properties such as reflection, refraction, diffraction, absorption, scattering.

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

(i) Ground or Surface waves:-

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



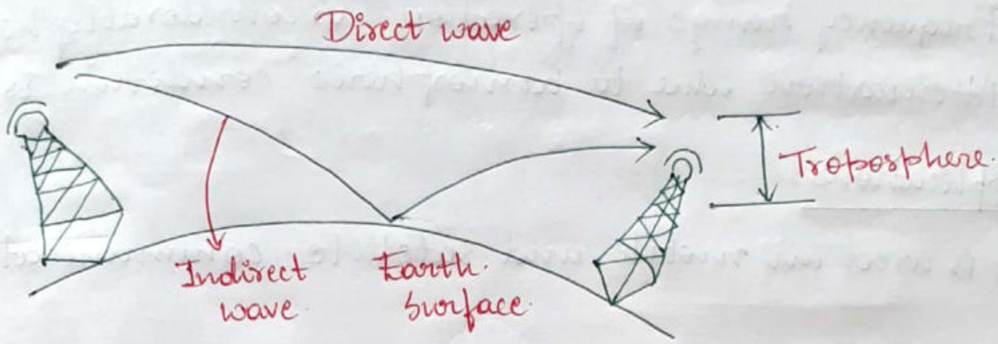
Frequency range : 30 KHz to 3 MHz.
Transmission distance : 100 to 1000 km.
Example : AM radio broadcast.

(ii) Space or Tropospheric Wave:-

→ In Space wave radio waves move in earths troposphere within about 12 km over the surface of the earth.

Frequency range :- 3 MHz to 30 MHz
Example :- TV transmission.

→ The space wave is made up of two components.
(i) Direct or line of sight wave from the transmitting to the receiving antenna.
(ii) Indirect or ground reflected wave traversing from the transmitting antenna to ground and reflected to the receiving antenna.

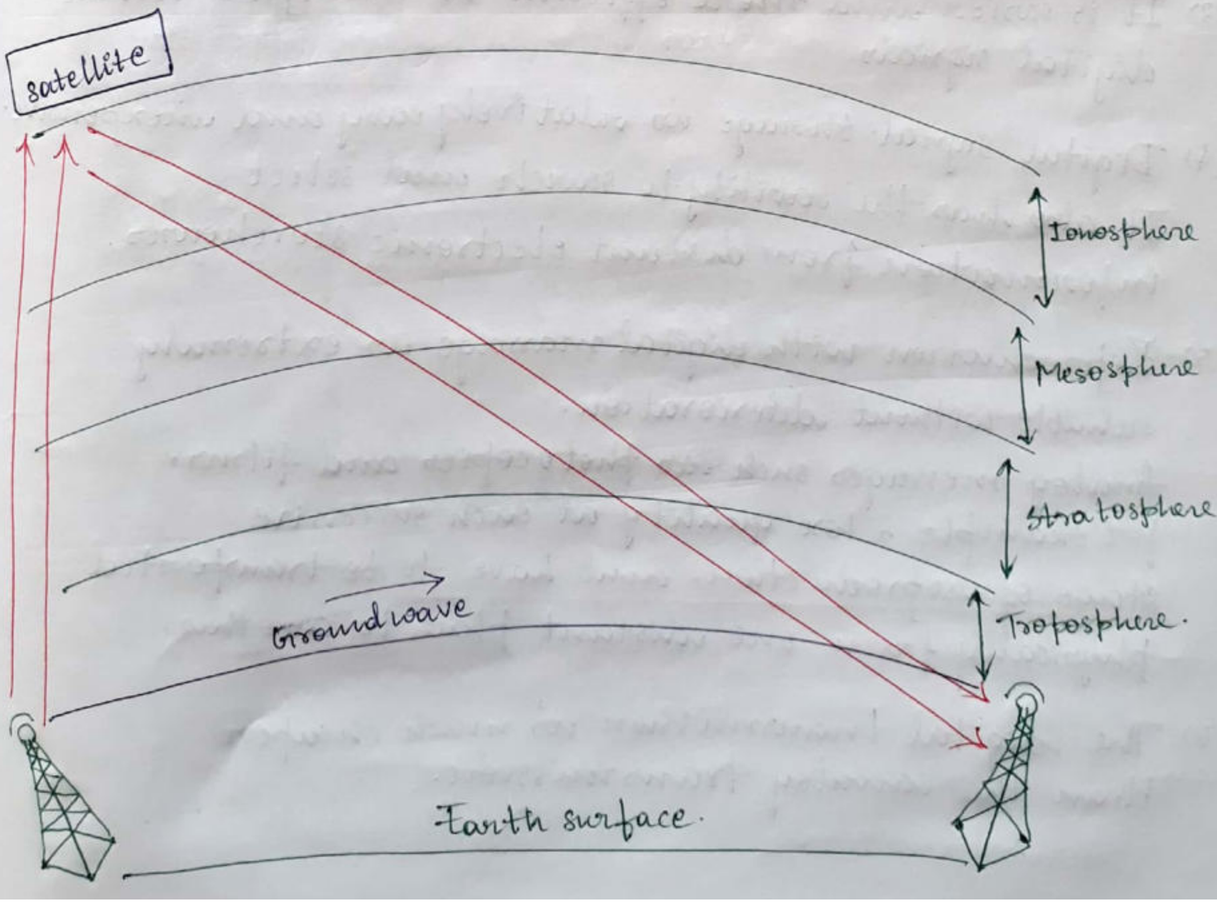


(iii) Sky Wave

→ Radio waves transmitted from the transmitting antenna reach the receiving antenna after reflection from the ionosphere.

→ Skywave is responsible for short wave transmission around the globe via successive reflections at the ionosphere and the earths surface.

→ Ionosphere is the ionized region extending about 80 km above the earth surface.



