TOPICS TO BE COVERED

1. Complete EM Waves
2. Complete Communication Systems
3. X rays
4. Questions

CONCEPT OF DISPLACEMENT CURRENT

at any time

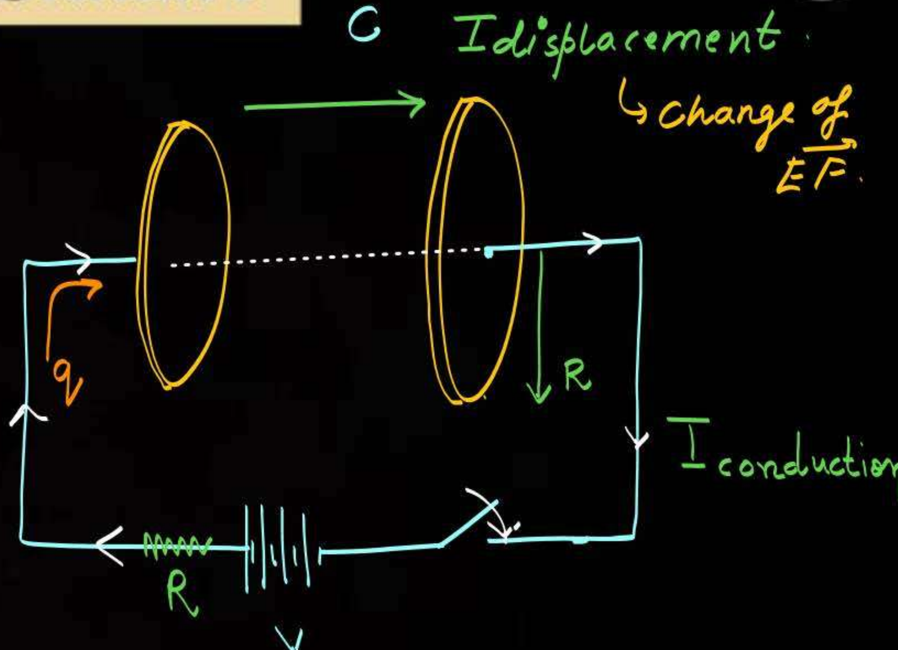
Charge on Capacitor

⊛ $\boxed{q = CV\left[1 - e^{-t/RC}\right]}$

differentiate wrt time

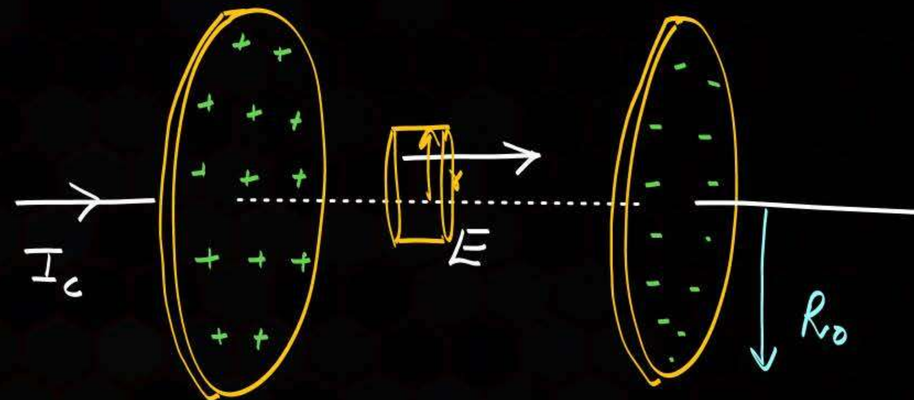
$$I_c = \frac{dq}{dt} = \cancel{C}V\left[0 + \frac{e^{-t/RC}}{R\cancel{C}}\right]$$

⊛ $\boxed{I_c = \frac{V}{R}e^{-t/RC}}$



⊛ Continuity of Current.

Electric field between plates of Capacitor.



$$E_i = \frac{\sigma}{\varepsilon_0}$$

$$\boxed{E_i = \frac{CV\left[1-e^{-t/RC}\right]}{\varepsilon_0 \pi R_0^2 \varepsilon_0}}$$

$$\sigma = \frac{q}{A} = \frac{CV\left[1-e^{-t/RC}\right]}{\pi R_0^2}$$

EF is varying with time.

$$\phi_i = E_i \pi r^2 = \frac{CV(\cancel{\pi} r^2)\left[1-e^{-t/RC}\right]}{\varepsilon_0 \cancel{\pi} R_0^2}$$

$$\phi_i = \frac{CV r^2}{\varepsilon_0 R_0^2}\left[1-e^{-t/RC}\right]$$

(4)

$$\phi_{Total} = \frac{q_i}{\varepsilon_0}$$

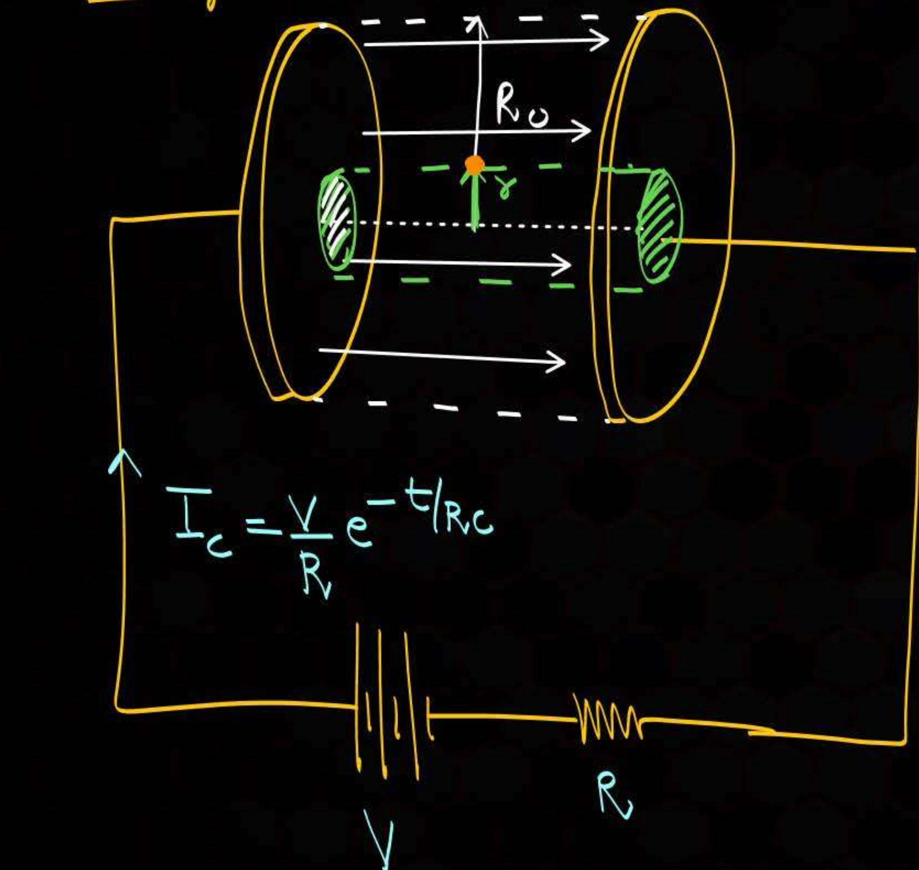
$$q_i = \varepsilon_0 \phi_{Total}$$

$$q_i = \varepsilon_0 \left[\frac{CVr^2}{\varepsilon_0 R_0^2}\left[1 - e^{-t/RC}\right]\right]$$

Rate of change of q_i $\quad \frac{dq_i}{dt} = \frac{\cancel{C}Vr^2}{R_0^2}\left[0 + \frac{e^{-t/RC}}{R\cancel{C}}\right]$

$$I_{dis} = \frac{V}{R}\left(e^{-t/RC}\right)\left[\frac{r^2}{R_0^2}\right]$$

Summary



$$I_{disp} = \frac{V}{R} e^{-t/RC} \left(\frac{r^2}{R_0^2} \right)$$

when $r = R_0$

$$\boxed{I_{dis} = \frac{V}{R} e^{-t/RC}} = I_{con}$$

directly Calculate

$$\pi R_0^2 \text{———} \frac{V}{R} e^{-t/RC}$$

$$1 \longrightarrow \frac{V}{R} e^{-t/RC} \frac{1}{\pi R_0^2}$$

$$\pi r^2 \longrightarrow \boxed{\frac{V}{R} e^{-t/RC} \cdot \frac{r^2}{R^2}}$$

1. between plates of Capacitor.

$$I_{dis} = \frac{V}{R} e^{-t/RC} \left(\frac{r^2}{R_0^2}\right)$$

$$I_{dis\ Total} = \frac{V}{R} e^{-t/RC}$$

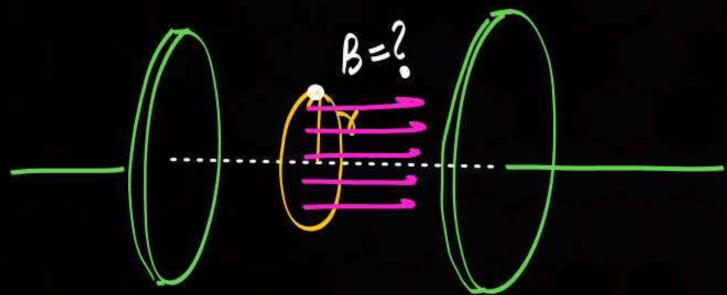
$r = R_0$

$$I_{cond} = \frac{V}{R} e^{-t/RC}$$

$$\boxed{I_{dis} = \varepsilon_0 \left(\frac{d\phi_E}{dt}\right)}$$

$$\boxed{\oint \vec{B} \cdot \vec{dl} = \mu_0 \left[I_c + \varepsilon_0 \frac{d\phi_E}{dt} \right]}$$

Magnetic field between plates of Capacitor



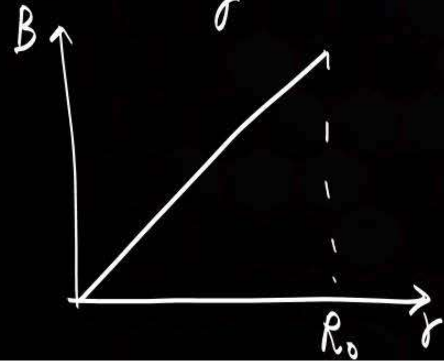
Ampere Circuital Law.

