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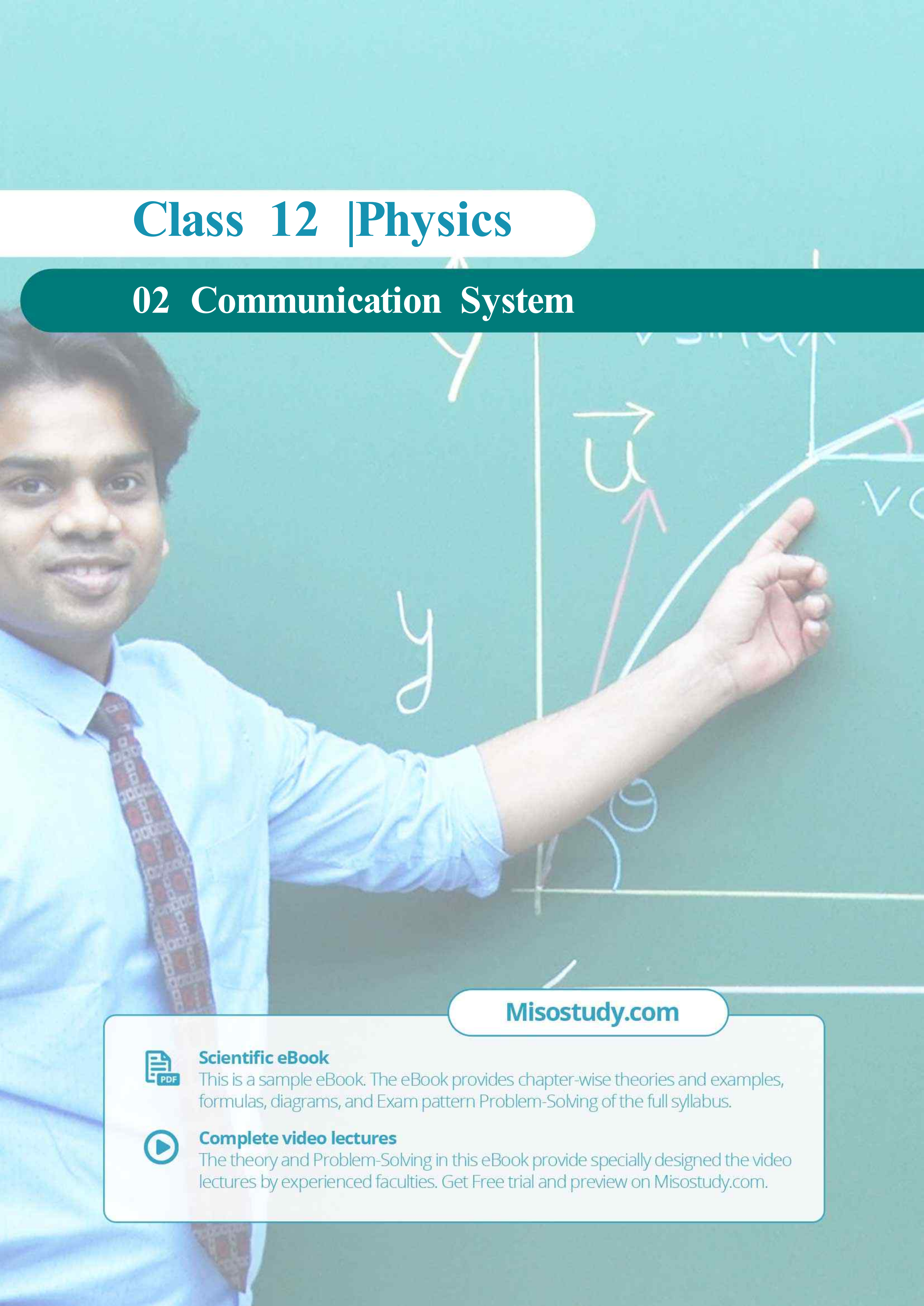


Class 12 |Physics

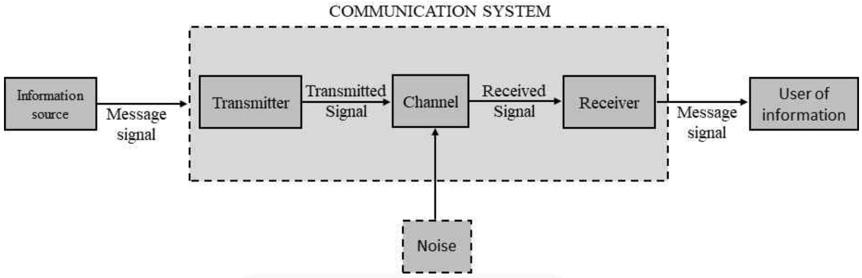
02 Communication System

01. Introduction

The act of transmission and reception of information is known as communication.

