Other Important Chapter/Topics for Competitive Examinations Preparation.

UNIT – X

Communication Systems

CHAPTER 15 COMMUNICATION SYSTEMS

Chapter Analysis

List of Topics	2016		2017		2018
	D	OD	D	OD	D/OD
Elements of Communication System	–	1 Q (2 marks) 1 Q (3 marks)	1 Q (2 marks)	1 Q (3 marks)	–
Modulation	1 Q (1 mark) 1 Q (3 marks)	1 Q (1 mark)	1 Q (3 marks)	1 Q (3 marks)	1 Q (2 marks) 1 Q (3 marks)

TOPIC-1
Elements of Communication System

Revision Notes

TOPIC - 1
Elements of Communication System ... P. 391

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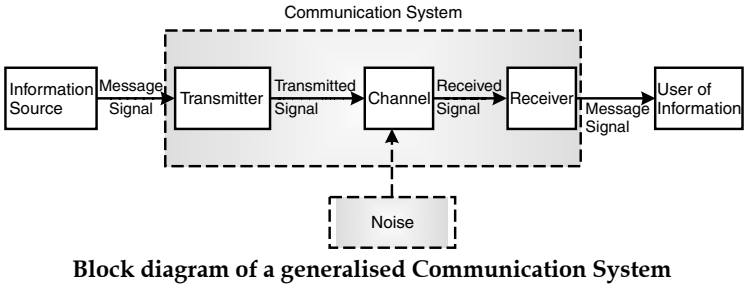
Modulation .... P. 399

- Communication is the method of transmitting and receiving information of data.
- **There may be two types of communication :**
  - **Point to point communication :** In this type of communication transmitter and receiver are single point. **Example :** Telephonic communication.
  - **Broadcasting communication :** In this type of communication, there is one transmitter and many receivers. **Example :** transmission of radio or television.
- When input message (any form of signal variation) is combined with some intelligence input (encoding and compatibility in machine language), it becomes information.
- **Generalised communication system :**



Block diagram of a generalised Communication System

Important terminology and their application in communication system

- **Information source :** The information source is the generator of information which we want to communicate. It may be audio, video or data.
- **Electric Transducer :** Electric transducer convert physical variable into electrical signal variable.
- **Signal:** Information converted in electrical form and suitable for transmission is called signal.
- **Transmitter :** Process of the incoming message signal and making it suitable for transmission through particular channel.
- **Noise :** Unwanted signal which interferes with the information signal and disturbs the information.
- **Channel :** It is the medium through which signal from transmitter propagates to the receiver. For example : optical fibre, coaxial cables etc.
- **Receiver :** Collects the message from the channel and extracts signal.
- **Attenuation :** Signal loses energy during propagation through channel. This is called attenuation.
- **Amplifier :** It is the device which increases the strength by increasing its amplitude.
- **Range :** Maximum distance between transmitter and receiver at which signal can be recovered is called the range of communicating system.
- **Bandwidth :** It is the frequency range over which an equipment operates or range of frequencies a signal has.
- **Modulation :** Mixing of signal with carrier frequency is known as modulation.
- **Demodulation :** Extracting of signal from carrier frequency is known as demodulation.
- **Repeater :** It receives the signal, reconditions it and then retransmits it.

Signal may be classified in two categories :

- **Analog Signal :** Continuous variation of signal with respect to time is known as analog signal. For example : telephonic signal, video signal etc.
  In modern technology we can convert analog signal to digital signal for communicating and convert back to analog signal at receiver.
- **Digital Signal :** Discrete value of signal variation with respect to time is known as digital signal. For example : computer etc.
  - Coding helps in sending digital signal with much more accuracy. There are several coding techniques. For example in computer data, we employ suitable combinations of number systems such as the binary coded decimal (BCD), American Standard Code for Information Interchange (ASCII)
- **Operational advantages of digital communication system over analog communication systems are.**
  - An improved form of sending messages securely.
  - Increased immunity to noise and external interference.
  - A common format for encoding different kinds of message signals for the purpose of transmission.
  - Flexibility in configuration of digital communication system.
- Hence in modern technology, analog signals are transmitted through digital communication. In the final stage they are converted back to analog signals.
- Different types of message signals have different range of frequencies.
  - Audio signal – 20 Hz to 20kHz
  - Video signal – 4.2 MHz
  - TV signal – 6 MHz (audio + video)
- Large bandwidth is required to accommodate complete information of wave.
- **Frequency bands of some important wireless communications :**

Service	Frequency bands	Comments
Standard AM broadcast	540-1600 kHz	
FM broadcast	88-108 MHz	
Television	54-72 MHz	VHF (very high frequencies)
	76-88 MHz	TV
	174-216 MHz	UHF (ultra high frequencies)
	420-890 MHz	TV
Cellular Mobile Radio	896-901 MHz	Mobile to base station
	840-935 MHz	Base station to mobile
Satellite Communication	5.925-6.425 GHz	Uplink
	3.7-4.2 GHz	Downlink

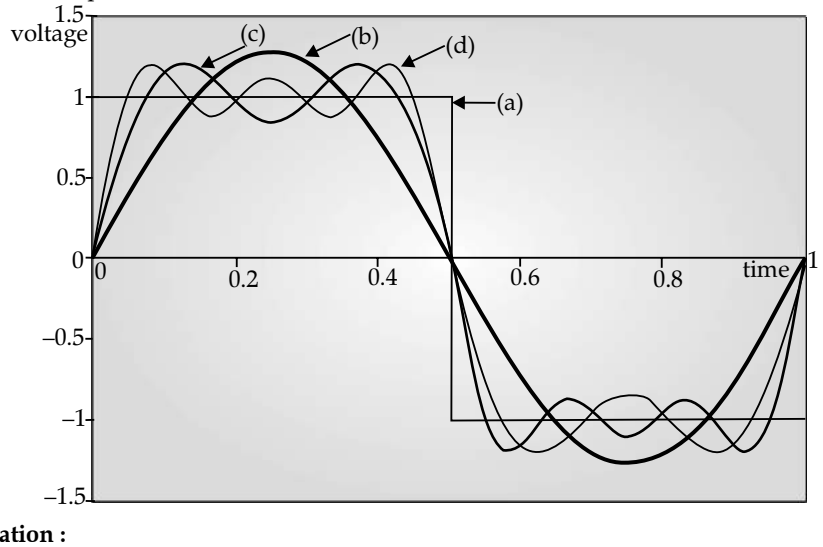
Propagation of Electromagnetic wave :

- Earth's atmosphere plays a vital role in propagation of electromagnetic wave. There are three ways of communication through electromagnetic wave.
- **Ground Wave :**
  (i) The radio waves which travel through atmosphere following the surface of the earth are called ground waves or surface waves and their propagation is known as ground wave propagation or surface wave propagation.
  (ii) The ground waves have vertical orientation and travel parallel to the ground.
  (iii) The ground wave propagation is suitable for low and medium frequency, *i.e.*, from few hundred kHz to 2 MHz only.
  (iv) Its power is less as they operate in low frequency.
  (v) It can bend round the corners of the object on the earth, hence can jump the restriction. ($\theta = \frac{\lambda}{a}$, low frequency means λ is more so more bending)
  (vi) Attenuation is high for ground wave transmission and increases with increase in frequency. This is because more absorption of ground waves (near earth) takes place at higher frequency during propagation through atmosphere.
  (vii) Length of antenna is directly proportional to the wavelength of *EM* wave. Hence, for ground wave large antenna is required.
  (viii) The ground wave propagation is generally used for local band broadcasting and is commonly known as medium wave. Local transmitter, police walkie talkie , AM transmitter are some of its examples.

Sky wave propagation :

(i) The sky waves are the radio waves of frequency between few MHz to 40 MHz.
(ii) These radio waves can propagate in atmosphere and are reflected back by the ionosphere of earth's atmosphere.
(iii) The sky waves travel from transmitter antenna to receiver antenna, through sky they reflect back from ionosphere. Hence, their propagation is called sky wave propagation.
(iv) Critical frequency (f_c) is that highest frequency of radio waves, which when sent straight (*i.e.*, normally) towards the layer of ionosphere gets reflected and returns to the earth. If the frequency of radio waves is more than the critical frequency, it will not be reflected by the ionosphere.
(v) The value of *C.F.* is found to be 4 MHz, 5 MHz and 6 to 8 MHz for *D* (part of stratosphere), *E* (part of stratosphere), F_1 (part of mesosphere) and F_2 (Thermosphere) layers of ionosphere which are at heights about 110 km, 180 km and 300 to 350 km respectively from the surface of earth.
(vi) Its range is very large as compared to range of ground wave. Range can be targeted and can be increased by multiple transmitters.