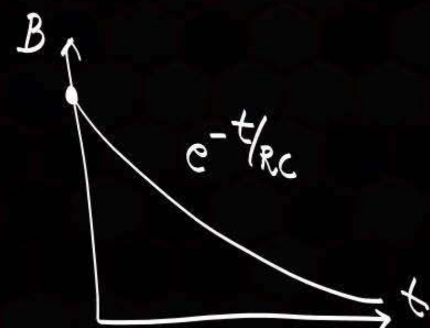
$$B \cdot 2\pi r = \mu_0 \left[\frac{V}{R} e^{-t/RC} \left(\frac{r^2}{R_0^2} \right) \right.$$

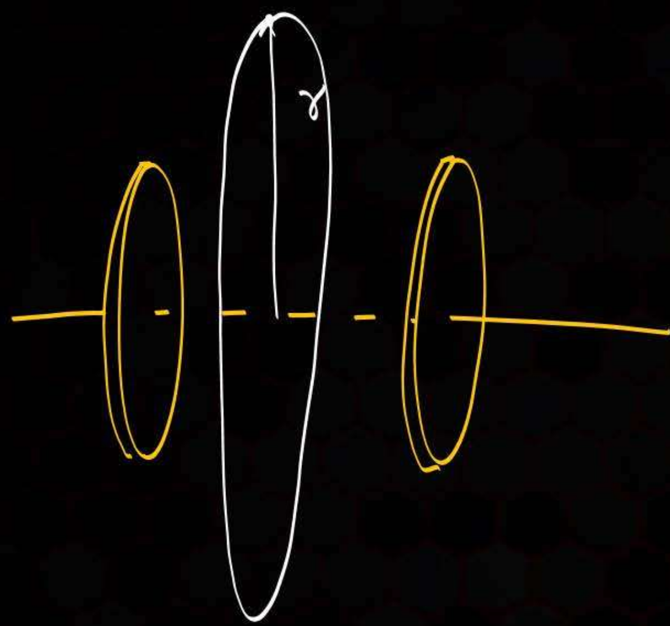
$$\boxed{B = \frac{\mu_0 V}{2\pi R} e^{-t/RC} \left(\frac{r}{R_0^2} \right)}$$

$$I_{dis} = \frac{V}{R} e^{-t/RC} \left(\frac{r^2}{R^2} \right)$$

at any time t.







$$B \cdot 2\pi r = \mu_0 \left[\frac{V}{R} e^{-t/RC} \frac{R_0^2}{R_0^2} \right]$$

$$B = \frac{\mu_0 V}{2\pi R} \frac{e^{-t/RC}}{r}$$

$$\boxed{B \propto \frac{1}{r}}$$

MAXWELL'S EQUATION

(1) Gauss law in electrostatics : $\oint \vec{E}.\vec{ds} = \frac{q_i}{\epsilon_0}$ ...(i)

(2) Gauss law in magnetism : $\oint \vec{B}.\vec{ds} = 0$ ...(ii)

(3) Faraday's law of electromagnetic induction : emf $= \oint \vec{E}.\vec{d\ell} = -\frac{d\phi_B}{dt}$ (TVMF) ...(iii)

(4) Maxwell - Ampere's circuital law : $\boxed{\oint \vec{B}.\vec{d\ell} = \mu_0 \left[I_c + \epsilon_0 \frac{d\phi_E}{dt}\right]}$ ... (iv)

Understanding Equation of travelling wave

for E.M. Wave → doesnot Require any Medium for prop.

This is produced by an accelerated charge Particle.

for Mechanical Transverse Wave

$$\boxed{y = A\sin(kx \pm \omega t)\,\hat{j}}$$

kx ⇒ dir of Prop of wave

$\pm$ → + (−ve dir), − (+ve dir).

$\hat{j}$ ⇒ direction of disp of Particle. (Y axis)

y ⇒ displacement of Particle

A ⇒ Amplitude

k ⇒ $\frac{2\pi}{\lambda} = k$

ω ⇒ $2\pi\nu$ or $\frac{2\pi}{T}$

$\boxed{\omega = k v}$

$\boxed{v_{wave} = \frac{\omega}{k}}$

Coefficient of t ⇒ ω = $\frac{2\pi}{T}$ = $2\pi\nu$

Coefficient (x, y, z) = $k = \frac{2\pi}{\lambda}$

(4)

1. $\vec{E}$ is $\perp$ to $\vec{B}$

$\vec{B}$ $\perp$ to dir of prop.

E $\perp$ to dir of prop

"Transverse Wave"

$$\boxed{\begin{aligned} \vec{E}\cdot\vec{B} &= 0 \\ \vec{E}\cdot\vec{K} &= 0 \\ \vec{B}\cdot\vec{K} &= 0 \end{aligned}}$$

K = Prop Vector = dir of flow of Energy

dir of propogation :- $(\vec{E}\times\vec{B})$.

2. Both $\vec{E}$ & $\vec{B}$ are in Same Phase. (EK Saath Max, Min).

$$E = E_0 \sin(Kx \pm \omega t)$$

$$B = B_0 \sin(Kx \pm \omega t)$$

* EM doesnot Require any Med for Propogation:-

Speed of EM Wave $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

$\mu_0 \Rightarrow$ magnetic Permeability

$\varepsilon_0 \Rightarrow$ Electrical Permitivity.

Vaccum $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

Medium $v = \frac{1}{\sqrt{\mu_m \varepsilon_m}} = \frac{1}{\sqrt{\varepsilon_r \varepsilon_0 \mu_r \mu_0}} = \frac{c}{\sqrt{\mu_r \varepsilon_r}}$

$\varepsilon_r = \frac{\varepsilon_m}{\varepsilon_0}$

$\mu_r = \frac{\mu_m}{\mu_0}$

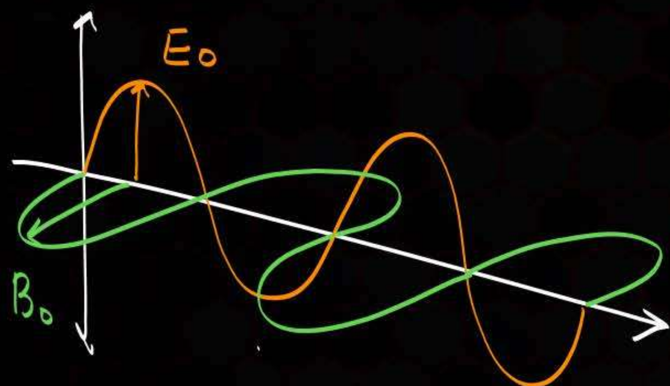
$v = \frac{c}{\sqrt{\mu_r \varepsilon_r}} \Rightarrow \boxed{\sqrt{\mu_r \varepsilon_r} = \frac{c}{v}}$

$$\boxed{RI_{medium} = \frac{c}{v} = \sqrt{\mu_r \varepsilon_r}}$$

In our Cases

non magnetic Material ($\mu_r = 1$), ε_r = dielectric Const (Question Given)

4.



$$\boxed{E_0 = CB_0}$$

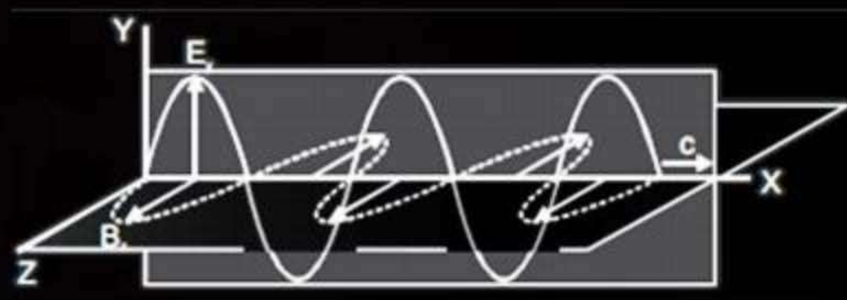
PROPERTIES OF ELECTROMAGNETIC WAVES

- The fundamental sources of electromagnetic waves are accelerating electric charges. For examples radio waves emitted by an antenna arises from the continuous oscillations (and hence acceleration) of charges within the antenna structure.
- Electromagnetic waves obey the principle of superposition.
- The electric vector of an electromagnetic field is responsible for all optical effects. For this reason electric vector is also called a light vector.

PROPERTIES OF ELECTROMAGNETIC WAVES

Electromagnetic waves travel through vacuum with the speed of light c, where

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \text{ m/s}$$



- The electric and magnetic fields of a sinusoidal plane electromagnetic wave propagating in the positive x-direction can also be written as
  $E = E_\omega \sin(kx - \omega t)$ and $B = B_\omega \sin(kx - \omega t)$
  where ω is the angular frequency of the wave and k is wave number which are given by
  $\omega = 2\pi f$ and $k = 2\pi/\lambda$

- The electric and magnetic fields of an electromagnetic wave are prependicular to each other and also perpendicular to the direction of wave propagation. Hence, these are transverse waves.

- The instantaneous magnitudes of $\vec{B}$ and $\vec{E}$ in an electromagnetic wave are related by the expression E/B = c

- Electromagnetic waves carry energy. The rate of flow of energy crossing a unit area is described by the Poynting vector $\vec{S}$. Where $\vec{S} = \frac{1}{\mu_0}(\vec{E} \times \vec{B})$

  Poynting Vector.

- The intensity of a sinusoidal plane electro-magnetic wave is defined as the average value of Poynting vector taken over one cycle.

$$S_{av} = \frac{E_\omega B_\omega}{2\mu_0} = \frac{E_\omega^2}{2\mu_0 C} = \frac{c}{2\mu_0} = B_\omega^2$$

Energy densities of EM Waves.

