DAY THIRTY SIX

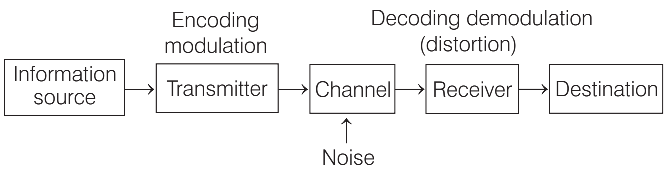
# Communication Systems

Learning & Revision for the Day

- Basic Elements of a Communication System
- Line Communication
- Optical Communication
- Modulation
- Demodulation or Detection
- Propagation of Electromagnetic Waves
- Satellite Communication

## Basic Elements of a Communication System

A communication system is a set up used to transmit information from one point to another. The essential parts of a communication system are transmitter, communication channel and receiver as shown in the following block diagram.




(i) **Transmitter** Transmitter converts the message signal produced by information source into a form (*e.g.*, electrical signal) that is suitable for transmission through the channel to the receiver.

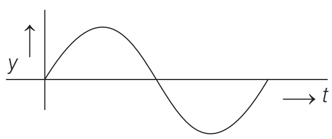
(ii) **Communication Channel** Communication channel is medium (transmission line, an optical fibre or free space) which connects a receiver and a transmitter. It carries the modulated wave from the transmitter to the receiver.

(iii) **Receiver** This set up receives the signals from the communication channel and converts these signals into their original form.

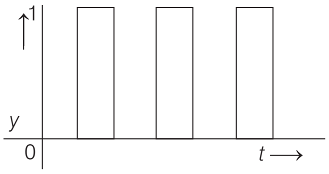
## Important Terms Used in Communication System

**Signal** Signal represents the electrical analog of the information. It can be analog or digital.

(a) **Analog Signal** Signal which varies continuously with respect to time is called analog signal.



(b) **Digital Signal** A digital signal has two levels of current or voltage represented by 0 or 1. It is usually in the form of pulses.




**Transducer** A device that converts the message signal into electrical signal before feeding it to transmitter. In other words, transducer converts one form of energy into another.

**Noise** It refers to the unwanted signals that tend to disturb the transmission and hence a distorted version of the transmitted signal reaches at receiver.

**Bandwidth** Bandwidth refers to the range over, which the frequencies in a signal vary.

**Amplification** It is the process of increasing the amplitude and thus strength of an electrical signal.

## Line Communication

In line communication, there is a physical connection between source and destination. The wired connections between two points are known as **transmission lines**.

The wires that are most popular for wired communication or line communication are

(i) Co-axial (ii) Parallel wire lines (iii) Twisted pair cables

## Optical Communication

Optical communication uses light waves in the frequency range $10^{12}$ to $10^{16}$ Hz as the guided wave medium for propagation of audio frequency signal.

Main advantage of optical communication system lies in the fact that here very high bandwidths of MHz and even GHz are possible. Consequently, a large number of messages can be transmitted through a single cable without any risk of their intermixing.

Moreover due to very little line loss the quality of reception is vastly superior.

An optical communication system consists of mainly three parts which are

(i) optical source and modulator

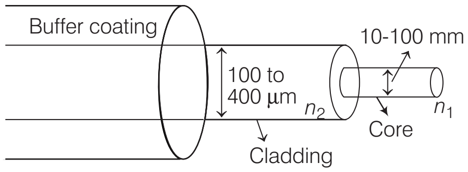
(ii) optical fibre cable, and (iii) optical signal detector.

### Optical Fibre

Optical fibre make use of the principle of total internal reflection of light. The refractive index $n_1$ of central core is higher than refractive index $n_2$ of cladding.

Total internal reflection will take place at core-cladding interface if angle of incidence there is

$$i = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$




For above condition to be fulfilled the light ray must enter the optical fibre at a maximum acceptance angle $\theta_0$ from the axis of fibre such that

$$(\theta_0)_{\max} = \sin^{-1}\left[\frac{\sqrt{n_1^2 - n_2^2}}{n_0}\right]$$

where, $n_0$ is the refractive index of the outer medium. For air, $n_0 = 1$ and then

$$(\theta_0)_{\max} = \sin^{-1}(\sqrt{n_1^2 - n_2^2})$$

NOTE
- Numerical Aperture (NA) $= n_0 \sin(\theta_0)_{\max} = \sqrt{n_1^2 - n_2^2}$
- All the information in optical fibre is carried out by the principal of total internal reflection and all the information is carried in core of the optical fibre.
- If angle of incidence is greater than $(\theta_o)_{\max}$, then total internal reflection will not take place and some information will be lossed.