Advantages of Skywave propogation:-

1) It supports large distance propogation.
2) Frequency range of operation is considerably high.
3) Attenuation due to atmospheric condition is less.

Applications:-

It is used in mobile and satellite communication.

DIGITAL MODULATION SCHEMES:-

Advantages of dital communication over analog communication.

(1) Digital hardware implementation is flexible and permits the use of microprocessors, mini processors, digital switching and large scale integrated circuit.

(2) Digital signals can be coded to yield extremely low error rates and high fidelity as well as privacy.

(3) It is easier and more efficient to multiplex several digital signals.

(4) Digital signal storage is relatively easy and inexpensive. It also has the ability to search and select information from distant electronic storehouses.

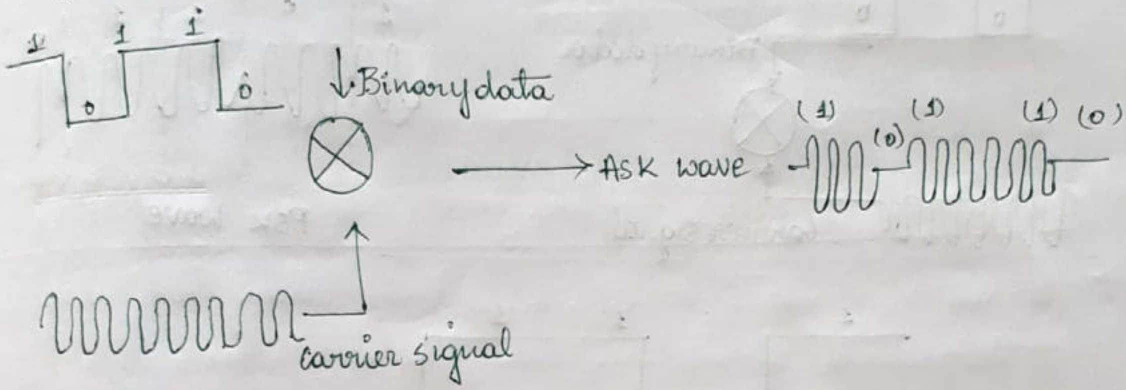
(5) Reproduction with digital massage is extremely reliable without deterioration.
Analog messages such as photocopies and films, for example, lose quality at each successive stage of reproduction, and have to be transported physically from one distant place to another.

(6) The digital transmission is much cheaper than the analog transmission.

(i) Amplitude Shift keying (ASK).

→ ASK represents digital data as variations in the amplitude of a carrier wave.

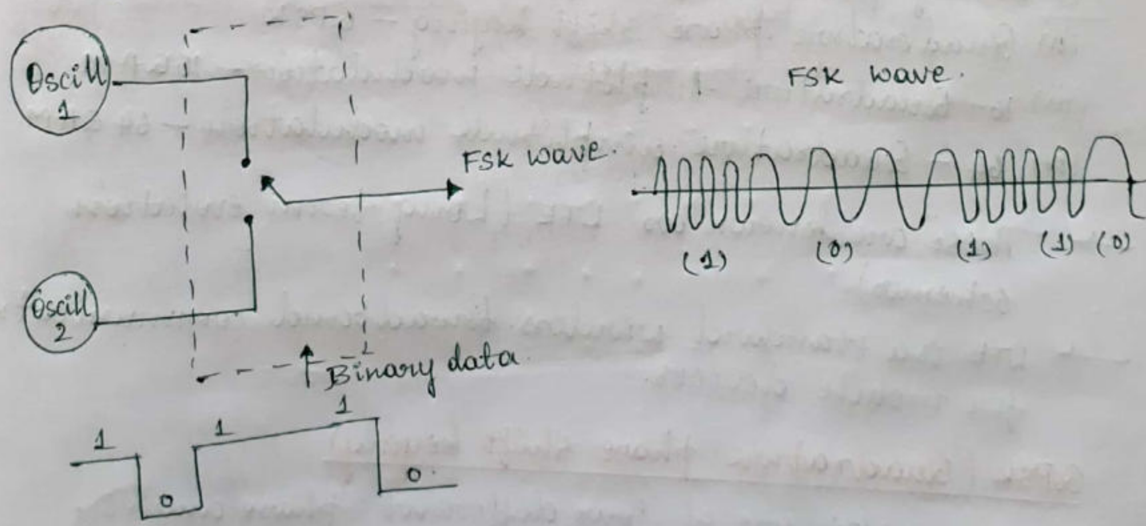
→ ASK signal can be generated when, the incoming binary data and the sinusoidal carrier are applied as product modulator inputs.



(ii) Frequency shift keying (FSK).

→ In this technique digital signal is transmitted by switching b/w low frequency and high frequency inorder to represent 0's and 1's.

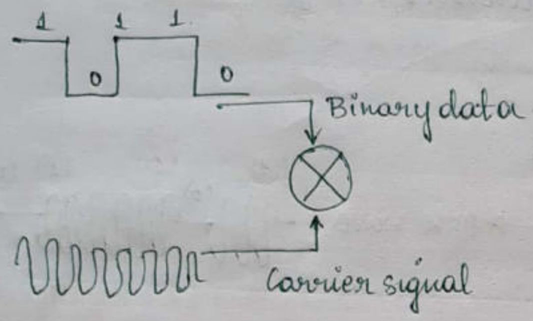
→ The simplest FSK is Binary FSK (BFSK). It uses a pair of discrete frequencies to transmit binary (0's and 1's) information.