EM Waves $\rightarrow$ EF $\quad u_E = \frac{1}{2}\varepsilon_0 E^2$

$\quad\quad\quad\quad\;\; \rightarrow$ MF $\quad u_B = \frac{B^2}{2\mu_0}$

1. EF (Energy density) $\quad$ EM Waves $= E_0 \sin(Kx - \omega t)$ $\rightarrow$ $E_{rms} = \frac{E_0}{\sqrt{2}}$

$E_{rms}^2 = \frac{E_0^2}{2}$

$u_E = \frac{1}{2}\varepsilon_0 E^2$ $\quad$ E_0 = Peak Value.

$u_E = \frac{1}{2}\varepsilon_0 E_0^2 \sin^2(Kx - \omega t)$

$\langle u_E \rangle = \frac{1}{2}\varepsilon_0 E_0^2\left[\frac{1}{2}\right] = \boxed{\frac{1}{4}\varepsilon_0 E_0^2} = \boxed{\frac{1}{2}\varepsilon_0 E_{rms}^2}$.

(4) Magnetic field

$$u_B = \frac{B^2}{2\mu_0}$$

$$u_B = \frac{B_0^2 \sin^2(Kx - \omega t)}{2\mu_0}$$

$$\boxed{\langle u_B \rangle = \frac{B_0^2}{4\mu_0} = \frac{B_{rms}^2}{2\mu_0}}$$

(*) $\boxed{\frac{u_E}{u_B} = 1}$ Energy of EM wave is Equally dis in EF & MF.

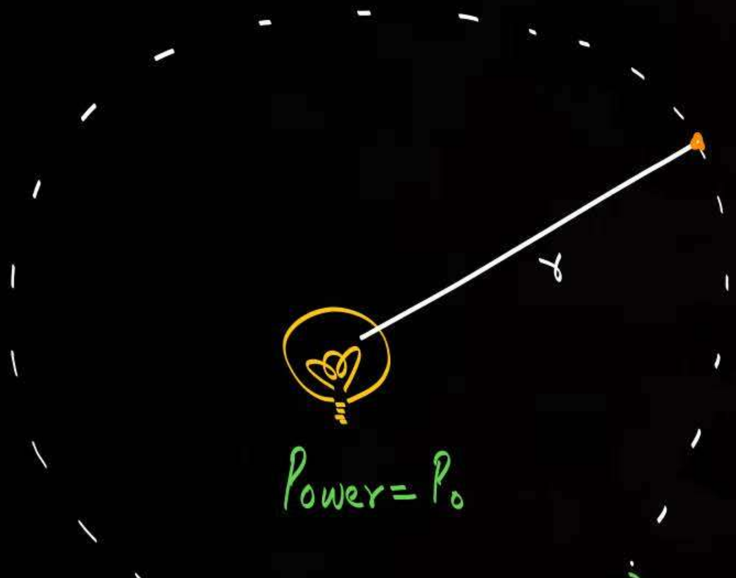
$$u_T = u_E + u_B$$

$$\boxed{\begin{aligned} u_T &= 2u_E \\ u_T &= 2u_B \end{aligned}}$$

$$u_{Total} = 2\left[\frac{B_0^2}{4\mu_0}\right] = \frac{B_0^2}{2\mu_0}$$

$$u_{Total} = 2\left[\frac{1}{4}\varepsilon_0 E_0^2\right] = \frac{1}{2}\varepsilon_0 E_0^2$$

❖ Intensity of EM waves:



Power = P_0

$$\text{Intensity} = \frac{\text{Energy}}{\text{Area} \times \text{time}}$$

$$\boxed{I = \frac{P_{bulb}}{4\pi r^2}}$$

$$\boxed{\begin{aligned} I &= \frac{1}{2}\varepsilon_0 E_0^2 c \\ &= \frac{B_0^2 c}{2\mu_0} \end{aligned}}$$

wavefront

(Point Source (bulb)) = wavefront → spherical. $(4\pi r^2 = A)$

Q. An electromagnetic wave of frequency v = 3.0 MHz passes from vacuum into a dielectric medium with permittivity $\in = 4.0$. Then: **[2004]**

$\varepsilon_r = 4.$

(A) Wave length is halved and frequency remains unchanged

Ans

(B) Wave length is doubled and frequency becomes half

(C) Wave length is doubled and the frequency remains unchanged

(D) Wave length and frequency both remains unchanged

when Light goes from one Med to another

$\boxed{\nu = \text{Constant}}$

Speed = $\nu \times \lambda$

half, const, half

Medium $RI = \sqrt{\mu_r \varepsilon_r} = \sqrt{4} = 2$

$\mu_r = 1$

$RI = 2 = \frac{c}{v}$

$\boxed{\text{Speed} = \frac{c}{2}}$

Q. The frequency of X-rays; γ-rays and ultraviolet rays are respectively a, b and c then: **[2012]** ×3

(A) a < b; b > c Ans

(B) a > b; b > c

(C) a < b < c

(D) a = b = c

VIBGYOR

Cosmic γ X UV Vis IR Micro Radio

Energy

ν

λ

b a c

$\boxed{b > a > c}$

Q. The magnetic field in a travelling electromagnetic wave has a peak value of 20 nT. The peak value of electric field strength is: **[2013]**

(A) 3 V/m

(B) 6 V/m Ans

(C) 9 V/m

(D) 12 V/m

$$B_0 = 20\,nT = 20 \times 10^{-9}\,T$$

$$\boxed{E_0 = B_0 c}$$

$$E_0 = 20 \times 10^{-9} \times 3 \times 10^{8}$$

$$= 60 \times 10^{-1}$$

$$= 6\ V/m$$

Q. An electromagnetic wave going through vacuum is described by $E = E_0 \sin(kx - \omega t)$; $B = B_0 \sin(kx - \omega t)$. Which of the following equations is true?

(2022).

(A) $E_0 k = B_0 \omega$ Ans

(B) $E_0 \omega = B_0 k$

(C) $E_0 B_0 = \omega k$

(D) $E_0 B_0 k = \omega$

$E = E_0 \sin(Kx - \omega t)$

$B = B_0 \sin(Kx - \omega t)$

$\omega = K v$

$v = \dfrac{\omega}{K}$

$E_0 = B_0 c$

$\Downarrow$

Velocity of wave.

$E_0 = B_0 \dfrac{\omega}{K}$

$\boxed{E_0 K = B_0 \omega}$

Q. Select the correct statement from the following:

[2013]

(A) Electromagnetic waves cannot travel in vacuum

(B) Electromagnetic waves are longitudinal waves

(Transverse)

(C) Electromagnetic waves are produced by charges moving with uniform velocity

(accelerated)

(D) Electromagnetic waves carry both energy and momentum as they propagate through space

Ans

$\Downarrow$

$u_T = 2u_E = 2u_B$

$\Downarrow$

Radiation pressure / Radiation force.

(Dual Nature).

Q. A plane electromagnetic wave in a non-magnetic $(\mu_r = 1)$ dielectric medium is given by $\vec{E} = \vec{E}_0 \sin(4 \times 10^{-7} x - 50t)$ with distance being in meter and time in seconds. The dielectric constant of the medium is: **[2013]**

(A) 2.4

(B) 5.8

(C) 8.2

(D) 4.8

$E = E_0 \sin(\underbrace{4\times10^{-7}}_{K} x - \underbrace{50}_{\omega} t)$

$\boxed{\omega = K v}$

$K = \varepsilon_r = ?$

$v_{wave} = \dfrac{\omega}{K}$

$RI = \sqrt{\varepsilon_r \mu_r} = \dfrac{c}{v}$

$c = 3\times10^8$

$\sqrt{K(1)} = \dfrac{3\times10^8 \times 4\times10^{-7}}{50}$

$K =$ ______ . Ans.

Q. During the propagation of electromagnetic waves in a medium:

[2014] (x4).

A. Electric energy density is double of the magnetic energy density

B. Electric energy density is half of the magnetic energy density

C. Electric energy density is equal to the magnetic energy density Ans

D. Both electric and magnetic energy densities are zero

Q. The energy associated with electric field is (U_E) and with magnetic field is (U_B) for an electromagnetic wave in free space. Then: **[2019]**

(A) $U_E = E_B/2$

(B) $U_E < E_B$

(C) $U_E = E_B$ Ans

(D) $U_E > E_B$

Q. An electromagnetic wave of frequency 1×10^{14} hertz is propagating along z-axis. The amplitude of electric field is 4 V/m. If $\varepsilon_0 = 8.8 \times 10^{-12} C^2/N - m^2$, then average energy density of electric field will be : **[2014]** ×3

(A) $35.2 \times 10^{-10} Jm^3$

(B) $35.2 \times \frac{10^{-11} J}{m^3}$

(C) $35.2 \times 10^{-12} J/m^3$

(D) $35.2 \times 10^{-13} J/m^3$

$\nu = 1 \times 10^{14}$ Hz (Z axis)

$E_0 = 4$ V/m

$\varepsilon_0 = 8.8 \times 10^{-12}$

$u_E = \frac{1}{2} \varepsilon_0 E^2$

$u_E = \frac{1}{2} \varepsilon_0 E_0^2 \sin^2(kx - \omega t)$

$\langle u_E \rangle = \frac{1}{4} \varepsilon_0 E_0^2 = \frac{1}{4} \times 8.8 \times 10^{-12} \times 4 \times 4 =$ Ans.

