PRINCIPLES OF COMMUNICATION

INTRODUCTION

Communication is the process of transmission of information e.g., teacher transfers information to the students. Obviously the communication to be successful it is essential that sender and receiver understand a common language. The electronic communication system basically requires source of information, transmitting medium (channel) and receiver. The, modern communication system have progressed in all the three basic components. The information processing and sorting before communication, the channels like optical fibre, space (satellites) and processing through computers before being delivered.

ELEMENTS OF A COMMUNICATION SYSTEM

As pointed out communication system has three essential stages. Transmitter, medium or channel and receiver as shown in figure 1.

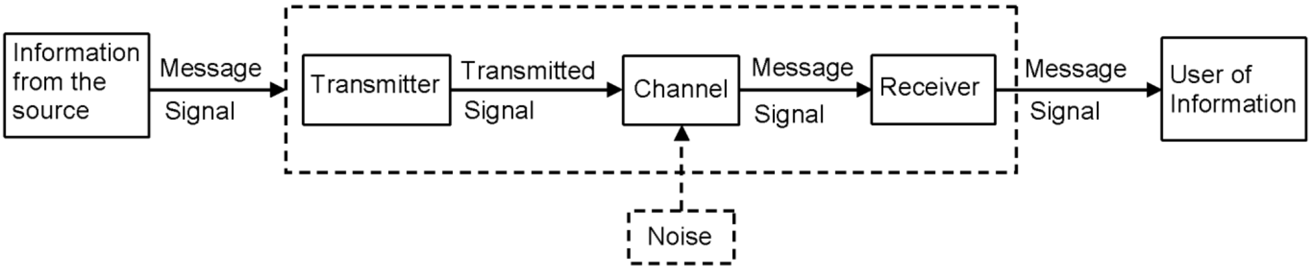

Figure1. Essential Elements of Communication System

The information may be message, speech, picture, audio video or their group. The information has to be transformed into electrical signals. The transmitter processes and encodes the information to make it suitable for transmission through the channel as well as for reception. This encoding process is modulation. Signal propagating through the channel may get distortion and we say noise is added to it due to channel imperfections. So receiver receives a corrupt version. The receiver has to process the corrupt signal to recognizable form of the original signal for delivering to the user. Basically there are two modes of communication.

(a) Point to point communication e.g. telephony where there is one transmitter and one receiver.

(b) broadcast mode involves one transmitter and large number of receivers e.g. Radio, TV etc. Also on the on the basis the signals used may analog or digital it may be mentioned that (i) The signals both digital and analogue are usually of low frequency and hence cannot be transmitted as such (ii) These signals require higher frequency waves on which these can ride over called carrier waves (iii) This process is called modulation.

BASIC TERMINOLOGY USED IN COMMUNICATION SYSTEM

Let us acquaint with basic terminology used in communications.

(i) **Transducer :** It is a device that converts one form of energy into the other. However in communication systems we have to convert all types of signals into electrical. So an electric transducer is a device that convert a physical signal (or variable) such as pressure, temperature, force displacement. Light sound, etc. into corresponding electrical signal

(ii) **Signal :** Information in electric form suitable for transmission is called a signal. If signal is in the form of continuous variation of voltage or current, it is called **analogue signal** as shown in figure 2. The variation has to be single valued. Since all periodic functions may be broken into sine and cosine components and hence sine wave is fundamental analogue signal. Sound and picture signals in TV are analogue is nature.

In digital signal figure 2 the voltage has only two values either low (0) or high (1). Thus a digital signal is discontinuous signal.

analogue signal Digital system

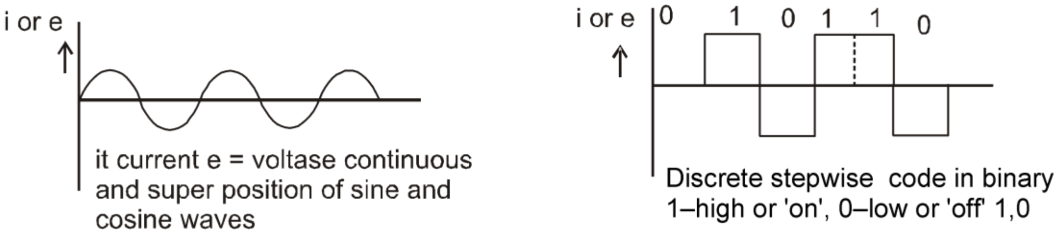

Figure 2 Analogue and Digital signals

There are several coding schemes suitable for digital communication systems. Binary coded decimal (BCD). American standard code for information Interchange (ASCII) is most popular digital code to represent numbers, letters and certain characters.

(iii) Noise : The unwanted signals generated inside and outside the system refers to noise.

(iv) Transmitter : It process the incoming signal to make is suitable for transmission through the channel.

(v) Receiver : Receiver extracts the relevant information form the received signal

(vi) Attenuation : The loss in the signal power or strength during transmission is called attenuation.

(vii) Amplification : Increasing signal strength by converting other energy (dc or other frequency) into signal energy using electronic circuitry is called amplification.

(viii) Range : It is largest distance between source and receiver where signal of sufficient strength is received.

(ix) Band width (BW) : The portion of the spectrum occupied by the signal or frequency range over which equipment operates is called band width.

(x) Modulation : Superimposing low frequency message over high frequency carrier wave is called modulation. It is AM (amplitude modulated), FM (frequency modulated or PM phase modulated) depending on which quantity, : amplitudes, frequency or phase of carrier wave varies with signal.

(xi) Demodulation : The process of retrieving information from received wave is called demodulation.

(xii) Repeater : These are used to increase the range. It receives a signal from transmitter amplifies it and retransmits after amplification. It may be at different frequency. It is thus a combination of receiver and transmitter. Figure (3) shows how range is extended beyond mountain. Satellite station is also a sort of repeater.

(xiii) Antenna or Aerial :

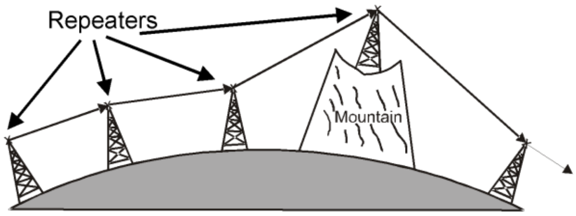

FIGURE-3: use of repeater station to increase the range of communication

BANDWIDTH OF SIGNALS

(a) Analogue signals : The communication signals are of varied nature and have different range of frequencies e.g. speech signal have frequency range 300 Hz to 3100 Hz. Thus the band width for speech is (3100 – 300) = 2800 Hz = 2.8 Hz. The audio range is 20 to 20 kHz the video signals have typical band width 4.2 MHz. A TV signal has both audio and video so its band width is 6 MHz

(b) Digital Signals : Digital signals are in the form of rectangular waves. However, a rectangular wave may be constructed using harmonic sine and or cosine waves of frequencies v, 2v, 3v ……..This implies infinite band width but for practical purposes higher harmonics can be neglected. No doubt the received waves are distorted version of original wave but information is not lost and rectangular signal is more or less received

Table 1 gives an over view of various signal channels.

Band - Widths of various signals used in communication

S.N.	SIGNAL TYPE	SIGNAL FREQUENCY	BAND WIDTH	EXAMPLE
1.	Voice	300 Hz - 3100 Hz	3100-300 = 2800 Hz	Telephone (Two wire)
2.	Music	20 Hz-2000 Hz 20Hz -20 KHz	20,00 Hz (20 KHz) (20.KHz) 88 to 108 MHz	Both point to point to board cast
3.	Picture only		4.2 MHz	Picture transmission
4.	Picture + Sound (TV)		6MHz	TV
5.	Computer Data		Depends on Data rate Generally GHz	Mobile / Desktop / Laptop etc.

BANDWIDTH OF TRANSMISSION MEDIUM

The transmission media also have different band widths e.g. widely used coaxial cable has band width ~750 MHz and operate below 18 GHz. The free space communication has wide range from 100 kHz to 10 GHz Optical fibre operates at Tera hertz frequencies and has quite wide range 1 THz to 1000 THz (micro waves to UV). It provides a band width ~100 GHz.