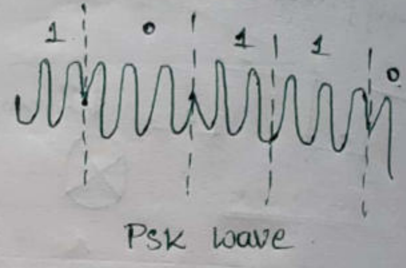


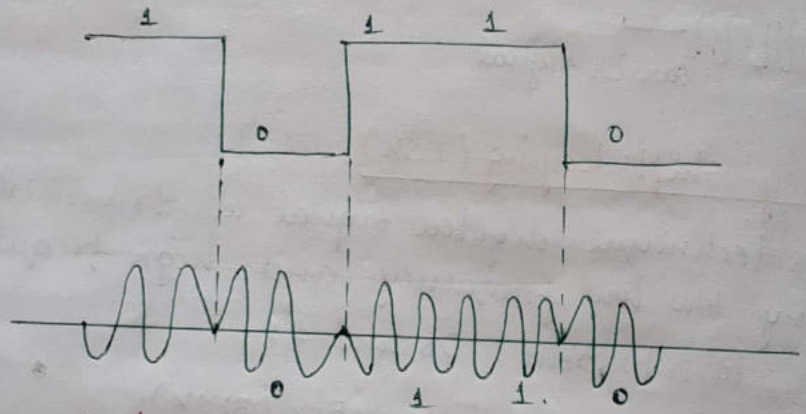
(iii) Phase shift keying (PSK).

→ In this technique carrier phase is shifted between 2 different phases (typically 0° and 180°) depending on whether 0 or 1 is transmitted.

→ Simplest form of PSK is BPSK (Binary PSK)







Radio signal transmission (LTE modulation scheme)

→ It is bascially four types of modulation schemes.

(i) Binary phase shift keying – BPSK.
(ii) Quadrature phase shift keying – QPSK
(iii) 16– Quadrature Amplitude modulation – 16QAM.
(iv) 64 – Quadrature amplitude modulation – 64 QAM.

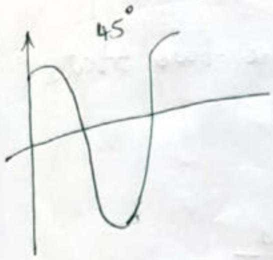
→ These are known as LTE (Long term evolution schemes).

→ LTE is a standard wireless broadband communication for mobile devices.

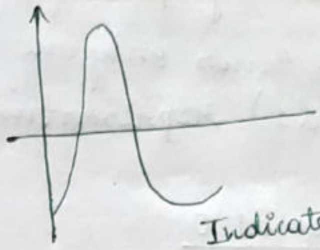
QPSK (Quadrature phase shift keying)

→ QPSK make use of four different phase angles. like 45°, 135°, 225° and 315°.

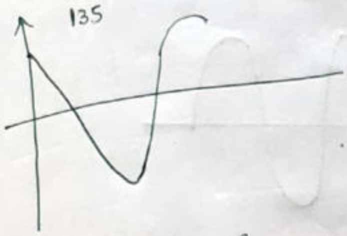
→ Since four phase angles, it can represent four two bits as given below.



Indicates: 00



Indicates: 11



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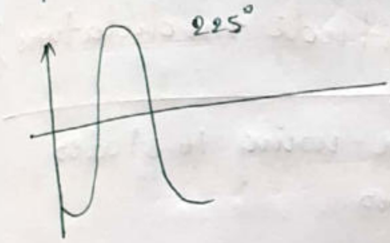
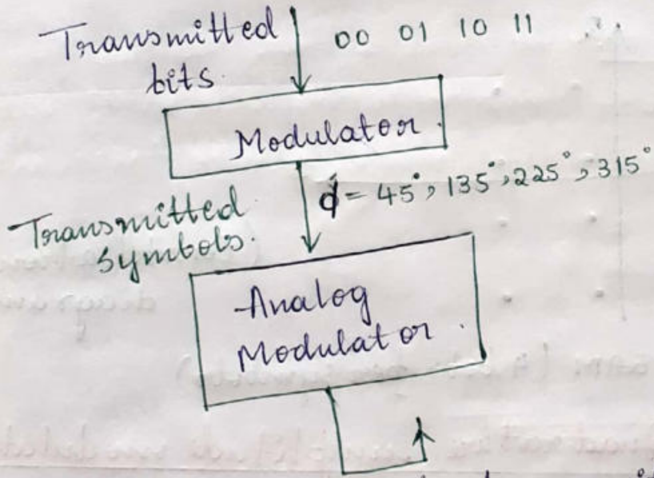
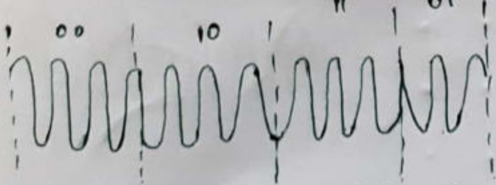


Indicates: 10.

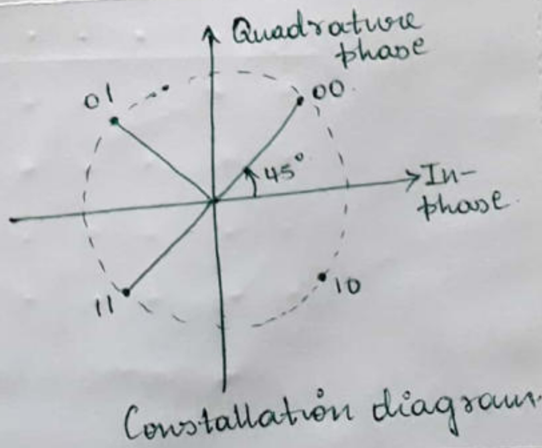


→ Wireless communication-transmitter. first accepts the incoming binary bits and converts it to symbols that represents amplitude and phase.

→ Second, ~~it~~ then it is passed over analog transmitter, which generates radio waves.



→ QPSK sends two bits at a-time using four states.