## Modulation

The phenomenon of superposition of information signal over a high frequency carrier wave is called modulation. In this process, amplitude, frequency or phase angle of a high frequency carrier wave is modified in accordance with the instantaneous value of the low frequency information.

### Need for Modulation

Digital and analog signals to be transmitted are usually of low frequency and hence, cannot be transmitted as such. These signals require some carrier to be transported.

(i) **Frequency of Signal** The audio frequency signals (20 Hz to 20 kHz) cannot be transmitted without distortion over long distances due to less energy carried by low frequency audio waves. The energy of a wave is directly proportional to square of its frequency. Even if the audio signal is converted into electrical signal, the later cannot be sent very far without employing large amount of power.

(ii) **Height of antenna** For efficient radiation and reception, the height of transmitting and receiving antennas should be comparable to a quarter wavelength of the frequency used.

$$\text{Wavelength} = \frac{\text{velocity}}{\text{frequency}} = \frac{3 \times 10^8}{\text{frequency (Hz)}} \text{ metre}$$

For 1 MHz it is 75 m and for 15 kHz frequency, the height of antennas has to be about 5 km which size is unthinkable.

(iii) **Number of channels** Audio frequencies are concentrated in the range 20 Hz to 20 kHz. This range is so narrow that there will be overlapping of signals. In order to separate, the various signals it is necessary to convert all of them to different portions of the electromagnetic spectrum.

There are two types of modulation

## 1. Amplitude Modulation (AM)

- Amplitude Modulation (AM) is the process of changing the amplitude $(A_c)$ of a carrier wave linearly in accordance with the amplitude of message signal $(A_m)$.
- The ratio $\mu = \frac{A_m}{A_c} = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$ is called the modulation index and in practice we maintain $\mu \le 1$, so as to avoid distortion.
- In AM modulated wave signal we have carrier wave of frequency $\omega_c$ and two side bands of frequencies $(\omega_c - \omega_m)$ and $(\omega_c + \omega_m)$, respectively. Thus, total bandwidth of AM signals is $2\omega_m$.
- Upper Side Band Frequency (USB) = $\nu_c + \nu_m$

  where, $\nu_c$ = carrier frequency, $\nu_m$ = signal frequency.
- Lower Side Band Frequency (LSB) = $\nu_c - \nu_m$

  where, $\nu_c$ = carrier frequency, $\nu_m$ = signal frequency
- Bandwidth $= \nu_{USB} - \nu_{LSB} = (\nu_c + \nu_m) - (\nu_c - \nu_m) = 2\,\nu_m$
- Power of carrier, $P_C = \frac{(A_c/\sqrt{2})^2}{R} = \frac{A_c^2}{2R}$
- Power of side band, $P_{sb} = \frac{1}{R}\left(\frac{\mu A_c}{2\sqrt{2}}\right)^2 + \frac{1}{R}\left(\frac{\mu A_c}{2\sqrt{2}}\right)^2 = \frac{\mu^2 A_c^2}{8R}$
- AM technique is simpler and cost effective. However, it suffers from noisy reception, low efficiency, small operating range and poor audio quality.
- **Power dissipated** in AM wave, $P = P_c\left[1 + \frac{\mu^2}{2}\right]$ where,

  $P_c = \frac{A_c^2}{2R}$ is power dissipated by unmodulated carrier wave and $\mu$ = modulation index.

## 2. Frequency Modulation (FM)

- Frequency modulation is the process of changing the frequency of a carrier wave in accordance with the frequency of message signal.
- In FM modulated wave the amplitude of wave and total transmitted power remains constant.
- Frequency of modulated signal consists of central band of frequency $\omega_c$ and side bands of frequencies $(\omega_c \pm \omega_m), (\omega_c \pm 2\omega_m), (\omega_c \pm 3\,\omega_m)$ .....

  The number of side bands depends on the modulation index.
- Total **bandwidth** of modulated signal $= 2n \cdot \omega_m$,

  where, $n$ = number of significant side band pairs.
- FM technique is more complex and costly. However, efficiency is more and audio quality is vastly improved. Noise level is negligible.

  In the FM wave, **modulation index** $m_f = \frac{\delta}{\nu_m}$

  where, $\delta$ = maximum frequency of deviation

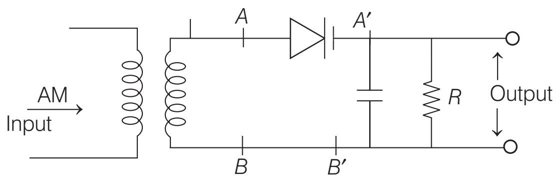
  $= (\nu_c - \nu_{min})$ or $(\nu_{max} - \nu_c)$

  $\nu_m$ = modulation frequency.