Table 2 summarizes various channel band widths

Band widths of Transmission Channel/ Media used in communications

S.N.	CHANNEL	BANDWIDTH	EXAMPLE
1.	Two wire	KHz	MW to SW
2.	Coaxial cable	750 Hz	HF
3.	Wave guides (hollow tube)	Dimension determine band width	Microwaves Tera-waves
4.	Optical fiber	1 THz to 1000 THz (IR to UV)	Optical
5.	Open space ground wave sky wave	< 1MHz 1 MHz-30 to 40 MHz	HF VHF
6.	Space wave	> 40 MHz	VHF

SPACE COMMUNICATION : PROPAGATION OF ELECTROMAGNATIC WAVES IN SPACE

In space radio communication, an antenna at the transmitter radiates electromagnetic waves which travel through space and reach the receiving antenna at the other end. During propagation not only the signal diminish but there are several factors that influence the propagation. Atmosphere is highly dynamic system whose properties change not only with elevation but also with seasons. The propagation characteristics also depend on frequency band. The following frequency bands are used in radio communication

(a) Medium Frequency Band (MF) 300 – 3000 kHz

(b) High Frequency Band (HF) 3.0 – 30 MHz

(c) Very High Frequency Band (VHF) 30 – 300 MHz

(d) Ultra High Frequency Band (UHF) 300 – 3000 MHz

(e) Super High Frequency Band (SHF) 3.0 – 30 GHz

The following are the modes of communication through space :

GROUND WAVE TRANSMISSION

For efficient signal radiation by antenna, its height should be in multiples of ($\lambda/4$) where λ is wavelength of CW used. For high λ i,e. lower frequencies, the antenna size is large and these have to be localed near to the ground. In standard AM broad cast ground base towers are used for broadcast. The waves propagate parallel to the ground. The propagation is called ground wave propagation. The wave induces current in the ground where from it passes. Therefore it gets attenuated. It is understandable that higher is frequency greater will be the attenuation. Therefore range depends on power and frequency. The used frequency is less than a few MHz.

SKY WAVE TRANSMISSION

The radio waves having frequency 2 to 30 MHz where propagating up the sky are reflected by ionosphere and return back to the earth. These waves used for communication, are known as sky waves. At a height 65 to 400 km above the earth the atmospheric gas absorb ultraviolet and other high energetic cosmic radiations coming from sky and subsequently ionize there creating on ionic layer called ionosphere. Even in single refection wave can cover about 4000 km distance, hence sky wave propagation is long range transmission as shown in figure 4. Round the globe communication

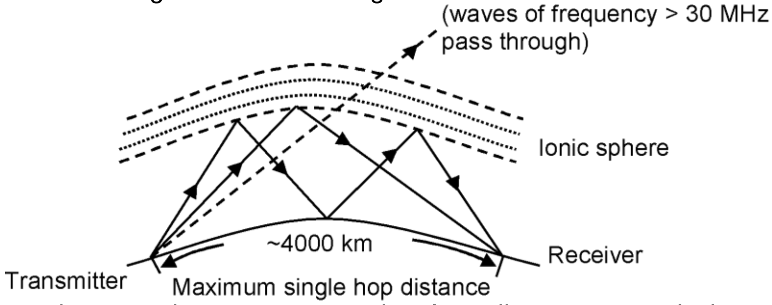

Figure 4. Sky wave propagation, long distance transmission

Is possible using sky wave propagation. A few terms are important in sky wave propagation

(a) Virtual Height : The reflection of sky wave is through gradual bending like total reflection in the formation of mirage. Hence virtual height is the height through which angle of incidence is calculated to send waves at a given point as shown in figure 5.

(b) Critical Frequency (f_c) : The maximum frequency reflected when beamed straight towards the layer. Frequency $f > f_c$ is not reflected

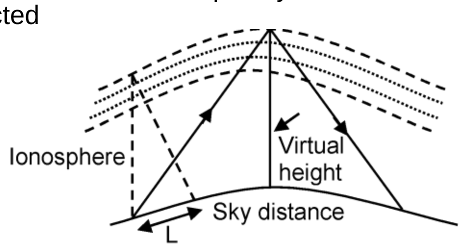

Figure 5 Virtual height defined

(c) Maximum Usable Frequency (MUF) : Radio waves when sent at an angle θ, the maximum usable frequency (MUF) is

$$MUF = f_c/\cos\theta \qquad \text{.......(1)}$$

(d) Skip Distance : The smallest distance of receiver from the transmitter where wave of given frequency reaches. Obviously it follows from figure 5 that higher is angle of incidence on ionic layer more is the skip distance.

Fading : Due to arrival of many signals at the receiver emitted from the source simultaneously but reach receiver in time delay due to taking different paths diminish signal due to destructive interference. This is **fading**.

SPACE WAVE PROPAGATION

In space wave mode of propagation the waves travel in straight line from transmitter to receiving antenna i.e., communication is in the line of sight (LOS). The curvature of the earth limits the range. As pointed out earlier this communication is above 40 MHz. At these frequencies antenna are smaller and may be placed at heights many wavelength above the ground. To increase the range to the desired level, satellite is used as repeater which effectively increases antenna height to the height of the satellite. T.V, mobile, radar system are the examples.

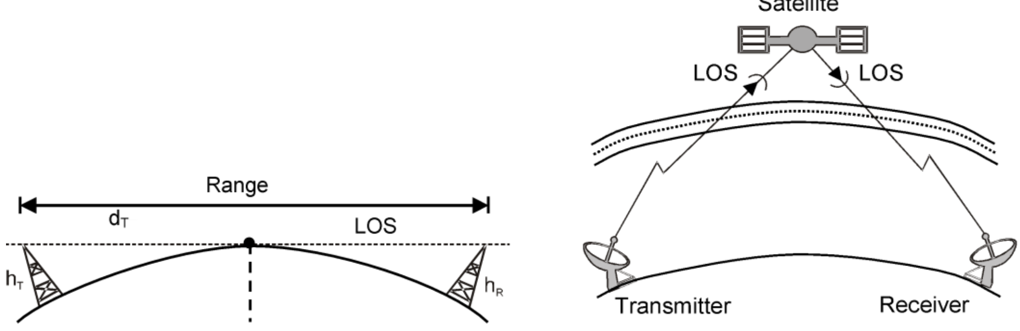

Figure 6. Space wave or line of sight LOS communication

The range versus antenna height relation may easily be determined using geometry of Figure 7. In ΔHMO, $HO^2 = HM^2 + MO^2$

$\Rightarrow$ $(R + h_t)^2 = d_t^2 + R^2$, R = radius of the earth

$R^2 + h_t^2 + 2Rh_t = d_t^2 + R^2$

$2Rh_t + h^2 = d_t^2$, $h << R$

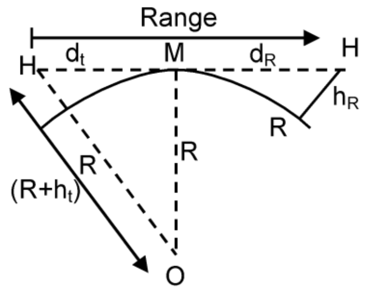

Figure 7. Ranger versus antenna height relation

$d_T = \sqrt{2Rh_t}$

Similarly $d_R = \sqrt{2Rh_R}$ …….(2)

Hence range $d_m = (d_t + d_R) = \sqrt{2Rh_t} + \sqrt{2Rh_R}$ …….(3)

In case satellite located at a height h then

$d_m = d_R = d = \sqrt{2Rh}$ …….(4)

Area covered $\pi d^2 = 2\pi Rh$ …….(5)

Solved Examples

Example 1. In which frequency range, space waves are normally propagated **[EAMCET 2002]**

(1) HF (2) VHF (3) UHF (4) SHF

Ans. 3

Example 2. An antenna behaves as resonant circuit only when its length is **[MNS 2002]**

(1) $\frac{\lambda}{2}$ (2) $\frac{\lambda}{4}$ (3) λ (4) $\frac{\lambda}{2}$ or integral multiple of $\frac{\lambda}{2}$

Ans. 4

Example 3. The process of superimposing signal frequency (i.e. audio wave) on the carrier wave is known as **[AIIMS 1987]**

(1) Transmission (2) Reception

(3) Modulation (4) Detection

Solution. (3) Carrier + signal → modulation.