02. Elements of a Communication System

Every communication system has three essential elements, transmitter, medium and receiver.



There are two basic modes of communication: point-to-point and broadcast.

03 Basic Terminology of Communication Systems

(i) **Transducer :** Device that converts one from of energy into another.

(ii) **Signal:** Information converted in electrical from and suitable for transmission. Signals can be either *analog or digital*.

(iii) **Noise:** The unwanted singles that tend to disturb the transmission and processing of message signals

(iv) **Transmitter:** Processes the incoming message signal so as to make it suitable for transmission through a channel and subsequent reception

(v) **Receiver:** Extracts the desired message signals from the receive signals at the channel output.

(vi) **Attenuation:** It is the loss of strength a signal while propagating through a medium.

(vii) **Amplification:** The process of increasing the amplitude of a signal using an electronic circuit called the amplifier.

(viii) **Range :** Largest distance between a source and a destination up to which the signal is received with sufficient strength

(ix) **Bandwidth:** Frequency range over which an equipment operates or the portion of the spectrum occupied by the signal.

(x) **Modulation:** Original low frequency message/information signal cannot be transmitted to long distances because of obvious reasons. Therefore, at the transmitter, information contained in the low frequency message signal is superimposed on a high frequency wave, which acts as a carrier of the information

(xi) **Demodulation:** The process of extraction of information from the carrier wave at the receiver

(xii) **Repeater:** A combination of receiver and a transmitter. Communication satellite is essentially a repeater station ins space.

NOTE ☞ Undesirable effects in the course of signal transmission are
(i) **Attenuation :** decrease in signal strength due to energy loss.
(ii) **Distortion :** waveform perturbation
(iii) **Interference :** contamination by extraneous signals.
(iv) **Noise :** due to random electrical signal

03. Types of Transmission Media

Broadly, transmission media have been divided into two types

(i) **Guided transmission medium:** That communication medium of channel which is used in point to point communication between a single transmitter and receiver.

(ii) **Unguided transmission medium:** communication medium which is used, where there is no point to point contact between the transmitter and receiver.

Characteristics and quality of transmission medium depends upon

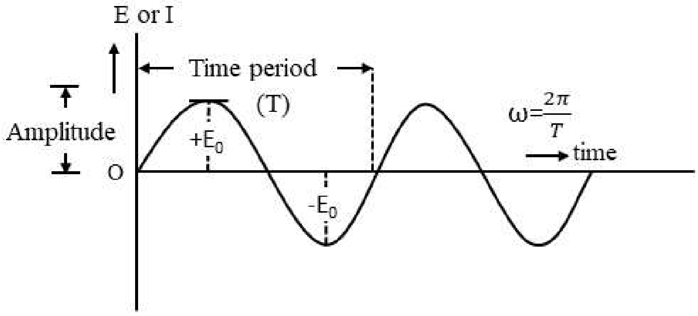
(i) Nature of transmission medium

(ii) Nature of signal

The electrical signals are of two types:

(i) **Analog signals:** An analog signal is that in which current or voltage value varies continuously with time

$$\boxed{E = E_0 \sin(\omega t + \phi)}$$



Examples of Analog signals are speech, music, sound produced by a vibrating tuning fork.

(ii) **Digital signals:** A digital signal is discontinuous function of time, in contrast to an analog signal, wherein current or voltage value varies continuously with time.

Examples of Digital signals are (i) letters printed in a book (ii) listing of any data (iii) output of a digital computer (iv) electronic transmission of document at a distant place via telephone

04. Propagation of Electromagnetic Waves

An antenna at the transmitter in communication using radio waves, radiates the electromagnetic waves which travel through space and reach the receiving antenna at the other end.