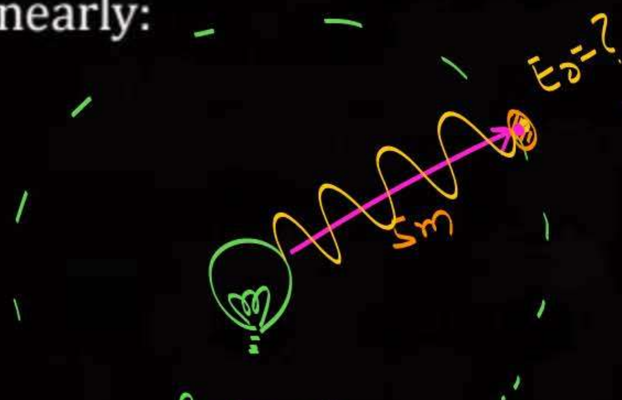
Q. A lamp emits monochromatic green light uniformly in all directions. The lamp is 3% efficient in converting electrical power to electromagnetic waves and consumes of power 100W. The amplitude of the electric field associated with the electromagnetic radiation at a distance of 5m from the lamp will be nearly: **[2014]** × 3

(A) 1.34 V/m

(B) 2.68 V/m

(C) 4.02 V/m

(D) 5.36 V/m



$P = 100\,W$

3%

$P_{out} = \frac{3}{100} \times 100\,W = 3\,W.$

$$I = \frac{P_{eff}}{4\pi r^2} = \frac{3}{4\pi (5)^2} = \frac{1}{2}\varepsilon_0 E_0^2 c$$

OR

$$\frac{B_0^2}{2\mu_0} \times c$$

$$\frac{E_{Total}}{\text{Area} \times \text{time}}$$

$$\boxed{\varepsilon_0 = 8.85 \times 10^{-12}}$$

$$\frac{3}{4\pi(5)^2} = \frac{1}{2}\varepsilon_0 E_0^2 c.$$

$$E_0 = \sqrt{\frac{3}{2\pi \times 25 \times 8.8\times10^{-12} \times 3\times10^{8}}}$$

Q. An electromagnetic wave with frequency ω and wavelength λ travels in the +y direction. Its magnetic field is along +x-axis. The vector equation for the associated electric field (of amplitude E_0) is : **[2012]**

(A) $\vec{E} = -E_0 \cos\left(\omega t + \frac{2\pi}{\lambda} y\right)\hat{x}$ → dir of prop (−Y)

(B) $\vec{E} = E_0 \cos\left(\omega t - \frac{2\pi}{\lambda} y\right)\hat{x}$

(C) $\vec{E} = E_0 \cos\left(\omega t - \frac{2\pi}{\lambda} y\right)\hat{z}$ Ans

(D) $\vec{E} = -E_0 \cos\left(\omega t + \frac{2\pi}{\lambda} y\right)\hat{z}$ (−Y)

dir of prop = +Y

$\vec{B}$ = (+x) axis.

$\bar{E} \times \bar{B}$ = dir of prop

$\boxed{\hat{z} \times \hat{i} = +\hat{j}}$

Q. An electromagnetic wave in vacuum has the electric and magnetic field $\vec{E}$ and $\vec{B}$, which are always perpendicular to each other. The direction of polarization is given by $\vec{X}$ and that of wave propagation by $\vec{k}$. Then : **[2012]** wave optics

dir of polarisation is same dir of EF.

A $\vec{X} \parallel \vec{B}$ and $\vec{k} \parallel \vec{B} \times \vec{E}$

B $\vec{X} \parallel \vec{E}$ and $\vec{k} \parallel \vec{E} \times \vec{B}$ Ans

↳ Prop vector (dir of prop of wave)

$\vec{X} \parallel \vec{E}$

$\vec{X} \perp \vec{B}$

$\vec{X} \perp \vec{K}$

C $\vec{X} \parallel \vec{B}$ and $\vec{k} \parallel \vec{E} \times \vec{B}$

D $\vec{X} \parallel \vec{E}$ and $\vec{k} \parallel \vec{B} \times \vec{E}$

Q. For plane electromagnetic waves propagating in the z-direction, which one of the following combination gives the correct possible direction for $\vec{E}$ and $\vec{B}$ field respectively? **[2015]**

(A) $\vec{E}$ $(2\hat{i} + 3\hat{j})$ and $\vec{B}$ $(\hat{i} + 2\hat{j})$ $\quad \bar{E}\cdot\bar{B} = 2\times1 + 3\times2 \neq 0$

(B) $(-2\hat{i} - 3\hat{j})$ and $(3\hat{i} - 2\hat{j})$ $\quad \bar{E}\cdot\bar{B} = -2\times3 + 3\times2 = 0$ ✓

(C) $(3\hat{i} + 4\hat{j})$ and $(4\hat{i} - 3\hat{j})$ $\quad \bar{E}\cdot\bar{B} = 12 - 12 =$ ✓

(D) $(\hat{i} + 2\hat{j})$ and $(2\hat{i} - \hat{j})$ $\quad \bar{E}\cdot\bar{B} = 1\times2 - 2 =$ ✓

dir of prop = $\hat{z}$.

$\vec{E}\cdot\vec{B} = 0$.

$\bar{E}\times\bar{B}$ = dir of prop.

a) $-2\hat{i} - 3\hat{j}$ & $(3\hat{i} - 2\hat{j})$

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -2 & -3 & 0 \\ 3 & -2 & 0 \end{vmatrix}$$

$$= \hat{i}(0-0) - \hat{j}(0-0) + \hat{k}(4+9)$$

$$= 13\hat{k}$$

b)

$$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & 4 & 0 \\ 4 & -3 & 0 \end{vmatrix}$$

$$\hat{i}(0-0) - \hat{j}(0-0) + \hat{k}(-9-16)$$

$$= -25\hat{k}$$

(dir. is $-z$ axis)

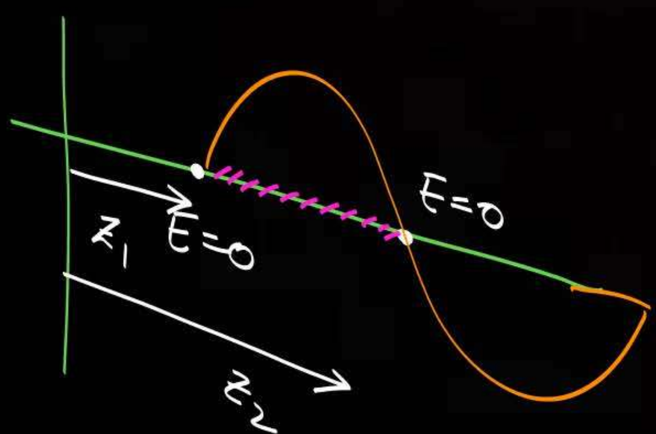
Q. A plane polarized monochromatic EM wave is travelling a vacuum along z-direction such that at $t = t_1$ it is found that the electric field is zero at a spatial point z_1. The next zero that occurs in its neighbourhood is at z_2. The frequency of the electromagnetic wave is: **[2018]**

(A) $\dfrac{3 \times 10^8}{|z_2 - z_1|}$

(B) $\dfrac{6 \times 10^8}{|z_2 - z_1|}$

(C) $\dfrac{1.5 \times 10^8}{|z_2 - z_1|}$ Ans

(D) $\dfrac{1}{t_1 + \dfrac{|z_2 - z_1|}{3 \times 10^8}}$



$z_2 - z_1 = \lambda/2$

$2(z_2 - z_1) = \lambda$

$c = \nu\lambda$

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

$\dfrac{c}{2(z_2 - z_1)} = \nu$

Q. A plane electromagnetic wave of wavelength λ has an intensity I. It is propagating along the positive Y-direction. The allowed expressions for the electric and magnetic fields are given by: **[2018]**

(A) $\vec{E} = \sqrt{\frac{I}{\epsilon_0 C}} \cos\left[\frac{2\pi}{\lambda}(y - ct)\right]\hat{\imath}; \vec{B} = \frac{1}{c}E\hat{k}$

(B) $\vec{E} = \sqrt{\frac{I}{\epsilon_0 C}} \cos\left[\frac{2\pi}{\lambda}(y - ct)\right]\hat{k}; \vec{B} = -\frac{1}{c}E\hat{k}$

(C) $\vec{E} = \sqrt{\frac{2I}{\epsilon_0 C}} \cos\left[\frac{2\pi}{\lambda}(y - ct)\right]\hat{k}; \vec{B} = +\frac{1}{c}E\hat{\imath}$

(D) $\vec{E} = \sqrt{\frac{2I}{\epsilon_0 C}} \cos\left[\frac{2\pi}{\lambda}(y + ct)\right]\hat{k}; \vec{B} = \frac{1}{c}E\hat{\imath}$

dir of prop = +Y.

$I = \frac{1}{2}\varepsilon_0 E_0^2 c$

$E_0 = \sqrt{\frac{2I}{\varepsilon_0 c}}$

$\Rightarrow \hat{E} = \hat{k}$

dir of $\vec{B}$: $+\hat{\imath}$

Q. A plane electromagnetic wave having a frequency ν = 23.9 GHz propagates along the positive z -direction in free space. The peak value of the electric field is 60 V/m. Which among the following is the acceptable magnetic field component in the electromagnetic wave? **(Main 2019)**

(A) $\vec{B} = 2 \times 10^{7} \sin(0.5 \times 10^{3} z + 1.5 \times 10^{11} t)\hat{\imath}$ $(-z)$

(B) $\vec{B} = 2 \times 10^{-7} \sin(1.5 \times 10^{2} x + 0.5 \times 10^{11} t)\hat{\jmath}$ $(-x)$

(C) $\vec{B} = 2 \times 10^{-7} \sin(0.5 \times 10^{3} z - 1.5 \times 10^{11} t)\hat{\imath}$ $(+z)$

(D) $\vec{B} = 60 \sin(0.5 \times 10^{3} x + 1.5 \times 10^{11} t)\hat{k}$

dir of pro = +z

$E_0 = 60\ V/m$

$B_0 = \frac{E_0}{c} = \frac{60}{3 \times 10^8}$

$= 20 \times 10^{-8}$

$= 2 \times 10^{-7}$ //

Q. For a plane electromagnetic wave, the magnetic field at a point x and time t is $\vec{B}(x,t) = [\underbrace{1.2 \times 10^{-7}}_{B_0} \sin(\underbrace{0.5 \times 10^3}_{K} x + \underbrace{1.5 \times 10^{11}}_{\omega} t)\hat{k}]T$

The instantaneous electric field $\vec{E}$ corresponding to $\vec{B}$ is:

→ dir of Prop = $-x$.

$\hat{B} = \hat{K}$

$\bar{E} \times \bar{B}$ = dir of prop.