# Demodulation or Detection

The process of recovering the original audio signal from the modulated wave is called demodulation.

Demodulation can be done by using a diode and a capacitor filter as shown under




**Working of *R-C* Circuits** The value of *R-C* is so selected such that $\frac{1}{f_c} << RC$, where $f_c$ = frequency of carrier wave.

For AM modulated wave, a *p-n* junction diode or a vacuum tube diode is used as a demodulator. A diode basically acts as a rectifier and thus, reduces the modulated carrier wave into positive envelope only. This positive envelope is sent through a *R-C* circuit. Carrier wave passes through the capacitor and *AF* signal is regenerated across *R*.

# Propagation of Electromagnetic Waves

It is that category of communication in which no line or cable is used as a communication channel and the modulated signal is propagated through free space.

Different types of propagation depending upon properties are

## 1. Ground Wave Propagation

In this type of communication, transmitting and receiving antenna are close to surface of the earth. This type of propagation can be sustained only at low frequency ($\approx 500$ kHz to 1500 kHz). Due to such less frequency range, it is also called medium wave propagation.

## 2. Sky Wave Propagation

Sky wave is the radiowave which is directed towards the sky and reflected back by the ionosphere towards the desired location on the earth. Radiowaves of frequencies 2 MHz to 20 MHz can be reflected by the ionosphere.

- **Critical Frequencies** It is the maximum frequency of the radiowaves which can be reflected from ionosphere and returns to the earth. The radiowave will penetrate the ionosphere above this frequency. It is given by

$$f_c = 9(N_{max})^{1/2}$$

where, $N_{max}$ is the maximum electron density of the ionosphere.

The sky waves being electromagnetic in nature, changes the dielectric constant and refractive index of the ionosphere. The effective refractive index of ionosphere is

$$\mu = \mu_0 \sqrt{1 - \frac{81.45\,N}{v^2}}$$

where, $N$ = electron density of ionosphere,

$\nu$ = frequency of electromagnetic wave in Hz and

$\mu_0$ = refractive index of free space

- **Bandwidth of a Communication Channel** The difference between the highest and lowest frequencies that a communication channel allows to pass through it is called its bandwidth.

$$\text{Number of channels} = \frac{\text{Total bandwidth of channel}}{\text{Bandwidth per channel}}$$

- **Maximum Usable Frequency (MUF)** In this the sky waves with maximum frequencies are sent at some angles towards the ionosphere. Then these rays will again be reflected by the ionosphere to the earth.

$$\text{MUF} = \frac{\text{Critical Frequency (CF)}}{\cos\theta} = CF \sec\theta$$

This is the angle which is formed along the direction of the incident wave and the normal.

- **Skip distance** When the sky wave is reflected back from the ionosphere having a constant frequency, but less than that of the critical frequency, then the smallest distance from the transmitter to the earth's surface covered by the sky wave is known as skip distance.

## 3. Space Wave Propagation

The transmitted signal is received by the direct interception of the signal by receiving antenna. The, frequency range is (100 MHz to 220 MHz). The maximum range of this transmission depends upon the height of transmitting antenna and is given by,

$$d = \sqrt{2hR},\ R >> h.$$

where, $h$ = height of the antenna and $R$ = radius of the earth.

## Satellite Communication

- It is mainly done with the help of a geostationary satellite orbiting the earth in the equatorial plane from West to East at a height of about 36000 km above the surface of the earth, so that its revolution time is 24 h.
- The transmitted signal from the earth station is uplinked to satellite. The satellite receives it, demodulate it, amplify it and remodulate it and transmit it back. Now it is downlinked to the earth station. A radio transponder does all these jobs in a satellite.
- Uplink frequency and downlink frequency are kept widely different, so as to avoid their interference in free space.
- For world wide coverage three geostationary satellites are required at 120° apart from each other.

DAY PRACTICE SESSION 1

# FOUNDATION QUESTIONS EXERCISE

**1** The minimum length of antenna required to transmit a radio signal of frequency 20 MHz is

(a) 5 m (b) 7.5 m (c) 2 m (d) 3.75 m

**2** Repeaters are required for transmitting microwave terrestrial communication system over a 40-50 km distance because

(a) microwave power decreases rapidly with distance
(b) the curvature of the earth limits the distance over which the line of sight can be established
(c) signal to noise ratio decreases rapidly with distance
(d) signal distortion creeps in rapidly with distance

**3** The characteristic impedance of a coaxial cable is of the order of

(a) 50 Ω (b) 200 Ω
(c) 270 Ω (d) None of these

**4** If $\mu_1$ and $\mu_2$ are the refractive indices of the materials of core and cladding of an optical fibre, then the loss of light due to its leakage can be minimised by having