Example.4 Long distance short-wave radio broadcasting uses **[AFMS 1996]**

(1) Ground wave (2) Ionospheric wave (3) Direct wave (4) Sky wave

Ans. 3

Example.5 The maximum distance up to which TV transmission from a TV tower of height h can be received is proportional to **[AIIMS 2003]**

(1) $h^{1/2}$ (2) h (3) $h^{3/2}$ (4) h^2

Solution. (1) $d = \sqrt{2hR}$ $\Rightarrow$ $d \propto h^{1/2}$

Example.6 A transmitting antenna at the top of a tower has a height 32 m and the height of the receiving antenna is 50 m. What is the maximum distance between them for satisfactory communication in LOS mode? Given radius of earth 6.4×10^6 m.

Solution. $d_m = \sqrt{2 \times 64 \times 10^5 \times 32} + \sqrt{2 \times 64 \times 10^5 \times 50}$ m

$= 64 \times 10^2 \times \sqrt{10} + 8 \times 10^3 \times \sqrt{10}$ m

$= 144 \times 10^2 \times \sqrt{10}$ m = 45.5 km

Example.7 In a communication system, noise is most likely to affect the signal

(1) At the transmitter (2) In the channel or in the transmission line
(3) In the information source (4) At the receiver

Ans. (2)

Example.8 The waves used in telecommunication are

(1) IR (2) UV (3) Microwave (4) Cosmic rays

Solution. (3) In telecommunication microwaves are used.

Example.9 Television signals on earth cannot be received at distances greater than 100 km from the transmission station. The reason behind this is that **[DCE 1995]**

(1) The receiver antenna is unable to detect the signal at a distance greater then 100 km
(2) The TV programme consists of both audio and video signals
(3) The TV signals are less powerful than radio signals
(4) The surface of earth is curved like a sphere

Ans. (4)

Example.10 AM is used for broadcasting because

(1) It is more noise immune than other modulation systems
(2) It requires less transmitting power compared with other systems
(3) Its use avoids receiver comlexity
(4) No other modulation system can provide the necessary bandwidth faithful transmission

Ans. (3)

Example.11 Range of frequencies allotted for commercial FM radio broadcast is **[MNR 1997]**

(1) 88 to 108 MHz (2) 88 to 108 kHz (3) 8 to 88 MHz s (4) 88 to 108 GHz

Ans. (1)

Example 12 At shich of the following frequencies the communication will not be reliable beyond horizon

(1) 1KHz (2) 1 MHz (3) 10 GHz (4) 100 GHz

Ans. (2) MHz travel is line of sight.

Example 13 Modulation is used to

(1) Reduce the band width used
(2) Isolate transmission of different users
(3) Ensure transmission of intelligence to long distance
(4) To reduce size of antenna to useable range

Ans. (1) Band width is reduced; 2 f_m

Example 14 AM is used for broad costing because

(1) The signal to noise ratio is low
(2) It needs less transmission power
(3) AM receiver system is simple width complexity
(4) No other modulation provides faithful band width

Ans. (3) The receive system is quite simple and cheap.

Example 15: UHF frequencies normally propagate via

(1) ground wave (2) sky wave (3) surface wave (4) space waves

Ans. (4) UHF travels as space wave

Example 16: A microwave link operates at central frequency 10 GHz and 2% is used for telephone channels. If telephone is allotted a band width of 8 kHz the number of channels that can be operated simultaneously is

(1) 12.5×10^5 (2) 12.5×10^3 (3) 2.5×10^7 (4) 2.5×10^3

Ans. (3) Band width available $\frac{2}{100} \times 10^9$, one channel needs 8 kHz No of channels operating

$= \frac{2 \times 10^7}{8.5 \times 10^3} = 2.5 \times 10^4$

MODULATION AND IT'S NECESSITY

The signals to be transmitted (audio, vedio or data) are low frequency signals and there are inherent difficulties in transmitting these signals directly as discussed below. So these signals are superimposed in any of the properties of high frequency waves called carries. When superimposed in amplitude i.e. resultant wave amplitude varies with signal and we have **amplitude modulated** wave (AM). When superimposed in frequency, the frequency of resultant wave varies with signal, we have **frequency modulated** (FM) wave and similarly if superimposed in phase the phase of resultant wave varies with signal and we have **phase modulated** wave (PM). As shown in Figure. 8 we now outline difficulties in low frequency transmission.

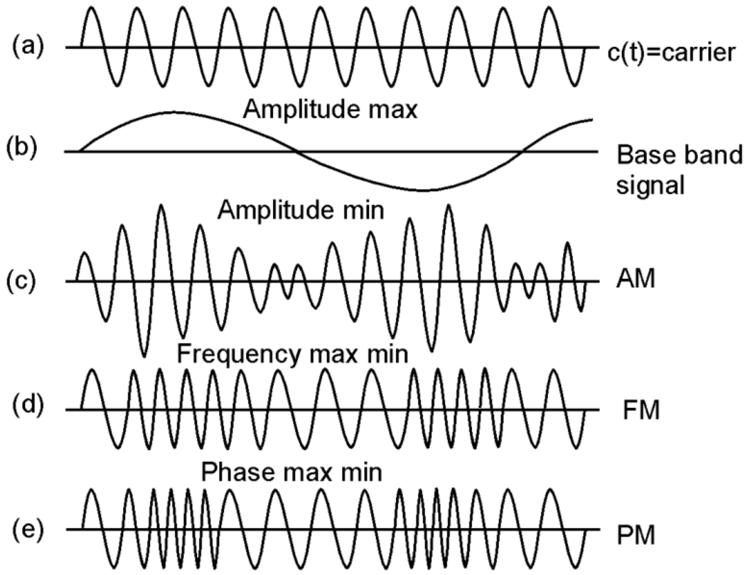

Fig. 8 Modulation of a carrier wave : (a) a sinusoidal carrier wave; (b) a modulating signal; (c) amplitude modulation; (d) frequency modulation; and (e) phase modulation.

SIZE OF ANTENNA OR AERIAL

As pointed out earlier the minimum size of the antenna / aerial required is $\frac{\lambda}{4}$. For transmitting 20 kHz signal we require minimum antenna size $\ell = \frac{\lambda}{4} = \frac{1}{4} \times \frac{3 \times 10^8}{20 \times 10^3} \simeq 3.75\,\text{km}$. Obviously this much long antenna is not possible. If instead the signal (or base band signal) is modulated with CW of frequency 10 MHz the size required is $\ell = \frac{1}{4} \times \frac{3 \times 10^8}{20 \times 10^3} \simeq 7.5\,\text{m}$. Which is practically possible.