$(-\hat{j} \times \hat{K}) = -\hat{i}$

(A) $\vec{E}(x,t) = [-36 \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\hat{j}] \frac{V}{m}$ Ans

(B) $\vec{E}(x,t) = [36 \sin(1 \times 10^3 x + 1.5 \times 10^{11} t)\hat{j}] \frac{V}{m}$

$(+\hat{j})$

(C) $\vec{E}(x,t) = [36 \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)\hat{k}] \frac{V}{m}$ ×

(D) $\vec{E}(x,t) = [36 \sin(1 \times 10^3 x + 1.5 \times 10^{11} t)\hat{i}] \frac{V}{m}$

$(+\hat{i})$ $\vec{E} \perp \vec{K}$

Q. If the magnetic field of a plane electromagnetic wave is given by (The speed of light = 3×10^8 m/s) $B = \underset{B_0}{\underline{100 \times 10^{-6}}} \sin\left[2\pi \times 2 \times 10^{15}\left(t - \frac{x}{c}\right)\right]$, then the maximum electric field associated with it is: **[2019]**

(A) 4×10^4 N/C

(B) 4.5×10^4 N/C

(C) 6×10^4 N/C

(D) 3×10^4 N/C

$$\boxed{E_0 = B_0 c}$$

Q. A plane electromagnetic wave travels in free space along the x-direction. The electric field component of the wave at a particular point of space and time is $E = 6\ Vm^{-1}$ y-direction. Its corresponding magnetic field component, B would be **[2019]**

(A) 6×10^{-8} T along z-direction

(B) 6×10^{-8} T along x-direction

(C) 2×10^{-8} T along z-direction Ans

(D) 2×10^{-8} T along y-direction

dir of prop = +X.

$E = 6\ V/m\ (+Y)$

$B_0 = \frac{E_0}{c} = \frac{6}{3 \times 10^8} = 2 \times 10^{-8}$

$\vec{E} \times \vec{B}$ = dir of prop

Class-12

Communication

(1 Ques → balle balle)

→ NCERT Reading → Must.

We dont have NCERT!

(Dont worry!)

(No need of notes)

+ Imp points

(Summary).

15.2 Elements of a Communication System

Communication pervades all stages of life of all living creatures. Irrespective of its nature, every communication system has three essential elements-

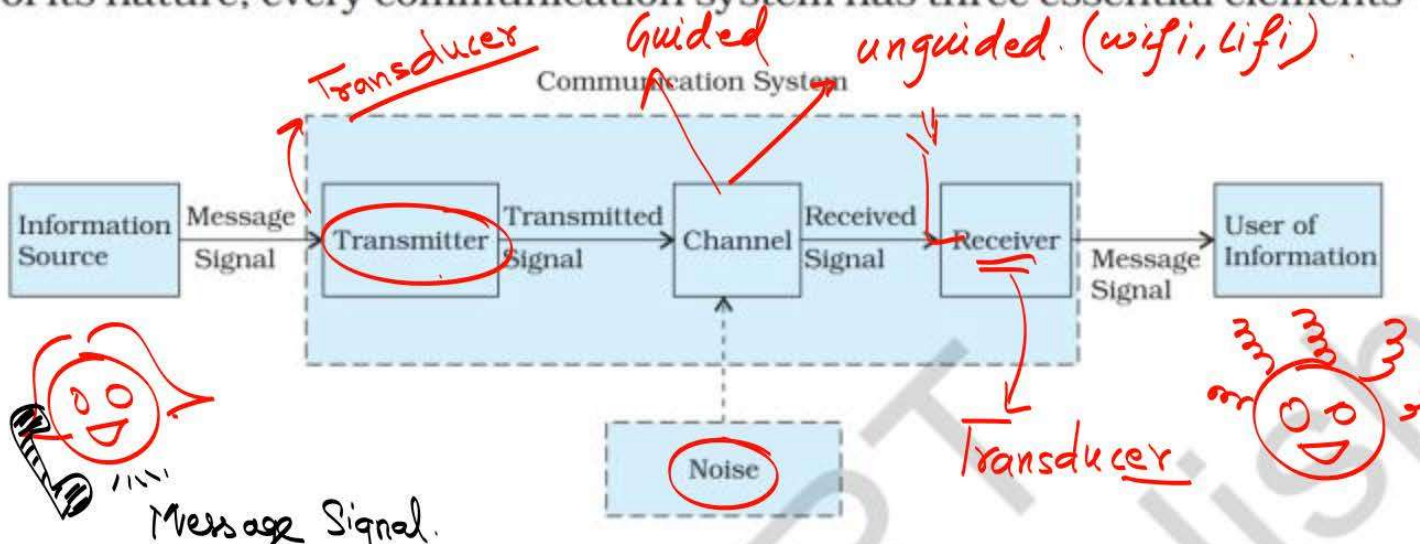
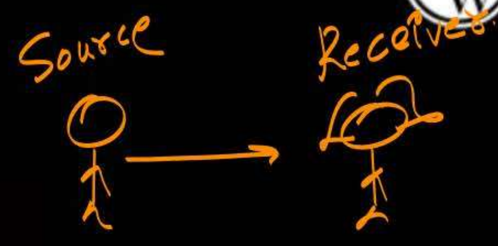
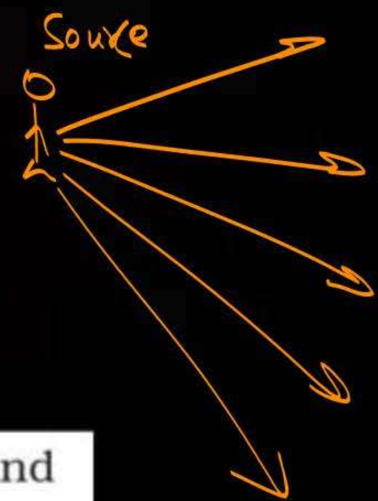


FIGURE 15.1 Block diagram of a generalised communication system.

In a communication system, the transmitter is located at one place, the receiver is located at some other place (far or near) separate from the transmitter and the channel is the physical medium that connects them. Depending upon the type of communication system, a channel may be in the form of wires or cables connecting the transmitter and the receiver or it may be wireless. The purpose of the transmitter is to convert the message signal produced by the source of information into a form suitable for transmission through the channel. If the output of the information source is a non-electrical signal like a voice signal, a transducer converts it to electrical form before giving it as an input to the transmitter. When a transmitted signal propagates along the channel it may get distorted due to channel imperfection. Moreover, noise adds to the transmitted signal and the receiver receives a corrupted version of the transmitted signal. The receiver has the task of operating on the received signal. It reconstructs a recognisable form of the original message signal for delivering it to the user of information.



Point to Point



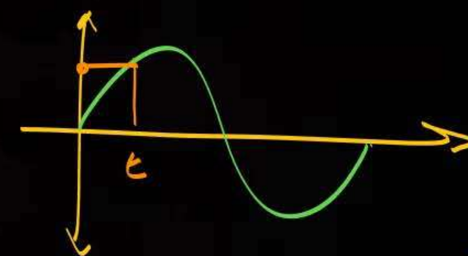
There are two basic modes of communication: *point-to-point* and *broadcast*.

15.3 Basic Terminology Used in Electronic Communication Systems

(i) *Transducer:* Any device that converts one form of energy into another can be termed as a transducer. In electronic communication systems, we usually come across devices that have either their inputs or outputs in the electrical form. An electrical transducer may be defined as a device that converts some physical variable (pressure, displacement, force, temperature, etc) into corresponding variations in the electrical signal at its output.

(ii) *Signal:* Information converted in electrical form and suitable for transmission is called a signal. Signals can be either *analog or digital*. Analog signals are continuous variations of voltage or current. *They are essentially single-valued functions of time*. Sine wave is a fundamental analog signal. All other analog signals can be fully understood in terms of their sine wave components. Sound and picture signals in TV are analog in nature. Digital signals are those which can take only discrete stepwise values. Binary system that is extensively used in digital electronics employs just two levels of a signal. '0' corresponds to a low level and '1' corresponds to a high level of voltage/ current. There are several coding schemes useful for digital communication. They employ suitable combinations of number systems such as the binary coded decimal (BCD)*. American Standard Code for Information Interchange (ASCII)** is a universally popular digital code to represent numbers, letters and certain characters.

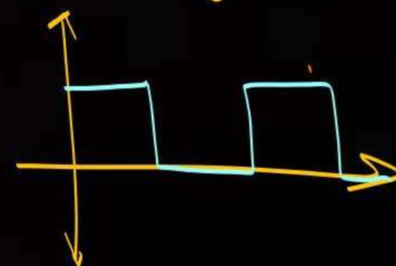
⇒ analog Signal



Single Valued function

⇒ Digital Signal.

→ discrete Step wise Value.



bits 0, 1

⇓ ⇓

0V 5V.

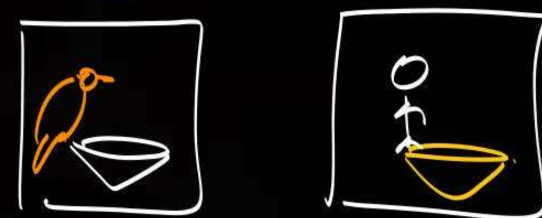
(iii) *Noise:* Noise refers to the unwanted signals that tend to disturb the transmission and processing of message signals in a communication system. The source generating the noise may be located inside or outside the system.

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

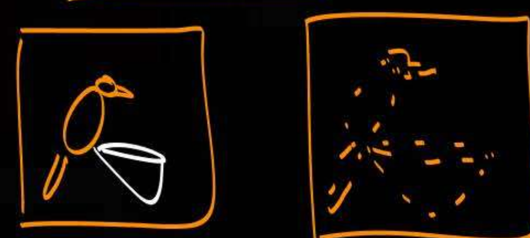
(v) *Receiver:* A receiver extracts the desired message signals from the received signals at the channel output.

