15

Communication System

Multiple Choice Questions (MCQs)

Q. 1 Three waves *A*, *B* and *C* of frequencies 1600 kHz, 5 MHz and 60 MHz, respectively are to be transmitted from one place to another. Which of the following is the most appropriate mode of communication?

(a) *A* is transmitted *via* space wave while *B* and *C* are transmitted *via* sky wave

(b) *A* is transmitted *via* ground wave, *B via* sky wave and *C via* space wave

(c) *B* and *C* are transmitted *via* ground wave while *A* is transmitted *via* sky wave

(d) *B* is transmitted *via* ground wave while *A* and *C* are transmitted *via* space wave

Thinking Process

Mode of communication depend on the frequencies of a wave.

Ans. ***(b)*** *Mode of communication frequency range*

Ground wave propagation – 530 kHz to 1710 kHz

Sky wave propagation –1710 kHz to 40MHz

Space wave propagation – 54MHz to 4.2GHz

Q. 2 A 100m long antenna is mounted on a 500m tall building. The complex can become a transmission tower for waves with λ

(a) ~ 400 m (b) ~ 25 m (c) ~ 150 m (d) ~ 2400 m

Ans. ***(a)*** Given, length of the building (l) is given by

$$l = 500\,\text{m}$$

we know that, wavelength of the wave which can be transmitted by

$$\lambda \sim 4l = 4 \times 100 = 400\,\text{m}$$

Q. 3 A 1 kW signal is transmitted using a communication channel which provides attenuation at the rate of – 2dB per km. If the communication channel has a total length of 5 km, the power of the signal received is

[gain in dB $= 10\log\left(\frac{P_0}{P_i}\right)$]

(a) 900 W (b) 100 W (c) 990 W (d) 1010 W

Ans. *(b)* Given, power of signal transmitted is given $P_i = 1\,\text{kW} = 1000\text{ W}$

Rate of attenuation of signal $= -2\,\text{dB/km}$

Length of total path $= 5\,\text{km}$

Thus, gain in $dB = 5 \times (-2) = -10\text{ dB}$

Also, $$\text{gain in } dB = 10 \log\left(\frac{P_0}{P_i}\right) \quad \ldots\text{(i)}$$

Here P_0 is the power of the received signal.

Putting the given values in Eq. (i),

$$-10 = 10 \log\left(\frac{P_0}{P_i}\right) = -10 \log\left(\frac{P_i}{P_0}\right)$$

$$\Rightarrow \log\frac{P_i}{P_0} = 1 \Rightarrow \log\frac{P_i}{P_0} = \log 10$$

$$\Rightarrow \frac{P_i}{P_0} = 10 \Rightarrow 1000\text{W} = 10\,P_0$$

$$\Rightarrow P_o = 100\text{ W}$$

Q. 4 A speech signal of 3 kHz is used to modulate a carrier signal of frequency 1 MHz, using amplitude modulation. The frequencies of the side bands will be

(a) 1.003 MHz and 0.997 MHz
(b) 3001 kHz and 2997 kHz
(c) 1003 kHz and 1000 kHz
(d) 1 MHz and 0.997 MHz

Thinking Process

The amplitude modulated signal consists of the carrier wave of frequency ω_c with two additional sinusoidal waves, one of frequency $(\omega_c - \omega_m)$ and other of frequency $(\omega_c + \omega_m)$. These two waves are called side bands and their frequencies are called side band frequency.

Ans. *(a)* Given, frequency of carrier signal is $\omega_c = 1\,\text{MHz}$

and frequency of speech signal $= 3\,\text{kHz}$

$= 3 \times 10^{-3}$ MHz

$= 0.003$ MHz

Now, we know that,

Frequencies of side bands $= (\omega_c \pm \omega_m)$

$= (1 \pm 0.003)$

$= 1.003$ MHz and 0.997 MHz

Q. 5 A message signal of frequency ω_m is superposed on a carrier wave of frequency ω_c to get an Amplitude Modulated Wave (AM). The frequency of the AM wave will be

(a) ω_m
(b) ω_c
(c) $\frac{\omega_c + \omega_m}{2}$
(d) $\frac{\omega_c - \omega_m}{2}$

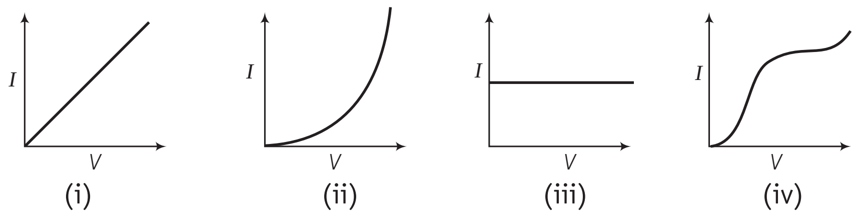
Thinking Process

In amplitude modulation, the frequency of modulated wave is equal to the frequency of carrier wave.