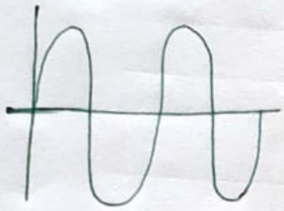


Constallation diagram

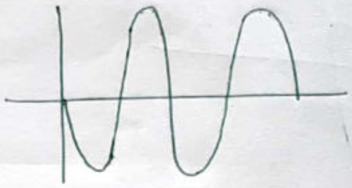
(ii) BPSK (Binary phase shift keying)

→ BPSK sends only one bit a time using the two states (0 and 1) representing phases 0° and 180°.

symbol 0

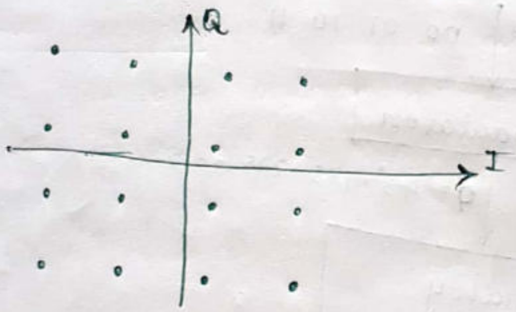


Symbol 1



(iii) 16-QAM (16-Quadrature amplitude modulation)

→ 16-QAM sends four bits at a time using 16 states to represent amplitude and phases.

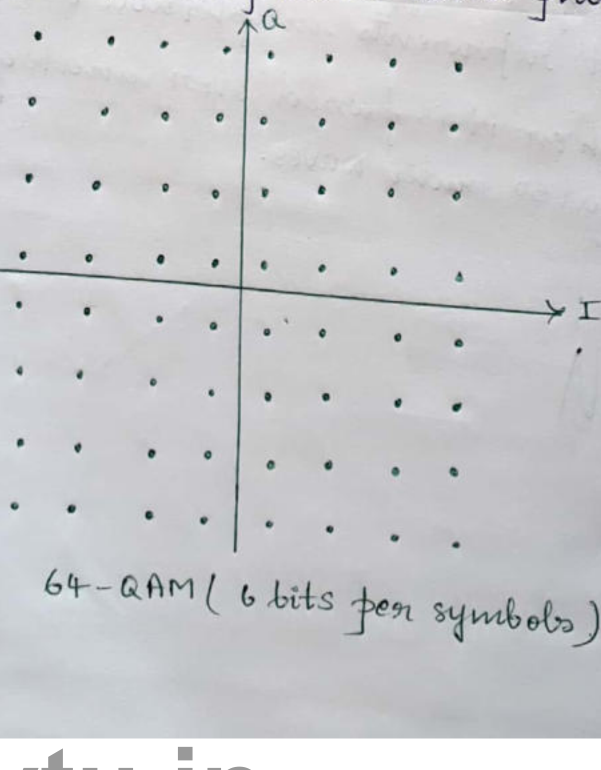


(Constellation diagram)

16-QAM (4 bits per symbols).

(iv) 64-QAM (64-Quadrature amplitude modulation)

→ Sends six bits at a time using 64 states to represent the amplitude and phases.



64-QAM (6 bits per symbols).

Communication Systems.

Introduction.

3 Eras of communication. (3 phases)

* The era of electrical communi-
-cation began in 1844 with a successful demonstration of sending a message through a telegraph line.

* The invention of vacuum-tube tetrode in 1906 revolutionized the field of electrical communication & opened the door for wireless communication.

First phase (1906 - 1947)

* The first phase of development of electronics and communication engineering.

* The era witnessed the rapid development of wireless telegraphy & telephony, radio & television broad casting, teletypewriter, radar and the first electronic digital computer, Electronic Numerical Integrator and computer (ENIAC).

Second phase.

* The discovery of transistor in 1947 started the second phase of advancement in electronics and communication engineering.

* Some most remarkable communication systems that were developed during the second phase are:

(i) Microwave communication links.
(ii) colour television.
(iii) satellite communication.
(iv) stereo FM broadcast.
(v) Digital communication.
(vi) cable Television system.
(vii) optical fiber communication.

Golden Era of computers.

* The breakthrough of the single chip microprocessor Intel 4004 by Intel Corporation in 1971 started the fascinating golden era of computers.

* computers & Very Large Scale Integration (VLSI) technology which is used to fabricate integrated circuits (ICs), introduced different modes of communication systems, e.g. fax optical fiber communication, cellular mobile communication, personal mobile communication ...

* In digital domain, the modulation process involves switching or keying the amplitude, frequency or phase of the carrier in accordance with the input data.

* 3 types of modulation technique for transmission of digital data, namely ASK (Amplitude-shift keying), Frequency-shift keying (FSK) and PSK (phase-shift keying).

Digital communication.

* Basically - 2 types of signals continuous - time & discrete - time signals.

* Advantage of discrete - time signals.
  Processing of discrete - time signals is more flexible & is also preferable.

* That is why in practice we have to convert a continuous - time signal into discrete - time signal.

* This is done by fundamental mathematical tool known as sampling theorem.

* Sampling theorem - provides mechanism for representing a continuous - time signal by a discrete - time signal.

Advantages of digital communication on analog communication.

* Ruggedness to channel noise.
* External interface unmatched by any analog communication system.
* Flexible operation.
* Integration of diverse sources.
* Security of information.

* But, to handle the transmission of analog message signal by digital means, it has to undergo A/D conversion.

<u>Wave-coding techniques.</u>

* The disadvantages of PAM can be subsidized by using wave coding techniques.

* With wave coding techniques, the analog PAM signal is converted to digital signal.

* Next step in digital transmission is the generation of coded version of the signal.

* PCM provides method to fulfill this requirement.

* PCM → belongs to a class of signal coders known as waveform coders.

* In digital communications, modulating signal consists of binary data.

* This data is used to modulate a carrier wave with a constant high frequency.