POWER RADIATED

The power radiated by antenna is determined by length to wavelength ratio (ℓ/λ). Obviously more power is radiated at high frequencies making communication better. The power transmitted varies as frequency square (f^2)

MIXING OF SIGNALS FROM DIFFERENT TRANSMETTERS

If signals are transmitted at base band (original frequency band) then receiver shall receive signal from many transmitters simultaneously and they get mixed. If these signals are modulated on different carrier frequencies, the mixing is avoided and the receiver shall get desired signal by tuning at that CW frequency. In digital communication carrier wave is in the form of pulses the modulation may be pulse amplitude, pulse duration and pulse width modulation as illustrated in Figure 9

The flow chart of figure 10 below summarizes various types of modulations

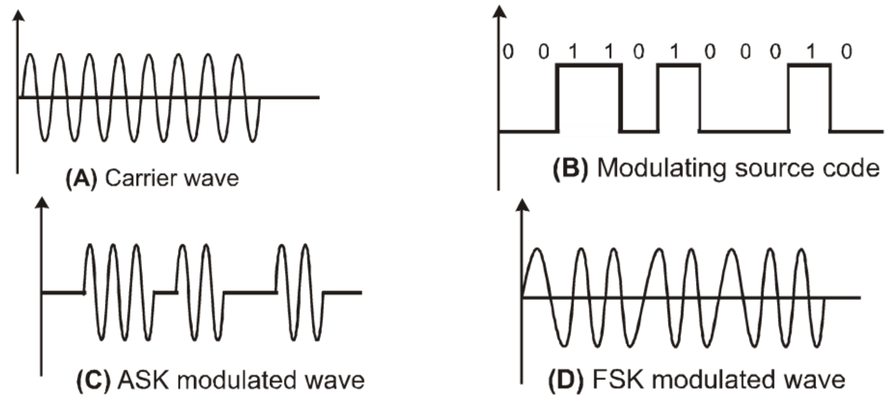

Fig. 9. Modulations in digital communication system

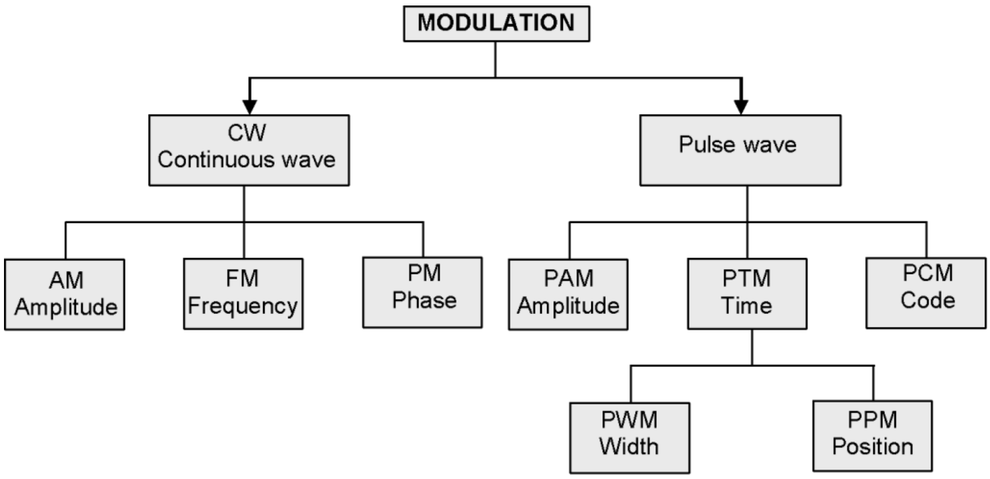

Figure 10. Modulation type

PROPERTIES OF AMPLITUDE MODULATION :

(a) **Frequency spectrum :** In amplitude modulated (AM) wave the amplitude of carrier wave varies with signal i.e signal is superimpored in amplitude. If carrier wave be $C(t) = A_C \sin \omega_C t$ and the message signal be $m(t) = A_m \sin \omega_m t$ then modulated signal will be

$C_m(t) = (V_C + V_m \sin \omega_m t) \sin \omega_C t$ ……..(6)

$C_m(t) = (V_C + V_m \sin \omega_m t) \sin \omega_C t$

$= V_C \left(1 + \frac{V_m}{V_c} \sin\omega_m t\right) \sin \omega_c t$ …….. (7)

Where $\mu = \frac{V_m}{V_C}$ is called modulation index.

$C_m(t) = V_C \sin \omega_m t + \left(\frac{V_m}{V_c}\right) \sin \omega_C t \; V_C \sin \omega_c t$

$= V_C \sin \omega_C t + \mu V_C \sin \omega_m t \sin \omega_c t$

It is generally less than 1 ($\mu < 1$)

$C_m(t) = V_c \sin \omega_c t + V_C\left(\frac{1}{2} \cos (\omega_c - \omega_m) t - \frac{1}{2} \cos (\omega_c + \omega_c) t\right.$ ……..(8)

Equation (8) shows three set of angular frequencies original carrier viz., (ω_c), ($\omega_c - \omega_m$) known as **lower side band** and ($\omega_c + \omega_m$) **upper side band** of frequencies. The amplitude modulated frequency spectrum is shown in figure 11. ($f = \omega/2\pi$)

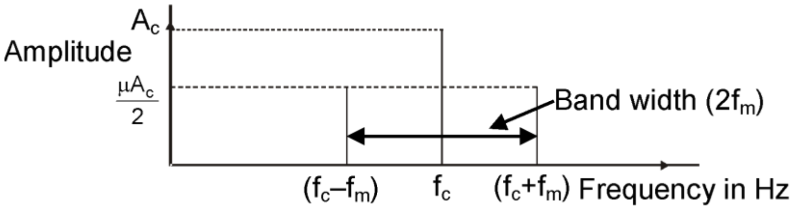

Figure 11. Frequency spectrum of AM

It follows from Figure 11 that if broadcasted bands are sufficiently separated so that side bands do not overlap, different stations can operate with out any interference.

(b) Modulation Index : The ratio of change in amplitude of the carrier wave to amplitude of original carrier wave is called modulation index or modulation factor, m_a

$m_a = \frac{kV_m}{V_C}$, factor k determines the maximum change in amplitude for given amplitude of the modulating wave. On amplitude modulation, the maximum and minimum amplitudes are A_{max} and A_{min} then maximum change in amplitude is (V_{max} – V_C) and so

$$m_a = \frac{V_{max} - V_C}{V_C} \quad \text{……….(9)}$$

For example (i) if V_C = V and $V_m = \frac{V}{2}$ then

$m_a = \frac{V + \frac{V}{2} - V}{}$ = V/2 = 50%

(ii) If V_C = V_C and V_m = V then V_{max} = 2V

(iii) If V_C = V, V_m = 3/2V then V_{max} = 5/2 V

$m_a = \frac{2V - V}{V} = 1$ or 100% and $m_a = \frac{(5/2)V - V}{2} = \frac{3}{2}$ or 150% V

In this case the carrier is over modulated > 100% it may be noted that modulation factor m_a, determines the strength and quality of the signal transmitted. Audio signal is generally AM modulated and hence higher is modulation the stronger and clearer will be the signal.

If μ = 1 modulation index may be expressed in terms of maximum and minimum amplitude, V_{max} and V_{min}

$$m_a = \frac{V_{max} - V_{min}}{V_{max} + V_{min}} \quad \text{……….(10)}$$

If carrier wave is modulated with many signals then total modulation index is given by

$$m_t = \sqrt{m_1^2 + m_2^2 + m_3^2 ....} \quad \text{…………(11)}$$

(c) Bandwidth Required : The required band width is from lower side band to upper side band hence,

$$\Delta f = \frac{(\omega_c + \omega_m)}{2\pi} - \frac{\omega_c - \omega_m}{2\pi} = \frac{2\omega_m}{2\pi} = 2f_m \quad \text{………..(12)}$$

(d) Power in AM Wave : Power dissipated in any circuit having resistance R and supplied at rms voltage V_{rms}, is given by $\left(\frac{V_{rms}^2}{R}\right)$. The total power is the sum of the power in side bands plus the power in carrier wave. Total power transmitted

(i) $P_{Total} = P_{LSB} + P_{USB} + P_{CW}$

$$= \left(\frac{m_a V_C}{2 \times \sqrt{2}}\right)^2 \frac{1}{R} + \left(\frac{m_a V_C}{2 \times \sqrt{2}}\right)^2 \frac{1}{R} + \left(\frac{V_C}{\sqrt{2}}\right)^2 \frac{1}{R} = \frac{V_C^2}{2R}\left(1 + \frac{m_a^2}{2}\right) \quad \text{...……..(13)}$$

(ii) The ratio of power transmitted to carrier power

$$\frac{P_{Total}}{P_{CW}} = \frac{\frac{V_C^2}{2R}\left(1+\frac{m_a^2}{2}\right)}{\left(\frac{V_C^2}{2R}\right)} = \left(1+\frac{m_a^2}{2}\right) \qquad \text{........(14)}$$

(iii) Fraction of power transmitted in the side band

$$\frac{P_{SB}}{P_{Total}} = \frac{\frac{1}{R}\left(\frac{m_a V_C}{2\sqrt{2}}\right)^2}{\frac{V_C^2}{2R}\left(1+\frac{m_a^2}{2}\right)} = \left(\frac{m_a^2/2}{1+m_a^2/2}\right) \qquad \text{.........(15)}$$

(iv) Distortion Free maximum power transfer. For distortion free transmission $m_a = 0$. so

$$\frac{I_{Total}}{I_{CW}} = \sqrt{1+\frac{m_a^2}{2}} \qquad \text{.........(16)}$$

PRODUCTION OF AMPLITUDE MODULATED WAVE

To add the signal to the amplitude of CW the voltage signal is mixed up in mixer and sampled by square law device. The output is filtered by a band pass filter centered around carrier frequency. The signal is amplified by power amplifier before transmission as shown in the following block diagram of Figure 12.