(vi) *Attenuation:* The loss of strength of a signal while propagating through a medium is known as attenuation.

distortion



attenuation



(vii) *Amplification*: It is the process of *increasing the amplitude* (and consequently the strength) of a signal using an electronic circuit called the amplifier (reference Chapter 14). Amplification is necessary to compensate for the attenuation of the signal in communication systems. The energy needed for additional signal strength is obtained from a DC power source. Amplification is done at a place between the source and the destination wherever signal strength becomes weaker than the required strength.

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

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

(x) *Modulation:* The original low frequency message/information signal cannot be transmitted to long distances because of reasons given in Section 15.7. Therefore, at the transmitter, information contained in the low frequency message signal is superimposed on a high frequency wave, which acts as a carrier of the information. This process is known as modulation. As will be explained later, there are several types of modulation, abbreviated as AM, FM and PM.

(xi) *Demodulation:* The process of retrieval of information from the carrier wave at the receiver is termed demodulation. This is the reverse process of modulation.

(xii) *Repeater:* A repeater is a combination of a receiver and a transmitter. A repeater, picks up the signal from the transmitter, amplifies and retransmits it to the receiver sometimes with a change in carrier frequency. Repeaters are used to extend the range of a communication system as shown in Fig. 15.2. A communication satellite is essentially a repeater station in space.

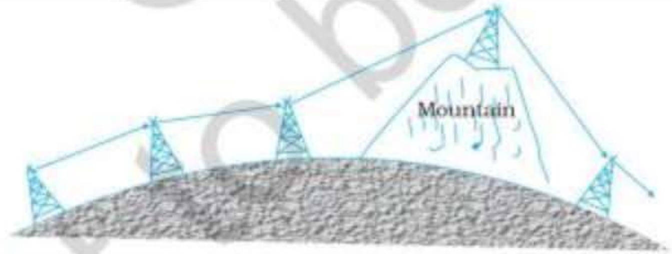


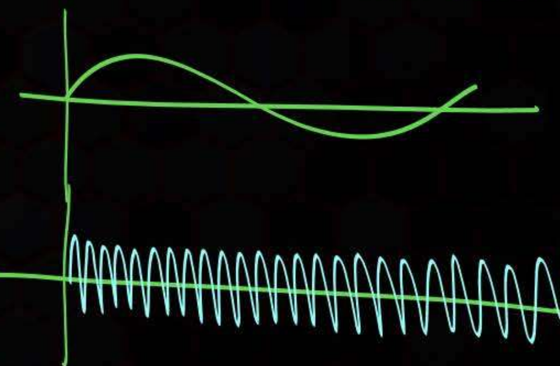
FIGURE 15.2 Use of repeater station to increase the range of communication.

Modulation
&
demodulation

When Signal of Low Energy is Superimposed on wave of high ν.
(Carrier Wave)

Low Strength Signal → (Short Range)

→ high Range
(Modulation)



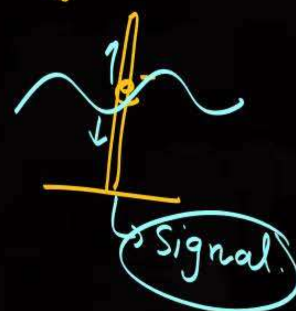
Antenna

Conductor → e^- undergo SHM.

⇓

EM waves

⇓



❖ **Hertz Antenna**

$\boxed{\text{length} = \lambda/2}$

wave $\lambda = 300\,m$

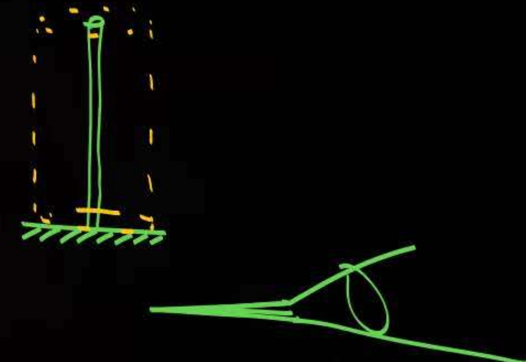
Length of antenna = $150\,m$

❖ **Marconi Antenna**

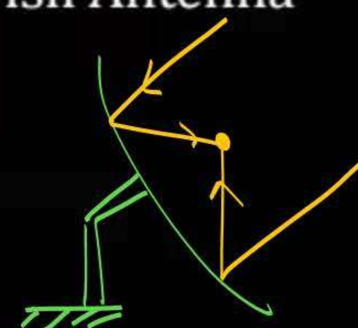
$\boxed{\text{length} = \frac{\lambda}{4}}$

Shape of Antenna

❖ Dipole Antenna



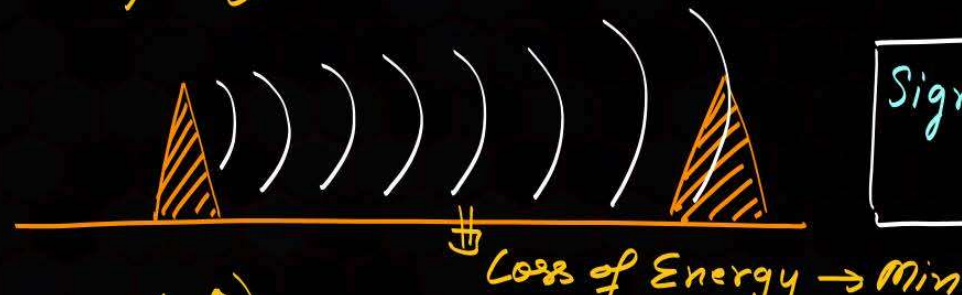
❖ Dish Antenna



unidirectional.

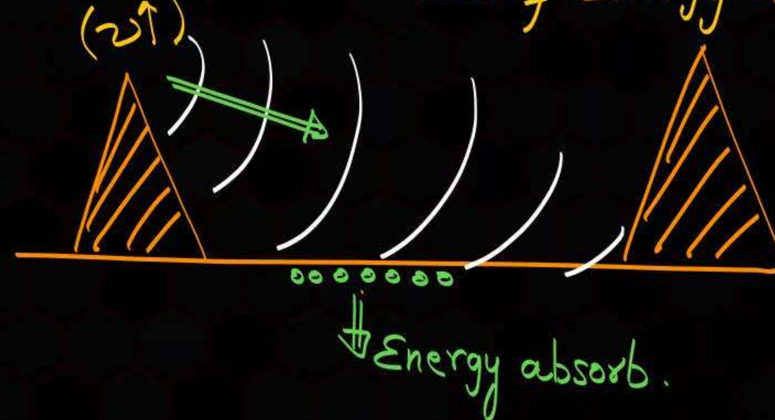
Three methods of propogation of Signal

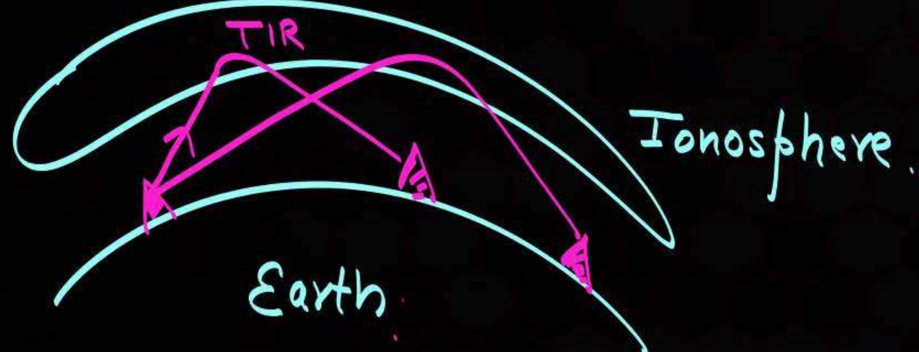
1. Ground wave



Signals of Low freq

2. Sky wave. Signal of higher freq





15.6.1 Ground wave

To radiate signals with high efficiency, the antennas should have a size comparable to the wavelength λ of the signal (at least ~ $\lambda/4$). At longer wavelengths (i.e., at lower frequencies), the antennas have large physical size and they are located on or very near to the ground. In standard AM broadcast, ground based vertical towers are generally used as transmitting antennas. For such antennas, ground has a strong influence on the propagation of the signal. The mode of propagation is called surface wave propagation and the wave glides over the surface of the earth. A wave induces current in the ground over which it passes and it is attenuated as a result of absorption of energy by the earth. The attenuation of surface waves increases very rapidly with increase in frequency. The maximum range of coverage depends on the transmitted power and frequency (less than a few MHz).