(a) $\mu_1 > \mu_2$
(b) $\mu_1 < \mu_2$
(c) $\mu_1 = \mu_2$
(d) None of the above

**5** Which of the following four alternatives is not correct? We need modulation → **AIEEE 2011**

(a) to increase the selectivity
(b) to reduce the time lag between transmission and reception of the information signal
(c) to reduce the size of antenna
(d) to reduce the fractional band width, i.e. the ratio of the signal band width to the centre frequency

**6** A message signal of frequency $\omega_m$ is superposed on a carrier wave of frequency $\omega_c$ to get an Amplitude Modulated wave (AM). The frequency of the AM wave will be

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

**7** 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

**8** In an amplitude modulated wave for audio frequency of 500 cycle/s, the appropriate carrier frequency will be

(a) 50 cycle/s (b) 100 cycle/s
(c) 500 cycle/s (d) 50000 cycle/s

**9** For what value of $m_a$ will the total power per cycle be maximum in the modulated wave?

(a) 0 (b) 1 (c) 1/2 (d) greater than 1

**10** In amplitude modulation, sinusoidal carrier frequency used is denoted by $\omega_c$ and the signal frequency is denoted by $\omega_m$. The bandwidth $(\Delta\omega_m)$ of the signal is such that $\Delta\omega_m << \omega_c$. Which of the following frequencies is not contained in the modulated wave? **→ JEE Main 2017 (Offline)**

(a) $\omega_c$ (b) $\omega_m + \omega_c$
(c) $\omega_c - \omega_m$ (d) $\omega_m$

**11** Choose the correct statement. **→ JEE Main 2016 (Offline)**

(a) In amplitude modulation, the amplitude of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal.
(b) In amplitude modulation, the frequency of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal.
(c) In frequency modulation, the amplitude of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal.
(d) In frequency modulation, the amplitude of the high frequency carrier wave is made to vary in proportion to the frequency of the audio signal.

**12** A signal of 5 kHz frequency is amplitude modulated on a carrier wave of frequency 2MHz. The frequencies of the resultant signal is/are **→ JEE Main 2015**

(a) 2 MHz only
(b) 2005 kHz and 1995 kHz
(c) 2005 kHz, 2000 kHz and 1995 kHz
(d) 2000 kHz and 1995 kHz

**13** An EM wave of maximum frequency 300 kHz and critical frequency 100 kHz is to be transmitted to a height equal to 150 km. Calculate the skip distance.

(a) 624 km (b) 849 km
(c) 636 km (d) 942 km

**14** The electron density of $E, F_1$ and $F_2$ layers of ionosphere is $2 \times 10^{11} \text{m}^{-3}$, $5 \times 10^{11} \text{m}^{-3}$ and $8 \times 10^{11} \text{m}^{-3}$, respectively. What is the ratio of critical frequency for reflection of radiowaves?

(a) 2 : 4 : 3 (b) 4 : 3 : 2 (c) 2 : 3 : 4 (d) 3 : 2 : 4

**15** On a particular day, the maximum frequency reflected from the ionosphere is 9 MHz. On another day, it was found to increase by 1MHz. What is the ratio of the maximum electron densities of the ionosphere on the two days?

(a) 1.23 (b) 1.0 (c) 1.43 (d) 0.75

**16** Maximum Usable Frequency (MUF) in F-region layers is $x$, when the critical frequency is 60 MHz and the angle of incidence is 70°, then $x$ is

(a) 150 MHz (b) 170 MHz (c) 175 MHz (d) 190 MHz

**17** Frequencies higher than 10 MHz were found not being reflected by the ionosphere on a particular day at a place. The maximum electron density of the ionosphere on the day was near to

(a) $1.5 \times 10^{10} \text{m}^{-3}$ (b) $1.24 \times 10^{12} \text{m}^{-3}$
(c) $3 \times 10^{12} \text{m}^{-3}$ (d) None of these

**18** How the sound waves can be sent from one place to another in space communication?

(a) Through wires
(b) Through space
(c) By superimposing it on undamped electromagnetic waves
(d) By superimposing it on damped electromagnetic waves

**19** To cover a population of 20 lakh, a transmitter tower should have a height of (Given radius of the earth = 6400 km, population per square km = 1000) is

(a) 25 m (b) 50 m (c) 75 m (d) 100 m

**20** The TV transmission tower in Delhi has a height of 240 m. The distance up to which the broadcast can be received. (Taking the radius of the earth to be $6.4 \times 10^6$ m) is

(a) 100 km (b) 60 km (c) 55 km (d) 50 km

**21** A radar has a power of 1 kW and is operating at a frequency of 10 GHz. It is located on a mountain top of height 500 m. The maximum distance upto which it can detect object located on the surface of the earth (Radius of earth $= 6.4 \times 10^6$ m) is **→ AIEEE 2012**