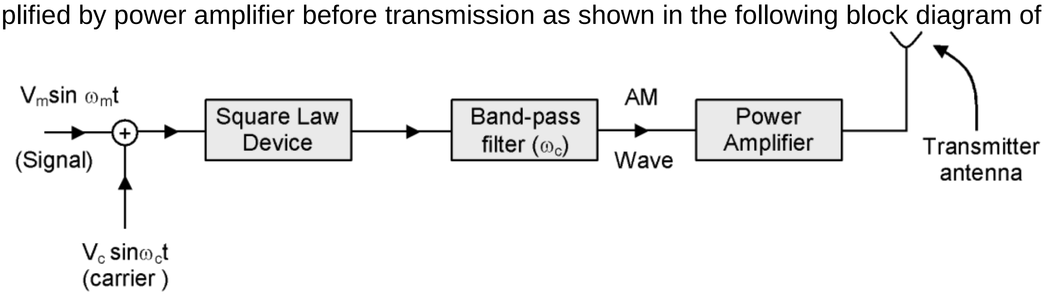

Figure 12. Production of AM signal

DETECTION OF AMPLITUDE MODULATED SIGNAL

The signal is received by receiving antenna. As received signal is weak due to attenuation in the channel, it has to be amplified. The detection or high frequency is difficult so, it is changed to low frequency called intermediate frequency, (IF). This converted signal is detected and amplified. The AM wave is rectified that rejects lower part of AM wave. Finally envelop is detected (filtering CW component). The entire process is shown in the following block diagram of Figure 13.

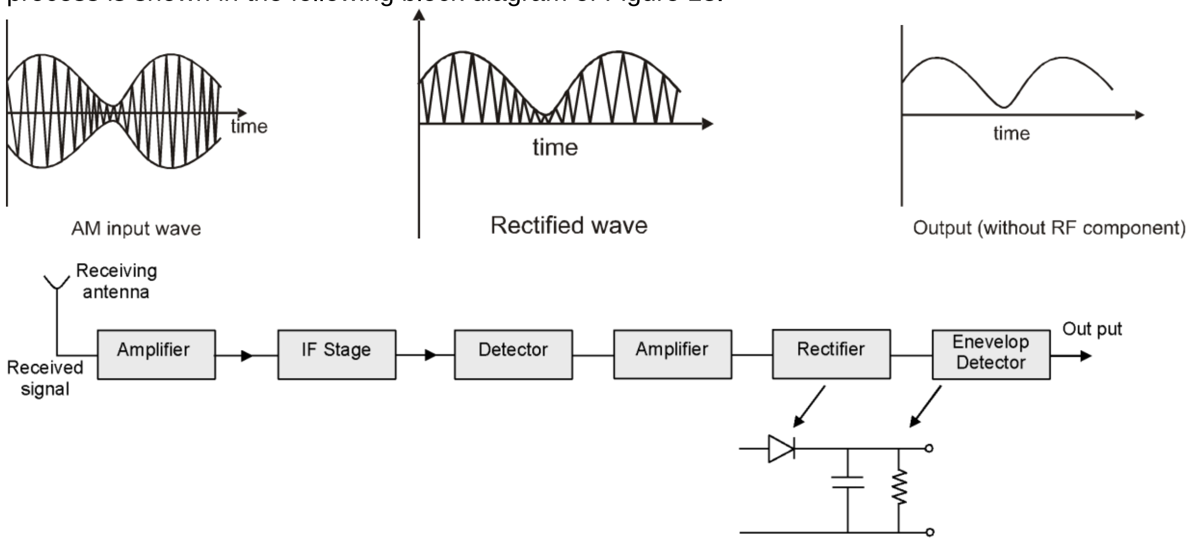

Figure 13 Block diagram of AM receiver

Limitations of AM wave Transmission

AM communication has the following problems

(i) Reception is noisy become audio noise caused by various

(ii) Efficiency is low, machines get mixed
(iii) Operating range is small
(iv) Audio quality is poor.

Solved Examples

Example.17 An AM wave has 1800 watt of total power content, for 100% modulation the carrier should have power content equal to
(1) 1000 watt (2) 1200 watt (3) 1500 watt (4) 1600 watt

Solution (2) $P_t = P_c\left(1+\frac{m_a^2}{2}\right)$; Here $m_a = 1$ ⇒ $1800 = P_c\left(1+\frac{(1)^2}{2}\right)$ ⇒ $P_c = 1200$ W

Example.18 A TV tower has a height of 75m. What is the maximum distance and area up to which this TV transmission can be received? Take radius of the earth as 6.4×10^6 m.

Solution $d = \sqrt{2Rh} = \sqrt{2\times 6.4\times 10^6 \times 75} = 3.1 \times 10^4$ m = 31 km
Area covered $= \pi r^2 =$ **3018 km^2**

Example.19 A TV tower has a height of 100 m. How much population is covered by the TV broadcast if the average population density around the tower is 1000 km^{-2} ? Given : radius of earth $= 6.37 \times 10^6$ m.

Solution h = 100m, $R = 6.37 \times 10^6$ m, Average population density = 1000 km^{-2} = $1000(10^3)^{-2}$m^{-2} = 10^{-3}m^{-2}
Distance up to which the transmission could be viewed, $d = \sqrt{2hR}$
Total area over which transmission could be viewed $= \pi d^2 = 2\pi hR$
Population covered $= 10^{-3} \times 2\pi hR = 10^{-3} \times 2 \times 3.14 \times 100 \times 6.37 \times 10^6 =$ **40 lakh**

Example.20 What is the modulation index of an over modulated wave
(1) 1 (2) zero (3) < 1 (4) > 1

Solution (4) When $m_a > 1$ then carrier is said to be over modulated.

Example.21 Which of the following is the disadvantage of FM over AM
(1) Larger band width requirement (2) Larger noise
(3) Higher modulation power (4) Low efficiency

Solution (1) Frequency modulation requires much wider channel (7 to 15 times) as compared to AM.

Example.22 When the modulating frequency is doubled, the modulation index is halved and the modulating voltage constant the modulation system is
(1) Amplitude modulation (2) Phase modulation
(3) Frequency modulation (4) All of the above

Ans. (3)

Example.23 Indicate which one of the following system is digital
(1) Pulse position modulation (2) Pulse code modulation
(3) Pulse width modulation (4) Pulse amplitude modulation

Ans. (2)

Example.24 In an FM system a 7 kHz signal modulates 108 MHz carrier so that frequency deviation is 50 kHz. The carrier swing is
(1) 7.143 (2) 8 (3) 0.71 (4) 350

Ans. (1)

Example.25 Sinusoidal carrier voltage of frequency 1.5 MHz and amplitude 50 V is amplitude modulated by sinusiodal voltage of frequency 10 kHz producing 50% modulation. The lower and upper side-band frequencies in kHz are
(1) 1490, 1510 (2) 1510, 1490 (3) $\frac{1}{1490},\frac{1}{1510}$ (4) $\frac{1}{1510},\frac{1}{1490}$

Solution (1) Here, $f_c = 1.5$ MHz = 1500 kHz, $f_m = 10$ kHz
∴ Lower side band frequency $= f_c = f_m$ = 1500 kHz – 10 kHz = 1490 kHz
Upper side band frequency $= f_c + f_m$ = 1500 kHz + 10 kHz = 1510 kHz

FREQUENCY MODULATED WAVE

Most of the noises affect the amplitude of the signal and hence signal to noise ratio is greatly improved if amplitude of CW remains unaffected. This is what is done in frequency modulation where the frequency of CW varies with the signal as shown in Figure 8 (d).