05. Ground Wave

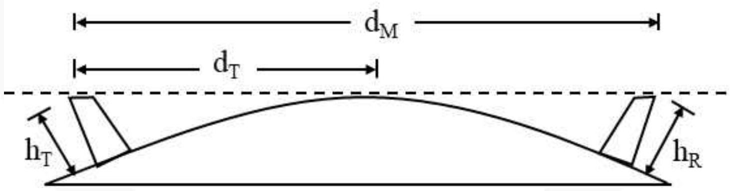
The antennas should have a size comparable to wavelength of signal. At longer wavelengths the antennas have large physical size and they are located on or very near to the ground.

06. Sky Waves

Long distance communication can be achieved by ionospheric reflection of radio waves back towards the earth. The phenomenon of bending of em waves so that they are diverted towards the earth is similar to total internal reflection.

07. Space wave

A space wave travels n a straight line from transmitting antenna to the receiving antenna. Space waves are used for line-of-sight (LOS) communication as well as satellite communication.



Where R is the radius of the earth

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

where h_R is the height of receiving antenna.

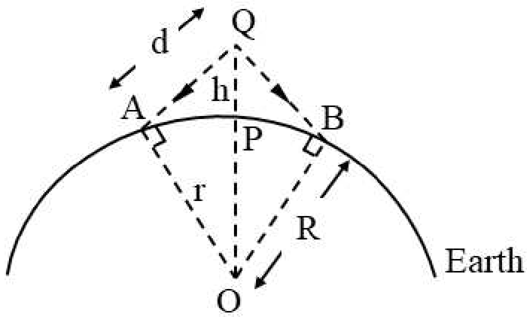
08. Determination of range

The range is determined by the height of transmitting antenna. The range *AP* or *PB* can be easily calculated by geometrical consideration. Suppose height of the tower is h and the radius of earth is r (that is OA = OB = OP = r). in the right-angled triangle OQA, we have

$$OQ^2 = QA^2 + OA^2$$
$$\because QA \simeq AP = d$$

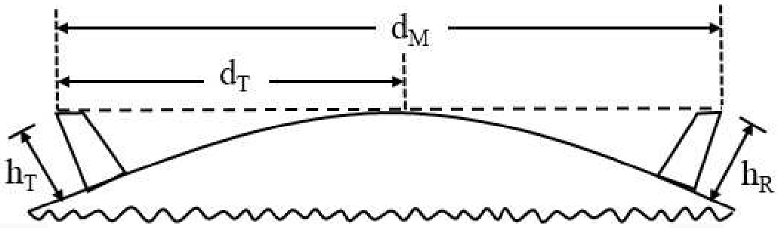
Therefore

$$(R+h)^2 = R^2+d^2$$
$$R^2+h^2+2Rh = R^2+d^2$$
$$\because\ R^2 >> h^2$$
$$\therefore\ d^2 = 2Rh$$
$$d = \sqrt{2Rh}$$



For a height of 500 m, d = 80 km

Hence maximum line-of-sight distance between two antennas will be calculated as follows



$$d_M = \sqrt{2R.h_T} + \sqrt{2R.h_R}$$

Where d_M : Maximum line-of-sight distance between two antennas

d_T : Radio horizon of transmitting antenna

h_T : Height of transmitting antenna

h_R : Height of receiving antennas

09. Modulation And its Necessity

Size of the antenna or aerial : An antenna or aerial is needed, both for transmission and reception. Each antenna should have a size comparable to the wavelength of the signals, (at least $\lambda/4$ in size) so that time variation of the signal is properly sensed by the antenna.

Effective power radiated by antenna : Theoretical studies reveal that power P radiated from a linear.

antenna of length l is proportional $(l/\lambda)^2, i.e., P \propto \left(\frac{1}{\lambda}\right)^2$

Modulation is the phenomenon of superimposing the low audio frequency baseband message or information signals (called the modulation signals) on a high frequency wave (called, the carrier wave). The resultant wave is called the modulated wave, which is transmitted.

10. Amplitude Modulation

The amplitude modulation is produced by varying the amplitude of the carrier waves in accordance with the amplitude of the modulating wave (audio signal). Let the instantaneous values of the voltage of the carrier waves and the modulating signal be represented by

$$e_c = E_c \sin \omega_c t \qquad \text{...(i)}$$

and $$e_m = E_m \sin \omega_m t \qquad \text{...(ii)}$$

respectively. Here, $\omega_c = 2\pi f_c$ and $\omega_m = 2\pi f_m$ are the angular frequencies of the carrier waves and the modulating signal respectively.