- **Limitations :** 3 MHz to 30 MHz is very small bandwidth of frequency for present application. Higher frequencies penetrate the ionosphere and can't be reflected.



Space wave propagation :

(i) It is used for very high frequency (> 40 MHz). These can penetrate ionosphere more efficiently.
(ii) Due to high frequency, wavelength is very small and energy is very high.
(iii) Television broadcast, microwave links and satellite communication are some examples of communication systems that use space wave mode of propagation.

Line of sight communication by space wave :

- We also use this space wave in ground transmission. It is known as line of sight transmission.
- These are (space wave) high frequency hence they travel nearly in a line. Mobile transmission or microwave links are based upon this.
- Earth's curvature restrict the range of line of sight transmission. There is limited space between two antennas.
- If h is the height of transmitting antenna then its signal range is $d = \sqrt{2hR}$
- The range of communication d_M between the transmitting antenna of height h_T and the receiving antenna of height h_R is given by $d_M = \sqrt{2h_TR} + \sqrt{2h_RR}$

where, R is the radius of the earth.

Area covered through one tower $= \pi d^2 = \pi \times 2hR$

Population covered = population density × area covered.

Satellite Communication :

- The satellite communication is a mode of communication of signal between a transmitter and a receiver through a satellite.
- The satellite communication is like a line of sight microwave communication.
- Since, the satellite communication is through space hence, it is also part of space communication.
- A communication satellite is a space craft, provided with microwave receiver and transmitter. It is placed in an orbit around the earth.
- In satellite communication, a beam of modulated microwave from the transmitter is sent directly towards the communication satellite, which receives the coming signal, amplifies it and returns it to the earth. Transmitting frequency (uplink) and receiving frequency (downlink) are different to avoid interference between the uplink and the downlink.
- A satellite communication is possible through geostationary satellites.
- A single geostationary satellite cannot cover the whole part of the earth for microwave communication. It is so because, the large part of the earth is out of sight due to the curvature of the earth. One satellite roughly covers one third of earth.
- In order to have global transmission, at least three geostationary satellites are required, which are at particular distance from each other.
- Global positioning system is also based upon satellite communication.

Very Short Answer Type Questions (1 mark each)

Q. 1. Which mode of propagation is used by short wave broadcast service ? R

Ans. Sky wave propagation is used in short wave broadcast service. Its frequency range is from few MHz upto 40 MHz. **1**

Q. 2. Name the essential components of a communication system. R **[O.D. I, II, III 2016]**

Ans. Transmitter, Medium or Channel and Receiver. **1**

Q. 3. Why are micro waves considered suitable for radar systems used in aircraft navigation ?

R **[2016 Delhi All set-3]**

Ans. Due to their short wavelengths, they are suitable for radar system used in aircraft navigation. **1**

Q. 4. What is the meaning of the term 'attenuation' used in communication system ?

R **[O.D. Comptt. I, II, III 2014]**

Ans. Attenuation is the loss of strength of a signal, while propagating through a medium. **1**

[CBSE Marking Scheme, 2014]

Q. 5. Give one example of point-to-point communication mode. R **[O.D. Comptt. I, II, III 2014]**

Ans. Telephony service is based upon point to point communication. **1**

Q. 6. How does the effective power radiated from a linear antenna depend on the wavelength of the signal to be transmitted ?

U **[Delhi Comptt. I, II, III 2014]**

Ans. Effective power $\propto \frac{1}{\lambda^2}$

Alternatively, The effective power which is radiated decreases with an increase in wavelength. **1**

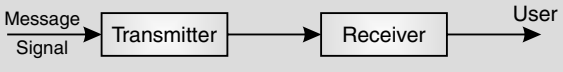
[CBSE Marking Scheme, 2014]

Q. 7. Draw a block diagram of a generalized communication system.

R **[Delhi Comptt. I, II, III 2014]**

Ans. Refer Block diagram (Topic-I) Revision Notes

Alternatively, Also accept if the student gives only the following diagram :



[CBSE Marking Scheme, 2014] 1

Short Answer Type Questions-I (2 marks each)

Q. 1. (i) What is line of sight communication ?
(ii) Why is it not possible to use sky waves for transmission of TV signals? Upto what distance can a signal be transmitted using an antenna of height 'h'? R **[2017 Delhi set-3]**

Ans. (i) Communication, using waves which travel in straight line from transmitting antenna to receiving antenna is called line of sight communication. **1**

(ii) Because T.V. signal waves are not reflected back by the ionosphere ½

$$d = \sqrt{2hR}$$ ½

[CBSE Marking Scheme, 2017]

Q. 2. Which basic mode of communication is used in satellite communication ? What type of wave propagation is used in this mode ? Write, giving reason, the frequency range used in this mode of propagation. R **[2017 Delhi set-1]**

Ans. Broadcast/point to point, mode of communication ½

Space wave propagation ½

Above 40 MHz ½

Because *EM* waves, of frequency above 40 MHz, are not reflected back by the ionosphere / penetrate through the ionosphere. ½

[CBSE Marking Scheme, 2017]

Q. 3. Distinguish between a transducer and a repeater. R **[2017 Delhi set-2]**

Ans. Transducer : A device which converts one form of energy into another. **1**

Repeater : A combination of receiver and transmitter. It picks signals from a transmitter; amplifies and retransmits them. **1**

[CBSE Marking Scheme, 2017]

Commonly Made Error

- Many students couldn't define the tansducer.

Q. 4. A TV transmission tower antenna is at a height of 20 m. How much range can it cover if the receiving antenna is at a height of 25 m? R **[CBSE-SQP -2018]**

Ans. Range $d = \sqrt{2hR} + \sqrt{2h_R R}$ **1**

$$d = \sqrt{2\times 20\times 6{\cdot}4\times 10^6} + \sqrt{2\times 25\times 6{\cdot}4\times 10^6}$$

$d = 33.9$ km **1**

[CBSE Marking Scheme, 2018]

Q. 5. Distinguish between broadcast mode and point-to-point mode of communication and give one example for each. R **[2017-Foreign Sets-I, II, III]**

Ans. In point-to-point communication mode, communication takes place over a link between a single transmitter and a single receiver. ½

In the broadcast mode, there are large number of receivers corresponding to a single transmitter. ½

Example : Point-to-point : telephone (any other) ½

Broadcast : T.V. Radio (any other) ½

[CBSE Marking Scheme, 2017]

Q. 6 A device X used in communication system can convert one form of energy into another. Name the device X. Explain the function of a repeater in a communication system. R **[2016- Foreign Sets-I, II, III]**

Or

Write the function of a (i) transducer and (ii) repeater in a communication system.

[2016 -OD; south]

Ans. 'X' is a transducer It is a device which converts one form of energy to another. **1**

A repeater picks up the signal from the transmitter, amplifies and transmits it to the receiver sometimes with a change in carrier frequency. Repeaters are used to extend / increase the range of a communication system. **1**

Q. 7. State the concept of mobile telephony and explain its working. R **[2016-OD, east]**

Ans. Concept of mobile telephony is to divide the service area into a suitable number of cells centered on an office MTSO (Mobile Telephone Switching Office). Mobile telephony means that you can talk to any person from anywhere. **1**

Explanation :

(i) Entire service area is divided into smaller parts called cells.

(ii) Each cell has a base station to receive and send signals to mobiles.

(iii) Each base station is linked to MTSO. MTSO co-ordinates between base station and TCO (Telephone Control Office) **1**

Q. 8. Distinguish between any two types of propagation of electromagnetic waves with respect to (i) frequency range over which they are applicable, (ii) communication systems in which they are used. U **[CBSE SQP 2016]**

Ans.

Type of EM wave propagation	Frequency range	Use
Ground wave	500–1500 KHz	Standard AM broadcast
Space wave	Above 40 MHz	Television

½ + ½ + ½ + ½

Q. 9. Write the functions of the following in communication systems :
(i) Transmitter
(ii) Modulator R **[Delhi 2014]**

Ans. (i) Device used for communication which transmits the signal by amplifying it.

(ii) Device which merges the high frequency carrier wave and low frequency base-band signal. **1+1**

Q. 10. Write the functions of the following in communication systems :

(i) Transducer

(ii) Repeater R **[O.D. I, II, III 2014]**

Ans. (i) Transducer : Any device that converts one form of energy to another. **1**

(ii) Repeater : A repeater accepts the signal from the transmitter, amplifies and retransmits it to the receiver. **[CBSE Marking Scheme, 2014] 1**

Q. 11. Distinguish between 'sky wave' and 'space wave' modes of propagation in a communication system. R **[Delhi Comptt., I, II, III, 2016]**

Ans.