* In digital domain, the modulation process involves switching or keying the amplitude, frequency or phase of the carrier in accordance with the input data.

* 3 types of modulation techniques for transmission of digital data, namely ASK (Amplitude-shift keying), Frequency-shift (FSK), and PSK (phase-shift keying).

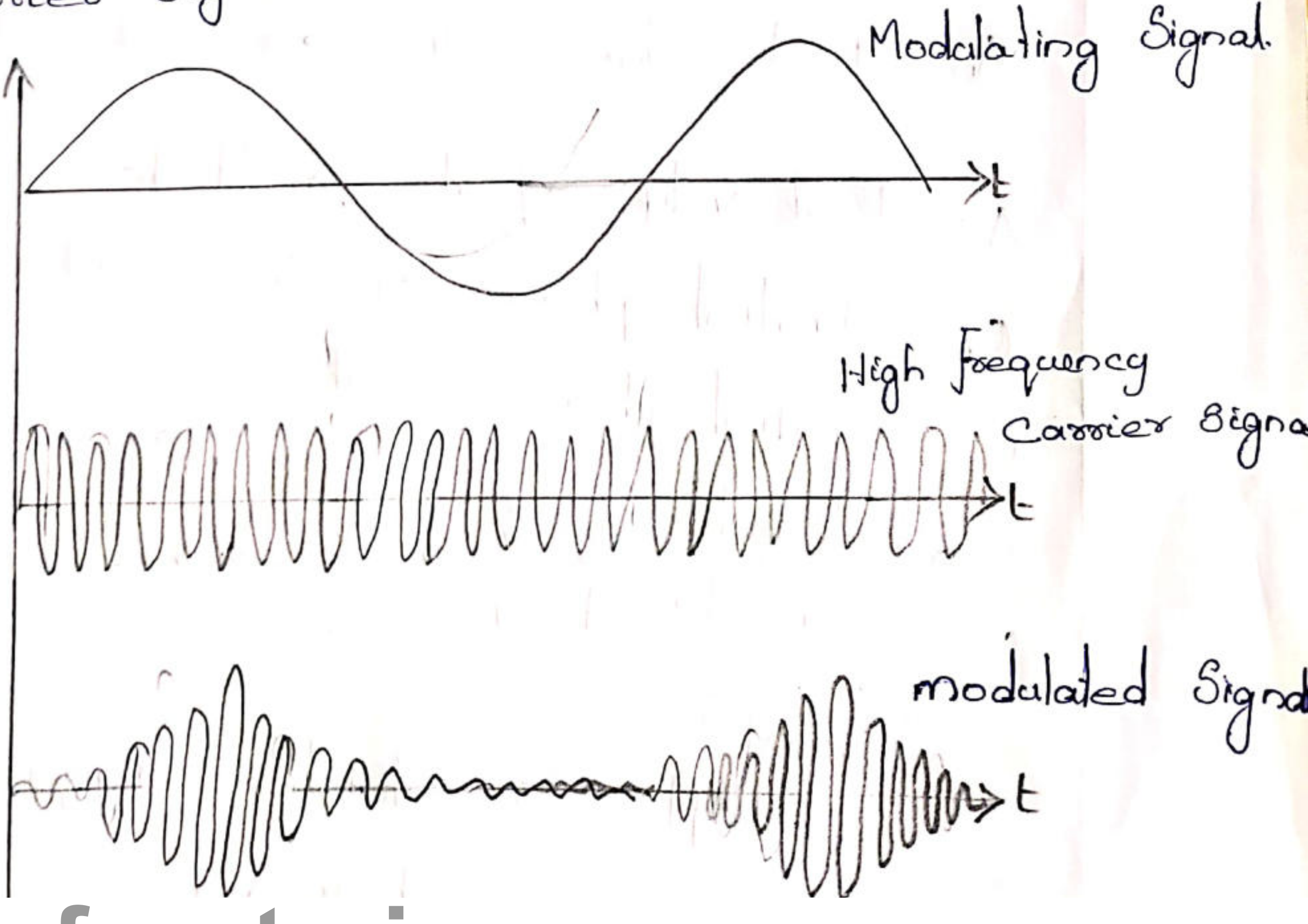
Amplitude Modulation:

Amplitude modulation is defined as the modulation technique in which the instantaneous amplitude of the carrier signal is varied in accordance with the instantaneous amplitude of the analog modulating signal to be transmitted.

→ The modulating signal is the analog baseband signal with low frequency

→ The carrier signal is always a sinusoidal wave with high frequency.

→ The Frequency and phase of the carrier signal is constant.



Equation of AM Waves :

To design a communication system, first step is mathematical modeling

→ The basic wave namely modulating signal is taken as a pure sinusoidal wave as given by the equation

$$s(t) = A_m \cos(\omega_m t + \theta_m) \rightarrow (1)$$

→ The carrier signal with high frequency is given by

$$c(t) = A_c \cos(\omega_c t + \theta_c) \rightarrow (2)$$

where,

$s(t)$ → instantaneous amplitude of modulating signal

$c(t)$ → instantaneous amplitude of Carrier Signal

A_m → Peak value of the amplitude of modulating Signal

A_c → Peak value of the amplitude of Carrier Signal

θ_m → Initial phase of the modulating Signal.