Ans. *(b)* Here, according to the question, frequency of carrier wave is ω_c.

Thus the amplitude modulated wave also has frequency ω_c.

Q. 6 *I-V* characteristics of four devices are shown in figure.



Identify devices that can be used for modulation

(a) (i) and (iii)
(b) only (iii)
(c) (ii) and some regions of (iv)
(d) All the devices can be used

K **Thinking Process**

A square law device is something where either current or voltage depends on the square of the other.

Ans. *(c)* The device which follows square law is used for modulation purpose. Characteristics shown by (i) and (iii) corresponds to linear devices.

Characteristics shown by (ii) corresponds to square law device. Some part of (i) also follow square law.

Hence, (ii) and (iv) can be used for modulation.

Q. 7 A male voice after modulation-transmission sounds like that of a female to the receiver. The problem is due to

(a) poor selection of modulation index (selected $0 < m < 1$)
(b) poor bandwidth selection of amplifiers
(c) poor selection of carrier frequency
(d) loss of energy in transmission.

K **Thinking Process**

The frequency of male voice less than that of a female voice.

Ans. *(b)* Here, in this question, the frequency of modulated signal received becomes more, which is possible with the poor bandwidth selection of amplifiers.

This happens because bandwidth in amplitude modulation is equal to twice the frequency of modulating signal.

But, the frequency of male voice is less than that of a female.

Q. 8 A basic communication system consists of

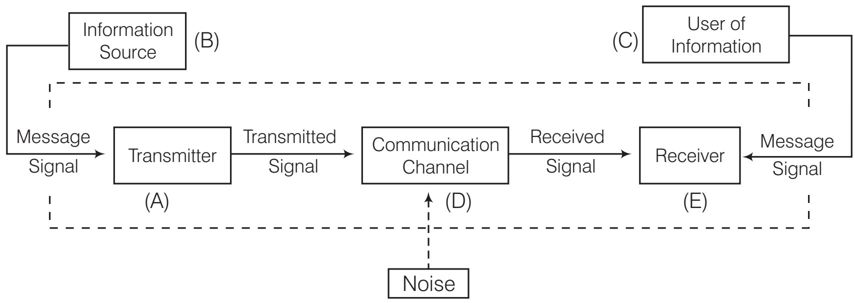
A. transmitter.
B. information source.
C. user of information.
D. channel.
E. receiver.

Choose the correct sequence in which these are arranged in a basic communication system.

(a) ABCDE
(b) BADEC
(c) BDACE
(d) BEADC

Ans. *(b)* A communication system is the set-up used in the transmission and reception of information from one place to another.

The whole system consist of several elements in a sequence. *It can be represented as the diagram given below*



Q. 9 Identify the mathematical expression for amplitude modulated wave

(a) $A_c \sin[\{\omega_c + k_1 V_m(t)\}t + \phi]$ (b) $A_c \sin\{\omega_c t + \phi + k_2 V_m(t)\}$

(c) $\{A_c + k_2 V_m(t)\} \sin(\omega_c t + \phi)$ (d) $A_c V_m(t) \sin(\omega_c t + \phi)$

K **Thinking Process**

An arbitrary change in phase angle of the modulating signal is given by ϕ.

Ans. ***(c)*** Consider a sinusoidal modulating signal represented by

$$m(t) = A_m \sin\omega_m t \qquad \ldots(i)$$

where, A_m = Amplitude of modulating signal ω_m = Angular frequency = $2\pi V_m = \phi V_m$

Also consider a sinusoidal carrier wave represented by $C(t) = A_c \sin\omega_c t$ ...(ii)

Thus, modulated wave is given by

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

$$= A_c[1 + \frac{A_m}{A_c}\sin\omega_m t)\sin\omega_c t$$

Here, $\frac{A_m}{A_c} = M$

$\Rightarrow$ $C_m(t) = (A_c + A_c \times \mu \sin\omega_m t)\sin\omega_c t$ ...(iii)