S.No	Sky Wave	Space Wave
(i)	Restricted up to a few MHz frequency (3 to 40 MHz).	Can take place (even) beyond 40 MHz frequency.
(ii)	Waves are reflected back from ionosphere.	Space waves travel in a straight line, either directly from transmitting antenna to receiving antenna or, through satellite.

[CBSE Marking Scheme, 2016] 2

Q. 12. Distinguish between 'Analog and Digital signals'. U **[Delhi I, II, III 2014]**

Ans. Analog signals are continuous variations of voltage or current. **1**

Digital signals are those which can take only discrete (step wise) values of current or voltage. **1**

[CBSE Marking Scheme, 2014]

Short Answer Type Questions-II **(3 marks each)**

Q. 1. What is sky wave propagation ? Which frequency range is suitable for sky wave propagation and why ? Over which range of frequencies can communication through free space using radio waves take place ? U **[2017, Foreign Set-II]**

Ans. In sky wave propagation, long distance communication is achieved by ionospheric reflection of radio waves back towards the earth. **1**

The frequency range is from a few Mega hertz to 30/40 Mega hertz. The ionospheric layers can act as a reflector over this frequency range (3 MHz to 30/40 MHz). Higher frequencies penetrate through it. **1**

The frequency range of radio frequencies is a few hundred kHz to a few GHz.

(waves having frequency beyond 40 MHz) **1**

[CBSE Marking Scheme, 2017]

Commonly Made Error

- Many students confused 'sky wave propogation' with' space wave propagation.'

Q. 2. What is space wave propagation ? Which systems of communication use space waves ? What is 'radio horizon' of a transmitting antenna of height h ? Why is space wave propagation suitable for frequencies above 40 MHz ? U **[2017 Foreign Set-III]**

Ans. Propagation of waves, along a straight path from the transmitting antenna to receiving antenna, using line of sight (LOS) communication is called space wave propagation. **1**

Relevant system of communication :

Television broadcast, microwave links and satellite communication **(any one)** ½

'Radio horizon' equals the distance between the transmitting antenna and the point on the earth where the direct waves get blocked due to the curvature of the earth.

[Also accept $d = \sqrt{2hR}$; h = height of transmitting antenna, R = Radius of the earth.]

At frequencies above 40 MHz, relatively smaller antennas are needed and communication is essentially limited to line of sight paths. **1**

[Alternatively,

At frequencies (more than 40 MHz), *EM* waves do not get bent or reflected by ionosphere. Therefore space wave propagation has to be used for frequencies above 40 MHz.] **1**

[CBSE Marking Scheme, 2017]

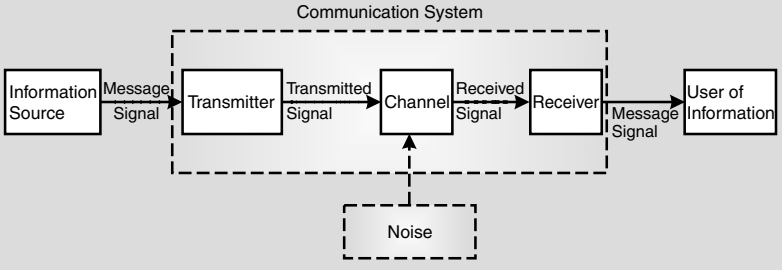
Q. 3. Draw a block diagram of a generalized communication system. Write the functions of each of the following :

(i) Transmitter

(ii) Channel

(ii) Receiver U **[2017, OD Set-III]**

Ans.



[Also accept the following diagram **1½**

Information source → Communication channel → Receiver of Information

(i) Transmitter : A transmitter processes the incoming message signal so as to make it suitable for transmission through a channel and subsequent reception. ½

(ii) Channel : It carries the message signal from a transmitter to a receiver. ½

(iii) Receiver : A receiver extracts the desired message signals from the received signals at the channel output. ½

[CBSE Marking Scheme, 2017]

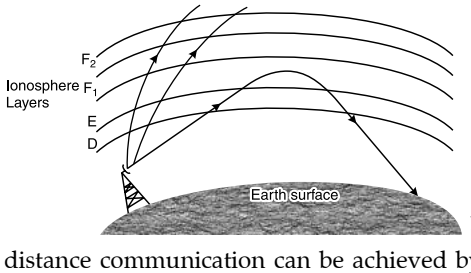
Commonly Made Error

- Few students couldn't write the function of channel.

Q. 4. (i) Which mode of propagation is used by shortwave broadcast services having frequency range from a few MHz up to 30 MHz ? Explain diagrammatically how long distance communication can be achieved by this mode.

(ii) Why is there an upper limit to frequency of waves used in this mode ? U **[O.D. I, II, III, 2016]**

Ans. (i) Sky wave propagation. ½



1

Long distance communication can be achieved by reflection of radio waves by the ionosphere, back towards the Earth. This ionosphere layer acts as a reflector only for a certain range of frequencies. (few MHz to 30 MHz) ½

(ii) Electromagnetic waves of frequencies higher than 30 MHz, penetrate the ionosphere and escape whereas the waves less than 3 MHz are reflected back to the earth by the ionosphere. **1**

Q. 5. (i) Distinguish between point to point and broadcast modes of communication. Give an example of each.

(ii) Explain the basic concept of mobile telephone.

U **[2016 Foreign Set-1]**

Ans. (i) In point to point communication mode, communication takes place over a link between a single transmitter and a receiver.

In broadcast mode , there are a large number of receivers corresponding to a single transmitter. Examples; Point to point : telephony Broadcast : radio / Television. **1½**

(ii) The service area is divided into a suitable number of hexagonal cells centered on MTSO (Mobile Telephone Switching Office). Each cell contains a low-power transmitter called a base station and caters to a large number of mobile receivers / cell phones. When a mobile receiver crosses one base station it is handed over to another base station . It is called handover or handoff. **1½**

Q. 6. Mention three applications of the internet. Explain one of these in detail. U **[2016-OD, south]**

Ans. Application of internet–e-mail, social networking sites, e-commerce, mobile telephony, GPS.

[Any three] ½+½+½

Explanation of any one. **1½**

[CBSE Marking Scheme, 2016]

Detailed Answer :

One of the main use of internet is instant global connectivity. It is very useful in e-learning sector. Nowadays students from remote area can access quality of education from different educational website and e-lectures through internet. Interactive videos available in internet help them also.

Q. 7. What is global positioning system ? Explain its working in brief. U **[2016 OD, east]**

Ans. Global Positioning System (GPS) is method of identifying location or position of any point or a person on earth using a system of 24 satellites, which are continuously orbiting, observing, monitoring and mapping the earth. **1**

Working Principle :

(i) The unique location of GPS user is determined by measuring its distance from at least three GPS satellites. **1**

(ii) Using these values of distances, obtained from three satellites, a microprocessor, fitted in GPS device, determines the exact location. **1**

Q. 8. What is space wave propagation ? State the factors which limit its range of propagation. Derive an expression for the maximum line of sight distance between two antennas for space wave propagation. U **[2016; OD, North Set]**

Ans. Space Wave Propagation :

The mode of propagation in which radio waves travel, along a straight line, from the transmitting to the receiving antenna. **1**

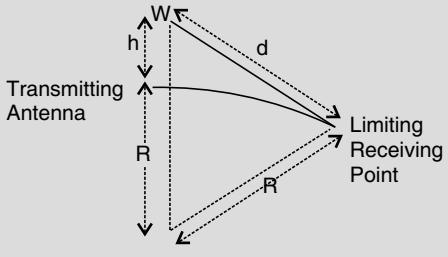
Limiting Factors :

(i) Curvature of the earth

(ii) Insufficient height of the receiving antenna

(Award this ½ mark if the student writes any one of these two factors) **1**

Derivation :



From the figure, we have

$$(R + h)^2 = R^2 + d^2$$

Or $2Rh \cong d^2$ (as $h^2 << 2Rh$) ½

$\therefore$ $d = \sqrt{2Rh}$

For a transmitting antenna of height h_T, and a receiving antenna of height h_R, the maximum line of sight distance becomes

$\therefore$ $d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}$

[Note : Give 1 mark if the student writes the expression of d_M] ½

[CBSE Marking Scheme, 2016]

Q. 9. Give (brief) reasons for the following :

(i) We use the 'sky wave' mode of propagation, of electromagnetic waves, only for frequencies up to 30 to 40 MHz.

(ii) The LOS (Line of sight) communication via space waves base (fairly) limited range.