(a) Analysis

Consider a voltage signal $v_m = V_m \cos \omega_m t$ to be frequency modulated on a carrier voltage wave $v_c = V_c \cos (\omega_c t + \theta_0)$. Where $\omega_m = 2\pi f_m$, $\omega_c = 2\pi f_c$ are respectively angular frequencies of signal and the carrier waves and V_m and V_c are their amplitude θ_0 is initial phase of carrier. The instantaneous phase of carrier wave (CW)

$$\phi(t) = \omega_c t + \theta_0$$

The angular frequency of modulated wave shall be

$$\omega = \omega_c + k V_m \cos \omega_m t$$

Where k is frequency conversion factor which is constant. The phase of FM wave at any instant shall be

$$\phi(t) = \int \omega dt = \int (\omega_c + kV_m \cos \omega_m t) dt$$

$$\phi(t) = \omega_c t + \frac{kV_m}{\omega_m} \sin \omega_m t \qquad \text{……….(17)}$$

Hence equation of FM voltage wave is

$$v_{FM}(t) = V_c \sin\left[\omega_c t + \frac{kV_m}{\omega_m} \sin \omega_m t\right] \qquad \text{………..(18)}$$

The instantaneous frequency of FM wave is given by

$$\frac{1}{2\pi}\frac{\partial\phi(t)}{dt}$$

$$\therefore \quad f = \frac{1}{2\pi}\omega_c + \frac{kV_m}{2\pi}\cos \omega_m t \qquad \text{……….(19)}$$

The maximum and minimum frequencies are obviously,

$$f_{max} = f_c + \frac{kV_m}{2\pi} \qquad \text{………(20 a)}$$

$$f_{min} = f_c - \frac{kV_m}{2\pi} \qquad \text{………(20 b)}$$

The maximum change in frequency from the mean value is called **frequency deviation**

$$f_d = (f_{max} - f_c) = (f_c - f_{min}) = \frac{kV_m}{2\pi} \qquad \text{………(21)}$$

The total variation of frequency from the maximum to minimum is called **carrier swing**. It is twice the frequency deviation.

$$CS = 2fd = \frac{kV_m}{\pi} \qquad \text{………..(22)}$$

Frequency modulation index m_f is defined as ratio of frequency deviation to the modulation frequency

$$m_f = \frac{f_d}{f_m} = \frac{\omega_d}{\omega_m} = \frac{kV_m}{\omega_m} \qquad \text{……….(23)}$$

The equation of FM wave becomes $v_{FM} = V_C \sin (\omega_c t + m_f \sin \omega_m t)$ ……….(24)

(c) Frequency spectrum

FM Side Bands :

Equation (23) may be expanded and trigonometric manipulations shall show that there are series of side bands ($f_c \pm f_m$), ($f_c \pm 2f_m$), ($f_c \pm 3f_m$) etc. with decreasing amplitudes. Side bands are equally spaced on either side of carrier frequency f_c as shown in Figure. 14

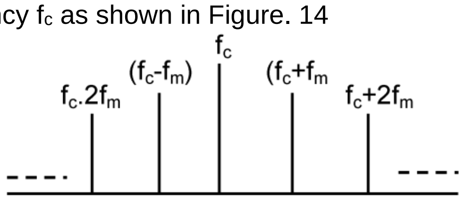

Figure 14. Frequency spectrum of FM signal

(d) Frequency bands in use

As pointed out frequency modulation (FM) has better quantity of transmission with large band width. The manmade noises and atmosphere changes do not affect transmission quality. Also the fidelity is good for the transmission of music. The frequency bands in use are :

(a) 88 to 108 MHz FM Radio
(b) 47 to 230 MHz VHF TV
(c) 470 to 960 MHz UHF TV

DIGITAL COMMUNICATION : DATA TRANSMISSION & RETRIVAL

Digital communication ensures less noise and less error communication. Hear, carrier is a digital pulsating wave in binary code 0 and 1. The signal which is analogue is digitized. There are many encoding steps : source coding channel coding, etc. Typical digital communication system is shown in figure 15.
There are normally three steps (i) converting signal into pulses of the same height and negligible width (ii) quantization and (iii) coding quantized pulses following some rule.

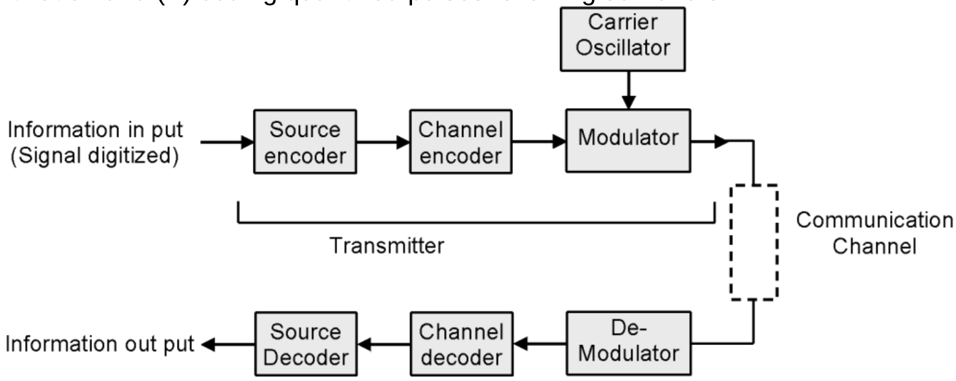

Figure 15. Digital communication system : Block diagram

MODEM

Is short term used for modulator and demodulator? As seen in Figure 15 modulator and demodulator are needed for two way communication and a single modem unit serves the purpose.

MODULATION USED

In digital communication modulation techniques used are shown in figure 9 which is quite illustrative. Modern communication system commonly use frequency shifting keys.

OPTICAL COMMUNICATION

Typical optical communication system is shown in figure 17. It uses optical frequency as carrier so it has the following advantages

(i) There is no electromagnetic interference
(ii) Enormous channel capacity
(iii) Requires optical fiber as communication channel
(iv) Mostly used in LAN (Local area networking)

Setup for digital communication (Block diagram)

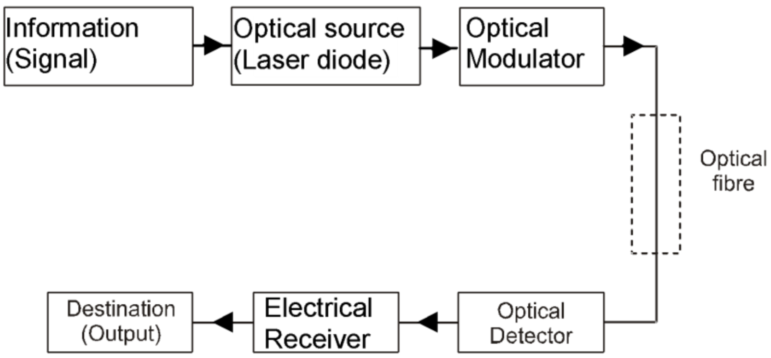

Fig. 17. Optical communication system : Transmitter and receiver sections use modem, modulator demodulator. Optical communication system is similar to digital communication system except the source is pulsating laser (IR), detector is optical diode and channel is optical fiber.