Now, we know that $A_c \times \mu = K$ [wave constant]

and $\sin\omega_m t = V_m$ [wave velocity]

Thus, Eq. (iii) becomes

$$C_m(t) = (A_c + K \times V_m)\sin\omega_c t$$

Now, consider a change in phase angle by ϕ then $\sin\omega_c t \rightarrow \sin(\omega_c t + \phi)$

Thus, $C_m(t) = (A_c + KV_m)(\sin\omega_c + \phi)$

Multiple Choice Questions (More Than One Options)

Q. 10 An audio signal of 15 kHz frequency cannot be transmitted over long distances without modulation, because

(a) the size of the required antenna would be at least 5 km which is not convenient

(b) the audio signal can not be transmitted through sky waves

(c) the size of the required antenna would be at least 20 km, which is not convenient

(d) effective power transmitted would be very low, if the size of the antenna is less than 5 km

K **Thinking Process**

Transmission of a signal depends on three factors. These are size of antenna, medium of transmission and power of transmitted wave.

Ans. ***(a, b, d)***

Given, frequency of the wave to be transmitted is

$$\nu_m = 15\,\text{kHz} = 15 \times 10^3\ \text{Hz}$$

$$\text{Wavelength } \lambda_m = \frac{c}{\nu_m} = \frac{3 \times 10^8}{15 \times 10^3} = \frac{1}{5} \times 10^5\text{m}$$

Size of the antenna required,

$$l = \frac{\lambda}{4} = \frac{1}{4} \times \left(\frac{1}{5} \times 10^5\right)$$

$$= 5 \times 10^3\text{m} = 5\text{km}$$

The audio signals are of low frequency waves. Thus, they cannot be transmitted through sky waves as they are absorbed by atmosphere.

If the size of the antenna is less than 5 km, the effective power transmission would be very low because of deviation from resonance wavelength of wave and antenna length.

Q. 11 Audio sine waves of 3 kHz frequency are used to amplitude modulate a carrier signal of 1.5 MHz. Which of the following statements are true?

(a) The side band frequencies are 1506 kHz and 1494 kHz

(b) The bandwidth required for amplitude modulation is 6kHz

(c) The bandwidth required for amplitude modulation is 3 MHz

(d) The side band frequencies are 1503 kHz and 1497 kHz

K **Thinking Process**

Here, in this question, options are giving the value of side band frequencies and band width of amplitude modulation. So, first of all find this quantities.

Ans. ***(b, d)***

Given,

$$\omega_m = 3\,\text{kHz}$$

$$\omega_c = 1.5\,\text{MHz} = 1500\,\text{kHz}$$

Now, side band frequencies

$$\omega_c \pm \omega_m = (1500 \pm 3)$$

$$= 1503\,\text{kHz and } 1497\,\text{kHz}$$

Also, bandwidth $= 2\omega_m = 2 \times 3 = 6\,\text{kHz}$

Q. 12 A TV transmission tower has a height of 240 m. Signals broadcast from this tower will be received by LOS communication at a distance of (assume the radius of earth to be $(6.4 \times 10^6$ m)

(a) 100 km (b) 24 km (c) 55 km (d) 50 km

K **Thinking Process**

Range $d_T = \sqrt{2Rh_T}$

Ans. ***(b,c,d)***

Given, height of tower $h = 240$ m

For LOS (line of sight) communication.

The maximum distance on earth from the transmitter upto which a signal can be received is given by

$$d = \sqrt{2Rh} \quad \text{...(i)}$$

Here R is the radius of the earth *i.e.,* $R = 6.4 \times 10^6$ m

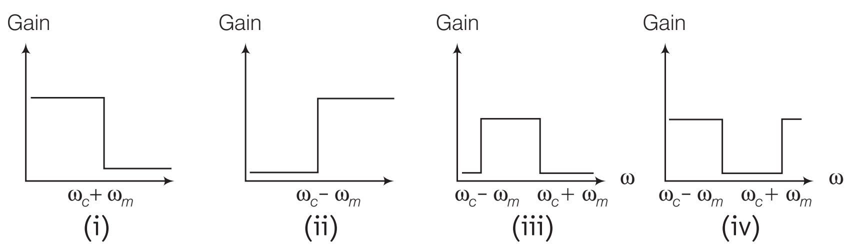
Putting all these values in Eq. (i),

we get $d = \sqrt{2Rh} = \sqrt{2 \times 6.4 \times 10^6 \times 240}$

$= 55.4 \times 10^3 \text{m} = 55.4$ km

Thus, the range of 55.4 km covers the distance 24 km, 55 km and 50 km.