(a) 80 km (b) 16 km (c) 40 km (d) 64 km

**Direction** (Q. Nos. 22-25) *Each of these questions contains two statements : Statement* I and Statement II. *Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes* (*a*), (*b*), (*c*) *and* (*d*) *given below*

(a) Statement I is true, Statement II is true; Statement II is the correct explanation for Statement I
(b) Statement I is true, Statement II is true; Statement II is not the correct explanation for Statement I
(c) Statement I is true; Statement II is false
(d) Statement I is false; Statement II is true

**22** **Statement I** Optical fibre communication has immunity to cross-talk.

**Statement II** Optical interference between fibres is zero.

**23** **Statement I** Transducer in communication system converts electrical signal into a physical quantity.

**Statement II** For information signal is to be transmitted directly to long distances, modulation is necessary.

**24** **Statement I** FM broadcast is preferred over AM broadcast.

**Statement II** Process of combining the message signals with carrier wave is called demodulation.

**25** **Statement I** Modem is a demodulator.

**Statement II** It works only in a transmitting and receiving mode.

## DAY PRACTICE SESSION 2

# PROGRESSIVE QUESTIONS EXERCISE

**1** A telephonic communication service is working at carrier frequency of 10 GHz. Only 10% of it is utilised for transmission. How many telephonic channels can be transmitted simultaneously, if each channel requires a bandwidth of 5 kHz? → **JEE Main 2018**

(a) $2 \times 10^3$ (b) $2 \times 10^4$ (c) $2 \times 10^5$ (d) $2 \times 10^6$

**2** A diode AM detector with the output circuit consisting of $R = 1\,k\Omega$ and $C = 1\mu F$ would be more suitable for detecting a carrier signal of

(a) 10 kHz (b) 1 kHz (c) 0.75 kHz (d) 0.5 kHz

**3** In optical communication system operating at 1200 nm, only 2% of the source frequency is available for TV transmission having a bandwidth of 5 MHz. The number of TV channels that can be transmitted is

(a) 2 million (b) 10 million (c) 0.1 million (d) 1 million

**4** If sky wave with a frequency of 50 MHz is incident on $D$ region at an angle of 30°, then angle of refraction is

(a) 15° (b) 30° (c) 60° (d) 45°

**5** 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

**6** Consider telecommunication through optical fibres. Which of the following statements is not true?

(a) Optical fibres can be graded refractive index
(b) Optical fibres are subjected to electromagnetic interference from outside
(c) Optical fibres have extremely low transmission loss
(d) Optical fibres may have homogeneous core with a suitable cladding

**7** A diode detector is used to detect an amplitude modulated wave of 60% modulation by using a condenser of capacity 250 pF in parallel with a load resistance 100 kΩ. Find the maximum modulated frequency which could be detected by it. → **JEE Main 2013**

(a) 10.61 MHz (b) 10.61 kHz (c) 5.31 MHz (d) 5.31 kHz

**8** What is the modulation index if an audio signal of amplitude one half of the carrier amplitude is used in AM?

(a) 1 (b) 0
(c) 0.5 (d) greater than 1

**9** For 100% modulation, the power carried by the side bands ($P_{SB}$) is given by

(a) $P_{SB} = P$ (b) $P_{SB} = 3P$ (c) $P_{SB} = \frac{1}{3}P$ (d) $P_{SB} = 0$

**Direction** (Q. Nos. 10-12) *Each of these questions contains two statements : Statement* I and Statement II. *Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below*

(a) Statement I is true, Statement II is true; Statement II is the correct explanation for Statement I
(b) Statement I is true, Statement II is true; Statement II is not the correct explanation for Statement I
(c) Statement I is true; Statement II is false
(d) Statement I is false; Statement II is true

**10** **Statement I** Sky wave signals are used for long distance radio communication. These signals are in general, less stable than ground wave signals.

**Statement II** The state of ionosphere varies from hour to hour, day to day and season to season. → **AIEEE 2011**

**11** **Statement I** Higher the modulation index, the reception will be strong and clear.

**Statement II** The degree, to which the carrier wave is modulated is called modulation index.

**12** **Statement I** Television signals are received through sky wave propagation.

**Statement II** The ionosphere reflects electromagnetic waves frequencies less than a certain critical frequency.

# ANSWERS

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| SESSION 1 | **1** (d) | **2** (b) | **3** (a) | **4** (a) | **5** (b) | **6** (b) | **7** (a) | **8** (d) | **9** (b) | **10** (d) |
| | **11** (a) | **12** (c) | **13** (b) | **14** (c) | **15** (a) | **16** (c) | **17** (b) | **18** (c) | **19** (b) | **20** (c) |
| | **21** (a) | **22** (a) | **23** (d) | **24** (c) | **25** (d) | | | | | |
| SESSION 2 | **1** (c) | **2** (a) | **3** (d) | **4** (b) | **5** (b) | **6** (b) | **7** (b) | **8** (c) | **9** (c) | **10** (b) |
| | **11** (b) | **12** (d) | | | | | | | | |