The instantaneous voltage of the modulated signal is given by

$$e = (E_c + E_m \sin \omega_m t) \sin \omega_c t$$

or $$e = E_c\left(1 + \frac{E_m}{E_c} \sin \omega_m t\right) \sin \omega_c t \qquad \text{...(iii)}$$

In amplitude modulation, the degree of modulation is defined by a term called ***modulation index***, which is given by

$$m_a = \frac{E_m}{E_c} \qquad \text{...(iv)}$$

The modulation index is also called ***modulation factor*** or ***depth of modulation***.

Therefore, the equation (iii) becomes

$$e = E_c(1 + m_a \sin \omega_m t) \sin \omega_c t$$

or $$e = (E_c + m_a E_c \sin \omega_m t) \sin \omega_c t \qquad \text{...(v)}$$

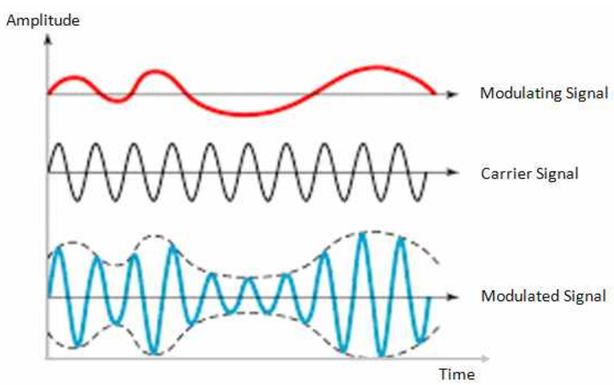
or $$e = E \sin \omega_c t\,,$$

where $$E = E_c + m_a E_c \sin \omega_m t \qquad \text{...(vi)}$$

represents the amplitude of the modulated signal. It follows that the amplitude of the modulated signal varies with time in accordance with the amplitude of the modulating signal, Fig. gives the sketch of amplitude modulated signal with time. The amplitude of the modulated signal varies between $E_{\min}(= E_c - E_m)$ and $E_{\max}(= E_c + E_m)$. It can be easily proved that

$$m_a = \frac{E_{\max} - E_{\min}}{E_{\max} + E_{\min}} \qquad \text{...(vii)}$$

It follows that the expression for instantaneous value of the voltage of the modulated signal consists of three terms. The first term represents a wave form of carrier frequency ω_c and the second term of frequency $\omega_c - \omega_m$ (slightly less than ω_c), known as ***lower sideband***. The third term represents a wave form of frequency $\omega_c + \omega_m$ (slightly greater than ω_c), called the ***upper sideband***.



Bandwidth :

The modulated signal lies in the frequency range from $\omega_c - \omega_m$ to $\omega_c + \omega_m$ *i.e.* $2\omega_m$. It is called the bandwidth of the modulated signal.

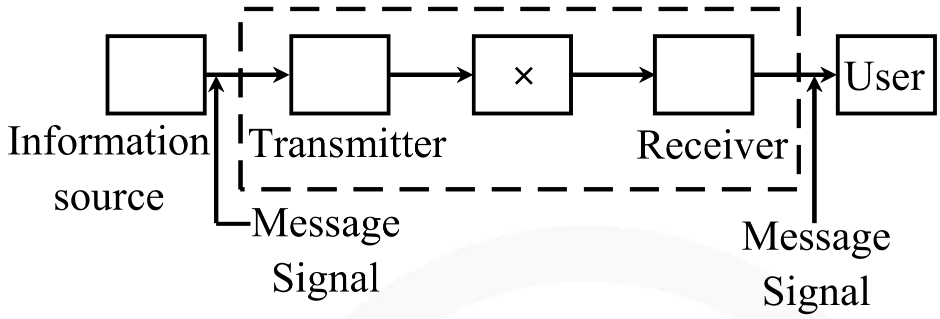
Thus,

$$band\ width\ =\ 2\ \times\ frequency\ of\ modulating\ signal$$

CBSE Exam Pattern Exercise
Subjective Questions (1)

(Q 1 to 3) One Mark

1. The figure given below shows the block diagram of a generalised communication system. Identify the element labelled X and write its function.