(iii) A mobile phone user gets an 'uninterrupted link to talk' while walking. U **[Foreign, 2016]**

Ans. (i) The ionosphere can act as a 'reflector' only for *EM* waves of frequencies up to 30 to 40 MHz. Higher frequency *EM* waves penetrate the ionosphere and escape. **1**

(ii) The range is (fairly) limited because the *EM* waves loose energy (fairly rapidly) when they glide over the surface of the earth. **1**

(iii) This is because of the presence of a network of base stations/cells which keep on passing the signals from one base station/cell to the other. **1**

Q. 10. (i) What is line of sight (LOS) communication ? What is the range of their frequencies ?

(ii) A transmitting antenna at the top of a tower has a height of 20 m and the height of the receiving antenna is 45 m. Calculate the maximum distance between them for satisfactory communication in LOS mode. (Radius of the Earth = 6.4×10^6 m)

U **[O.D. I, II, III, 2013]**

Ans. Space waves are used for the line of sight (LOS) communication. ½

The range of their frequencies is 40 MHz and above. ½

We have, height of transmitting antenna, $h_T = 20$ m and height of receiving antenna, $h_R = 45$ m.

Then, maximum distance between the two antennas,

$$d_M = \sqrt{2h_TR} + \sqrt{2h_RR}$$

$$d_M = \sqrt{2\times20\times6.4\times10^6} \quad \sqrt{2\times45\times6.4\times10^6}$$

$$= 20 \times 8 \times 100 + 8 \times 100 \times 30$$

$$= 8 \times 100\,(20 + 30)$$

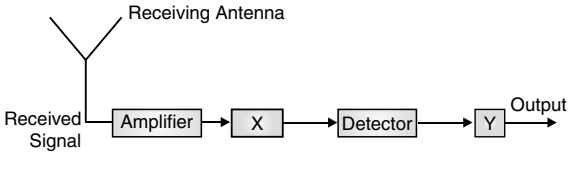
$$= 40000 \text{ m} = 40 \text{ km}$$ **2**

Long Answer Type Questions (5 marks each)

Q. 1. (i) Which mode of wave propagation is suitable for television broadcast and satellite communication, and why ? Draw a suitable diagram depicting this mode of propagation of wave.

U **[O.D. Comptt. I, II, III 2012]**

(ii) Block diagram of a receiver is shown in the figure.

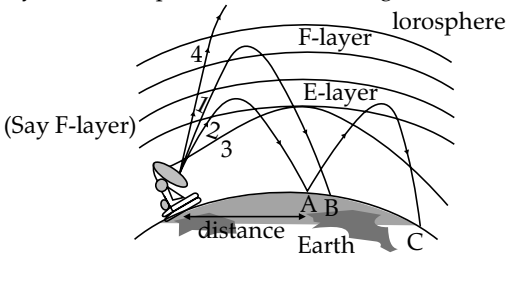


(a) Identify 'X' and 'Y'.

(b) Write their functions. **[Delhi I, II, III 2013]**

Ans. (i) The skywave propagation is suitable for television broadcast and satellite communication. ½

The radio waves from the transmitting antenna can reach the receiving antenna *R* from the different layers of ionospheres as shown in figure. ½

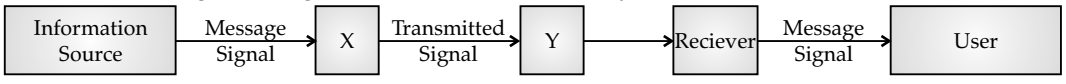


2

(ii) (a) *X : IF* stage
Y : Amplifier **1**

(b) The carrier frequency is changed to a lower frequency by intermediate frequency (*IF*) stage preceding the detection.
An amplifier increases the strength of the detected signal. **1**

Q. 2. (i) Given a block diagram of a generalized communication system.



Identify the boxes 'X' and 'Y' and write their functions.

(ii) Mention three different modes of propagation used in communication system. Distinguish between "Point to Point" and "Broadcast" modes of communication. U **[Delhi I, II, III 2015]**

Ans. (i) *X* : Transmitter
Y : Channel **1**

Their functions :
Transmitter : To convert the message signal into suitable form for transmission through channel. **1**
Channel : It sends the signal to the receiver. **1**

(ii) (a) Ground wave or surface wave propagation.
(b) Sky wave propagation or ionospheric propagation.
(c) Space wave propagation / Line of sight propagation **1**
In point to point mode, communication takes place between a single transmitter and receiver. In broadcast mode, large number of receivers are connected to a single transmitter. **1**

TOPIC-2
Modulation

Revision Notes

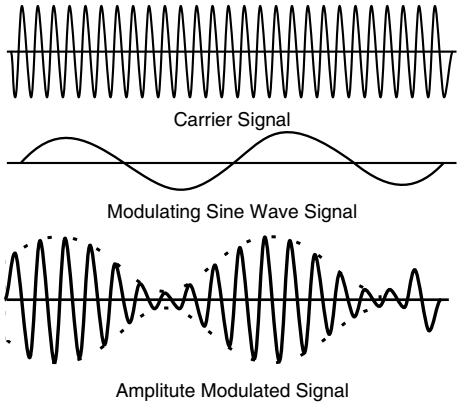
Low frequency signal could not travel large distance because of following reasons :

- Low frequency means low power, hence it gets attenuated i.e., loss of signal strength.
- Minimum size of antenna $= \frac{\lambda}{4}$ and low frequency means large wavelength so size of antenna becomes impractical.
- Overlapping of signals Difficult to incorporate multiple transmitting stations.
- Hence the signal should be transmitted at high frequency.
- Combining low frequency message signal with high frequency carrier wave is modulation.
- A high frequency wave has certain features like amplitude, frequency and phase.

$$y = a\cos(\omega t + \phi)$$

So, variable parameters are amplitude (a), frequency (ν) and phase (ϕ).

- Depending upon the parameter which we are varying in carrier wave with our signal, there are three main types of modulation techniques.
  - Amplitude modulation
  - Frequency modulation
  - Phase modulation
- **Amplitude Modulation :** The amplitude of the carrier wave changes according to the intensity of the signal. The amplitude variation of the carrier wave is at the signal frequency f_s.

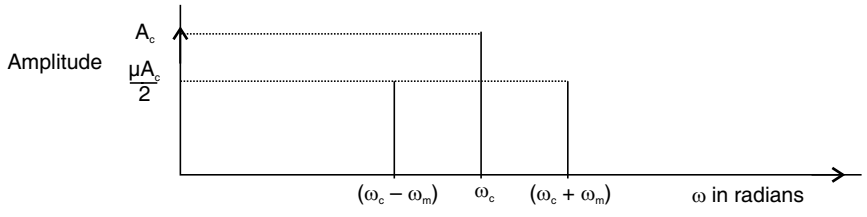


If message signal $m(t) = A_m \sin \omega_m t$

carrier wave $c(t) = A_c \sin \omega_c t$

are combined together then bandwidth of modulated wave is $(\omega_c - \omega_m)$ to $(\omega_c + \omega_m)$

- $(\omega_c - \omega_m)$ and $(\omega_c + \omega_m)$ are known as lower and upper sideband frequency respectively. Signal is in these side band frequencies.



Modulation Index : The ratio of change of amplitude of modulated wave to the amplitude of normal carrier wave is called modulation index (μ).

$\mu = \frac{A_m}{A_c}$ To prevent distortion $\mu \leq 1$.

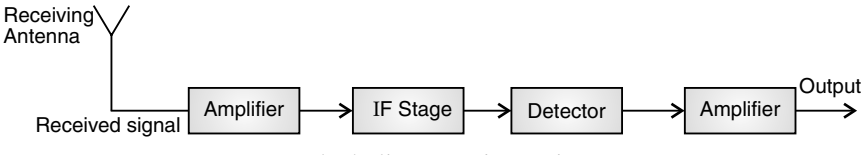
We can derive that $A_m = \frac{A_{max} - A_{min}}{2}$ and $A_c = \frac{A_{max} + A_{min}}{2}$

Hence, $\mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$

- **Effect of Noise on AM wave :** AM signal is more noisy than *FM* because in *AM* message is transmitted through modulating the amplitude of carrier signal. A low frequency noise can alter the amplitude of carrier message. In frequency modulation message is transmitted through frequency changes and hence amplitude of noise signal will not effected.

Detection of amplitude modulated wave :

- **Demodulation :** Demodulation is the process of recovering the signal frequency from a modulated carrier wave.
- The detected signal may not be strong enough to be made use of and hence is required to be amplified.
- Below is the block diagram of typical receiver circuit.