Earth Atmosphere

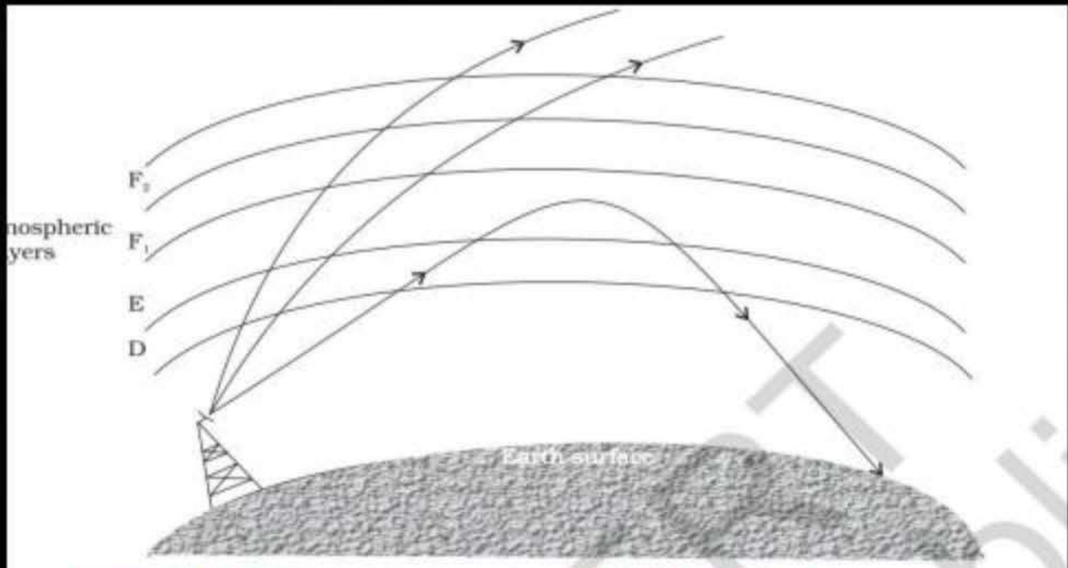
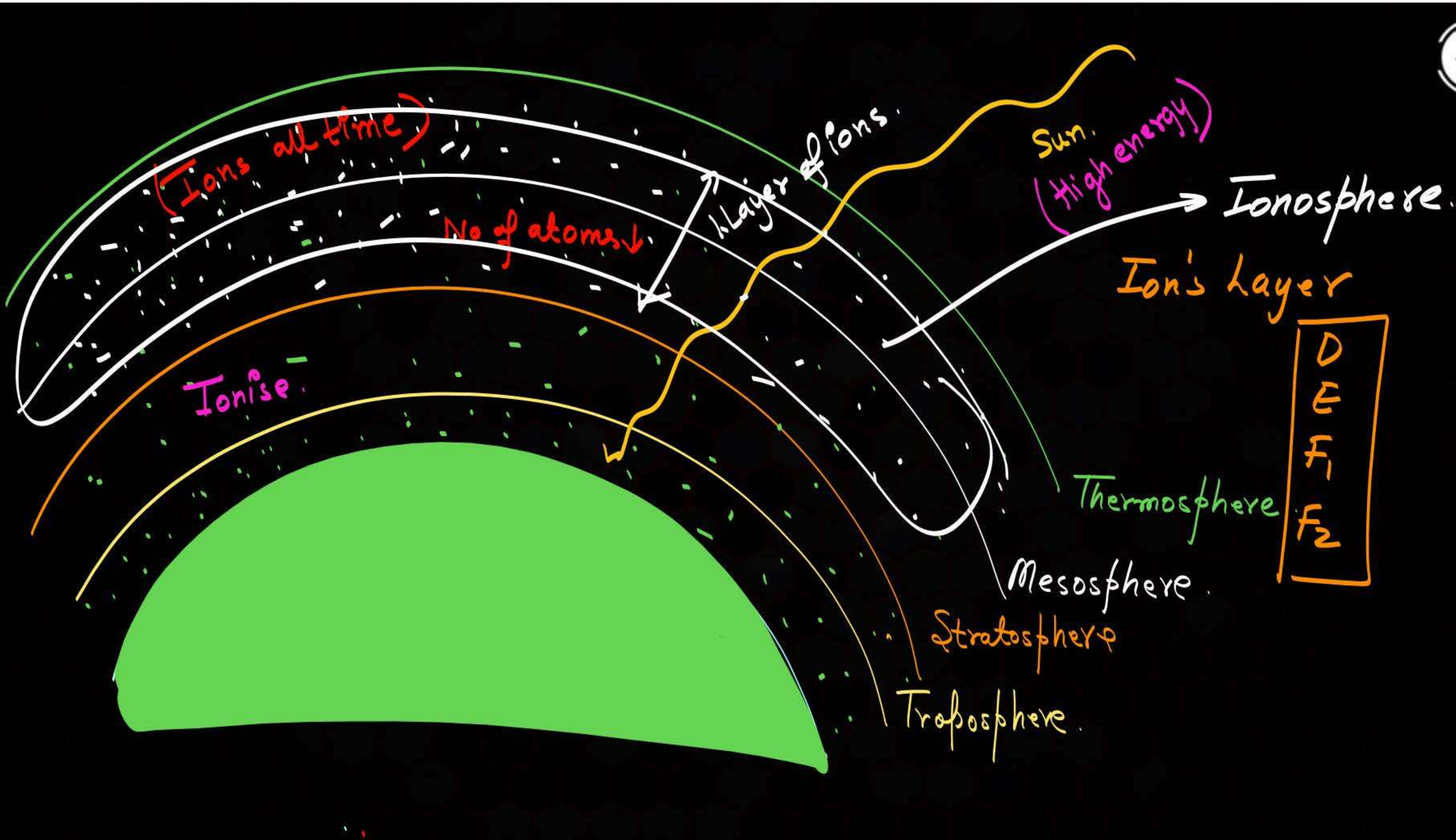


FIGURE 15.4 Sky wave propagation. The layer nomenclature is given in Table 15.3.



(Ions all time)
Layer of ions.
No of atoms↓
Sun.
(High energy)
Ionosphere.
Ion's Layer
D
E
F1
F2
Ionise.
Thermosphere
Mesosphere.
Stratosphere
Troposphere.

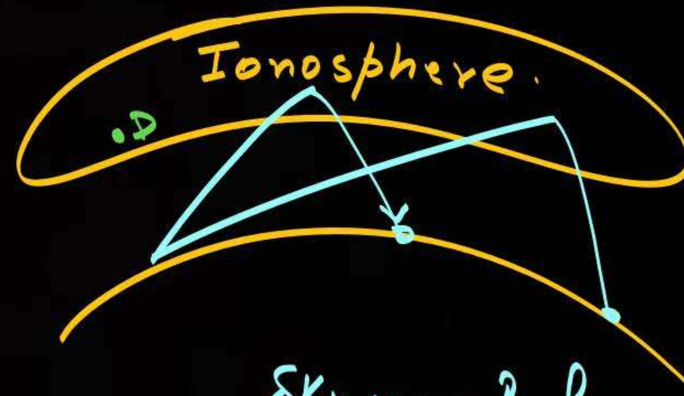
PROPAGATING ELECTROMAGNETIC WAVES					
Name of the stratum (layer)		Approximate height over earth's surface	Exists during	Frequencies most affected	
Troposphere		10 km	Day and night	VHF (up to several GHz)	
D (part of stratosphere)	PARTS OF IONOSPHERE	65-75 km	Day only	Reflects LF, absorbs MF and HF to some degree	$10^9\ /m^3$ = D
E (part of Stratosphere)		100 km	Day only	Helps surface waves, reflects HF	$2 \times 10^{11}\ /m^3$ = D
F_1 (Part of Mesosphere)		170-190 km	Daytime, merges with F_2 at night	Partially absorbs HF waves yet allowing them to reach F_2	$3 \times 10^{11}\ /m^3$ = D
F_2 (Thermosphere)		300 km at night, 250-400 km during daytime	Day and night	Efficiently reflects HF waves, particularly at night	$8 \times 10^{11}\ /m^3$ = D

Ions

15.6.2 Sky waves

In the frequency range from a few MHz up to 30 to 40 MHz, long distance communication can be achieved by ionospheric reflection of radio waves back towards the earth. This mode of propagation is called *sky wave propagation* and is used by short wave broadcast services. The ionosphere is so called because of the presence of a large number of ions or charged particles. It extends from a height of ~ 65 Km to about 400 Km above the earth's surface. Ionisation occurs due to the absorption of the ultraviolet and other high-energy radiation coming from the sun by air molecules. The ionosphere is further subdivided into several layers, the details of which are given in Table 15.3. The degree of ionisation varies with the height. The density of atmosphere decreases with height. At great heights the solar radiation is intense but there are few molecules to be ionised. Close to the earth, even though the molecular concentration is very high, the radiation intensity is low so that the ionisation is again low. However, at some intermediate heights, there occurs a peak of ionisation density. The ionospheric layer acts as a reflector for a certain range of frequencies (3 to 30 MHz). Electromagnetic waves of frequencies higher than 30 MHz penetrate the ionosphere and escape. These phenomena are shown in the Fig. 15.4. The phenomenon of bending of em waves so that they are diverted towards the earth is similar to total internal reflection in optics*.

3 to 30 MHz



Sky wave Prop.

What ν of Light Can undergo TIR

$$\boxed{\nu_{max} = 9\sqrt{D}}$$

D= Density of Ionsphere

15.6.3 Space wave

Another mode of radio wave propagation is by *space waves*. A space wave travels in a straight line from transmitting antenna to the receiving antenna. Space waves are used for line-of-sight (LOS) communication as well as satellite communication. At frequencies above 40 MHz, communication is essentially limited to line-of-sight paths. At these frequencies, the antennas are relatively smaller and can be placed at heights of many wavelengths above the ground. Because of line-of-sight nature of propagation, direct waves get blocked at some point by the curvature of the earth as illustrated in Fig. 15.5. If the signal is to be received beyond the horizon then the receiving antenna must be high enough to intercept the line-of-sight waves.

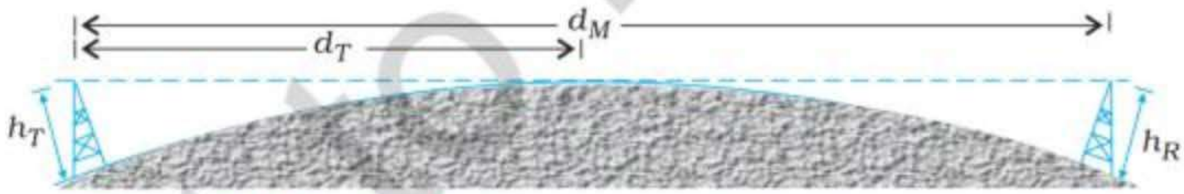


FIGURE 15.5 Line of sight communication by space waves.