θ_c → Initial phase of the carrier signal

ω_m → Angular frequency of the modulating Signal

ω_c → Angular frequency of the carrier signal

$(\omega = 2\pi f)$

→ After modulation, frequency and

→ For simplicity, ignore these two parameters from equation ① + ②

$$s(t) = A_m \cos \omega_m t \rightarrow ③$$

$$c(t) = A_c \cos \omega_c t \rightarrow ④$$

→ The modulated AM wave can be represented by

$$x(t) = A \cos \omega_c \cdot t \rightarrow ⑤$$

where

A → Peak amplitude of the modulated signal

$$A \propto (A_c + s(t)) \rightarrow ⑥$$

Angle Modulation

Angle modulation is defined as the modulation technique in which total phase angle of the carrier signal is varied in accordance with instantaneous value of the modulating signal while amplitude of carrier remains constant

Let the carrier signal be expressed as

$$c(t) = A_c \cos(\omega_c t + \theta_c) \quad \text{——} (1)$$

where;

A_c: Amplitude of carrier signal
ω_c: Angular frequency of carrier signal
θ_c: phase angle of carrier signal

Substituting $\omega_c t + \theta_c = \phi$;

$$c(t) = A_c \cos\phi \quad \text{——} (2)$$

where, ϕ = total phase angle of carrier signal

in a sinusoidal signal angular frequency is defined as rate of change of total phase angle wrt time

i.e., $$\omega_c = \frac{d\phi}{dt} \quad \text{——} (3)$$

It may be noted that $\frac{d\phi}{dt}$ is constant. However this derivative is not

So, the angular frequency is known as instantaneous angular velocity or instantaneous angular frequency ω_i

From eqn (3)

$$\Rightarrow \phi_i = \int \omega_i \cdot dt \quad \text{—— (4)}$$

Now if angle ϕ is varied in accordance with instantaneous value of message signal, the carrier signal is said to be angle modulated.

Types of angle modulation

1) Frequency modulation (FM)
2) Phase modulation (PM)

Frequency Modulation

Definition

FM is defined as the modulation in which instantaneous frequency of the carrier signal is changed according to instantaneous amplitude of modulating or message signal

Therefore after FM, frequency of carrier signal f_c will not remain constant, but it will vary in accordance with amplitude of modulating signal attains maximum at t4. hence frequency of the modulated signal also increases.

quarter IV (t4 to t5)

The modulating signal decreases during this quarter and becomes zero at t5. Therefore frequency of modulated signal decreases. It continues to decrease until time t5, where amplitude of modulating signal becomes zero and frequency of modulated signal becomes fc at time instant t5

Frequency deviation

Instantaneous frequency is

$$\omega_i = \omega_c + K_f \cdot x(t) \quad \text{——} (10)$$

The maximum change in instantaneous frequency from average frequency ω_c is frequency deviation. It is positive or negative depending upon sign of $K_f \cdot x(t)$

maximum frequency is generally denoted by $\Delta\omega$

$$\Delta\omega = |K_f\, x(t)|_{max}$$

Quarter I (t1 to t2)

At time t1, amplitude of modulating signal is zero, so there is no change in frequency of carrier signal

As it goes towards t2, amplitude increases and attains maximum negative peak at time t2. So from t1 to t2 frequency of modulated carrier signal decreases and reaches its minimum value at t2.

Quarter II (t2 to t3)

Amplitude of modulating signal increases from its negative peak value, at time t3 it becomes zero

from t2 to t3 frequency of modulated carrier signal increases from its minimum value at time t2 and becomes equal to fc at time t3

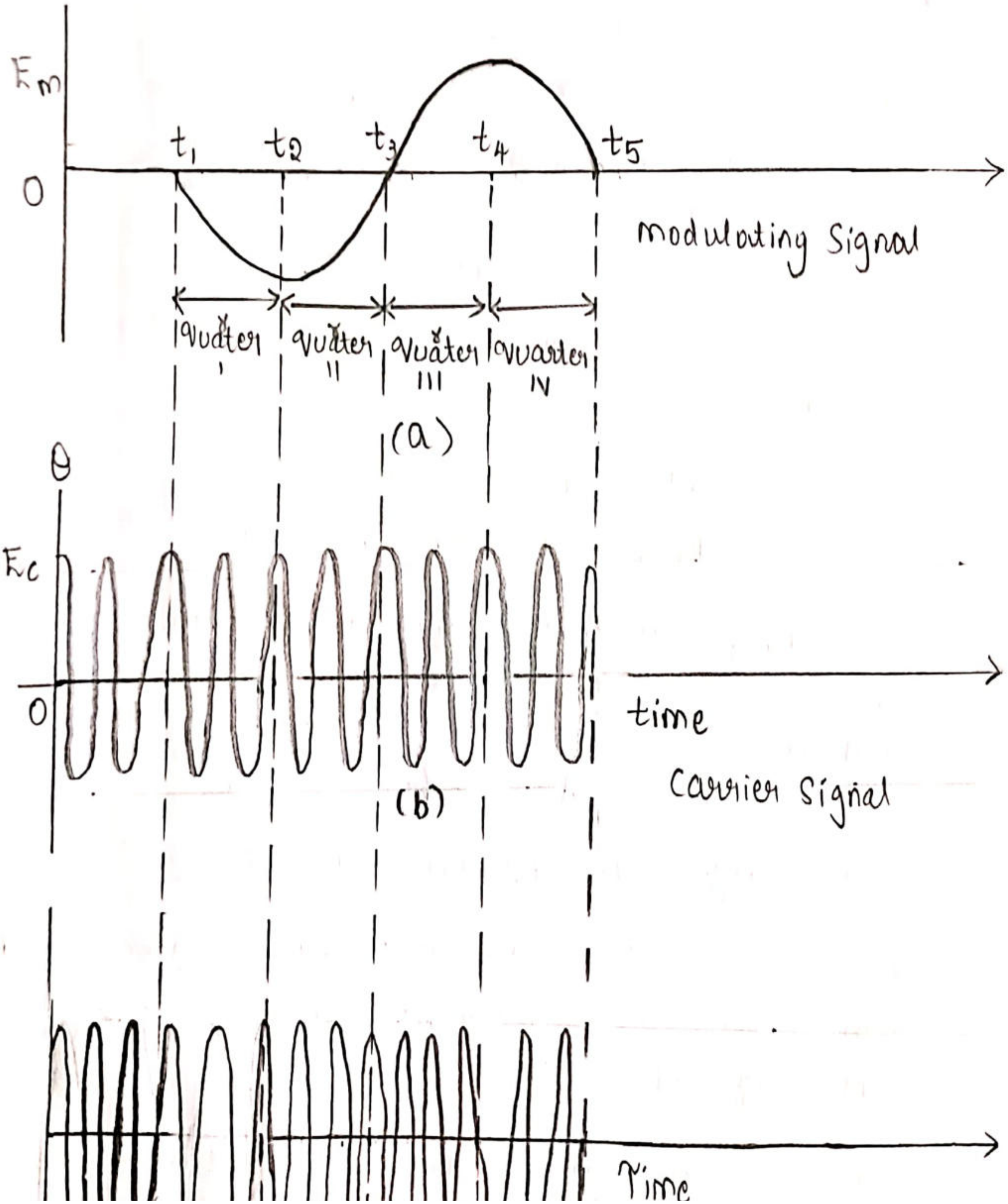
Quarter III (t3 to t4)