Block diagram of a receiver

- **Other communicating modes**
  Internet
  Facsimile (FAX)

Very Short Answer Type Questions (1 mark each)

Q. 1. A signal of 5 kHz frequency is amplitude modulated on a carrier wave of frequency 2 MHz. What are the frequencies of the side bands produced ? U **[2016- OD, North]**

Ans. (i) $\upsilon_{\text{side bands}} = \upsilon_c \pm \upsilon_m$ ½
$= 2005 \text{ kHz}; 1995 \text{ kHz}$ ½
(Give full 1 mark if the student straight away writes the answer as 2005 kHz and 1995 kHz)
[CBSE Marking Scheme, 2016]

Q. 2. Distinguish between amplitude modulation and frequency modulation. U **[O.D. I, II, III 2015]**

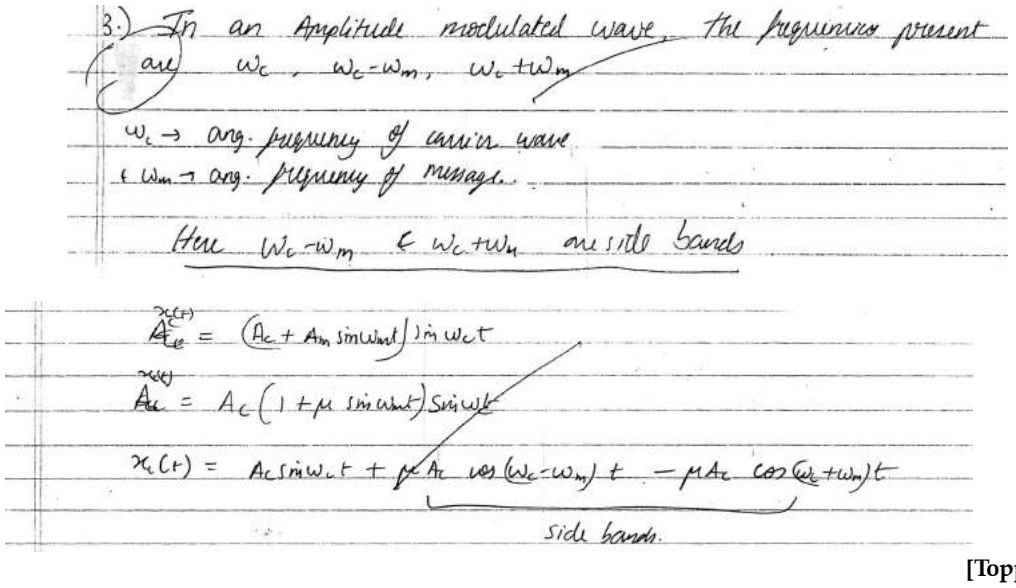
Ans. In amplitude modulation, the amplitude of the carrier wave, changes in accordance with the modulating signal, while in frequency modulation, frequency of the carrier wave varies in accordance with the modulating signal. **1**

Q. 3. How are side bands produced ?
U **[Delhi I, II, III 2015]**

Ans. Side bands are produced due to the superposition of carrier waves of frequency ω_c over modulating /audio signal of frequency ω_m. **1**
[CBSE Marking Scheme, 2015]

OR

Ans.



[Topper's Answer, 2015]

Q. 4. A carrier wave of peak voltage 12 V is used to transmit a message signal. Calculate the peak voltage of the modulating signal in order to have a modulation index of 75%. Why is modulation index generally kept less than one ?

[Delhi Comptt. I, II, III 2013]

Ans. $V_c = 12, m_a = 75\%$

$$\frac{75}{100} = \frac{12 - V_m}{12 + V_m}$$

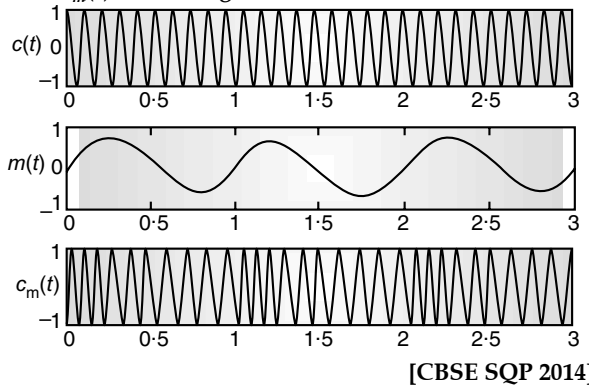
$$48 - 4V_m = 36 + 3V_m$$

$$7V_m = 12$$

$$V_m = \frac{12}{7} = 1.7 \text{ V}$$

Modulation index is kept less than 1 to avoid the distortion. **1**

Q. 5. In the given diagram C(t) stands for the carrier wave and $m(t)$ for the signal to be transmitted. What name do we give to the wave labelled as $C_m(t)$ in the diagram ?



[CBSE SQP 2014]

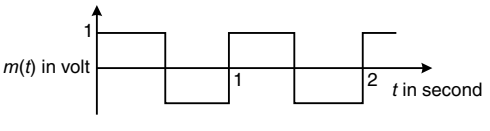
Ans. $C_m(t)$ is the frequency modulated wave. **1**

[CBSE Marking Scheme, 2014]

Q. 6. The carrier wave is given by

$$C(t) = 2\sin(8\pi t) \text{ volt.}$$

The modulating signal is a square wave as shown. Find modulation index.



[Delhi I, II, III 2014]

Ans. Modulation Index $= \frac{a_2}{a_1} = 1/2 = 0.5$ ½ + ½

[CBSE Marking Scheme, 2014]

Detailed Answer :

From the given equation of carrier wave amplitude of carrier wave, $A_c = 2$ volts

From the graph amplitude of signal wave,

$$A_m = 1 \text{ volts}$$

Hence modulation index,

$$\mu = \frac{A_m}{A_c} = \frac{1}{2} = 0.5$$

Short Answer Type Questions-I (2 marks each)

Q. 1. Define modulation index. Why it is kept low ? What is the role of a bandpass filter ?

R **[2016- OD centre]**

Ans. The modulation index is ratio of modulating signal voltage(V_m) to the carrier voltage (V_c).

$\mu = \frac{V_m}{V_c}$. It is kept low to prevent the signal distortion. **1**

A bandpass filter allows the desirable band of frequencies to pass and block the unwanted higher and lower frequencies. **1**

Q. 2. Explain the terms (i) Attenuation and (ii) Demodulation used in communication system.

R **[Delhi I, II, III 2016]**

Ans. (i) The loss of strength of a signal while propagating through a medium. **1**

(ii) The process of retrieval of information, from the modulated wave, at the receiver. **1**

[CBSE Marking Scheme, 2016]

Q. 3. (i) Give three reasons why modulation of a message signal is necessary for long distance transmission.

(ii) Show graphically an audio signal, a carrier wave and an amplitude modulated wave.

R **[Delhi/Outside Delhi 2018 Set I, II, III]**

OR

Why is the baseband signal not transmitted directly ? Give any two reasons.

[2016-OD, North]

Ans. (i) If base band signal were to be transmitted directly

(a) The height of the antenna needed will be impractically large. **1**

(b) The effective power radiated would be too low.

(c) There would be a high probability of different signals getting mixed up with one another. **1**

Kindly refer 'Revision Notes' of topic-2 for diagram.

[CBSE Marking Scheme, 2016]

Detailed Answer :

(i) (a) Modulation allows us to send a signal over a bandpass frequency range. If every signal gets its own frequency range, then we can transmit multiple signals simultaneously over a single channel.

(b) It allows the use of smaller antenna.

(c) Low frequency signals get attenuated in space while high frequency do not get attenuated in space as fast as low frequency and can travel long distances. **2**

Q. 4. Define the term modulation. Draw a block diagram of a simple modulator for obtaining *AM* signal.

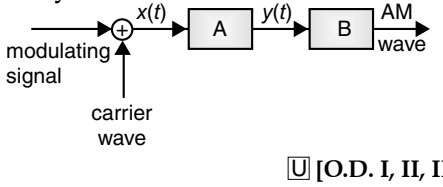
R **[Foreign 2014]**

Ans. The process of (appropriate) superimposition of low frequency message signal, over a high frequency carrier wave, is called modulation. **2**

[**Note :** For block diagram see Topic-2]

[CBSE Marking Scheme, 2014]

Q. 5. In the block diagram of a simple modulator for obtaining an *AM* signal, shown in the figure, identify the boxes *A* and *B*. Write their functions.



U **[O.D. I, II, III 2013]**

Ans. A = Square law device

B = Bandpass filter. **1**

Band pass filter rejects low and high frequencies and allows a band of frequencies to pass through. ½

Square law device is a non-linear device. It produces a non-linear output of message and carrier signals. ½

Q. 6. A message signal of frequency 10 kHz and peak voltage 10 V is used to modulate a carrier wave of frequency 1 MHz and peak voltage 20 V. Determine : A **[Delhi Comptt. I, II, III 2013]**

(i) The modulation index,

(ii) the side bands produced.

