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Communication System

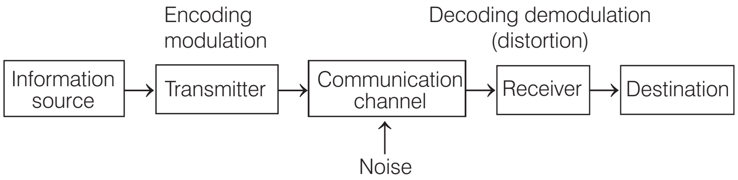
In this chapter, we introduce the concepts of communication, namely the mode of communication, the need for modulation, production and deduction of amplitude modulation.

IN THIS CHAPTER ....

- Basic Elements of Communication System
- Antenna
- Propagation of EM Waves
- Modulation and Demodulation
- Bandwidth

Basic Elements of 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



Antenna

An antenna is basically a conductor of small length which is used to radiate or receive electromagnetic waves.

It is of two types, *i.e.* dipole antenna and dish antenna.

Types of antenna are shown in following table relating its length with wavelength

Types of Antenna	Relation of Length (l) with Wavelength (λ)
Hertz antenna	$l = \lambda / 2$
Marconi antenna	$l = \lambda / 4$

Power Radiated by Antenna

The power radiated from a linear antenna of length l is given by

$$P \propto \left(\frac{1}{\lambda}\right)^2$$

For good transmission, for given antenna, length, wavelength λ should be small or frequency ν should be high.

Example 1. *The physical sizes of the transmitter and receiver antenna in a communication system are*

(a) proportional to carrier frequency **[JEE Main 2019]**
(b) inversely proportional to modulation frequency
(c) independent of both carrier and modulation frequency
(d) inversely proportional to carrier frequency

Sol. (*d*) Size of antenna is directly proportional to the wavelength of the signal.

Also, the speed at which signal moves = carrier frequency × wavelength

$$\Rightarrow \quad f\lambda = c \Rightarrow \lambda \propto \frac{1}{f}$$

$\therefore$ Size of antenna $\propto \frac{1}{f}$.

Note Minimum size of the antenna is $\lambda / 4$.

Propagation of EM Waves

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

Different layers of the atmosphere and their interaction with the propagating electromagnetic waves are given in following table

Name of the stratum (layer)	Approximate height over earth's surface	Exists during	Frequencies most affected
Troposphere	10 km	Day and night	VHF(upto several GHz)
D (part of stratosphere)	65-75 km	Day only	Reflects LF absorbs MF and HF to some degree
E (part of stratosphere)	100 km	Day only	Helps surface waves, reflects HF
F_1 (part of mesosphere)	170-190 km	Day time merges with F_2 at night	Partially absorbs HF waves yet allowing them to reach F_2
F_2 (thermosphere)	300 km at night 250-400 km during day time	Day and night	Efficiently reflects HF waves, particularly at night.

Different types of propagation of EM wave depending upon properties of medium are given below

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).

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

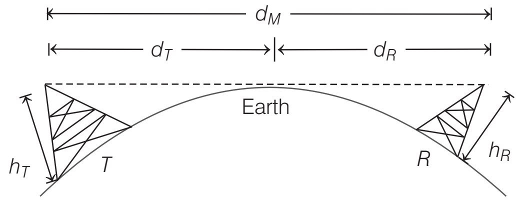
where, h = height of the antenna

and R = radius of the earth.

Maximum line of sight distance between two antenna (transmitting and receiving) as per diagram,

$$d_{\max} = d_T + d_R = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

where, d_T = radio horizon of transmitting antenna,
d_R = radio horizon of receiving antenna
and $d_{\max}$ = maximum line of sight distance between two antennas.



Sky Wave Propagation

Sky wave is the radio wave which is directed towards the sky and reflected back by the ionosphere towards the desired location on the earth. Radio waves of frequencies 2 MHz to 20 MHz can be reflected by the ionosphere by the phenomenon of total internal reflection.

Terms related to sky wave propagation along with their definitions are shown below.

Terms	Definitions	Expressions
Critical Frequency	Maximum frequency of radio waves reflected from ionosphere	$\nu_C \approx 9(N_{\max})^{1/2}$ where, $N_{\max}$ = maximum electron density of ionosphere.
MUF (Maximum Usable Frequency)	The highest radio frequency that can be used for transmission.	MUF = $\nu_C \sec\theta$ where, θ = angle between normal and the direction of incident wave.
Skip distance	Shortest distance from a transmitter, measured along the earth's surface at which a sky wave of fixed frequency will be first received after reflection from ionosphere.	$D_{\text{skip}} = 2h\sqrt{\left(\frac{\nu_{\max}}{\nu_c}\right)^2 - 1}$

Example 2. *On a particular day, the maximum frequency reflected from the ionosphere is 10 MHz. On another day, it was found to increase to 11 MHz. Calculate the ratio of maximum electron density of the ionosphere on the two days.*

(a) 1.21 (b) 0.82 (c) 0.50 (d) 0.25

Sol. (a) As, $f_c = 9\sqrt{N_{\max}}$

$$\therefore \quad N_{\max} = \frac{f_c^2}{81} \propto f_c^2$$

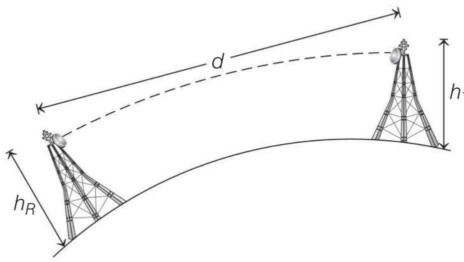
$$\Rightarrow \quad \frac{(N_2)_{\max}}{(N_1)_{\max}} = \left(\frac{11}{10}\right)^2 = \frac{121}{100} = 1.21$$

Example 3. *In a line of sight radio communication, a distance of about 50 km is kept between the transmitting and receiving antennas. If the height of the receiving antenna is 70 m, then the minimum height of the transmitting antenna should be (Take, radius of the earth $= 6.4 \times 10^6$ m)*

[JEE Main 2019]

(a) 20 m (b) 32 m (c) 40 m (d) 51 m

Sol. (b) Here in figure, h_R and h_T is the height of receiving and transmitting antenna, respectively.



Given, $d = 50 \text{ km} = 50 \times 10^3$ m,

$h_R = 70$ m, $R = 6.4 \times 10^6$ m

Then, distance between transmitting and receiving antenna, i.e.

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

$$50 \times 10^3 = \sqrt{2R}(\sqrt{h_T} + \sqrt{h_R}) = \sqrt{2 \times 6.4 \times 10^6}(\sqrt{h_T} + \sqrt{70})$$

$$\Rightarrow \quad \sqrt{h_T} \approx \frac{50 \times 10^3}{3577.7} - 8.37 = 13.98 - 8.37 = 5.61$$

or $\quad h_T = 31.5 \approx 32$ m

Modulation and Demodulation

Modulation and demodulation are explained below.

Modulation

Modulation is process in which characteristics (amplitude, frequency and phase) of carrier wave changes according to the message (or base band) signal.

Need for Modulation

Some important needs for modulation are

(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.

(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.

(iii) **Number of channels** Modulation increases the number of channels, *i.e.*

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

Example 4. *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) 2×10^3 (b) 2×10^4

(c) 2×10^5 (d) 2×10^6

Sol. (c) 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

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

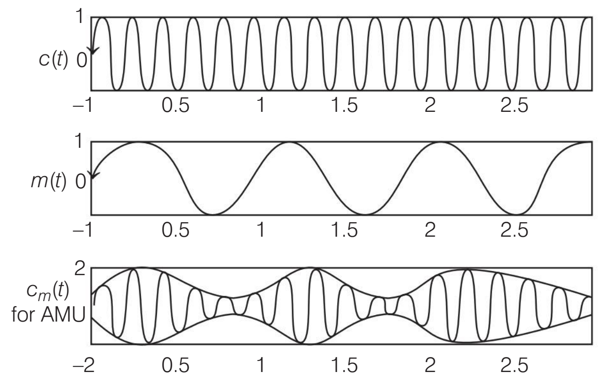
$$\Rightarrow \quad n = 2 \times 10^5$$

Frequency Modulation

The phenomenon of superposition of information signal over a high frequency carrier wave such that the frequency of the carrier wave is modified according to frequency of information signal, keeping the amplitude of the carrier wave constant is called amplitude modulation. Frequency modulation is preferred for music or TV transmission.