OPTICAL FIBRE

Principle : Light travels in a optical fibre through total internal reflection from opposite walls. For total reflection (a) light must travel from densor to rarer medium and that (b) the angle of incidence from densor to rarer interface should be greater than the critical angle, $\theta_c = \sin^{-1}\left(\frac{\mu_{rarer}}{\mu_{dens}}\right)$.
μ's are corresponding refractive indices

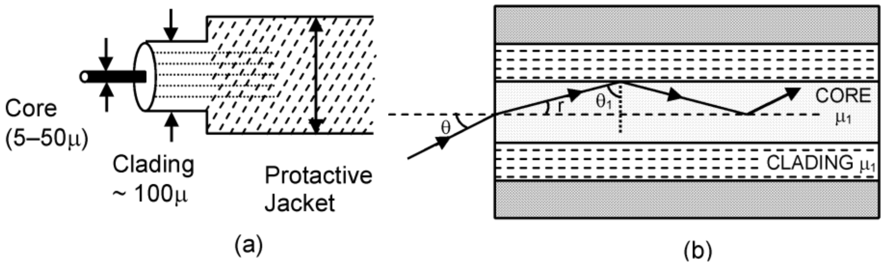

Figure 18 (a) Typical dimensions (b) principle of operation illustrated; numerical aperture (NA).

CONSTRUCTION

Optical fibre consists of inner transparent cylindrical core say of refractive index μ_1 surrounded by transparent cylindrical cladding of refractive index μ_2 ($< \mu_1$). The core – cladding system is secured against mechanical shocks by multilayered polyester nylons etc.,

Let a light ray is incident making an angle θ with the axis of fiber as shown in figure 18.

The ray incident on core face is refracted into core and falls on core-cladding interface at an angle θ_1. Using Snells law

$\mu_0 \sin\theta = \mu_1 \sin r$, r = angle of refraction …………(25)

Where μ_0 is refractive index of outer medium for air $\mu_0 = 1$. For ray to be totally reflected from core-cladding interface.

$\theta_1 \geq \theta_c$ where $\sin\theta_c = \frac{\mu_2}{\mu_1}$ …………(26)

Since $\angle r = (90 - \theta_c)$, hence value of angle θ for total reflection at core - clad interface is

$$\mu_0 \sin\theta = \mu_1 \sin(90 - \theta_c) = \mu_1 \cos\theta_c = \mu_1\sqrt{1-\sin^2\theta_c}.$$

or $$\sin\theta = \mu_1\sqrt{1-\left(\frac{\mu_2}{\mu_1}\right)^2} = \sqrt{\mu_1^2 - \mu_2^2}$$ ……….(27)

When θ increases, r increases but θ_1 decreases therefore value of angle θ given by Equation (27) is maximum permissible value and it is called **maximum angle** of acceptance

$$\theta_m = \sin^{-1}\left(\sqrt{\mu_1^2 - \mu_2^2}\right)$$ …………(28)

The quantity $\mu_0 \sin\theta_m$ gives the **light gathering capacity** of the fibre. It is called **numerical aperture**. (NA)

$$NA = \mu_0 \sin\theta_m = \sqrt{\mu_1^2 - \mu_2^2}$$ …………(29)

or $$NA = \sqrt{(\mu_1 + \mu_2)(\mu_1 - \mu_2)}$$

Since $(\mu_1 - \mu_2)$ is small so $\mu_2 = \mu_1$

$$= \mu_1\sqrt{2\left(\frac{\mu_1 - \mu_2}{\mu_1}\right)} = \mu_1\sqrt{2\Delta}$$ …………..(30)

$$\Delta = \frac{\mu_1 - \mu_2}{\mu_1}$$ …………..(31)

is called **fractional change in refractive** index.

SATELLITE COMMUNICATIONS

In the age of IT explosion where enormous data need be transmitted and received, there occurs a need of higher frequency bands and more channels. This is possible only with satellite communication. As discussed earlier, the signal from the transmitting station is sent to communication satellite equipped with transmitting and receiving systems known as **radio Transponder** (RT). The signal transmitted and received by satellite is called **up-link** where as transmitted by satellite and received at ground is called **down link** to avoid confusion the frequencies of up and down links are kept different. The commonly used satellite system consists of three geostationary satellites located on the vertices of an equilateral triangle having verticals on a geostationary orbit to cover entire globe space. Most of the satellites are in geostationary orbit yet there are two more orbits which are used for communication satellites. These are **polar circular orbit** near the earth about 1000 km, high, its inclination is 90º. The another is highly elliptical orbit inclined at 63º to fulfill the need of high altitude regions. Commonly know as 63º slot
Finally figure 18 shows the summary of various communication systems.

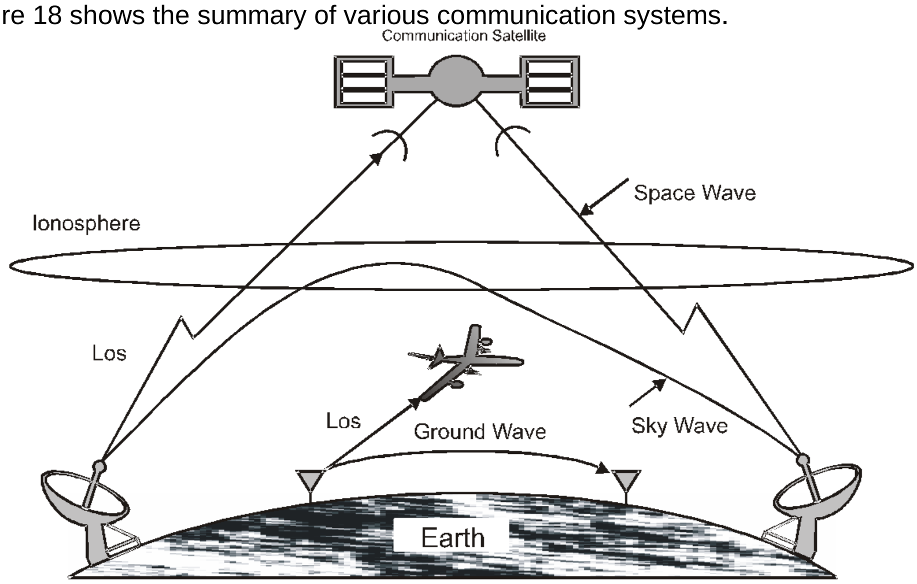

Figure-19: Various Communication systems and Propagation Modes of EM Waves

Example.26 If f_0 and f_f represent the carrier wave frequencies for amplitude and frequency modulations respectively, then
(1) $f_0 > f_f$ (2) $f_0 < f_f$ (3) $f_0 = f_f$ (4) $f_0 \geq f_f$

Ans. (2)

Example.27 The frequency of a FM transmitter without signal input is called
(1) Lower side band frequency (2) Upper side band frequency
(3) Resting frequency (4) None of these

Ans. (3)

Example.28 What type of modulation is employed in India for radio transmission
(1) Amplitude modulation (2) Frequency modulation
(3) Pulse modulation (4) None of these

Ans. (1)

Example.29 While tuning in a certain broadcast station with a receiver, we are actually
(1) Varying the local oscillator frequency
(2) Varying the frequency of the radio signal to be picked up
(3) Tuning the antenna
(4) None of these

Ans. (1)

Example.30 Consider telecommunication through optical fibres. Which of the following statements is not true
(1) Optical fibres may have homogeneous core with a suitable cladding **[AIEEE 2003]**
(2) Optical fibres can be of graded refractive index
(3) Optical fibres are subject to electromagnetic interference from outside

(4) Optical fibres have extremely low transmission loss

Ans. (3)

Example.31 The phenomenon by which light travels in an optical fibres is **[DCE 2001]**

(1) Reflection (2) Refraction
(3) Total internal reflection (4) Transmission

Ans. (3)

Example.32 Consider an optical communication system operating at λ = 800 nm. Suppose, only 1% of the optical source frequency is the available channel bandwidth for optical communication. How many channels can be accommodated for transmitting audio signals requiring a bandwidth for transmitting audio signals requiring a bandwidth of 8 kHz.