Ans. (i) Modulation index, $\mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$

or $\mu = \frac{A_m}{A_c}$

Given, $A_{max} - V_{min} = 10\ V$

$A_{max} + A_{min} = 20\ V$

Hence $\mu = \frac{20-10}{20+10} = \frac{1}{3}$ **1**

(ii) sidebands $= f_c - f_m$ and $f_c + f_m$

Given $f_m = 10$ kHz

$f_c = 1$ MHz

hence sidebands

$f_c + f_m = 1000$ kHz + 10 kHz

$= 1010$ kHz

$f_c - f_m = 1000$ kHz – 10 kHz

$= 990$ kHz **1**

Q. 7. A carrier wave of frequency 1.5 MHz and amplitude 50 V is modulated by a sinusoidal wave of frequency 10 kHz producing 50% modulation. Calculate the amplitude of *AM* wave and frequencies of the side bands produced.

A **[Delhi Comptt. I, II, III 2013]**

Ans. Given, $f_m = 10$ kHz

$f_c = 1.5$ MHz
$V_c = 50$ V
$\mu = 0.5$

(i) modulation index, $\mu = \dfrac{V_c - V_m}{V_c + V_m}$

$$0.5 = \frac{50 - V_m}{50 + V_m}$$

$$25 + 0.5\,V_m = 50 - V_m$$
$$1.5\,V_m = 25$$
or $V_m = 16.66\ V$ **1**

Sidebands $= f_c - f_m$ and $f_c + f_m$
Given $f_m = 10$ kHz
$f_c = 1.5$ MHz
Hence sidebands
$f_c + f_m = 1500$ kHz + 10 kHz
$= 1510$ kHz
$f_c - f_m = 1500$ kHz – 10 kHz
$= 1490$ kHz **1**

Q. 8. A carrier wave of peak voltage 15 V is used to transmit a message signal. Find the peak voltage of the modulating signal in order to have a modulation index of 60%.

[CBSE Delhi &All India-2018]

Ans. Formula for modulation index 1
Finding the peak value of the modulating signal 1

We have, $\mu = \dfrac{A_m}{A_c}$ **1**

Here, $\mu = 60\% = \dfrac{3}{5}$ ½

$\therefore$ $A_m = \mu A_c = \dfrac{3}{5} \times 15\ V = 9\ V$ ½

[CBSE Marking Scheme, 2018]

Detailed Answer :

The modulation index μ is given by

$$\mu = \frac{A_m}{A_C},$$

where $A_m \rightarrow$ Peak voltage of modulating signal.
$A_C \rightarrow$ Peak voltage of carrier wave.

$A_m = \mu \; A_C$
$= \dfrac{60}{100} \times 15 = 9\ V$ $\boxed{A_m = 9\ V}$

Short Answer Type Questions-II

(3 marks each)

Q. 1. Define the term 'amplitude modulation'. Explain any two factors which justify the need for modulating a low frequency base band signal.

R [2017- Delhi Set-I, II, III]

Ans. It is the process of superposition of information / message signal over a carrier wave in such a way that the amplitude of carrier wave is varied according to the information signal / message signal. **1**

Direct transmission, of the low frequency base band information signal, is not possible due to the following reasons :

(i) Size of Antenna : For transmitting a signal, minimum height of antenna should be $\dfrac{\lambda}{4}$, with the help of modulation wavelength of signal decreases, hence height of antenna becomes manageable. **1**

(ii) Effective power radiated by an antenna : Effective power radiated by an antenna varies inversely as λ^2, hence effective power radiated into the space, by the antenna, increases. ½+½

(iii) To avoid mixing up of signals from different transmitters. **(Any two)**

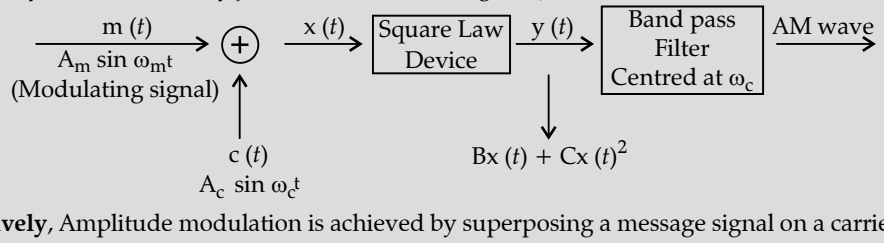
[CBSE Marking Scheme, 2017]

Q. 2. (i) How is amplitude modulation achieved ?

(ii) The frequencies of two side bands in an *AM* wave are 640 kHz and 660 kHz respectively. Find the frequencies of carrier and modulating signal. What is the bandwidth required for amplitude modulation ? **R [2017, OD set-1]**

Ans. (i) Amplitude modulation can be achieved by applying the message signal, and the carrier wave, to a non linear (square law device) followed by a band pass filter.

(Alternatively, The student may just draw the block diagram.)



(**Alternatively**, Amplitude modulation is achieved by superposing a message signal on a carrier wave in a way that causes the amplitude of the carrier wave to change in accordance with the message signal.) **1**

(ii) Frequencies of side bands are :

$(\nu_c + \nu_m)$ and $(\nu_c - \nu_m)$ ½

$\therefore \quad \nu_c + \nu_m = 660$ kHz

and $\quad \nu_c - \nu_m = 640$ kHz

$\therefore \quad \nu_c = 650$ kHz ½

$\therefore \quad \nu_m = 10$ kHz ½

Bandwidth $= (660 - 640)$ kHz

$= 20$ kHz ½

[CBSE Marking Scheme, 2017]

Q. 3. (i) Define the term 'modulation index,' used in communication system. Why is its value kept less than or equal to one ?

(ii) A message signal of frequency 10 kHz and peak voltage of 10 V is used to modulate a carrier frequency 1 MHz and peak voltage 10 V. Determine the (i) modulation index, and (ii) side bands produced. R **[Foreign Set-I, 2017]**

Ans. (i) Modulation index is the ratio of Amplitude modulated wave to the amplitude of carrier wave.

$$\mu = \frac{A_m}{A_c} \quad \textbf{1}$$

$\mu \leq 1$ to avoid distortion of signal. ½

(ii) $\mu = \frac{10\text{V}}{10\text{V}} = 1$ ½

$\nu_c - \nu_m = (1000 - 10)$ kHz

$= 990$ kHz ½

$\nu_c + \nu_m = (1000 + 10)$ kHz

$= 1010$ kHz ½

[CBSE Marking Scheme, 2017]

Q. 4. (i) Explain any two factors which justify the need of modulating a low frequency signal.

(ii) Write two advantages of frequency modulation over amplitude modulation.

R **[2016- Delhi Set-I, II, III]**

Ans. (i) A low frequency signal is modulated for the following purposes :

(a) It reduces the wavelength of transmitted signal, and the minimum height of antenna for effective communication is $\lambda/4$. Therefore height of antenna becomes practically achievable.

(b) Power radiated into the space by an antenna is inversely proportional to λ^2. Therefore, the power radiated into the space increases and signal can travel larger distance. **1+1**

(ii) (a) High efficiency **(b)** Less noise **(c)** Maximum use of transmitted power **1**

Q. 5. (i) Write the factors that prevent a baseband signal of low frequency to be transmitted over long distances.

(ii) What is to be done to overcome these factors ? Draw a block diagram to obtain the desired signal.

R **[CBSE SQP 2016]**

Ans. The factors that prevent a baseband signal of low frequency to be transmitted over long distances are :

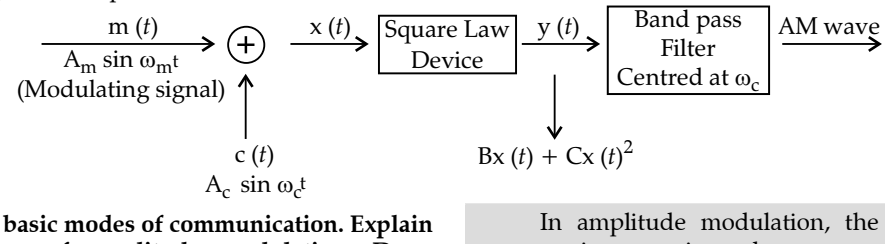
(i) Size of the antenna

Effective power radiated by the antenna

Mixing up of signals from different transmitters **1**

(ii) Modulation of the baseband signal of low frequency overcomes above problems and transmit them over long distances. **1**

Block diagram of amplitude modulation



1

Q. 6. Write two basic modes of communication. Explain the process of amplitude modulation. Draw a schematic sketch showing how amplitude modulated signal is obtained by superposing a modulating signal over a sinusoidal carrier wave.