Amplitude Modulation

In amplitude modulation, the amplitude of the carrier is varied in accordance with the amplitude of information or message signal. Let $c(t) = A_c \sin \omega_c t$ represent carrier wave and $m(t) = A_m \sin \omega_m t$ represent the message or the modulating signal, where, $\omega_m = 2\pi f_m$ is the angular frequency of the message signal. The modulated signal $c_m(t)$ can be written as



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

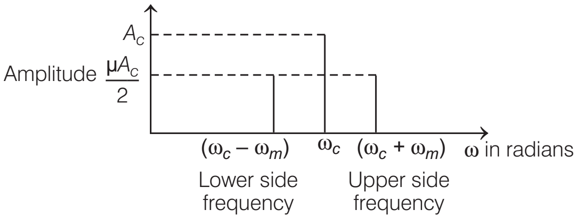
or $\quad c_m(t) = A_c \sin \omega_c t + \mu A_c \sin \omega_m t \sin \omega_c t$

where, $\mu = \dfrac{A_m}{A_c}$ is the modulation index in practice μ is kept ≤ 1 to avoid distortion.

It can be further written as

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

Here, $(\omega_c - \omega_m)$ and $(\omega_c + \omega_m)$ are respectively called the lower side and upper side frequencies. The frequency spectrum of the amplitude modulated signal is as follows



Example 5. *A message signal of frequency 10 kHz and peak voltage of 10 V is used to modulate a carrier of frequency 1 MHz and peak voltage of 20 V. The modulation index is* ***[NCERT]***

(a) 1 (b) 0.5 (c) 0.2 (d) 1.2

Sol. (b) Modulation index is given by, $m_a = \dfrac{A_m}{A_c}$

where, A_m is amplitude of the message signal and A_c represents the amplitude of carrier signal.

Given carrier signal amplitude, $A_c = 20$

and message signal amplitude, $A_m = 10$

$\therefore \qquad \mu = \dfrac{10}{20} = 0.5$

Modulation Index in Amplitude Modulation

It can be defined as the ratio of the change in amplitude of the carrier wave to the amplitude of the original carrier wave. It is also called modulation index. It used to determine the quality of transmitted signal.

$$m_a = \frac{A_m}{A_c} = \frac{E_{\max} - E_{\min}}{E_{\max} + E_{\min}}$$

where,

$A_{\max}$ = maximum voltage of amplitude modulation wave.

$A_{\min}$ = minimum voltage of amplitude modulation wave.

Modulation Index in Frequency Modulation

Ratio of frequency deviation to the modulating frequency is called modulation index.

$$m_f = \frac{\Delta_f}{f_m}$$

Sideband Frequencies of Amplitude Modulation Wave

- Original carrier wave frequency, $f_c = \dfrac{\omega_c}{2\pi}$ and amplitude $= A_c$.
- The sum of carrier frequency and modulating frequency is called USB (Upper Side Band) frequency $= f_c + f_m$.
- The difference of carrier frequency and modulating frequency is called LSB (Lower Side Band) frequency $= f_c - f_m$.

Power and Current Relations in Amplitude Modulation Wave

Average power in the unmodulated wave, $P_c = \dfrac{A_c^2}{2R}$

Total power in the modulated wave is $P_t = P_c\left(1 + \dfrac{m^2}{2}\right)$

or $$\frac{P_t}{P_c} = 1 + \frac{m^2}{2}$$

where, m = modulation index

As, $P_t = I_t^2 R$ and $P_c = I_c^2 R$

$$\therefore \qquad \frac{I_t}{I_c} = \sqrt{1 + \frac{m^2}{2}}$$

Demodulation

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

Example 6. *An amplitude modulated wave is represented by the expression $V_m = 5(1 + 0.6 \cos 6280t) \sin(211 \times 10^4 t)$ volt. The minimum and maximum amplitudes of the amplitude modulated wave are, respectively* ***[JEE Main 2020]***

(a) 3 V, 5 V (b) $\frac{5}{2}$ V, 8V (c) $\frac{3}{2}$ V, 5V (d) 5 V, 8 V

Sol. (b) Equation of amplitude modulated wave given as

$$V = 5(1 + 0.6 \cos 6280\, t) \sin(211 \times 10^4 t)$$
$$= (5 + 3 \cos 6280\, t) \sin(211 \times 10^4 t)$$

Comparing above equation with standard equation,

$$V = (A_c + A_m \cos \omega_m t) \cdot \sin \omega_c t$$

We get, amplitude of carrier signal $(A_c) = 5$ V

Amplitude of message signal $(A_m) = 3$ V

Maximum amplitude of modulated signal

$$= A_c + A_m = 5 + 3 = 8 \text{ V}$$

Minimum amplitude of modulated signal

$$= A_c - A_m = 5 - 3 = 2 \text{ V}$$

The answer is close to option (b).

Note Due to phase shift minimum/maximum amplitudes may differ slightly.

Example 7. *A signal $A\cos\omega t$ is transmitted using $v_0 \sin\omega_0 t$ as carrier wave. The correct amplitude modulated (AM) signal is* **[JEE Main 2019]**

(a) $(v_0 \sin\omega_0 t + A\cos\omega t$

(b) $(v_0 + A)\cos\omega t \sin\omega_0 t$

(c) $v_0 \sin[\omega_0(1 + 0.01A\sin\omega t)t]$

(d) $v_0 \sin\omega_0 t + \frac{A}{2}\sin(\omega_0 - \omega)t + \frac{A}{2}\sin(\omega_0 + \omega)t$

Sol. (d) Given, modulating signal, $A_m = A\cos\omega t$

Carrier wave, $A_c = v_0 \sin\omega_0 t$

In amplitude modulation, modulated wave is given by

$$Y_m = (A_0 + A_m)\sin\omega_0 t$$

where, A_0 is amplitude of the carrier wave (given as v_0)

$$\therefore \quad Y_m = (v_0 + A\cos\omega t)\sin\omega_0 t$$

$$= v_0 \sin\omega_0 t + A\sin\omega_0 t\cos\omega t$$

$$= v_0 \sin\omega_0 t + \frac{A}{2}[\sin(\omega_0 + \omega)t + \sin(\omega_0 - \omega)t]$$

$$= v_0 \sin\omega_0 t + \frac{A}{2}\sin(\omega_0 - \omega)t + \frac{A}{2}\sin(\omega_0 + \omega)t$$

Example 8. *The modulation frequency of an AM radio station is 250 kHz, which is 10% of the carrier wave. If another AM station approaches you for license, what broadcast frequency will you allot?* **[JEE Main 2019]**

(a) 2000 kHz (b) 2250 kHz

(c) 2900 kHz (d) 2750 kHz

Sol. (a) For a given carrier wave of frequency f_c with modulation frequency f_m, the bandwidth is calculated by $f_{\text{upper}} = f_c + f_m$

$$f_{\text{lower}} = f_c - f_m \quad \dots \text{(i)}$$

To avoid overlapping of bandwidths, next broadcast frequencies can be

$$f_1 = f_c \pm 2f_m,\ f_2 = f_c \pm 3f_m$$

So, next immediate available broadcast frequency is $f_1 = f_c + 2f_m$

and $f_1' = f_c - 2f_m$

Given, $f_m = 250$ kHz

and also that f_m is 10% of f_c, i.e. $f_c = 2500$ kHz.

So, $f_1 = 2500 + (2 \times 250) = 3000$ kHz

and $f'_1 = 2500 - (2 \times 250) = 2000$ kHz

Bandwidth

It is defined as the difference between the upper side and lower side frequency present in the amplitude modulation wave.

Bandwidth $= (f_c + f_m) - (f_c - f_m) = 2f_m$

Bandwidth of Transmission Medium

The commonly used transmission media are wire, free space and fibre optics cable. Coaxial cable offers a bandwidth of approximately 750 MHz. Such cables are normally operated below 18 GHz.

Service	Frequency bands	Comments
Standard AM broadcast	540-600 kHz	
FM broadcast	88-108 MHz	[VHF (Very high frequency)]
Television	54-72 MHz	VHF (very high frequency)
	76-88 MHz	TV
	174-216 MHz	UHF (ultra high frequency)
	420-890 MMz	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 3.7-4.2 GHz	Up link Downlink

Example 9. *Given below in the left column are different modes of communication using the kinds of waves given in the right column.* **[JEE Main 2019]**

A.	Optical fibre communication	P.	Ultrasound
B.	Radar	Q.	Infrared light
C.	Sonar	R.	Microwaves
D.	Mobile phones	S.	Radio waves

From the options given below, find the most appropriate match between entries in the left and the right column.

(a) A-Q, B-S, C-R, D-P

(b) A-S, B-Q, C-R, D-P

(c) A-Q, B-S, C-P, D-R

(d) A-R, B-P, C-S, D-Q

Sol. (c) In optical fibre communication, infrared light is used to transmit information from one point to another.

RADAR (Radio detection and ranging) is a detection system that uses radio waves to determine range, angle or velocity of objects.