Q. 13 The frequency response curve (figure) for the filter circuit used for production of AM wave should be



(a) (i) followed by (ii) (b) (ii) followed by (i)

(c) (iii) (d) (iv)

Ans. ***(a, b, c)***

Here, for the production of amplitude modulated wave, bandwidth is given by = frequency of upper side band – frequency of lower side band

$$= \omega_{USB} - \omega_{LSB} = (\omega_c + \omega_m) - (\omega_c - \omega_m)$$

Q. 14 In amplitude modulation, the modulation index m, is kept less than or equal to 1 because

(a) $m > 1$, will result in interference between carrier frequency and message frequency, resulting into distortion

(b) $m > 1$, will result in overlapping of both side bands resulting into loss of information

(c) $m > 1$, will result in change in phase between carrier signal and message signal

(d) $m > 1$, indicates amplitude of message signal greater than amplitude of carrier signal resulting into distortion

Ans. ***(b, d)***

The modulation index (m) of amplitude modulated wave is

$$m = \frac{\text{amplitude of message signal } (A_m)}{\text{amplitude of carrier signal } (A_c)}$$

If $m > 1$, then $A_m > A_c$.

In this situation, there will be distortion of the resulting signal of amplitude modulated wave.

Maximum modulation frequency (m_f) of A_m wave is

$$m_f = \frac{\Delta\nu_{\text{max}}}{\nu_m(\text{max})}$$

$$= \frac{\text{frequency deviation}}{\text{maximum frequency value of modulating wave}}$$

If $m_f > 1$, then $\Delta\nu_{\text{max}} > \nu_m$. It means, there will be overlapping of both side bands of modulated wave resulting into loss of information.

Very Short Answer Type Questions

Q. 15 Which of the following would produce analog signals and which would produce digital signals?

(a) A vibrating tuning fork

(b) Musical sound due to a vibrating sitar string

(c) Light pulse

(d) Output of NAND gate

Ans. Analog and digital signals are used to transmit information, usually through electric signals. In both these technologies, the information such as any audio or video is transformed into electric signals.

The difference between analog and digital technologies is that in analog technology, information is translated into electric pulses of varying amplitude. In digital technology, translation of information is into binary formal (zero or one) where each bit is representative of two distinct amplitudes.

Thus, (a) and (b) would produce analog signal and (c) and (d) would produce digital signals.

Q. 16 Would sky waves be suitable for transmission of TV signals of 60 MHz frequency?

Ans. A signal to be transmitted through sky waves must have a frequency range of 1710 kHz to 40 MHz.

But, here the frequency of TV signals are 60 MHz which is beyond the required range.

So, sky waves will not be suitable for transmission of TV signals of 60 MHz frequency.

Q. 17 **Two waves A and B of frequencies 2MHz and 3MHz, respectively are beamed in the same direction for communication *via* sky wave. Which one of these is likely to travel longer distance in the ionosphere before suffering total internal reflection?**

Ans. As the frequency of wave B is more than wave A, it means the refractive index of wave B is more than refractive index of wave A (as refractive index increases with frequency increases).

For higher frequency wave (*i.e.,* higher refractive index) the angle of refraction is less *i.e.,* bending is less. So, wave B travel longer distance in the ionosphere before suffering total internal reflection.

Q. 18 **The maximum amplitude of an AM wave is found to be 15 V while its minimum amplitude is found to be 3 V. What is the modulation index?**

Ans. Let A_c and A_m be the amplitudes of carrier wave and modulating wave respectively. So,

$$\text{Maximum amplitude} \longrightarrow A_{\max} = A_c + A_m = 15\text{ V} \quad \text{...(i)}$$

$$\text{Minimum amplitude} \longrightarrow A_{\min} = A_c - A_m = 3\text{ V} \quad \text{...(ii)}$$

Adding Eqs. (i) and (ii), we get

$$2A_c = 18$$

or $$A_c = 9\text{ V}$$

and $$A_m = 15 - 9 = 6\text{ V}$$

$$\text{Modulating index of wave } \mu = \frac{A_m}{A_c} = \frac{6}{9} = \frac{2}{3}$$

Q. 19 **Compute the LC product of a tuned amplifier circuit required to generate a carrier wave of 1 MHz for amplitude modulation.**

K **Thinking Process**

For tuned amplifier $f = \frac{1}{2\pi\sqrt{LC}}$

Ans. Given, the frequency of carrier wave is 1 MHz.
Formula for the frequency of tuned amplifier,

$$\frac{1}{2\pi\sqrt{LC}} = 1\text{MHz}$$

$$\sqrt{LC} = \frac{1}{2\pi \times 10^6}$$

$$LC = \frac{1}{(2\pi \times 10^6)^2} = 2.54 \times 10^{-14}\text{ s}$$

Thus, the product of LC is 2.54×10^{-14} s.