2. Why are broadcast frequencies (carrier waves) sufficiently spaced in amplitude modulated wave?

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

(Q 4 to 7) Two Marks

4. Mention the function of any two of the following used in communication system.
   (i) Transducer
   (ii) Repeater
   (iii) Transmitter
   (iv) Bandpass filter

5. A message signal of frequency 10 kHz and peak voltage 10 V is used to modulate a carrier of frequency 1 MHz and peak voltage 20 V.
   Determine
   (i) the modulation index
   (ii) the side bands produced.

6.
   (i) What is line of sight communication?
   (ii) Why is it not possible to use sky wave propagation of transmission of TV signals?

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

(Q 8 to 10) Three Marks

8.
   (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?

9. Optical communication system having an operating wavelength λ (in meters) can use only x% of its source frequency as its channel bandwidth. The system is to be used for transmitting TV signals requiring a bandwidth of F hertz. How many channels can this system transmit simultaneously? Assuming all other factors to remain constant, show graphically the dependence of the number of channels that can be transmitted simultaneously on the operating wavelength of the system.

10. A signal is to be transmitted along a cable system of total length 125 km. The cable has an attenuation of 7 dB km^{-1}. Amplifiers, each having a gain of 43 dB, are placed at 6 km intervals along the cable
   (a) State what is meant by the attenuation of a signal.
   (b) Calculate (i) the total attenuation cased by the transmission of the signal along the cable, (ii) the total signal gain as a result of amplification by all of the amplifiers along the cable.
   (c) The input signal has a power of 450 mW. Use your answers in (b) to calculate the output power of the signal as it leaves the cable system.

Answer & Solution

Q1.
Labelled element X represents the channel. Its function is to transmit information from one place to another.

Q2.
To avoid mixing up of signal from different transmitters the broadcast frequencies are sufficiently spaced in amplitude modulated wave.
This can be done by modulating the signals on high frequency carrier waves, e.g. frequency band for satellite communication is 5.925-6.425 GHz.

Q3
The power radiated by a linear antenna of length L is proportional to $(L/\lambda)^2$, where λ is the signal wavelength. Since for efficient transmission, the signal should be transmitted with high power, the signal should be of small wavelength or high frequency.

Q4
(i) **Transducer :**
Any device which converts one converts pressure, temperature, etc. into varying electrical signals I.e. transducer converts physical signals into electrical signals.

(ii) **Repeater :**
It picks up the signals from the transmitter, amplifies it and transmit it to the receiver. Thus, repeater comprises up of receiver, transmitter and amplifier. Its function is to extend the range of communication.

(iii) **Transmitter :**
It comprises of message signal source, modulator and transmitting antenna. Transmitter make signals compatible for communication channel *via* modulator and antenna.

(iv) **Bandpass filter :**
A device which passes the signals with certain frequency range only.

Q5

(i) Modulation index, $\dfrac{E_m}{E_c} = \dfrac{10}{20} = 0.5$

(ii) Side band frequencies = $f_c \pm f_m$

f_m = 10 kHz $\Rightarrow$ f_c = 1 MHz = 1000 kHz

$\therefore$ Side band frequencies = 1000 ± 10

= 1010 kHz, 990 kHz

Q6

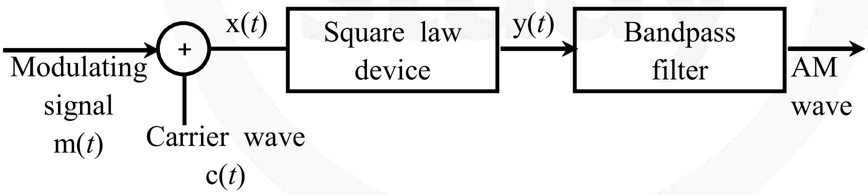
(i) Line of Sight (LOS) is a type of propagation that can transmit & receive data only where transmit & receive stations are in view of each other without any sort of obstacle between them.

Ex – FM radio, Microwave & Satellite Transmission.

(ii) The frequency of waves used for transmission of TV signals are of range 100 MHz-220 MHz. But ionosphere may be able to reflect waves back on earth of frequency up to 30 MHz. Therefore, ionosphere is unable to reflect TV waves (space waves) back on the earth.