SONAR (Sound navigation and ranging) is also a detection system that uses ultrasound to detect under water objects, submarines, etc.

Mobile phone is a portable telephone that can make and receive calls, which make use of microwave.

$\therefore$ Correct sequence is

$$A \to Q,\ B \to S,\ C \to P \text{ and } D \to R$$

Practice Exercise

ROUND I Topically Divided Problems

Basics of Communication Systems

1. Range of frequencies allotted for commercial UHF, TV broadcast is
(a) 470-960 kHz (b) 47-960 MHz
(c) 470-960 MHz (d) 47-960 kHz

2. A 100 m long antenna is mounted on a 500 m tall building. The complex can become a transmission tower for waves with λ **[NCERT Exemplar]**
(a) ~ 400 m (b) ~ 25 m
(c) ~ 150 m (d) ~ 2400 m

3. Digital signals **[NCERT]**
(i) do not provide a continuous set of values
(ii) represent values as discrete steps
(iii) can utilise binary system and
(iv) can utilise decimal as well as binary systems

Which of the above statements are true?
(a) (i) and (ii)
(b) (ii) and (iii)
(c) (i), (ii) and (iii)
(d) All of (i), (ii), (iii) and (iv)

4. In satellite communication, the communication satellite
(a) acts as a reflector for a beam of modulated microwave from transmitter sent directly towards it
(b) acts as a repeater for a signal reaching there, without any change in frequency
(c) receives the coming modulated microwave signal, amplifies it and returns it to earth at a different frequency
(d) None of the above

5. The radio waves of frequency 30 MHz to 300 MHz belong to
(a) high frequency band
(b) very high frequency band
(c) ultra high frequency band
(d) super high frequency band

6. Frequency range for microwaves is
(a) 3×10^4 to 3×10^9 Hz
(b) 3×10^4 to 3×10^{12} Hz
(c) 3×10^5 to 3×10^8 Hz
(d) 1×10^9 to 3×10^{11} Hz

7. Ozone layer above earth's atmosphere will not
(a) prevent infrared radiations from sun reaching on earth
(b) prevent infrared radiations originated from earth from escaping earth's atmosphere
(c) prevent ultraviolet rays from sun
(d) reflect back radio waves

8. Which one of the following is correct?
(a) A single geostationary satellite can cover the whole part of the earth for microwave communication
(b) Atleast three geostationary satellites in the same orbit around earth's can cover the whole part of the earth for microwave communication
(c) The first Indian communication satellite is Apple
(d) The satellite communication is not like the line of sight microwave communication

9. A communication between a fixed base station and several mobile units, located on ships or aircraft utilising two way radio communication in the VHF and UHF is of frequency band
(a) 3 to 30 MHz (b) 30 to 300 MHz
(c) 30 to 470 MHz (d) 30 to 600 MHz

10. The diameter of an optical fibre is
(a) 10^{-5} m (b) 10^{-4} cm
(c) 10^{-3} cm (d) 10^{-2} cm

11. Optical fibre communication is generally preferred over general communication system because
(a) it is more efficient
(b) it has signal security
(c) it cannot be jammed as easily as radio waves
(d) All of the above

12. A laser is a coherent source because it contains
(a) many wavelengths
(b) uncoordinate waves of particular wavelength
(c) coordinated waves of many wavelength
(d) coordinated waves of particular wavelength

13. Quality of transmission depends upon
(a) nature of medium only
(b) nature of signal only
(c) Both (a) and (b)
(d) Neither (a) nor (b)

Propagation of EM Waves

14. Point to point communication requires the use of
(a) a guided medium only
(b) unguided medium only
(c) any medium
(d) None of the above

15. 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? **[NCERT Exemplar]**
(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

16. Is it necessary for a transmitting antenna to be at the same height as that of the receiving antenna for line of sight communication? A TV transmitting antenna is 81 m tall. How much service area can it cover, if the receiving antenna is at the ground level? **[NCERT]**
(a) 3800 km ^{2} (b) 3260 km ^{2}
(c) 7400 km ^{2} (d) 3320 km ^{2}

17. 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 $\left[\text{Gain in dB} = 10\log\left(\frac{P_0}{P_i}\right)\right]$ **[NCERT Exemplar]**
(a) 900 W (b) 100 W (c) 990 W (d) 1010 W

18. A signal emitted by an antenna from a certain point can be received at another point of the surface in the form of
(a) sky wave (b) ground wave
(c) sea wave (d) Both (a) and (b)

19. Which of the following frequencies will be suitable for beyond the horizon communication using sky waves? **[NCERT Exemplar]**
(a)10 kHz (b) 10 MHz
(c) 1 GHz (d) 1000 GHz

20. Two identical antennas mounted on identical towers are separated from each other by a distance of 45 km. What should nearly be the minimum height of receiving antenna to receive the signals in line of sight? (Assume radius of earth is 6400 km) **[JEE Main 2021]**
(a) 19.77 m (b) 39.55 m
(c) 79.1 m (d) 158.2 m

21. In earth's atmosphere, for F_1-layer; the virtual height and critical frequency are
(a) 150 km and 3 MHz (b) 160 km and 3.5 MHz
(c) 170 km and 4.5 MHz (d) 180 km and 5 MHz

22. When electromagnetic waves enter the ionised layer of ionosphere, then the relative permittivity, *i.e.* dielectric constant of the ionised layer
(a) does not change
(b) appears to increase
(c) appears to decrease
(d) sometimes appears to increase and sometimes to decrease

23. The highest frequency of radio waves which when sent at some angle towards the ionosphere, gets reflected from that and returns to the earth is called
(a) critical frequency
(b) maximum unusable frequency
(c) polarisation of waves
(d) None of the above

24. In earth's atmosphere, for E-layer, the virtual height and critical frequency are
(a) 80 km and 3 MHz (b) 90 km and 3.5 MHz
(c) 120 km and 4.5 MHz (d) 110 km and 4 MHz

25. In space communication, the information can be passed from one place to another at a distance of 100 km in
(a) 1 s (b) 0.5 s
(c) 0.003 s (d) None of these

26. A TV transmission tower antenna is at a height of 20 m. Suppose that the receiving antenna is at
(i) ground level (ii) a height of 5 m
The increase in antenna range in case (ii) relative to case (i) is $n\%$. The value of n, to the nearest integer, is
(a) 40 (b) 50 (c) 25 (d) 60

27. Which mode of communication is/are employed for the transmission of TV signals?
(a) Ground wave propagation
(b) Sky wave propagation
(c) Space wave propagation
(d) None of the above

28. Frequencies in the UHF range normally propagate by means of
(a) ground waves (b) sky waves
(c) surface waves (d) space waves

29. A TV tower has a height of 75 m. What is the maximum area upto which this TV communication can be possible?
(a) 1509 km^2 (b) 3018 km^2
(c) 2254 km^2 (d) 6036 km^2

30. The maximum distance upto which TV transmission from a TV tower of height h can be received is proportional to
(a) $h^{3/2}$ (b) h (c) $h^{1/2}$ (d) h^2

31. Maximum usable frequency (MUF) infregion layer is x. When the critical frequency is 60 MHz and the angle of incidence is 70°, then n is
(a) 140 MHz (b) 175 MHz
(c) 180 MHz (d) 160 MHz

Modulation and Demodulation

32. In amplitude modulation, carrier wave frequencies are
(a) lower compared to those in frequency modulation
(b) higher compared to those in frequency modulation
(c) same as in frequency modulation
(d) lower sometimes and higher sometimes to those in frequency modulation

33. Sinusoidal carrier voltage of frequency 1.5 MHz and amplitude 50 V is amplitude modulated by sinusoidal voltage of frequency 10 kHz producing 50% modulation. The lower and upper side band frequencies in kHz are
(a) 1490, 1510 (b) 1820, 1012
(c) $\frac{1}{1510}, \frac{1}{1490}$ (d) 2490, 1510

34. 1000 Hz carrier wave is amplitude modulated by the signal frequencies 200-4000 Hz. The channel width of this case is
(a) 3 kHz (b) 8 kHz (c) 10 kHz (d) 14 kHz

35. A male voice after modulation-transmission sounds like that of a female to the receiver. The problem is due to **[NCERT Exemplar]**
(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

36. When the modulation percentage is 75, an AM transmitter produces 10 kW. How much of this is carrier power?
(a) 10 kW (b) 13.33 kW
(c) 7.5 kW (d) 7.81 kW

37. For an amplitude modulated wave, the maximum amplitude is found to be 10 V while the minimum amplitude is found to be 2 V. Determine the modulation index μ. **[NCERT]**
(a) $\frac{2}{3}, 1$ (b) $1, \frac{2}{3}$ (c) $\frac{4}{5}, 1$ (d) $1, \frac{4}{5}$