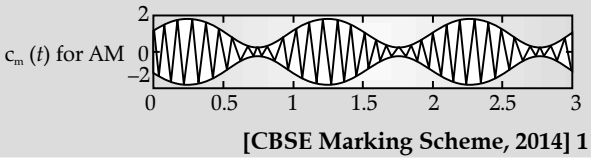
U **[O.D. 2014]**

Ans. Two basic modes of communication are :

(i) Point – to – point ½

(ii) Broadcast ½

In amplitude modulation, the amplitude of a carrier wave is made to vary, with time, in the same way as the modulating signal varies with time. **1**

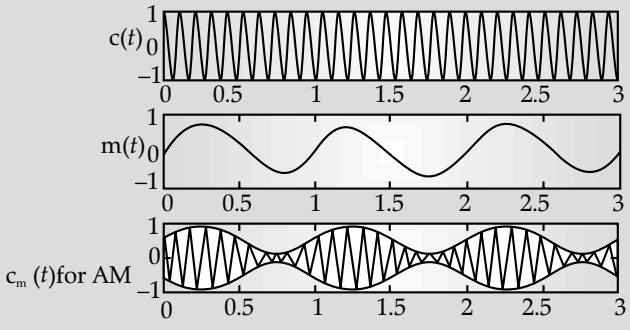


[CBSE Marking Scheme, 2014] 1

Q. 7. Write three important factors which justify the need of modulating a message signal. Show diagrammatically how an amplitude modulated wave is obtained when a modulating signal is superimposed on a carrier wave.

U **[Delhi I, II, IIsI 2013, Delhi I, II, III 2012]**

Ans. (i) Practical Size of the antenna or aerial ½
(ii) Effective power radiated by an antenna ½
(iii) Mixing up of signals from different transmitters ½



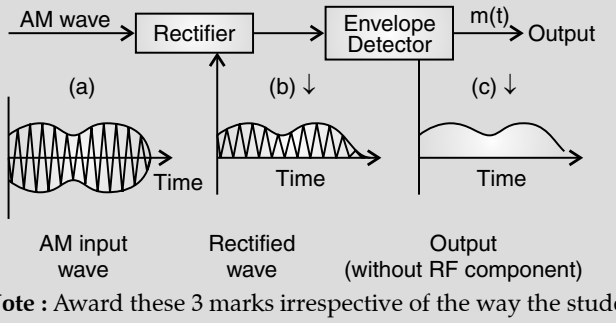
½ ½ ½

[CBSE Marking Scheme, 2013, 12, 10]

Q. 8. Draw a block diagram of a detector for *AM* signal and show, using necessary processes and the waveforms, how the original message signal is detected from the input *AM* wave.

U **[Delhi I, II, III 2015]**

Ans.



1

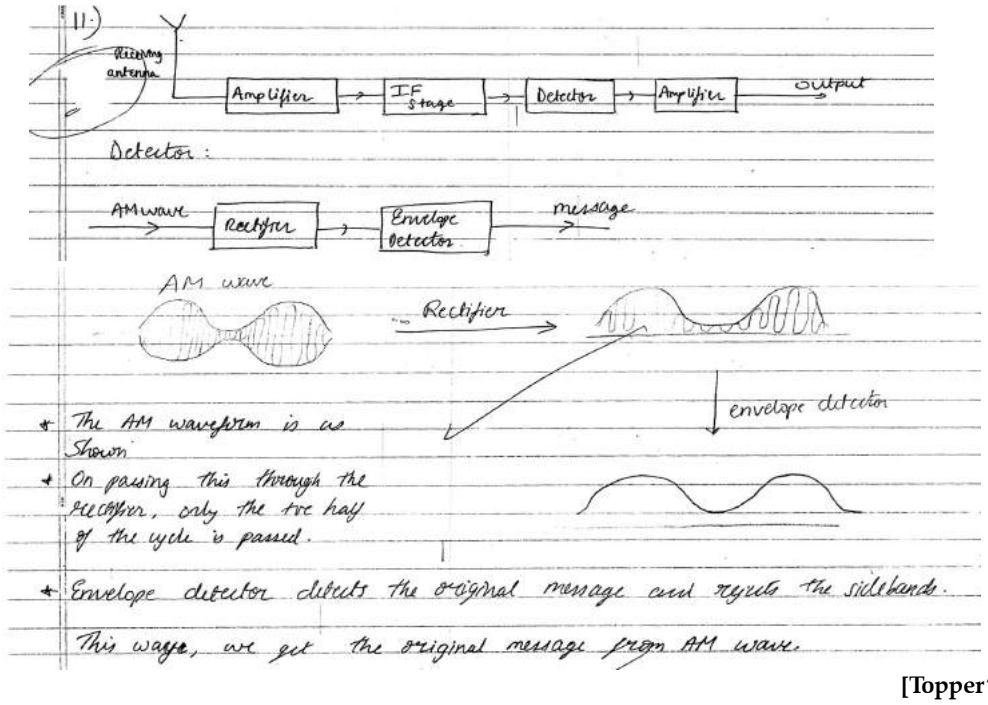
[**Note :** Award these 3 marks irrespective of the way the student attempts the question.] **1 + 1**

[CBSE Marking Scheme, 2015]

Commonly Made Error

- Many students couldn't draw the output of 'envelope detector'.

OR



[Topper's Answer, 2015]

Q. 9. A (sinusoidal) carrier wave

$C(t) = A_c \sin \omega_c t$

is amplitude modulated by a (sinusoidal) message signal

$m(t) = A_m \sin \omega_m t$

Write the equation of the (amplitude) modulated signal. Use this equation to obtain the values of the frequencies of all the sinusoidal waves present in the modulated signal. U **[CBSE SQP 2014]**

Ans. The equation of the (amplitude) modulated signal is

$C_m(t) = [(A_c + A_m \sin \omega_m t)] \sin \omega_c t$ **1**

This can be rewritten as

$C_m(t) = [A_c (1 + \mu \sin \omega_m t)] \sin \omega_c t$

where, $\mu = A_m/A_c$ = modulation index ½

$\therefore \quad C_m(t) = A_c \sin \omega_c t + \frac{\mu A_c}{2} 2\sin \omega_m t . \sin \omega_c t$ ½

$= A_c \sin \omega_c t + \frac{\mu A_c}{2} [\cos(\omega_c - \omega_m)t$

$- \cos (\omega_c + \omega_m)t]$ ½

There are the three sinusoidal waves present in the amplitude modulated signal.

The frequencies of these three waves are

$f_1 = \frac{\omega_c}{2\pi}$

$f_2 = \frac{\omega_c - \omega_m}{2\pi}$

and $f_3 = \frac{\omega_c + \omega_m}{2\pi}$ ½

[CBSE Marking Scheme, 2014] ½

Q. 10. A sinusoidal carrier wave of amplitude A_c and angular frequency ω_c is modulated in accordance with a sinusoidal information signal of amplitude A_m and angular frequency ω_m. Show that the amplitude modulated signal contains three frequencies centered around ω_c. Draw the frequency spectrum of the resulting modulated signal. **[CBSE -SQP-2018]**

Ans. The modulated signal :

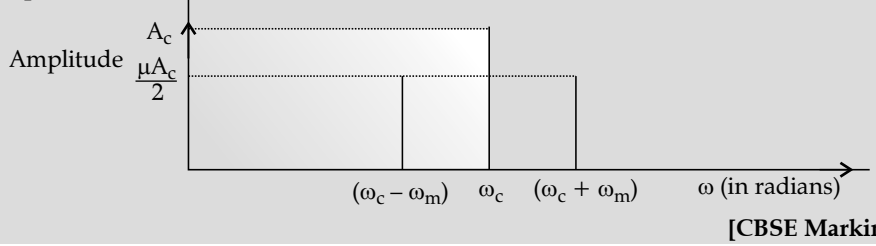
$C_m(t) = (A_c + A_m \sin \omega_m t) \sin \omega_c t$ ½

$= A_c \left(1 + \frac{A_m}{A_c} \sin \omega_m t\right) \sin \omega_c t$ ½

$C_m(t) = A_c \sin \omega_c t + \mu A_c \sin \omega_m t \sin \omega_c t$ ½

$C_m(t) = A_c \sin \omega_c t + \frac{\mu A_c}{2} \cos(\omega_c - \omega_m)t - \frac{\mu A_c}{2} \cos(\omega_c - \omega_m)t$ ½

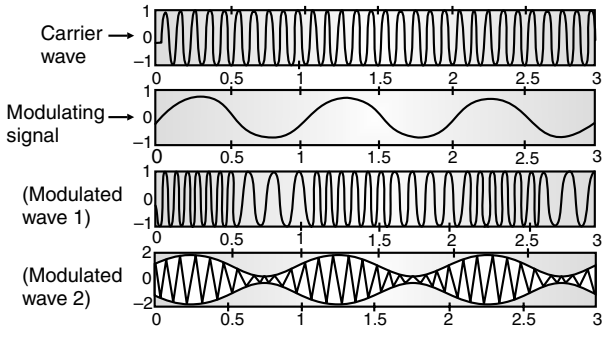
Frequency Spectrum :



[CBSE Marking Scheme, 2018]

Q. 11. What does the term 'Modulation', used in communication system, mean ?

Identify the two types of modulation shown here. Give two advantages of any one of these over the other. R



Ans. Modulation is a process in which one of the characteristics (amplitude, frequency, phase) of a high frequency carrier wave is made to change in accordance with a low frequency message signal.