At time t3, amplitude of modulating signal is zero, so frequency of modulated carrier is fc

At time ~~t4~~ t3 to t4 ~~frequency~~ amplitude

Frequency deviation $f_d = |K_f \cdot x(t)|$

To explain FM, divide one complete cycle $(x(t))$ into 4 quarters



As the instantaneous frequency is given

$$\omega_i = \omega_c + K_f \cdot x(t) \quad \text{——(5)}$$

K_f - proportionality constant or frequency sensitivity of the modulator

based on eqn(4), expression for instantaneous phase angle can be expressed as

$$\phi_i = \int \omega_i \cdot dt \quad \text{——(6)}$$

putting value of ω_i from eqn(5) in eqn(6), we get

$$\phi_i = \int [\omega_c + K_f \cdot x(t)] dt$$

$$\phi_i = \omega_c t + K_f \int x(t) \cdot dt \quad \text{——(7)}$$

According to definition of FM, the expression for frequency modulated signal will be

$$s(t) = A_c \cdot \cos\phi_i \quad \text{——(8)}$$

putting eqn(7) in ean(8)

$$s(t) = A_c \cdot \cos[\omega_c t + K_f \int x(t) \cdot dt]$$

which is the required equation for FM signal

The maximum change in instantaneous frequency from average frequency ω_c

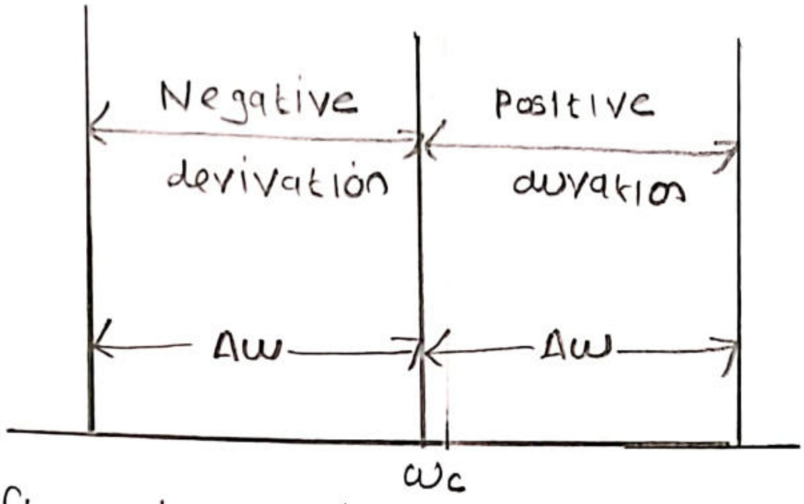


fig 7 illustration of frequency derivation

The above figure illustrace concept of frequency deviation

The total variation in frequency from lowest to highest point is carrier swing which is twice the frequency deviation

$$\text{carrier swing} = 2 \cdot \Delta\omega$$

* Digital Modulation Techniques.

→ When it is required to transmit digital signals on a bandpass channel, the amplitude frequency or phase of the sinusoidal carrier is varied in accordance with the incoming digital data

→ For this purpose digital modulation techniques are used.

→ classified into two types.

① Coherent ASK, BPSK, FSK

② Non-coherent : QAM,

① Coherent Digital Modulation Technique

→ In this, the local carrier generated at the receiver is phase locked with the carrier at the transmitter.

→ Also known as synchronous detection.

→ Detection is done by correlating the received noisy signal and locally generated carrier.

② Non-coherent Digital Modulation Technique

→ In this, the detection process doesnot require receiver carrier to be phase locked with

Poor Radiation and Penetration:

When an antenna transmits a signal, it radiates electromagnetic waves into space.

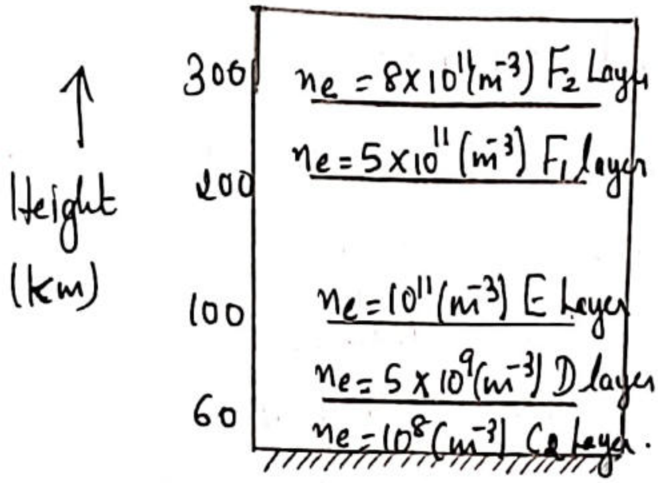
High Frequency - More radiation
Low Frequency - Less Radiation

So radiation depends on signal frequency.
When a signal does not radiate strongly from the antenna, it becomes weak and emits poor radiation. Therefore in order to get sufficient radiated power from the antenna, the frequency of the transmitted signal should be increased. This is achieved by modulation.