38. The 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 **[NCERT Exemplar]**
(a) 1.003 MHz and 0.997 MHz
(b) 1.954 MHz and 2.0 MHz
(c) 40.5 MHz and 27.6 MHz
(d) 5 MHz and 0.997 MHz

39. 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 **[NCERT Exemplar]**
(a) ω_m (b) ω_c
(c) $\frac{\omega_c + \omega_m}{2}$ (d) $\frac{\omega_c - \omega_m}{2}$

40. A carrier wave of peak voltage 12 V is used to transmit a message signal. What should be the peak voltage of the modulating signal in order to have a modulation index of 75%? **[NCERT]**
(a) 7V (b) 6V (c) 9V (d) 8V

41. A carrier wave is modulated by a number of sine waves with modulation indices $m_1, m_2, m_3, \ldots,$. The total modulation index (m) of the wave is
(a) $m_1 + m_2 + m_3 + \ldots$ (b) $m_1 - m_2 + m_3 + \ldots$
(c) $\sqrt{m_1^2 + m_2^2 + m_3^2 + \ldots}$ (d) $\sqrt{\frac{m_1^2 + m_2^2 + m_3^2 + \ldots}{n}}$

42. The antenna current of an AM broadcast transmitter modulated by 50% is 11. Find the carrier current.
(a) 9.25 A (b) 10 A
(c) 10.35 A (d) 5.5 A

43. The total power content of AM wave is 900 W. For 100% modulation, the power transmitted by each size band is
(a) 150 W (b) 140 W
(c) 100 W (d) 90 W

44. The antenna current of an AM transmitter is 8 A when only the carrier is sent, but it increases to 8.93 A when the carrier is sinusoidal modulated. The percentage modulation is nearly
(a) 90% (b) 80%
(c) 75% (d) 70%

45. A carrier is simultaneously modulated by two sine waves having modulation indices of 0.3 and 0.4. The total modulation index will be
(a) 0.1 (b) 0.5
(c) 0.7 (d) 0.35

46. How many 600 kHz waves can be on a 5 mile transmission line simultaneously?
(a) 11 (b) 12
(c) 14 (d) 16

47. A 600 W carrier is modulated to a depth of 75% by a 400 Hz sine. Find the total antenna power.
(a) 769 W (b) 796 W
(c) 679 W (d) 637.5 W

48. A transmitter radiates 12 kW power at 80% modulation index. The power in carrier is nearly
(a) 8.12 kW (b) 6.66 kW
(c) 7.4 kW (d) 9.09 kW

49. When only carrier is transmitted antenna current observed is 8A. When it is modulated with 500 Hz sine wave antenna current becomes 9.6 A. Find % modulation.
(a) 80% (b) 20% (c) 94.26% (d) 83.76%

50. If minimum voltage in an AM wave was found to be 2V and maximum voltage 10V. Find % modulation index.
(a) 80% (b) 66.67%
(c) 64.25% (d) 76.25%

ROUND II Mixed Bag

Only One Correct Option

1. With reference to ionospheric propagation, an electromagnetic wave with a critical frequency of 15 MHz and incident at an angle of 45° will have MUF of
(a) 15 MHz (b) $15\sqrt{2}$ MHz
(c) $15\sqrt{2}$ MHz (d) None of these

2. A TV tower has a height of 150 m. The area of the region covered, the TV broadcast is
(Take, radius of earth = 6.4×10^6 m)
(a) $9.6\pi \times 10^8$ km^2 (b) $19.2\pi \times 10^8$ km^2
(c) $19.2\pi \times 10^7$ km^2 (d) $1.92\pi \times 10^3$ km^2

3. A sky wave with a frequency 55 MHz is incident on the *D*-region of earth's atmosphere at 30°. The angle of refraction is (electron density for *D*-region is 400 electron/cc)
(a) 60° (b) 15° (c) 45° (d) 30°

4. If an electromagnetic wave is transmitted to the height equal to 150 km with maximum frequency 300 kHz and critical frequency 100 kHz, the skip distance is
(a) 426 km (b) 636 km (c) 824 km (d) 849 km

5. What is the value of frequency at which electromagnetic wave must be propagated for the *D*-region of atmosphere to have a refractive index of 0.5, if electron density for *D*-region is 400 electrons/cc.
(a) 200 kHz (b) 104.2 kHz
(c) 208.4 kHz (d) 312.6 kHz

6. The height of a TV antenna is 200 m. The population density is 4000 km^{-2}. Find the population benefitted.
(a) 3.2×10^8 (b) 3.2×10^7
(c) 3.2×10^6 (d) 3.2×10^5

7. A ground receiver station is receiving a signal at 5 MHz and transmitted from a ground transmitter at a height of 300 m, located at a distance of 100 km from the receiver station. The signal is coming *via* (Radius of earth = 6.4×10^6 m). $N_{\max}$ is ionosphere = 10^{12} m^3
(a) Space wave propagation
(b) Gromel wave propagation
(c) Sky wave propagation
(d) None of the above

8. Calculate the phase velocity of electromagnetic wave having electron density and frequency of *D*-layer, $N =$ 400 electron cc^{-1}, $\nu = 200$ kHz.
(a) 3×10^8 ms^{-1} (b) 3.5×10^8 ms^{-1}
(c) 6.9×10^8 ms^{-1} (d) 1.1×10^9 ms^{-1}

9. 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 (Take, radius of earth = 6.4×10^6 m) is **[AIEEE 2012]**
(a) 80 km (b) 16 km (c) 40 km (d) 64 km

10. 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 bandwidth, that is the ratio of the signal bandwidth to the centre frequency

11. Moon cannot be used as communication satellite of the earth because
(a) the distance between earth and moon is not proper
(b) the period of revolution of moon is 27.3 days
(c) the moon is not revolving in the equitorial plane of the earth
(d) None of the above

12. A signal wave of frequency 12kHz is modulated with a carrier wave of frequency 2.51 MHz. The upper and lower side band frequencies are respectively
(a) 2512 kHz and 2508 kHz
(b) 2522 kHz and 2488 kHz
(c) 2502 kHz and 2498 kHz
(d) 2522 kHz and 2498 kHz

13. In process of amplitude modulation of signal to be transmitted.
Signal to be modulated is given by
$m(t) = A_m \sin \omega_m t$, carrier wave is given by
$c(t) = A_c \sin \omega_c t$, modulated signal $c_m(t)$ is given by
(a) $c_m(t) = A_c \sin \omega_c t + A_m \sin \omega_m t$
(b) $c_m(t) = (A_c + A_m) \sin \omega_c t$
(c) $c_m(t) = [A_c + m(t)] \sin \omega_c t$
(d) None of the above

14. The wavelength of the carrier waves in a modern optical fibre communication network is close to **[JEE Main 2019]**

(a) 2400 nm (b) 1500 nm
(c) 600 nm (d) 900 nm

15. To double the covering range of a TV transmission tower, its height should be multiplied by **[JEE Main 2019]**

(a) $\sqrt{2}$ (b) 4
(c) 2 (d) $\frac{1}{\sqrt{2}}$

16. A 100 V carrier wave is made to vary between 160 V and 40 V by a modulating signal. What is the modulation index? **[JEE Main 2019]**

(a) 0.4 (b) 0.5
(c) 0.6 (d) 0.3

17. In communication system, only one per cent frequency of signal of wavelength 800 nm can be used as bandwidth. How many channel of 6MHz bandwidth can be broadcast this? ($c = 3 \times 10^8 \text{m/s}$, $h = 6.6 \times 10^{-34}$ J- s) **[JEE Main 2019]**

(a) 3.75×10^6 (b) 3.86×10^6
(c) 6.25×10^5 (d) 4.87×10^5

18. A TV transmission tower has a height of 140 m and the height of the receiving antenna is 40 m. What is the maximum distance upto which signals can be broadcasted from this tower in LOS (Line of Sight) mode? (Take, radius of earth $= 6.4 \times 10^6$ m) **[JEE Main 2019]**

(a) 65 km (b) 80 km
(c) 40 km (d) 48 km

19. A message signal of frequency 100 MHz and peak voltage 100 V is used to execute amplitude modulation on a carrier wave of frequency 300 GHz and peak voltage 400 V. The modulation index and difference between the two side band frequencies are **[JEE Main 2019]**

(a) $0.25 ; 1 \times 10^8$ Hz (b) $4 ; 1 \times 10^8$ Hz
(c) $0.25 ; 2 \times 10^8$ Hz (d) $4 ; 2 \times 10^8$ Hz