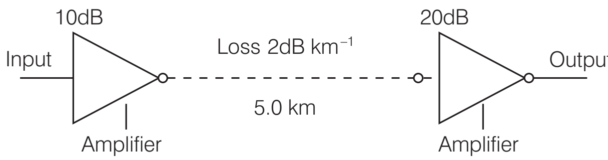
Q. 20 **Why is a AM signal likely to be more noisy than a FM signal upon transmission through a channel?**

Ans. In case of AM, the instantaneous voltage of carrier waves is varied by the modulating wave voltage. So, during the transmission, nosie signals can also be added and receiver assumes noise a part of the modulating signal.

In case of FM, the frequency of carrier waves is changed as the change in the instantaneous voltage of modulating waves. This can be done by mixing and not while the signal is transmitting in channel. So, noise does not affect FM signal.

Short Answer Type Questions

Q. 21 Figure shows a communication system. What is the output power when input signal is of 1.01 mW? [gain in dB = 10 $\log_{10}(P_0 / P_i)$]



Ans. The distance travelled by the signal is 5 km

Loss suffered in path of transmission = 2 dB/km

So, total loss suffered in 5 km = – 2 × 5 = – 10 dB

Total amplifier gain = 10 dB + 20 dB = 30 dB

Overall gain in signal = 30 – 10 = 20 dB

According to the question, gain in dB = $10 \log_{10} \frac{P_0}{P_i}$

$\therefore \quad 20 = 10 \log_{10} \frac{P_0}{P_i}$

or $\quad \log_{10} \frac{P_0}{P_i} = 2$

Here, P_i = 1.01 mW and P_0 is the output power.

$\therefore \quad \frac{P_0}{P_i} = 10^2 = 100$

$\Rightarrow \quad P_0 = P_i \times 100 = 1.01 \times 100$

or $\quad P_0 = 101 \text{mW}$

Thus, the output power is 101 mW.

Q. 22 A TV transmission tower antenna is at a height of 20 m. How much service area can it cover if the receiving antenna is (i) at ground level, (ii) at a height of 25 m? Calculate the percentage increase in area covered in case (ii) relative to case (i).

Ans. Given, height of antenna $h = 20$ m

Radius of earth = 6.4×10^6 m

At the ground level,

(i) Range = $\sqrt{2hR} = \sqrt{2 \times 20 \times 6.4 \times 10^6}$

$= 16000 \text{ m} = 16 \text{ km}$

Area covered $A = \pi (\text{range})^2$

$= 3.14 \times 16 \times 16 = 803.84 \text{ km}^2$

(ii) At a height of $H = 25$ m from ground level

Range = $\sqrt{2hR} + \sqrt{2HR}$

$= \sqrt{2 \times 20 \times 6.4 \times 10^6} + \sqrt{2 \times 25 \times 6.4 \times 10^6}$

$= 16 \times 10^3 + 17.9 \times 10^3$

$= 33.9 \times 10^3$ m

$= 33.9$ km

$$\text{Area covered} = \pi\,(\text{Range})^2$$
$$= 3.14 \times 33.9 \times 33.9$$
$$= 3608.52\ \text{km}^2$$
$$\text{Percentage increase in area} = \frac{\text{Difference in area}}{\text{Initial area}} \times 100$$
$$= \frac{(3608.52 - 803.84)}{803.84} \times 100$$
$$= 348.9\%$$

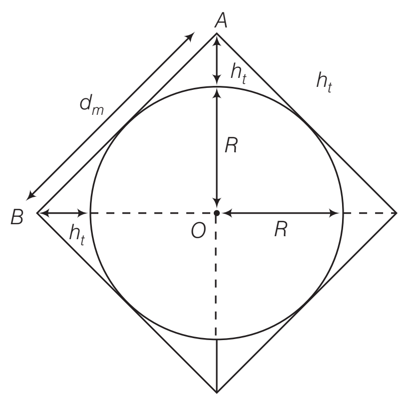
Thus, the percentage increase in area covered is 348.9%