# Hints and Explanations

## SESSION 1

**1** $\nu = 20\text{ MHz} = 20 \times 10^6\text{ Hz}$

Wavelength of antenna is,

$$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{20 \times 10^6} = 15\text{ m}$$

The minimum length of antenna

$$= \frac{\lambda}{4} = \frac{15}{4} = 3.75\text{ m}$$

**2** To increases the range of transmission of microwaves, a number of antennas are erected in between the transmitting and receiving antennas. Such antennas in between the transmitting and receiving antennas are known as repeaters.

**3** Coaxial cable have a characteristic impedance from 40 Ω to 150 Ω. So, option (a) is correct.

**4** Refractive index of core is always greater than refractive index of cladding, to minimise the loss of light.

**5** Modulation does not change time lag between transmission and reception.

**6** In amplitude modulation the frequency of modulated wave is equal to the frequency of carrier wave. Thus, option (b) is correct.

**7** Here, $\Delta\nu = 3\text{ kHz} = 0.003\text{ MHz}$

Using amplitude modulation, the frequencies of the side band

$$= (\nu + \Delta\nu) \text{ and } (\nu - \Delta\nu)$$
$$= (1 + 0.003) \text{ and } (1 - 0.003)$$
$$= 1.003 \text{ MHz and } 0.997\text{ MHz}$$

Thus, option (a) is correct.

**8** Carrier frequency is always greater than modulating frequency (i.e. audio frequency), so option (d) is appropriate carrier frequency.

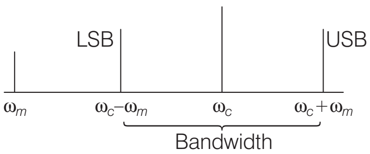
**9** Since, $P = P_c\left[1 + \frac{m_a^2}{2}\right]$

Power will be maximum, if $m_a = 1$

Therefore, $P_{\max} = P_c\left[1 + \frac{1}{2}\right]$

$$= \frac{3}{2}P_c = 1.5\,P_c$$

**10** Frequency spectrum of modulated wave is




Clearly, $\omega_m$ is not included in the spectrum.

**11** In amplitude modulation, the amplitude of the high frequency carrier wave is made to vary in proportion to the amplitude of the audio signal.

In frequency modulation, the frequency of the high frequency carrier signal varies with the frequency of audio signal.

**12** Frequency associated with AM are $f_c - f_m, f, f_c + f_m$

According to the question

$$f_c = 2\text{ MHz} = 2000\text{ kHz}$$
$$f_m = 5\text{ kHz}$$

Thus, frequency of the resultant signal is/are carrier frequency

$f_c = 2000\text{ kHz}$,

LSB frequency

$$f_c - f_m = 2000\text{ kHz} - 5\text{ kHz} = 1995\text{ kHz}$$

and USB frequency

$$f_c + f_m = 2005\text{ kHz}$$

**13** $\therefore D_{\text{skip}} = 2h\sqrt{\left(\frac{\nu}{\nu_c}\right)^2 - 1}$

$$= 2 \times 150\sqrt{\left(\frac{300}{100}\right)^2 - 1}$$
$$= 2 \times 150 \times 2\sqrt{2}$$
$$= 300 \times 2 \times 1.414$$
$$= 2.828 \times 300 = 848.4 \simeq 849\text{ km}$$

**14** Critical frequency for reflection of radiowaves is given by

$$\nu_c \propto N^{1/2}$$
$$\nu_{CE} : \nu_{CF_1} : \nu_{CF_2}$$
$$= (2 \times 10^{11})^{1/2} : (5 \times 10^{11})^{1/2} : (8 \times 10^{11})^{1/2}$$
$$= 2 : 3 : 4$$

**15** $\therefore \frac{N'_{\max}}{N_{\max}} = \left(\frac{V'_c}{V_c}\right)^2 = \left(\frac{9 + 1}{9}\right)^2$

$$= \left(\frac{10}{9}\right)^2 = 1.23$$

**16** $\therefore \text{MUF} = v_c / \cos i = 60 \times 10^6 / \cos 70°$

$$= 60 \times 10^6 \times \frac{1}{0.342}$$
$$= 175.43 \times 10^6$$
$$= 175.43\text{ MHz} \approx 175\text{ MHz}$$

**17** The critical frequency of a sky wave for reflection from a layer of atmosphere is, $\nu_c = 9(N_{\max})^{1/2}$

$N_{\max}$ = number density of ionosphere

$$\Rightarrow N_{\max} = \frac{\nu_c^2}{81} = \frac{(10 \times 10^6)^2}{81} = \frac{10^{14}}{81}\text{ m}^{-3}$$
$$= 1.24 \times 10^{12}\text{ m}^{-3}$$

**18** In space communication signals are sent directly from transmitting antenna to receiving antenna by superimposing it on undamped electromagnetic waves.