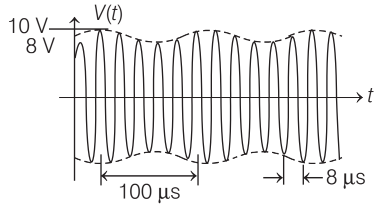
20. In an amplitude modulator circuit, the carrier wave is given by $C(t) = 4 \sin(20000\, \pi t)$ while modulating signal is given by, $m(t) = 2 \sin(2000\, \pi t)$. The values of modulation index and lower side band frequency are **[JEE Main 2019]**

(a) 0.5 and 10 kHz (b) 0.4 and 10 kHz
(c) 0.3 and 9 kHz (d) 0.5 and 9 kHz

21. An amplitude modulates signal is given by $v(t) = 10[1 + 0.3 \cos(2.2 \times 10^4 t)] \sin(5.5 \times 10^5 t)$. Here, t is in seconds. The side band frequencies (in kHz) are $\left(\text{Take}, \pi = \frac{22}{7}\right)$ **[JEE Main 2019]**

(a) 892.5 and 857.5 (b) 89.25 and 85.75
(c) 178.5 and 171.5 (d) 1785 and 1715

22. An amplitude modulated signal is plotted below



Which one of the following best describes the above signal? **[JEE Main 2019]**

(a) $[1 + 9 \sin(2\pi \times 10^4 t)] \sin(2.5\pi \times 10^5 t)$V
(b) $[9 + \sin(2\pi \times 10^4 t)] \sin(2.5\pi \times 10^5 t)$V
(c) $[9 + \sin(4\pi \times 10^4 t)] \sin(5\pi \times 10^5 t)$V
(d) $[9 + \sin(2.5\pi \times 10^5 t)] \sin(2\pi \times 10^4 t)$V

23. 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 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 15 km

24. Which of the following statements is/are correct?

(a) The space waves are the radio waves of frequency between 30 MHz to 300 MHz.
(b) The space waves cannot travel through atmosphere from transmitter antenna to receiver antenna either directly or after reflection from ground in the earth troposphere region.
(c) The space wave propagation is not a line of sight propagation.
(d) The ground wave communication is utilised in television communication, radar communication and microwave communication.

25. For sky wave propagation of 10 MHz signal, what should be the minimum electron density in ionosphere? **[AMU]**

(a) $\sim 1.2 \times 10^{12}\ \text{m}^{-3}$ (b) $\sim 10^6\ \text{m}^{-3}$
(c) $\sim 2.3 \times 10^4\ \text{m}^{-3}$ (d) $\sim 10^{22} \text{m}^{-3}$

26. The antenna current of an AM transmitter is 8 A when only the carrier is sent, but it increases to 8.93A when the carrier is modulated by single sine wave. Find the percentage modulation. **[VITEEE]**

(a) 60.1% (b) 70.1% (c) 80.1% (d) 50.1%

27. A TV transmitting antenna is 128 m tall. If the receiving antenna is at the ground level, the maximum distance between them for satisfactory communication in line of sight mode is (radius of the earth $= 6.4 \times 10^6$ km) **[EAMCET]**

(a) $64 \times \sqrt{10}$ km (b) $\frac{128}{\sqrt{10}}$ km
(c) $128 \times \sqrt{10}$ km (d) $\frac{64}{\sqrt{10}}$ km

28. A TV tower has a height 150 m. What is the total population covered by the TV tower, if the population density around the TV tower is $10^3\ km^{-2}$? Radius of the earth is 6.4×10^6 m. **[Guj CET]**

(a) 60.288 lakh (b) 40.192 lakh
(c) 100 lakh (d) 20.228 lakh

29. If sky wave with a frequency of 50 MHz is incident on D region at an angle of 30°, then angle of refraction is **[BVP]**

(a) 15° (b) 30°
(c) 60° (d) 45°

30. 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

31. The maximum electron density in the ionosphere in the morning is $10^{10}\ m^{-3}$. At noon time, it increases to $2\times 10^{10}\ m^{-3}$. Find the ratio of critical frequency at noon and the critical frequency in the morning. **[Guj CET]**

(a) 2.00 (b) 2.82
(c) 4.00 (d) 1.414

32. Match the following Column I with Column II.

Column I (Space communications)		Column II (Frequencies)	
I.	Ground wave propagation	A.	30 MHz to 300 MHz
II.	Sky wave propagation	B.	80 MHz to 200 MHz
III.	Space wave propagation	C.	2 MHz to 30 MHz
IV.	Television signal propagation	D.	500 kHz to 1500 kHz

Codes

(a) I-D, II-C, III-A, IV-B (b) I-A, II-B, III-C, IV-D
(c) I-B, II-A, III-D, IV-C (d) I-C, II-D, III-B, IV-A

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

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

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

34. A carrier signal $C(t) = 25\sin(2.512\times 10^{10}\,t)$ is amplitude modulated by a message signal $m(t) = 5\sin(1.57\times 10^{8}\,t)$ and transmitted through an antenna. What will be the bandwidth of the modulated signal? **[JEE Main 2021]**

(a) 8 GHz
(b) 2.01 GHz
(c) 1987.5 MHz
(d) 50 MHz

Numerical Value Questions

35. The value of radio frequency at which the electromagnetic wave must be propagated for the D-layer of atmosphere to have a refractive index of 0.5 is ……… kHz (Take, $N = 4\times 10^8\ m^{-3}$)

36. There is a transmitter at a height (h = 400 m) from the ground at place A, from which the radiowaves can be transmitted. If the station A sends the TV signals, then the maximum area on the earth upto which TV transmission can be received on the earth is … $\times 10^7$. Coverage population density around the tower is $1000\ km^{-2}$.

37. For VHF signal broadcasting, …… km^2 of maximum service area will be covered by an antenna tower of height 30 m, if the receiving antenna is placed at ground. Let radius of the earth be 6400 km. (Round off to the nearest integer) (Take π as 3.14) **[JEE Main 2021]**

Answers

Round I

1. (c)	2. (a)	3. (c)	4. (c)	5. (b)	6. (d)	7. (d)	8. (b)	9. (c)	10. (b)
11. (d)	12. (d)	13. (c)	14. (a)	15. (b)	16. (b)	17. (b)	18. (d)	19. (b)	20. (b)
21. (d)	22. (c)	23. (b)	24. (d)	25. (d)	26. (b)	27. (c)	28. (d)	29. (b)	30. (c)
31. (b)	32. (a)	33. (a)	34. (b)	35. (b)	36. (d)	37. (a)	38. (a)	39. (b)	40. (c)
41. (c)	42. (c)	43. (a)	44. (d)	45. (b)	46. (d)	47. (a)	48. (d)	49. (c)	50. (b)

Round II

1. (c)	2. (d)	3. (d)	4. (d)	5. (c)	6. (b)	7. (c)	8. (c)	9. (a)	10. (b)
11. (d)	12. (d)	13. (c)	14. (b)	15. (b)	16. (c)	17. (c)	18. (a)	19. (c)	20. (d)
21. (b)	22. (b)	23. (a)	24. (a)	25. (a)	26. (b)	27. (b)	28. (a)	29. (b)	30. (d)
31. (d)	32. (a)	33. (b)	34. (d)	35. 208	36. 1.6	37. 1206			

Solutions

Round I

1. For commercial UHF, TV broadcasts, the range allotted is 470-960 MHz.

2. For given buildings complex, $l = 100\,\text{m}, \lambda = ?$

As, $l = \dfrac{\lambda}{4}$ or $\lambda = 4\,l = 4 \times 100 = 400\,\text{m}$

3. A digital signal is a discontinuous function of time in contrast to an analog signal. The digital signals can be stored as digital data and cannot be transmitted along the telephone lines. Digital signal cannot utilise decimal signals.

4. A communication satellite receives the coming modulated microwave signal, amplifies it and return it to earth at a different frequency.

5. Radio waves of frequency 30 MHz to 300 MHz belong to very high frequency band.

6. Frequency range for microwaves is 1×10^9 to 3×10^{11} Hz.

7. Ozone layer will absorb UV rays; reflects the infrared radiation and does not reflect back radio waves.

8. At least three geostationary satellites in the same orbit around earth's can cover the whole part of the earth for microwave communication.

9. A communication link between a fixed base station and mobile units on a ship or aircraft works on 30 to 470 MHz.

10. The diameter of optical fibre is 10^{-4} cm.

11. An optical fibre is very efficient, has signal security and cannot be jammed as easily as radio waves.

12. Laser is a coherent source of coordinated waves of particular wavelength.

13. Quality of transmission is governed both by nature of signal and nature of communication channel/medium.

14. A guided medium alone can provide point to point communication.

15. 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.