Q. 23 **If the whole earth is to be connected by LOS communication using space waves (no restriction of antenna size or tower height), what is the minimum number of antennas required? Calculate the tower height of these antennas in terms of earth's radius.**

K **Thinking Process**

Range $d_T = \sqrt{2Rht}$

Ans. *Consider the figure given below to solve this question*



Suppose the height of transmitting antenna or receiving antenna in order to cover the entire surface of earth through communication is h_t and radius of earth is R

Then, maximum distance

$$d_m^2 = (R + h_t)^2 + (R + h_t)^2$$
$$= 2\,(R + h_t)^2$$
$$d_m = \sqrt{2h_t R} + \sqrt{2h_t R} = 2\sqrt{2h_t R}$$

$\therefore$ $$8h_t R = 2(R + h_t)^2$$

$\Rightarrow$ $$4h_t R = R^2 + 2Rh_t + h_t^2$$

$\Rightarrow$ $$R^2 - 2h_t R + h_t^2 = 0$$

$\Rightarrow$ $$(R - h_t)^2 = 0$$

$\Rightarrow$ $$R = h_t$$

Since, space wave frequency is used so $\lambda << h_t$,hence only tower height is to be taken into consideration. In three dimensions of earth, 6 antenna towers of each of height $h_t = R$ would be used to cover the entire surface of earth with communication programme.

Q. 24 The maximum frequency for reflection of sky waves from a certain layer of the ionosphere is found to be $f_{max} = 9\,(N_{max})^{1/2}$, where N_{max} is the maximum electron density at that layer of the ionosphere.

On a certain day it is observed that signals of frequencies higher than 5 MHz are not received by reflection from the F_1 layer of the ionosphere while signals of frequencies higher than 8 MHz are not received by reflection from the F_2 layer of the ionosphere. Estimate the maximum electron densities of the F_1 and F_2 layers on that day.

Ans. The maximum frequency for reflection of sky waves

$$f_{max} = 9\,(N_{max})^{1/2}$$

where, N_{max} is a maximum electron density.

For F_1 **layer,** $f_{max} = 5\,\text{MHz}$

So, $5 \times 10^6 = 9\,(N_{max})^{1/2}$

Maximum electron density

$$N_{max} = \left(\frac{5}{9} \times 10^6\right)^2 = 3.086 \times 10^{11}/\text{m}^3$$

For F_2 **layer,** $f_{max} = 8\,\text{MHz}$

So, $8 \times 10^6 = 9\,(N_{max})^{1/2}$

Maximum electron density

$$N_{max} = \left(\frac{8 \times 10^6}{9}\right)^2 = 7.9 \times 10^{11}/\,\text{m}^3$$

Q. 25 On radiating (sending out) and AM modulated signal, the total radiated power is due to energy carried by ω_c, $\omega_c - \omega_m$ and $\omega_c + \omega_m$. Suggest ways to minimise cost of radiation without compromising on information.

Ans. In amplitude modulated signal, only side band frequencies contain information. Thus only $(\omega_c + \omega_m)$ and $(\omega_c - \omega_m)$ contain information.

Now, according to question, the total radiated power is due to energy carried by

$$\omega_c,\ (\omega_c - \omega_m) \text{ and } (\omega_c + \omega_m).$$

Thus to minimise the cost of radiation without compromising on information ω_c can be left and transmitting. $(\omega_c + \omega_m)$, $(\omega_c - \omega_m)$ or both $(\omega_c + \omega_m)$ and $(\omega_c - \omega_m)$.

Long Answer Type Questions

Q. 26 The intensity of a light pulse travelling along a communication channel decreases exponentially with distance x according to the relation $I = I_0 e^{-\alpha x}$, where I_0 is the intensity at $x = 0$ and α is the attenuation constant.

(a) Show that the intensity reduces by 75 % after a distance of $\left(\frac{\ln 4}{\alpha}\right)$.

(b) Attenuation of a signal can be expressed in decibel (dB) according to the relation $\text{dB} = 10 \log_{10}\left(\frac{I}{I_0}\right)$. What is the attenuation in dB/km for an optical fibre in which the intensity falls by 50 % over a distance of 50 km?

Ans. (a) Given, the intensity of a light pulse $I = I_0 e^{-\alpha x}$

where, I_0 is the intensity at $x = 0$ and α is constant.