**19** Area of region covered $= \pi(2hR)$

In 1 $km^2$ = 1000 people

$$\frac{1}{1000} \times 20 \times 10^6 = 2 \times 10^3 = A$$

$$2 \times 10^3 = \pi\,(2 \times h \times 6400)$$

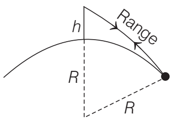
$$\Rightarrow \quad h = \frac{2 \times 10^3}{\pi \times 2 \times 6400} = 0.0497 \text{ km}$$

$$= 49.7 \text{ m} \approx 50 \text{ m}$$

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

$$= \sqrt{2 \times 6.4 \times 10^6 \times 240} \text{ m} = 55 \text{km}$$

**21** Range of radar on earth surface (optical distance, for space wave, i.e. line of view).




$$\text{Range} = \sqrt{(R + h)^2 - R^2}$$

$$= \sqrt{2Rh + h^2} \simeq \sqrt{2Rh}$$

$$= \sqrt{2 \times 6400 \times \frac{1}{2}} \text{ km} = 80 \text{ km}$$

**22** Optical communication is a system by which we transfer the informations on any distance from one location to other through optical range of frequency using optical fibre. The optical interference between fibres is zero. Hence, optical fibre communication has immunity to cross-talk.

**23** In any communication system information (a physical quantity) is first converted into an electrical signal by a device called transducer. Most of the speech or information signal cannot be directly transmitted to long distances. For this an intermediate step of modulation is necessary in which the information signal is loaded or superimposed on a high frequency wave which acts as a carrier wave.

**24** In AM modulation, the amplitude of the carrier signal varies in accordance with the information signal. AM signals are noisy because electrical noise signals significantly affect this. In FM modulation, amplitude of carrier wave is fixed while its frequency is changing. FM gives better quality transmission. It is preferred for transmission of music.

Demodulation is the process in which the original modulating voltage is recovered from the modulated wave.

**25** Modem is a modulating and demodulating device. It acts as a modulator in transmitting mode and as demodulator in receiving mode.

## SESSION 2

**1** Only 10% of 10 GHz is utilised for transmission.

$\therefore$ Band available for transmission

$$= \frac{10}{100} \times 10 \times 10^9 \text{ Hz}$$

$$= 10^9 \text{ Hz}$$

Now, if there are $n$ channels each using 5 kHz, then

$$n \times 5 \times 10^3 = 10^9$$

$$\Rightarrow \quad n = 2 \times 10^5$$

**2** Given, $R = 1\ k\Omega$

$$R = 1 \times 10^3\,\Omega,\ C = 1\mu F = 1 \times 10^{-6} \text{ F}$$

In this condition frequency of carrier signal, $\dfrac{1}{RC} << f_c$

$$\frac{1}{1 \times 10^3 \times 10^{-6}} << f_c$$

$$\Rightarrow \quad f_c >> 1 \text{ kHz}$$

Because frequency is greater than 1

$$f_c = 10 \text{ kHz}$$

**3** The frequency optical communication

$$\nu = \frac{c}{\lambda}$$

$$\Rightarrow \quad \nu = \frac{3 \times 10^8}{1200 \times 10^{-9}}$$

$$= 25 \times 10^{13} \text{ Hz}$$

But only 2% of the source frequency is available for TV transmission

$$\nu' = 2.5 \times 10^{14} \times 2\%$$

$$\nu' = 2.5 \times 10^{14} \times \frac{2}{100}$$

$$\nu' = 5 \times 10^{12} \text{ Hz}$$

$$\text{Number of channels} = \frac{\nu'}{\text{bandwidth}}$$

$$\text{Number of channels} = \frac{5 \times 10^{12}}{5 \times 10^6} = 10^6$$

$$= 1 \text{ million}$$

**4** For $D$-region, $N = 10^9 m^{-3}$

$$\mu = \sqrt{1 - \frac{81.45N}{\nu^2}}$$

$$= \sqrt{1 - \frac{81.45 \times 10^9}{(50 \times 10^6)^2}} \approx 1$$

$$\mu = \frac{\sin i}{\sin r} = 1$$

or $\quad \sin r = \sin i$

or $\quad r = i = 30°$

**5** For ground wave propagation, the frequency range is 530 kHz to 1710 kHz. For sky wave propagation, the frequency range is 1710 kHz to 40 MHz. For space wave propagation, the frequency range is 54 MHz to 4.2 GHz. Thus, option (b) is correct.