16. Given, height of antenna, $h = 81$ m

Radius of earth, $R = 6.4 \times 10^6$ m

No, it is not necessary for line of sight communication, the two antennas may not be at the same height.

$$\text{Area} = \pi d^2$$

$$\because \quad \text{Range, } d = \sqrt{2hR}$$

$$\therefore \quad \text{Service area} = \pi \times 2hR = \frac{22}{7} \times 2 \times 81 \times 6.4 \times 10^6$$

$$= 3258.5 \times 10^6\ \text{m}^2 = 3258.5\ \text{km}^2$$

$$\simeq 3260\ \text{km}^2$$

17. Here, $P_i = 1$ kW $= 1000$ W, length of path $= 5$ km; $P_0 = ?$

Loss of power at a distance of 5 km $= -2 \times 5 = -10$ dB.

As gain in dB $= 101 \log \dfrac{P_0}{P_i}$

$$\therefore \quad 10 = 10 \log \frac{P_0}{P_i} = 10 \times \log \frac{P_i}{P_0}$$

$$\text{or} \quad \log \frac{P_i}{P_0} = 1 = \log 10 \quad \text{or} \quad \frac{P_i}{P_0} = 10$$

$$\text{or} \quad P_0 = \frac{P_i}{10} = \frac{1000}{10} = 100\ \text{W}$$

18. A signal emitted by an antenna from a certain point can be received at another point of the surface in the form of sky wave and ground wave depending upon the frequency of signal.

19. 10 kHz frequency cannot be radiated due to large antenna size, 1 GHz and 1000 GHz will be penetrated the ionosphere. Hence, option (b) is correct.

20. $d = 2\sqrt{2Rh}$

$$h = \frac{d^2}{8R} = \frac{(45)^2}{8 \times 6400}\ \text{km} \cong 39.55\ \text{m}$$

21. Virtual height is 180 km while critical frequency is 5 MHz.

22. When electromagnetic waves enter the ionised layer of ionosphere, then the relative permittivity of the ionised layer appears to decrease.

23. The highest frequency of radio waves that can be reflected by the ionosphere is called maximum unusable frequency.

24. The virtual height and critical frequency of E-layer is 110 km and 4 MHz.

25. In space communication, the information can be passed from one place to another with the speed of light ($c = 3 \times 10^8\ \text{ms}^{-1}$). Hence, time taken for a distance of 100 km $= \dfrac{100 \times 10^3}{3 \times 10^8} = 3.3 \times 10^{-4}$ s

26. Range $= \sqrt{2Rh}$

Range (i) $= \sqrt{2Rh}$

Range (ii) $= \sqrt{2Rh} + \sqrt{2Rh'}$

where, $h = 20$ m and $h' = 5$ m

$$= \frac{\sqrt{2Rh'}}{\sqrt{2Rh}} \times 100\% = \frac{\sqrt{5}}{\sqrt{10}} \times 100\% = 50\%$$

27. The mode of communication used for TV signals transmission is either space wave propagation or line of sight propagation of satellite communication.

28. The frequencies in UHF range normally propagate by means of space waves.

29. Area covered $= \pi \times 2\,Rh$

$$= \frac{22}{7} \times 2 \times 6.4 \times 10^6 \times 75$$

$$= 3017.1 \text{ km}^2 \simeq 3018 \text{ km}^2$$

30. As, $h = d^2/2R$ or $d^2 = 2\,hR$

$\therefore \quad d = \sqrt{(2\,hR)}$

or $\quad d \propto h^{1/2}$

31. Maximum usable frequency (MUF) $= \nu_c \sec i$

$$= (60 \times 10^6) \sec 70^\circ$$

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

32. In AM, carrier wave frequencies are lower (0.5-20 MHz) compared to those in frequency modulation (80 MHz onwards).

33. Here, $f_c = 1.5$ MHz $= 1500$ kHz, $f_m = 10$ kHz

$\therefore$ Low side band frequency

$$= f_c + f_m = 1500 \text{ kHz} - 10 \text{ kHz} = 1490 \text{ kHz}$$

Upper side band frequency

$$= f_c + f_m = 1500 \text{ kHz} + 10 \text{ kHz}$$
$$= 1510 \text{ kHz}$$

34. Bandwidth is equal to twice the frequency of modulating signals.

$\therefore$ Bandwidth $= 2\,\nu_m = 2 \times 4000$ Hz $= 8000$ Hz $= 8$ kHz

35. The frequency of male voice is less than that of a female voice. In the given problem, the frequency of modulated signal received becomes more, which is possible with the poor band width selection of amplifiers. It is so because bandwidth in amplitude modulation = twice the frequency of modulating signal.

36. As, $P_t = P_c\,(1 + m^2/2)$

So, $\quad P_c = \dfrac{P_t}{1 + m^2/2} = \dfrac{10}{1 + \frac{1}{2}\left(\frac{3}{4}\right)^2} = \dfrac{10 \times 32}{41}$

$\Rightarrow \quad P_c = 7.81$ kW

37. Given, maximum amplitude, $A_{\max} = 10$ V

Minimum amplitude, $A_{\min} = 2$ V

Let A_c and A_m be the amplitudes of carrier wave and signal wave.

$\therefore \quad A_{\max} = A_c + A_m = 10 \quad \ldots$(i)

and $\quad A_{\min} = A_c - A_m = 2 \quad \ldots$(ii)

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

$$2A_c = 12$$

or $\quad A_c = 6$ V

and $\quad A_m = 10 - 6 = 4$ V

Modulation index, $\mu = \dfrac{A_m}{A_c} = \dfrac{4}{6} = \dfrac{2}{3}$

When the minimum amplitude is zero, *i.e.* $A_{\min} = 0$

$A_c + A_m = 10 \quad \ldots$(iii)

$A_c - A_m = 0 \quad \ldots$(iv)

By solving Eqs. (iii) and (iv), we get

$$2A_m = 10$$

or $\quad A_m = 5$

and $\quad A_c = 5$

Modulation index, $\mu = \dfrac{A_m}{A_c} = \dfrac{5}{5} = 1$

38. The frequencies of the side bands will be $f_m + f_c = 1.003$ MHz and $f_c - f_m = 0.997$ MHz.

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

40. Given, peak voltage, $V_0 = 12$ V

Modulation index, $\mu = 75\% = \dfrac{75}{100}$

We know that, modulation index

$$(\mu) = \frac{\text{peak voltage of modulating signal } (V_m)}{\text{peak voltage } (V_0)}$$

So, peak voltage of modulating signal,

$$V_m = \mu \times \text{Peak voltage}$$
$$= \frac{75}{100} \times 12 = 9 \text{ V}$$

41. Total modulation index of the wave,

$$m = \sqrt{m_1^2 + m_2^2 + m_3^2 + \ldots}$$

42. $I_{\text{carrier}} = \dfrac{I_{\text{total}}}{(1 + m_a^2/2)^{1/2}} = \dfrac{11}{\sqrt{1 + (0.5)^2/2}} = 10.35$ A

43. $P_c = P_t\left(\dfrac{2}{2 + m^2}\right) = 900\left(\dfrac{2}{2+1}\right) = \dfrac{900 \times 2}{3} = 600$ W

Now, $\quad P_{\text{LSB}} = \dfrac{m^2}{4} \times P_c = \dfrac{1}{4} \times 600 = 150$ W

44. As, $\sqrt{1 + \dfrac{m^2}{2}} = \dfrac{I_t}{I_c} = \dfrac{8.93}{3} = 1.11625$

$\Rightarrow \quad \dfrac{m^2}{2} = (1.11625)^2 - 1$

$\Rightarrow \quad m = 0.70 = 70\%$

$\Rightarrow \quad m = 70\%$

45. Here, $m_1 = 0.3$ and $m_2 = 0.4$

$\because \quad m = \sqrt{m_1^2 + m_2^2} = \sqrt{0.3^2 + 0.4^2}$

$$= \sqrt{0.09 + 0.16} = \sqrt{0.25} = 0.5$$

46. Given, $f = 600$ kHz, $d = 5$ mile

First determine the wavelength of the 600 kHz, signal using

$$f\lambda = c$$

Use 186000 mile per second as the speed of light, since the line length is given in mile and no figure is given for the velocity factor.