According to the question, $I = 25\%$ of $I_0 = \frac{25}{100} \cdot I_0 = \frac{I_0}{4}$

Using the formula mentioned in the question,

$$I = I_0 e^{-\alpha x}$$

$$\frac{I_0}{4} = I_0 e^{-\alpha x}$$

or $$\frac{1}{4} = e^{-\alpha x}$$

Taking log on both sides, we get

$$\ln 1 - \ln 4 = -\alpha x \ln e \qquad (\because \ln e = 1)$$

$$-\ln 4 = -\alpha x$$

$$x = \frac{\ln 4}{\alpha}$$

Therefore, at distance $x = \frac{\ln 4}{\alpha}$, the intensity is reduced to 75% of initial intensity.

(b) Let α be the attenuation in dB/km. If x is the distance travelled by signal, then

$$10 \log_{10}\left(\frac{I}{I_0}\right) = -\alpha x \qquad \ldots\text{(i)}$$

where, I_0 is the intensity initially.

According to the question, $I = 50\%$ of $I_0 = \frac{I_0}{2}$ and $x = 50$ km

Putting the value of x in Eq. (i), we get

$$10 \log_{10} \frac{I_0}{2I_0} = -\alpha \times 50$$

$$10 [\log 1 - \log 2] = -50\alpha$$

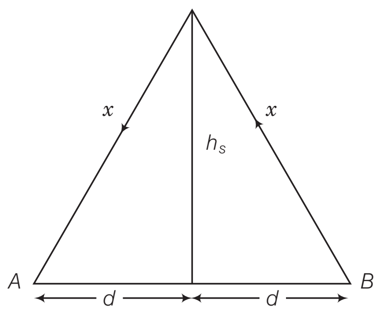
$$\frac{10 \times 0.3010}{50} = \alpha$$

$\therefore$ The attenuation for an optical fibre

$$\alpha = 0.0602 \text{ dB/km}$$

Q. 27 A 50 MHz sky wave takes 4.04 ms to reach a receiver *via* re-transmission from a satellite 600 km above Earth's surface. Assuming re-transmission time by satellite negligible, find the distance between source and receiver. If communication between the two was to be done by Line of Sight (LOS) method, what should size and placement of receiving and transmitting antenna be?

Ans. Let the receiver is at point *A* and source is at *B*.



Velocity of waves $= 3 \times 10^8$ m/s

Time to reach a receiver $= 4.04$ ms $= 4.04 \times 10^{-3}$ s

Let the height of satellite is $h_s = 600$ km

Radius of earth $= 6400$ km

Size of transmitting antenna $= h_T$

We know that $\dfrac{\text{Distance travelled by wave}}{\text{Time}} = \text{Velocity of waves}$

$$\frac{2x}{4.04 \times 10^{-3}} = 3 \times 10^8$$

or $$x = \frac{3 \times 10^8 \times 4.04 \times 10^{-3}}{2}$$

$$= 6.06 \times 10^5 = 606 \text{ km}$$

Using Phythagoras theorem,

$$d^2 = x^2 - h_s^2 = (606)^2 - (600)^2 = 7236$$

or $$d = 85.06 \text{ km}$$

So, the distance between source and receiver $= 2d$

$$= 2 \times 85.06 = 170 \text{ km}$$

The maximum distance covered on ground from the transmitter by emitted EM waves

$$d = \sqrt{2Rh_T}$$

or $$\frac{d^2}{2R} = h_T$$

or size of antenna $$h_T = \frac{7236}{2 \times 6400}$$

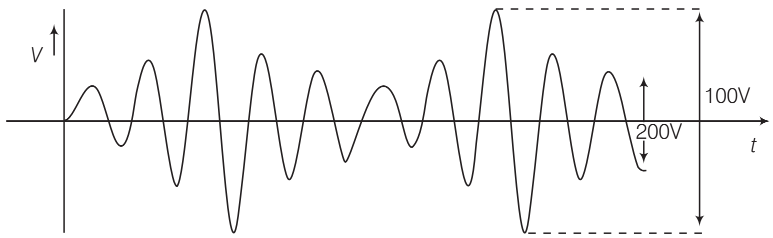
$$= 0.565 \text{ km} = 565 \text{ m}$$

Q. 28 An amplitude modulated wave is as shown in figure. Calculate

(i) the percentage modulation,

(ii) peak carrier voltage and

(iii) peak value of information voltage



Ans. From the diagram,

$$\text{Maximum voltage } V_{max} = \frac{100}{2} = 50\,V$$

$$\text{Minimum voltage } V_{min} = \frac{20}{2} = 10\,V$$

(i) Percentage modulation, $\mu = \dfrac{V_{max} - V_{min}}{V_{max} + V_{min}} \times 100 = \dfrac{50 - 10}{50 + 10} \times 100$

$$= \frac{40}{60} \times 100 = 66.67\%$$

(ii) Peak carrier voltage, $V_c = \dfrac{V_{max} + V_{min}}{2} = \dfrac{50 + 10}{2} = 30\,V$