1

Modulated wave 1 : Frequency Modulation ½

Modulated wave 2 : Amplitude Modulation ½

Two advantages of FM over AM :

(i) Lower noise, better power efficiency. ½

(ii) Higher operating range ½

(iii) Higher fidelity reception.

[**Alternatively,** Two advantages of AM over FM

(i) Simple circuits are required. ½

(ii) Lower frequency space for transmission. ½

Commonly Made Error

- Few students couldn't identify the "Frequency Modulation."
- Many students couldn't write the advantages of FM over AM.

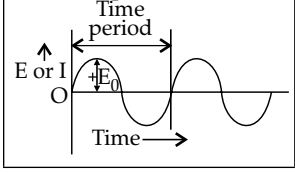
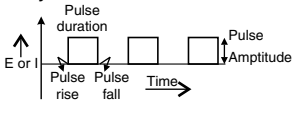
Long Answer Type Questions (5 marks each)

Q. 1. (i) Distinguish between sinusoidal and pulse-shaped signals.

(ii) Explain, showing graphically, how a sinusoidal carrier wave is superimposed on a modulating signal to obtain the resultant amplitude modulated (AM) wave.

U [O.D. Comptt. I, II, III 2012; O.D. I, II, III 2014]

Ans. (i)

Sinusoidal signal (analog signal)	Pulse signal (Digital signal)
(a) It is a continuous signal value, which at any instant lies within the range, of a maximum and minimum value.	**(a)** These signals are those which can only take discrete stepwise values such a signal is usually in form of pulses.
(b) Sine wave is a fundamental analog signal	**(b)** Each pulse have two levels of current of voltage represented by 0 and 1.
(c) It is represented as 	**(c)** It is represented graphically as 

2

(ii) Amplitude Modulation : When a wave is superimposed on a high frequency carrier wave in a manner that the frequency of modulated wave is same as that of the carrier wave, but its amplitude is made proportional to the instantaneous amplitude of the audio frequency modulating voltage, the process is called amplitude modulation (AM).

Let the instantaneous carrier voltage (e_c) and modulating voltage (e_m) be represented by

$$e_c = E_c \sin \omega_c t \quad ...(i)$$

$$e_m = E_m \sin \omega_m t \quad ...(ii)$$ **1**

Thus, in amplitude modulation, amplitude A of modulated wave is made proportional to the instantaneous modulating voltage e_m

i.e., $$A = E_c + ke_m \quad ...(iii)$$

where, k is a constant of proportionality.

In amplitude modulation, the proportionality constant k is made equal to unity. Therefore, maximum positive amplitude of AM wave is given by

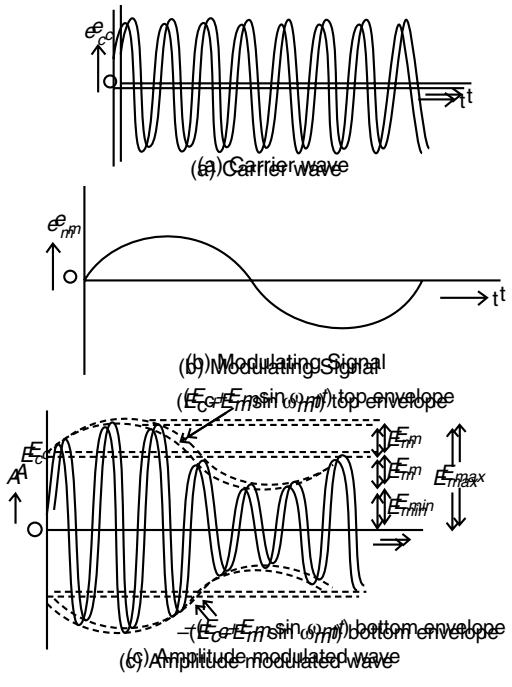
$$A = E_c + e_m = E_c + E_m \sin \omega_m t \quad ...(iv)$$

It is called top envelope.

The maximum negative amplitude of AM wave is given by

$$-A = -E_c - e_m$$
$$= -(E_c + E_m \sin \omega_m t) \quad ...(v)$$

This is called bottom envelope. **1**



1

Q. 2. (a) Describe briefly three factors which justify the need for modulation of audio frequency signals over long distances in communication. (b) Draw the waveforms of (i) carrier wave, (ii) a modulating signal and (iii) amplitude modulated wave.

[CBSE Comptt- 2018]

Ans. (a) Describing the three factor **3**

(b) Drawing the wave forms **2**

(a) It is necessary to modulate the audio frequency signals because of the following three reasons :

(i) Size of the antenna or aerial ½

This size needs to be comparable to the wavelength of the signal. it would be unmanageably large for audio frequency signals. ½

(ii) Effective power readiated ½

Power radiated, being proportional to $\left(\frac{l}{\lambda}\right)^2$

would be very small for a audio frequency signal. ½

(iii) Mixing up of different signals ½

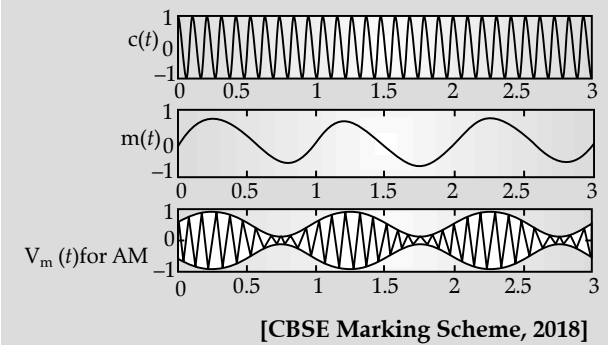
The audible frequency range is quite small. Hence if transformation is done at audio frequencies, the chances of mixing up of different signals are very high. ½

(b) The required wave forms are as shown

(i) Carrier wave

(ii) Modulating Signal

(iii) Amplitude Modulated wave



[CBSE Marking Scheme, 2018]

Detailed Answer :

(a) For a long distance Transmission of message signal we need modulation because of following reasons.

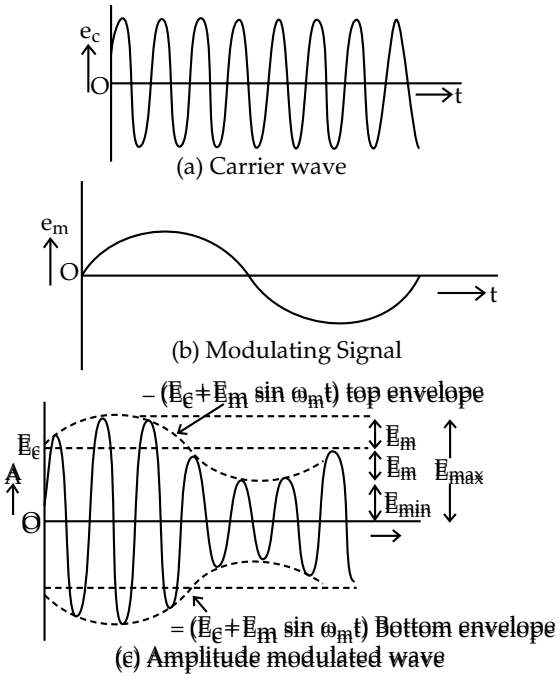
(i) Low energy: The message signals when converted to e.m. waves, do not have the sufficient energy to travel up to long distance ,because of their low frequency. Hence these message signals are modulated with high frequency carrier signals before being send because carrier signals have high energy for long distance transmission.

(ii) Size of Antenna: For the effective Transmission by an antenna ,the size of antenna should be at least of the size $\frac{\lambda}{4}$, where λ is the wavelength of signal to be send. Thus for an em wave of audio signal of frequency is 20 kHz, we need an antenna of size nearly 3.75 km, which is practically impossible. Hence, these low frequency signals first modulated to high frequency signals before transmission to get the proper size of antenna.

(iii) Mixing of signals : When number of signals are transmitted simultaneously, all these signals will get mixed up and at the end we get mixed signal, which is very difficult to separate. Therefore to remove this limitation, transmission is done at high frequency and a band of frequency is allotted to each user at the end, as done for radio and TV channels.

Q. 3. (a) Give three reasons why modulation of a message signal is necessary for long distance transmission. (b) Show graphically an audio signal, a carrier wave and an amplitude modulated wave. [CBSE SQP-2018]

Ans.



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