Substituting numerical values,

$$600 \times 10^3 \ \lambda = 186000$$

$$\lambda = \frac{186000}{600 \times 10^3} = 0.31 \text{ mile}$$

Knowing the wavelength of the signal and the length of the line, the number of cycle on the line can be found from

$$n = \frac{d}{\lambda} = \frac{5}{0.31} = 16.13 \simeq 16$$

47. Total power in the modulated wave,

$$P_{\text{total}} = P_{\text{carrier}}\left(1 + \frac{m_a^2}{2}\right)$$

$$= 600\left(1 + \frac{(0.75)^2}{2}\right) = 768.75\text{W} \simeq 769 \text{ W}$$

48. Power of carrier wave,

$$P_{\text{carrier}} = \frac{P_{\text{total}}}{1 + \frac{m_a^2}{2}}$$

$$= \frac{12}{\left[1 + \frac{(0.80)^2}{2}\right]} = \frac{12}{1.32} = 9.09 \text{ kW}$$

49. $\left(\frac{I_t}{I_C}\right) = \sqrt{1 + \frac{\mu^2}{2}}$

or $\quad \mu = \sqrt{2\left[\left(\frac{I_t}{I_c}\right)^2 - 1\right]} = \sqrt{2[(1.20)^2 - 1]}$

$= 94.26\%$

50. Modulation index,

$$m_a = \frac{E_{\text{max}} - E_{\text{min}}}{E_{\text{max}} + E_{\text{min}}}$$

$$= \frac{10 - 2}{10 + 2} = \frac{2}{3}$$

$$= 66.67\%$$

Round II

1. MUF $= \nu \sec\theta = 15 \sec 45° = 15\sqrt{2}$ MHz

2. Area of region covered $= \pi d^2 = \pi\,(2\,hR)$

$$= \pi \times 2 \times 150 \times 6.4 \times 10^6$$

$$= 1.92\,\pi \times 10^9 \text{ m}^2 = 1.92\,\pi \times 10^3 \text{ km}^2$$

3. For D-region, $\nu = 55 \times 10^6$ Hz; $i = 30°$

and $\quad N = 400 \times 10^6 \text{ m}^{-3}$

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

$$\mu = \sqrt{1 - \frac{81.45 \times 400 \times 10^6}{(55 \times 10^6)}} \approx 1$$

Also $\quad \mu = \frac{\sin i}{\sin r}$

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

or $\quad i = r = 30°$

4. As, $h = 150$ km, $\nu = 300$ kHz

$$\nu_c = 100 \text{ kHz}$$

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

$$= 2 \times 150 \times 10^5 \sqrt{\left(\frac{300 \times 10^8}{100 \times 10^8}\right) - 1}$$

$$= 849 \text{ Hz}$$

5. Here, $N = 400$ electrons/cc $= 400 \times 10^6$ electrons m^{-3}

$$\mu = 0.5 = \sqrt{1 - \frac{81.56\,N}{\nu^2}}$$

$$= \sqrt{\frac{1 - 81.56 \times 400 \times 10^6}{\nu^2}}$$

On solving, $\quad \nu = 208.4$ kHz

6. As, $d = \sqrt{2\,Rh}$

Population covered $= \pi d^2 \times$ Population density

$$= \pi\,(2\,Rh) \times \rho$$

$$= \frac{22}{7} \times 2 \times 6400 \times 0.2 \times 4000$$

$$= 3.2 \times 10^7$$

7. Maximum distance covered by space wave communication, $\sqrt{2\,Rh} = 62$ km

Critical frequency, $\nu_c = 9\,(N_{\text{max}})^{1/2} = 9$ MHz

5 MHz $< \nu_c$, sky wave propagation, *i.e.* ionospheric propagation.

8. $\mu = \sqrt{1 - \frac{81.45\,N}{\nu^2}} = \sqrt{1 - \frac{81.45 \times 400 \times 10^6}{(200 \times 10^3)^2}} = 0.43$

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

$\therefore$ Phase velocity, $v = \frac{c}{\mu} = \frac{3 \times 10^8}{0.43} = 6.9 \times 10^8 \text{ ms}^{-1}$

9. Range of radar on the earth surface optional distance for space wave, *i.e.* line of view.

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

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

10. Modulation does not change time lag between transmission and reception of the information or message signal.

11. For a communication satellite, the distance between the satellite and earth should be about 36000 km. The period of revolution is 24 days and it is revolving in the equatorial plane of the earth.

12. Upper Side Band (USB) frequency $= f_c + f_m$

$$= (2.51) \text{ MHz} + (12) \text{ kHz}$$
$$= (2510 + 12) \text{ kHz} = 2522 \text{ kHz}$$

Lower Side Band (LSB) frequency $= f_c - f_m$

$$= (2.51) \text{ MHz} - (12) \text{ kHz}$$
$$= (2510 - 12) \text{ kHz} = 2498 \text{ kHz}$$

13. In amplitude modulation, amplitude of carrier wave varies with signal to be modulated. So, modulated signal $c_m(t)$ is given by

$$c_m(t) = [A_c + m(t)] \sin \omega_c t$$

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

As, $m(t) = A_m \sin \omega_m t$ (given)

14. In optical fibre communication network, the signals are transmitted by laser light operating in range of 1310 nm-1550 nm.

So, the closest value is 1500 nm.

15. Range of TV transmitting tower, $d = \sqrt{2hR}$

where, h is the height of the transmission tower. When range is doubled, then

$$2d = 2\sqrt{2hR} = \sqrt{2(4h)R}$$

So, height must be multiplied with 4.

16. Modulation index is given by

$$\mu = \frac{A_{\max} - A_{\min}}{A_{\max} + A_{\min}} = \frac{V_{\max} - V_{\min}}{V_{\max} + V_{\min}}$$
$$= \frac{160 - 40}{160 + 40} = \frac{120}{200} = 0.6$$

17. Here, signal wavelength, $\lambda = 800 \text{ nm} = 8 \times 10^{-7}$ m

Frequency of source is

$$f = \frac{c}{\lambda} = \frac{3 \times 10^8}{8 \times 10^{-7}} = 3.75 \times 10^{14} \text{ Hz}$$

$\therefore$ Total bandwidth used for communication

$$= 1\% \text{ of } 3.75 \times 10^{14}$$
$$= 3.75 \times 10^{12} \text{ Hz} \quad \text{...(i)}$$

So, number of channel for signals

$$= \frac{\text{total bandwidth available for communication}}{\text{bandwidth of TV signal}}$$

$$= \frac{3.75 \times 10^{12}}{6 \times 10^6} = 0.625 \times 10^6 = 6.25 \times 10^5$$

18. Maximum distance of transmission is given by

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

where, h_T = height of transmitter, = 140 m,

h_R = height of receiver = 40 m and

R = radius of earth $= 6.4 \times 10^6$ m.

Substituting the values, we get

$$d = \sqrt{2 \times 6.4 \times 10^6}\,(\sqrt{140} + \sqrt{40}) = 65 \text{ km}$$

19. Given, $f_m = 100 \text{ MHz} = 100 \times 10^6 \text{ Hz}$, $A_m = 100$ V,

$$A_c = 400 \text{ V}$$

Range of frequency in case of amplitude modulation is $(f_c - f_m)$ to $(f_c + f_m)$.

$\therefore$ Bandwidth $= 2f_m = 2 \times 100 \times 10^6$ Hz

$$= 2 \times 10^8 \text{Hz}$$

and modulation index, $\text{MI} = \frac{A_m}{A_c} = \frac{100}{400} = 0.25$

20. Given, carrier wave, $C(t) = 4 \sin(20000\, \pi t)$

Modulating signal, $m(t) = 2 \sin(2000\, \pi t)$

So, carrier wave's amplitude and frequency are

$$A_c = 4 \text{ V}, \;\; \omega_c = 20000\,\pi = 2\pi \times 10^4 \text{ rad/s}$$

$\Rightarrow$ $$f_c = \frac{\omega_c}{2\pi} = 10^4 \text{ Hz} = 10 \text{ kHz}$$

and modulating signal's amplitude and frequency are

$$A_m = 2 \text{ V}, \; \omega_m = 2000\pi = 2\pi \times 10^3 \text{ rad/s}$$

$\Rightarrow$ $$f_m = \frac{\omega_m}{2\pi} = 10^3 \text{ Hz} = 1 \text{ kHz}$$

So, modulating index is $m = \frac{A_m}{A_c} = \frac{2}{4} = 0.5$

and lower side band frequency is,

$$f_{\text{LSB}} = f_c - f_m = 10 - 1 = 9 \text{ kHz}$$

21. $v(t) = 10\,[1 + 0.3 \cos(2.2 \times 10^4 t)]\,[\sin(5.5 \times 10^5\, t)]$

Upper band angular frequency,

$$\omega_U = (2.2 \times 10^4 + 5.5 \times 10^5) \text{ rad/s}$$
$$= 572 \times 10^3 \text{ rad/s}$$

Similarly, lower band angular frequency,

$$\omega_L = (5.5 \times 10^5 - 2.2 \times 10^4) \text{ rad/s}$$
$$= 528 \times 10^3 \text{ rad/s}$$

$\therefore$ Side band frequency are,

$$f_u = \frac{\omega_U}{2\pi} = \frac{572}{2\pi} \text{ kHz} \simeq 91 \text{ kHz}$$

and $$f_L = \frac{\omega_L}{2\pi} = \frac{528}{2\pi} \text{ kHz} \simeq 84 \text{ kHz}$$

Thus, the approximate side band frequencies are 89.25 and 85.75.