**6** Some of the characteristics of an optical fibre are as follows

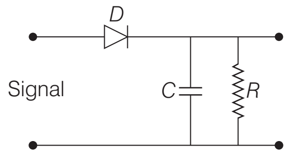
(i) It works on the principle of total internal reflection.

(ii) It consists of core made up of glass/silica/plastic with refractive index $n_1$, which is surrounded by a glass or plastic cladding with refractive index $n_2\,(n_2 > n_1)$. The refractive index of cladding can be either changing abruptly or gradually changing (graded index fibre).

(iii) There is a very little transmission loss through optical fibres.

(iv) There is no interference from stray electric and magnetic fields to the signals through optical fibres.

**7**




$$\tau = RC = 100 \times 10^3 \times 250 \times 10^{-12} \text{ s}$$

$$= 2.5 \times 10^7 \times 10^{12} \text{ s}$$

$$= 2.5 \times 10^{-5} \text{ s}$$

The highest frequency which can be detected with tolerable distortion is

$$f = \frac{1}{2\pi m_a RC}$$

[where, $m_a$ is modulation]

$$= \frac{1}{2\pi \times 0.6 \times 2.5 \times 10^{-5}} \text{ Hz}$$

$$= \frac{100 \times 10^4}{25 \times 1.2\,\pi} \text{ Hz} = \frac{4}{1.2\,\pi} \times 10^4 \text{ Hz}$$

$$= 10.61 \text{ kHz}$$

This condition is obtained by applying the condition that rate of decay of capacitor voltage must be equal or less than the rate of decay modulated signal voltage for proper detection of modulated signal.

**8** Here, $E_m = \dfrac{1}{2} E_c$

Therefore,

$$E_{\max} = E_c + E_m = E_c + \frac{1}{2} E_c = 1.5\,E_c$$

$$E_{\min} = E_c - E_m = E_c - \frac{1}{2} E_c = 0.5\,E_c$$

Also, $m_a = \dfrac{E_{\max} - E_{\min}}{E_{\max} + E_{\min}}$

$$= \frac{1.5\,E_c - 0.5\,E_c}{1.5E_c + 0.5\,E_c}$$

$$m_a = \frac{E_c}{2.0E_c} = 0.5$$

**9** $P_{SB} = \frac{1}{R}\left(\frac{m_a E_c}{2\sqrt{2}}\right)^2 + \frac{1}{R}\left(\frac{m_a E_c}{2\sqrt{2}}\right)^2$

$$\left[\because P_c = \frac{E_c^2}{2R}\right]$$

$$P_{SB} = \frac{m_a^2 E_c^2}{4R} = \frac{m_a^2 P_c}{2} = \frac{P_c}{2} \qquad [\because m_a = 1]$$

Also, $P = P_c\left[1 + \frac{m_a^2}{2}\right]$

Here, $m_a = 1$

$\Rightarrow \quad P = P_c\left[1 + \frac{1}{2}\right] = \frac{3}{2} P_c$

Hence, $\frac{P_{SB}}{P} = \frac{P_c / 2}{\frac{3}{2} P_c} = \frac{1}{3}$

or $P_{SB} = \frac{1}{3} P$

**10** In radio communication, sky wave refers to the propagation of radio waves reflected or refracted back towards earth from the ionosphere.

Since, it is not limited by the curvature of the earth, sky wave propagation can be used to communicate beyond horizon. Ionosphere is a region of upper atmosphere and induces the thermosphere and parts of mesosphere and exosphere. It is distinguished because it is ionised by solar radiation. It plays an important part in atmospheric electricity.

**11** The modulation index determines the strength and quality of the transmitted signal.

If the modulation index is small the amount of variation in the carrier amplitude will be small consequently the audio signal being transmitted will not be strong.

Hence, for high modulation index or greater degree of modulation, the audio signal reception will be clear and strong.

**12** In sky wave propagation, the radiowaves which have frequency between 2 MHz to 30 MHz, are reflected back to the ground by the ionosphere. But radio waves having frequency greater than 30 MHz cannot be reflected by the ionosphere because at this frequency they penetrates the ionosphere. It makes the sky wave propagation less reliable for propagation of TV signal having frequency greater than 30 MHz.

Critical frequency is defined as the highest frequency that is returned to the earth by the ionosphere. Thus, about this frequency a wave whether it is electromagnetic will penetrate the ionosphere and is not reflected by it. Hence, option (d) is correct.