(1) 4.8×10^8 (2) 48 (3) 6.2×10^8 (4) 4.8×10^5

Ans. (1)

Example.33 A ground receiver station is receiving a signal at (i) 5 MHz and transmitted from a ground transmitter at a height of 300 m, located at distance of 100 km from the receiver station. The signal is coming via. Radius of earth = 6.4×10^6 m. N_{max} of isophere = $10^{12} m^3$.

(1) Space wave (2) Sky wave propagation
(3) Satellite transponder (4) All of these

Ans. (2)

Example.34 A antenna current of an AM broadcast transmitter modulated by 50% is 11 A. The carrier current is

(1) 10.35 A (2) 9.25 A (3) 10 A (4) 5.5 A

Ans. (1)

Example.35 If a number of sine waves with modulation indices n_1, n_2, n_3,………modulate a carrier wave, then total modulation index (n) of the wave is

(1) $n_1 + n_2$…….. + 2 ($n_1 + n_2$…..) (2) $\sqrt{n_1 - n_2 + n_3 \ldots\ldots}$
(3) $\sqrt{n_1^2 + n_2^2 + n_3^2 \ldots\ldots}$ (4) None of these

Ans. (3)

Example.36 A transmitter supplies 9 kW to the when unmodulated. The power radiated when modulated to 40% is

(1) 5 kW (2) 9.72 kW (3) 10 kW (4) 12 kW

Ans. (2)

Example.37 In an FM system a 7 kHz signal modulates 108 MHz carrier so that frequency deviation is 50 kHz. The carrier swing is

(1) 7.143 (2) 8 (3) 0.71 (4) 350

Ans. (1)

Example.38 The modulation index of an FM carrier having a carrier swing of 200 kHz and a modulating signal 10 kHz is

(1) 5 (2) 10 (3) 20 (4) 25

Ans. (2)

PHASE VELOCITY

It is defined as velocity with which peak of sinusoidal pattern is moving.
consider wave : cos [ψ (xt)]
cos (kx – wt)
there is peak at ψ = 0 or θ = 0, so kx – wt = 0

x – w/k t = 0 ⇒ $V_p = \frac{w}{k}$

so for particular frequency (w) relating with time phase velocity is the rate at which phase of the wave propagates in space.

In transmission line group of waves travel out with one particular phase velocity is V_P = W/K (depending upon frequency 'w' oscillation per sec)

GROUP VELOCITY

It is defined as the velocity with which the overall shape of wave amplitude (known as modulation envelope of the wave) propagate

$v_{group} = \frac{dw}{dK}$ ω = wave's angular frequency

if w $\propto$ k then **group velocity = phase velocity**

VELOCITY VELOCITY

The velocity of propagation of a signal in a transmission line is usually expressed as a percentage of velocity of light in free space this percentage is called the velocity factor (V_F). For example, a transmission line with a V_F of 66% will transmit signals at about 66% of the velocity of light

V_F = velocity factor

$V_F = \frac{V_P}{c} \times 100\%$ V_P = velocity of propagation

$V_F = \frac{\text{Ratio of phase velocity}}{\text{velocity of light}}$

C = Velocity light in free space (3×10^8 m/s) or 9.8×10^8 ft /sec

Critical frequency : It is the minimum frequency which gets reflected by ionosphere.

$f_c = C_F = \sqrt{81 N_{max}}$ here (N_{max} = maximum ionization density)

MUF (maximum usable frequency) : Its is the maximum frequency for given angle of incidence which gets reflected from ionosphere. It depends on angle of incidence.

MUF = $\frac{\text{critical frequency}}{\cos\theta}$

RELATIVE PERMITTIVITY (DIELECTRIC CONSTANT)

The velocity of propagation of a signal in a transmission line is determined mainly by the permittivity of the dielectric material used to construct to the line. Permittivity is a measure of the ability of the dielectric material to maintain a difference in electric charge over a given distance.

$\varepsilon_r = \frac{C^2}{V_P^2}$ ⇒ $\varepsilon_r = \frac{1}{(\text{velocity factor})^2}$ ⇒ velocity factor = $\frac{1}{\sqrt{\varepsilon_r}}$

where ε_r = Relative permittivity (dielectric constant)

C = Velocity of light in free space (3×10^8 m/s)

V_P = Velocity of propagation (m/s)

ROLE OF IONOSPHERE IN RADIO - COMMUNICATION

The ionosphere plays a great role in broadcasting, ship and air-craft communication and navigation by reflecting the radio signals back to the receivers. However, its effectiveness depends on the frequency of transmitted signal. This is critical because the behavior of ionosphere often shows marked differences during day and night. Moreover it is known for changing its behavior during different seasons. The ionosphere refractive index as represented by the Appleton – Hartee equation is.

$$n = \left(1 - \frac{f_p^2}{f^2}\right)^{1/2} \simeq 1 - \frac{1}{2}\frac{f_p^2}{f^2} = 1 - \frac{40.3\,N}{f^2} \qquad \text{.......(1)}$$

where

f_p : electron plasma frequency in H_z

N : electron number density in m^{-3}

from (1), the magnitude of phase velocity can be derived as

$$V_p = \frac{w}{k} = \frac{w}{n} \cong C\left(1+\frac{40.3N}{f^2}\right)$$

f_P : depends on the refractive index and frequency the group velocity can be obtained by the equation

$$vg = \frac{\partial w}{\partial K} = \frac{C}{\left(\frac{\partial(nf)}{\partial f}\right)} \cong C\left(1-\frac{40.3N}{f^2}\right)$$

when the velocity of the wave varies with the frequency, the medium is known as a dispersive medium. because of this dispersion, the idea of group velocity is introduced to represent the velocity of the crest of a group of interfering waves.

FORMULA'S

1. **V_p (phase velocity)= $\frac{\omega}{K}$**

2. **Vg (group velocity)= $\frac{d\omega}{dK}$**

$$= \frac{d}{dk}(v_pk) = V_p + k\frac{dv_p}{dk}$$

$$= v_p + \frac{2\pi}{\lambda} \times \frac{dv_p}{d(2\pi/\lambda)}$$

$$= v_p + \frac{1}{\lambda} \times \frac{dv_p}{-\frac{1}{\lambda^2}d\lambda}$$

3. **$V_g = Vp - \lambda\frac{dv_p}{d\lambda}$**

$$\omega = 2\pi v = 2\pi \times \frac{E}{h} = \frac{2\pi mc^2}{h}$$

$$\omega = \frac{2\pi c^2}{h} m_0 \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

V = velocity of particle

$$K = \frac{2\pi}{\lambda} = \frac{2\pi}{h} mv = \frac{2\pi v}{h} m_0 \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

4. **$V_g = \frac{\omega}{K} = \frac{c^2}{V}$**

$V_pV_g = C^2$ ($V_p > c$, $Vg < c$)

$$V_g = \frac{d\omega}{dk} = \frac{d\omega/dv}{dk/dv} = V$$

Experimental result $\mu = \left(1-\frac{f_p^2}{f^2}\right)^{1/2} = 1 - \frac{f_p^2}{2f^2} = 1 - \frac{40.3N}{f^2}$

$$V_p = \frac{c}{\mu} = C\left(1-\frac{40.3N}{f^2}\right)^{-1}$$

5. **$V_p = C\left(1+\frac{40.3N}{f^2}\right)$**

$V_pV_g = c^2$ (μ=refractive index, v_p = phase velocity, v_g = group velocity)

$V_g = \frac{c^2}{c\left(1+\frac{40.3N}{f^2}\right)}$

6. **$V_g = c\left(1-\frac{40.3N}{f^2}\right)$**

7. **$f_p = \sqrt{(80.6)N}$** (N = electron density, f_p = electron plasma frequency)

8. **MUF** (most useable frequency) = $\frac{f_c}{\cos i}$
(Here fc = critical frequency for normal incidence , i = angle of incidence)

9. $\mu = \sqrt{\varepsilon_r \mu_r}$

10. **Velocity factor =** VF = $\frac{1}{\mu} = \frac{1}{\sqrt{\varepsilon_r \mu_r}}$

Usually **$\mu_r = 1$** ∴ **VF =** $\frac{1}{\sqrt{\varepsilon_r}}$