22. Equation of an amplitude modulated wave is given by the relation, $C_m = (A_c + A_m \sin \omega_m t) \cdot \sin \omega_c \cdot t$ ...(i)

For the given graph,

maximum amplitude, $A_c + A_m = 10$ ...(ii)

and minimum amplitude, $A_c - A_m = 8$ ...(iii)

From Eqs. (ii) and (iii), we get

$$A_c = 9\text{V} \text{ and } A_m = 1 \text{ V} \quad \text{...(iv)}$$

$\because$ For angular frequency of message signal and carrier wave, we use a relation,

$$\omega_c = \frac{2\pi}{T_c} = \frac{2\pi}{8 \times 10^{-6}}$$

(as from given graph, $T_c = 8 \times 10^{-6}$ s)

$$= 2.5\pi \times 10^5 \text{ s}^{-1} \quad \text{...(v)}$$

and $\quad \omega_m = \dfrac{2\pi}{T_m} = \dfrac{2\pi}{100\times10^{-6}} = 2\pi\times10^4 \text{s}^{-1}$

(as from given graph, $T_m = 100\times10^{-6}$s)

When we put values of A_c, A_m, ω_c and ω_m in Eq. (i), we get

$C_m = [9+\sin(2\pi\times10^4 t)]\sin(2.5\pi\times10^5 t)$ V

23. Here, $\nu_m = 15$ kHz $= 15\times10^3$ Hz

$$\lambda_m = \frac{c}{\nu_m} = \frac{3\times10^8}{15\times10^3} = \frac{1}{5}\times10^5 \text{m}$$

Size of the antenna required,

$$l = \frac{\lambda}{4} = \frac{1}{4}\left(\frac{1}{4}\times10^5\right) = 5\times10^3 \text{ m} = 5 \text{ km}$$

The audio signals are of low frequency waves. 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.

24. The statement (a) is correct but statements (b), (c) and (d) are wrong as space wave propagation is a line of sight propagation.

25. We know that, $\quad f_c = 9\,(N_{\text{max}})^{1/2}$

$$10\times10^6 = 9(N_{\text{max}})^{1/2}$$

$$\frac{10^7}{9} = (N_{\text{max}})^{1/2} \Rightarrow \frac{10^{14}}{81} = N_{\text{max}}$$

$$\frac{100}{81}10^{12} = N_{\text{max}}$$

$$N_{\text{max}} \approx 1.2\times10^{12} \text{ m}^{-3}$$

26. The power dissipated in any circuit is a function of the square of voltage across the circuit and the effective resistance of the circuit. Equation of AM wave reveals that it has three components of amplitude E_c, $mE_c/2$ and $mE_c/2$. Clearly, power output must be distributed among these components.

Carrier power, $\quad P_c = \dfrac{(E_c/\sqrt{2})^2}{R} = \dfrac{E_c^2}{2R}$

Total power of side bands,

$$P_s = \frac{(mE_c/2\sqrt{2})^2}{R} + \frac{(mE_c/2\sqrt{2})^2}{R} = \frac{m^2E_c^2}{4R}$$

$\therefore \quad \dfrac{P_s}{P_c} = \dfrac{1}{2}m^2$ and

$$P_t = P_c + P_s = P_c\left(1+\frac{m^2}{2}\right)$$

$\therefore \quad \dfrac{P_t}{P_c} = 1+\dfrac{m^2}{2} \Rightarrow \left(\dfrac{I_t}{I_c}\right)^2 = 1+\dfrac{m^2}{2}$

Given that, $\quad I_T = 8.93$ A, $\quad I_C = 8$ A, $\quad m = ?$

$\therefore \quad \left(\dfrac{8.93}{8}\right)^2 = 1+\dfrac{m^2}{2}$

or $\quad 1.246 = 1+\dfrac{m^2}{2}$ or $\dfrac{m^2}{2} = 0.246$

or $\quad m = \sqrt{2\times0.246} = 0.701 = 70.1\%$

27. Height of transmitting antenna,

$$d = \sqrt{2R_e h_T}$$

Given, $\quad R_e = 6.4\times10^6$ m

$h_T = 128$ m

$d = ?$

The maximum distance,

$$d = \sqrt{2\times6.4\times10^6\times128} = \sqrt{128\times10^5\times128}$$

$$= \frac{128\times10^2\sqrt{10}}{\sqrt{10}}\times\sqrt{10} = \frac{128\times10^3}{\sqrt{10}} \text{ m} = \frac{128}{\sqrt{10}} \text{ km}$$

28. Given, $h = 150$ m, $R = 6.4\times10^6$ m

Average population density $= 10^3$ km

$$= 10^3\times(10^3)^{-2} = 10^{-3} \text{ m}$$

Distance upto which the transmission would be view

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

Total area over which transmission could be

$$= \pi d^2 = 2\pi hR$$

Population covered $= 10^{-3}\times2\pi hR$

$$= 10^{-3}\times2\times3.14\times150\times6.4\times10^{-6}$$

$$= 60.288 \text{ lakh}$$

29. For D-region, $\quad N = 10^9 \text{ m}^{-3}$

$$\mu = \sqrt{1-\frac{81.45\,N}{\nu^2}} = \sqrt{1-\frac{81.45\times10^9}{(50\times10^6)^2}} \approx 1$$

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

or $\quad \sin r = \sin i$ or $r = i = 30°$

30. The frequency optical communication,

$$\nu = \frac{c}{\lambda} \text{ or } \nu = \frac{3\times10^8}{1200\times10^{-9}}$$

$$\nu = 25\times10^{13} \text{ Hz}$$

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

$$\nu' = 2.5\times10^{14}\times2\,\% \quad\text{or}\quad \nu' = 2.5\times10^{14}\times\frac{2}{100}$$

or $\quad \nu' = 5\times10^{12}$ Hz

$\therefore$ Number of channels $= \dfrac{\nu'}{\text{Bandwidth}}$

or Number of channels $= \dfrac{5\times10^{12}}{5\times10^6} = 10^6 = 1$ million

31. Given, the maximum electron density in the morning,

$$N_{\text{max}} = 10^{10} \text{ m}^{-3}$$

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

$= 9\ (10^{10})^{1/2}$

Critical frequency, $f_c' = 9 \times 10^5$ Hz

The maximum electron density at noon,

$$N_{\max} = 2 \times 10^{10} \text{m}^{-3}$$

Critical frequency, $f_c'' = 9 \times (N_{\max})^{1/2}$

$= 9 \times (2 \times 10^{10})^{1/2}$

$= 9 \times \sqrt{2} \times 10^5$

The ratio of critical frequency at noon and critical frequency in the morning,

$$\frac{f_c''}{f_c'} = \frac{9 \times \sqrt{2} \times 10^5}{9 \times 10^5}$$

$$\Rightarrow \quad \frac{f_c''}{f_c'} = \sqrt{2}$$

$= 1.414$

32. I. Ground wave propagation $\rightarrow$ 500 kHz to 1500 kHz

II. Sky wave propagation $\rightarrow$ 2 MHz to 30 MHz

III. Space wave propagation $\rightarrow$ 30 MHz to 300 MHz

IV. Television signal propagation $\rightarrow$ 80 MHz to 200 MHz

33. Here both statements are correct but Statement II does not support Statement I.

34. Bandwidth $= 2f_m$

$$\omega_m = 1.57 \times 10^8 = 2\pi f_m$$

$$\text{BW} = 2f_m = \frac{10^8}{2} \text{ Hz} = 50 \text{ MHz}$$

35. Refractive index, $\mu = \mu_0 \sqrt{\dfrac{1 - 81.45\ N}{\nu^2}}$

$$\therefore \quad 0.5 = 1\sqrt{1 - \frac{81.45 \times 4 \times 10^8}{\nu^2}}$$

On solving, we get $\nu = 208.42$ kHz $= 208$ kHz

36. Population covered $= \rho\pi d^2 = \rho\pi\ (2\ hR)$

$$= (1000 \times 10^{-6}) \times \frac{22}{7} \times (2 \times 400 \times 6.4 \times 10^6)$$

$$= 1.6 \times 10^7$$

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

$A = \pi d^2$

Putting the value of d from Eq. (i), we get

$$A = \pi 2Rh = 3.14 \times 2 \times 6400 \times \frac{30}{1000}$$

$$A = 1205.76\ \text{km}^2$$

$$A \simeq 1206\ \text{km}^2$$