There are modes of propagation of radio waves in free space. One of the modes of propagation of radio signals through free space makes use of ionospheric layers of the atmosphere.

Ionosphere is the upper portion of the atmosphere which absorbs large quantities of radiant energy from the sun, becoming heated and ionized.

The most important ionizing agents are UV and α, β, γ radiation from sun as well as cosmic rays and meteors.

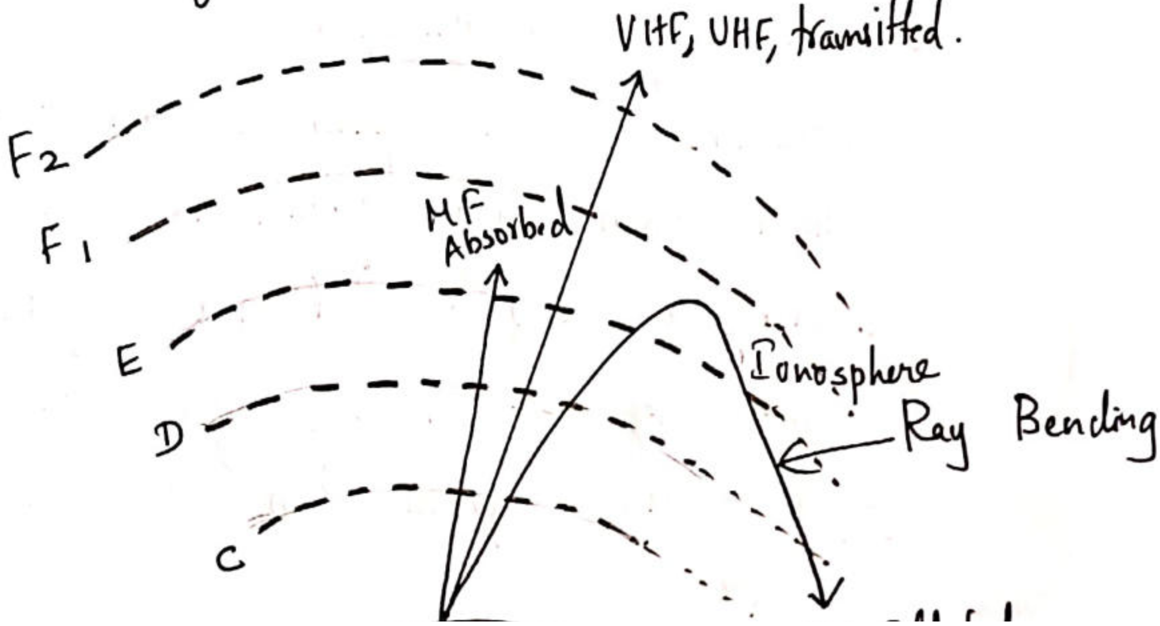


Ionospheric Layers

n_e = no. of free electrons per cubic meter

The ionosphere plays an important role in space communication. The propagation of radio waves through the ionosphere is affected by the electrons and ions in the ionosphere. The radio waves of HF frequency band having frequency range 3-30 MHz cannot penetrate through the ionosphere. These radio waves are reflected back towards the earth.

The effect of ionosphere on em waves with different layers is shown in figure below



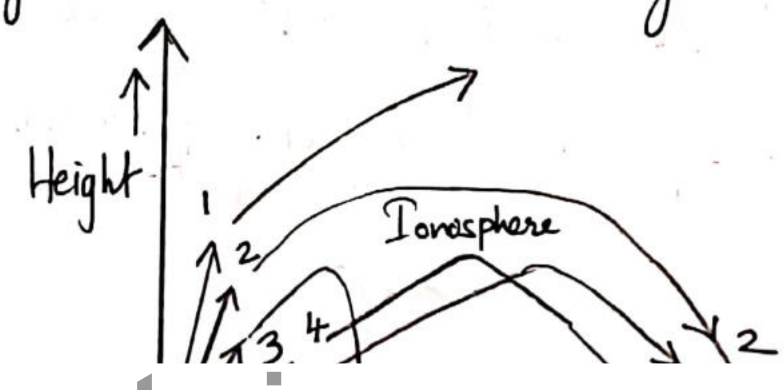
Sky Wave Propagation:

Sky Wave or radio waves with Frequencies between 2MHz to 30MHz. These radio waves propagate through the atmosphere and are reflected back by the ionospheric layer of the earth's atmosphere. Since these waves go from the transmitter antenna to the receiver antenna while travelling through the sky, their propagation is known as sky wave propagation.

Sky waves are of great importance at medium and high Frequencies (ie for medium and short waves) for long distance communication.

The sky wave propagation is also known as ionospheric propagation, as it reaches the receiver of the reflection from the ionosphere.

In a single reflection from the ionosphere, the radio waves cover a distance of not more than 4000 km. Using sky wave propagation, communication over long distances around the globe is possible.



Ray Trajectories in the Ionosphere for different angles of incidence

Terminologies related to sky wave propagation.

(i) **Critical Frequency (fc):**
It is the highest Frequency radio wave which when sent straight gets reflected from the ionosphere and returns to the earth.

(ii) **Maximum Usable Frequency (MUF)**
It is the highest frequency of radio wave that, when sent at an angle towards the ionosphere gets reflected and returns to the earth.

(iii) **Skip Distance:**
It is the smallest distance from the transmitter along the earth's surface at which a sky wave of a fixed frequency greater than the critical frequency (fc) is sent back to the earth.

(iv) **Fading:** It is the variation of the strength of a signal at the receiver due to the wave interferences.
Fading is greater at higher frequencies.