(iii) Peak value of information voltage,

$$V_m = \mu V_c = \frac{66.67}{100} \times 30 = 20V$$

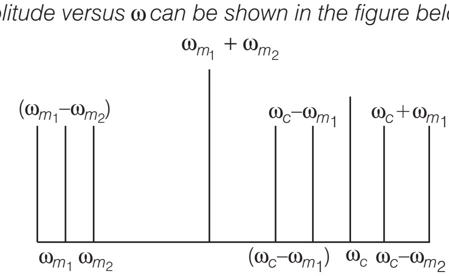
Q. 29 (i) Draw the plot of amplitude *versus* ω for an amplitude modulated were whose carrier wave (ω_c) is carrying two modulating signals, ω_1 and ω_2 $(\omega_2 > \omega_1)$.

(ii) Is the plot symmetrical about ω_c? Comment especially about plot in region $\omega < \omega_c$.

(iii) Extrapolate and predict the problems one can expect if more waves are to be modulated.

(iv) Suggest solutions to the above problem. In the process can one understand another advantage of modulation in terms of bandwidth?

Ans. **(i)** *The plot of amplitude versus ω can be shown in the figure below*



(ii) From figure, we note that frequency spectrum is not symmetrical about ω_c. Crowding of spectrum is present for $\omega < \omega_c$.

(iii) If more waves are to be modulated then there will be more crowding in the modulating signal in the region $\omega < \omega_c$. That will result more chances of mixing of signals.

(iv) To accommodate more signals, we should increase bandwidth and frequency carrier waves ω_c. This shows that large carrier frequency enables to carry more information (*i.e.,* more ω_m) and the same will in turn increase bandwidth.

Q. 30 An audio signal is modulated by a carrier wave of 20 MHz such that the bandwidth required for modulation is 3kHz. Could this wave be demodulated by a diode detector which has the values of R and C as

(i) $R = 1\ k\Omega,\ C = 0.01\mu F$.

(ii) $R = 10\ k\Omega,\ C = 0.01\mu F$.

(iii) $R = 10\ k\Omega,\ C = 0.1\mu F$.

Ans. Given, carrier wave frequency $f_c = 20\ \text{MHz}$
$= 20 \times 10^6\ \text{Hz}$

Bandwidth required for modulation is

$$2f_m = 3\text{kHz} = 3 \times 10^3 \text{Hz}$$

$$\Rightarrow \quad f_m = \frac{3 \times 10^3}{2} = 1.5 \times 10^3\ \text{Hz}$$

Demodulation by a diode is possible if the condition $\frac{1}{f_c} << RC < \frac{1}{f_m}$ is satisfied

Thus, $$\frac{1}{f_c} = \frac{1}{20 \times 10^6} = 0.5 \times 10^{-7} \quad \text{..(i)}$$

and $$\frac{1}{f_m} = \frac{1}{1.5 \times 10^3}\text{Hz} = 0.7 \times 10^{-3}\ \text{s} \quad \text{....(ii)}$$

Now, gain through all the options of R and C one by one, we get

(i) $RC = 1\ k\,\Omega \times 0.01\,\mu F = 10^3\,\Omega \times (0.01 \times 10^{-6} F) = 10^{-5}\ s$

Here, condition $\frac{1}{f_c} << RC < \frac{1}{f_m}$ is satisfied.

Hence it can be demodulated.

(ii) $RC = 10\ k\,\Omega \times 0.01\,\mu F = 10^4\,\Omega \times 10^{-8} F = 10^{-4}\ s$

Here condition $\frac{1}{f_c} << RC < \frac{1}{f_m}$ is satisfied.

Hence, it can be demodulated.

(iii) $RC = 10\ k\,\Omega \times 1\mu\mu F = 10^4\ \Omega \times 10^{-12} F = 10^{-8}\ s$

Here, condition $\frac{1}{f_c} > RC$, so this cannot be demodulated.