Q7

Modulation is the process in which low frequency message signal is superimposed on high frequency carrier wave so that they can be transmitted over long distance. The block diagram for a simple modulator for obtaining AM signal is shown as below :



Q8

(i) For amplitude modulation, message signal is used to modulate amplitude of a high frequency wave in input transistor of CE amplifier.

The output voltage is carrier signal varying in amplitude in accordance with biasing modulating voltage.

(ii) Given, USB frequency = 660 kHz

and LSB frequency = 640 kHz

As USB = $f_c + f_m$ = 660 kHz

and LSB = $f_c - f_m$ = 640 kHz

$\therefore$ $2f_c$ = 660 + 640 = 1300

So, carrier frequency

f_c = 650 kHz

and $2f_m$ = 20 kHz

Bandwidth of frequencies required
= USB – LSB = 660 – 640 = 20 kHz

Q9
Here, the wavelength of signal = λ

Therefore, frequency of the signal, $v = \dfrac{c}{\lambda}$

Since x % of the soure frequency can be used as the bandwidth,

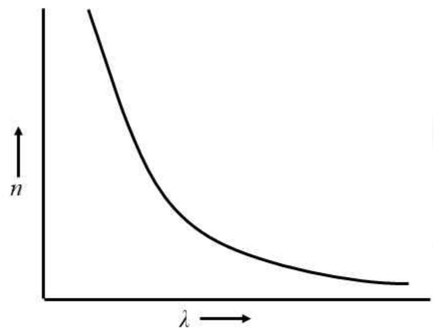
available bandwidth $= \dfrac{v \times x}{100} = \dfrac{cx}{\lambda \times 100}$

The bandwidth of the TV signal to be transmitted = F

Therefore, number of channels, the system can transmit,

$$n = \frac{\text{available bandwidth}}{\text{bandwidth of TV signal}}$$
$$= \frac{cx/\lambda \times 100}{F} = \frac{cx}{100\lambda F}$$

As n ∝ $1/\lambda$, the dependence of number of channels on the operating wavelength of the system will be as shown in Fig. below.



Q10
(a) The loss of power in a signal, as it travels, is called attenuation.

(b) (i) Here, attenuation = 7 dB km^{-1}
length of the cable = 125 km
Hence, total attenuation in the cable
= 7 × 125 = **875 dB**

(ii) Since amplifiers are placed at 6 km intervals along the cable of length 125 km, it follows that in total 20 amplifiers will have to be placed.
Gain of each amplifier = 43 dB
Therefore, total signal gain = 20 × 43 = **860 dB**

(c) Here, power of the input signal,
P_1 = 450 mW = 450 × 10^{-3} W
The overall gain = 860–875 = 15 dB
If P_2 is the output power, then

gain (or loss) in signal power $= 10 \log\frac{P_2}{P_1}$

or $-15 = 10 \log\frac{P_2}{450\times10^{-3}}$ or $\log\frac{P_1}{450\times10^{-3}} = -1.5$

or $\frac{P_2}{450\times10^{-3}} = 0.0316.$

or $P_2 = 0.0316 \times 450 \times 10^{-3} = 14 \times 10^{-3} =$ **14 mW**

CBSE Exam Pattern Exercise
Objective Questions (2)

1. Which process is used in optical fibres
   (a) T.I.R
   (b) Scattering
   (c) Reflection
   (d) Dispersion

2. An antenna behaves as a resonant circuit only when its length
   (a) equal $\frac{\lambda}{4}$
   (b) equal $\frac{\lambda}{2}$
   (c) equal $\frac{\lambda}{2}$ or its integral multiple
   (d) equal to 3λ

3. In modulation process, radio frequency wave is termed as
   (a) modulating wave
   (b) modulated wave
   (c) carrier wave
   (d) modified wave

4. A payload that is invariably found on all communication satellites is
   (a) optical telescope
   (b) camera
   (c) transponder
   (d) spectrometer

5. Attenuation in optical fibre is mainly due to
   (a) Scattering
   (b) Dispersion
   (c) Absorption and scattering
   (d) Reflection

Answer & Solution

1. (a)
   T.I.R

2. (c)
   equal $\frac{\lambda}{2}$ or its integral multiple

3. (c)
   carrier wave

4. (c)
   transponder

5. (c)
   Absorption and scattering