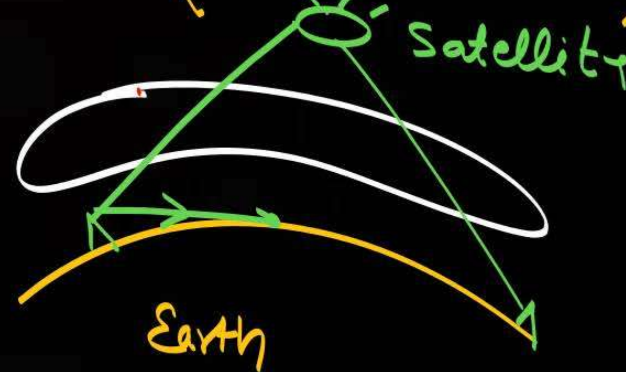
Space wave Comm

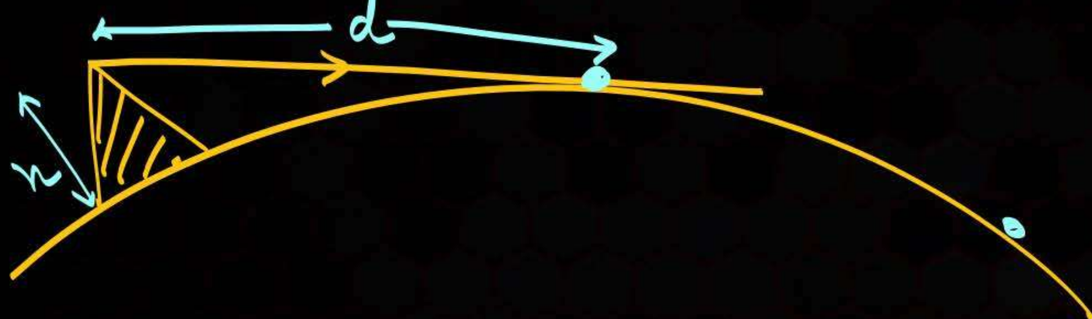
$\nu > 30\ MHz$

$\Downarrow$

Highly Energetic

(LOS Communication)





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

JEE Main 10-12 Que.

$\boxed{R = \text{Radius of Earth}}$

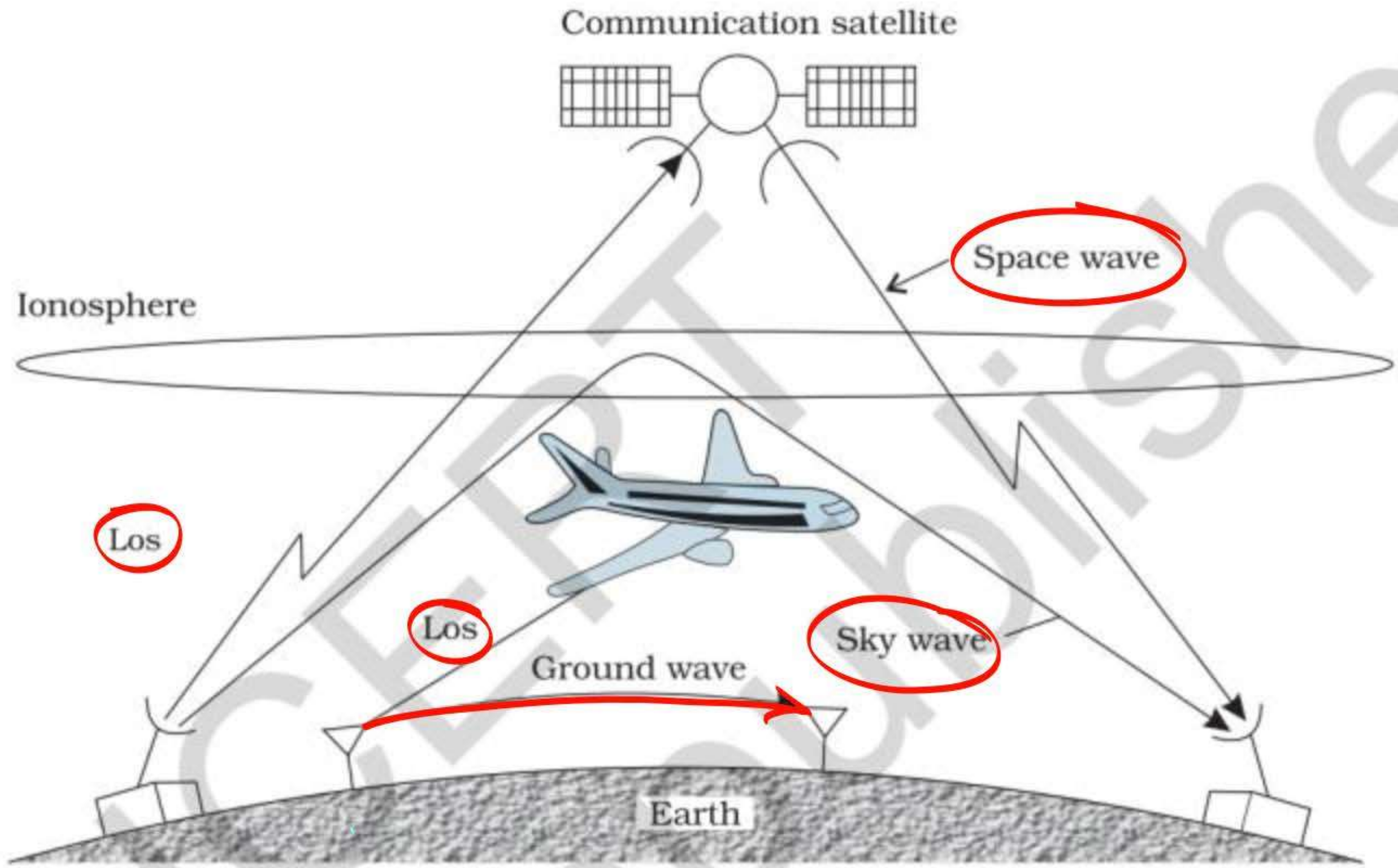


FIGURE 15.6 Various propagation modes for em waves.

15.7 Modulation and its Necessity

As already mentioned, the purpose of a communication system is to transmit information or message signals. Message signals are also called *baseband signals*, which essentially designate the band of frequencies representing the original signal, as delivered by the source of information. No signal, in general, is a single frequency sinusoid, but it spreads over a range of frequencies called the signal *bandwidth*. Suppose we wish to transmit an electronic signal in the audio frequency (AF) range (baseband signal frequency less than 20 kHz) over a long distance directly. Let us find what factors prevent us from doing so and how we overcome these factors.

Modulation

$\boxed{\text{Power of Antenna} \propto \frac{1}{\lambda^2}}$

Signal $\nu \downarrow$

$\lambda \uparrow$ Length of anetenna $\uparrow$

Power $\downarrow$.

15.7.1 Size of the antenna or aerial

For transmitting a signal, we need an antenna or an aerial. This antenna should have a size comparable to the wavelength of the signal (at least $\lambda/4$ in dimension) so that the antenna properly senses the time variation of the signal. For an electromagnetic wave of frequency 20 kHz, the wavelength λ is 15 km. Obviously, such a long antenna is not possible to construct and operate. Hence direct transmission of such baseband signals is not practical. We can obtain transmission with reasonable antenna lengths if transmission frequency is high (for example, if ν is 1 MHz, then λ is 300 m). Therefore, there is a need of *translating the information contained in our original low frequency baseband signal into high or radio frequencies before transmission.*

Higher ν ↑

λ ↓

Length of ant ↓

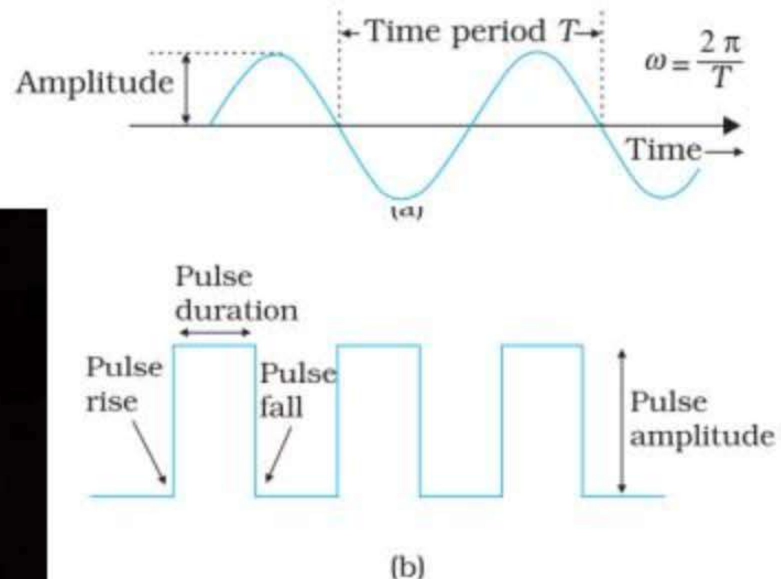
Power ↑.

15.7.2 Effective power radiated by an antenna

A theoretical study of radiation from a linear antenna (length l) shows that the power radiated is proportional to $(l/\lambda)^2$. This implies that for the same antenna length, the power radiated increases with decreasing λ, i.e., increasing frequency. Hence, the effective power radiated by a long wavelength baseband signal would be small. For a good transmission, we need high powers and hence this also points out to *the need* of using high frequency transmission.

15.7.3 Mixing up of signals from different transmitters

Another important argument against transmitting baseband signals directly is more *practical* in nature. Suppose many people are talking at the same time or many transmitters are transmitting baseband information signals simultaneously. All these signals will get mixed up and there is no simple way to distinguish between them. This points out towards a possible solution by using communication at high frequencies and allotting a *band* of frequencies to each message signal for its transmission.



The above arguments suggest that there is a *need for translating the original low frequency baseband message or information signal into high frequency wave before transmission such that the translated signal continues to possess the information contained in the original signal.* In doing so, we take the help of a high frequency signal, known as the *carrier wave*, and a process known as modulation which attaches information to it. The carrier wave may be continuous (sinusoidal) or in the form of pulses as shown in Fig. 15.7.

A sinusoidal carrier wave can be represented as

$$c(t) = A_c \sin(\omega_c t + \phi) \tag{15.2}$$

where $c(t)$ is the signal strength (voltage or current), A_c is the amplitude, $\omega_c (= 2\pi\nu_c)$ is the angular frequency and ϕ is the initial phase of the carrier wave. During the process of modulation, any of the three parameters, *viz* A_c, ω_c and ϕ, of the carrier wave can be controlled by the message or information signal. This results in three types of modulation: (i) Amplitude modulation (AM), (ii) Frequency modulation (FM) and (iii) Phase modulation (PM), as shown in Fig. 15.8.

Modulation

1. Amplitude Mod (AM)
2. freq Mod (FM)
3. Phase Mod. (PM).

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

$c(t) = A_c \sin \omega_c t$. (High freq)

Imp

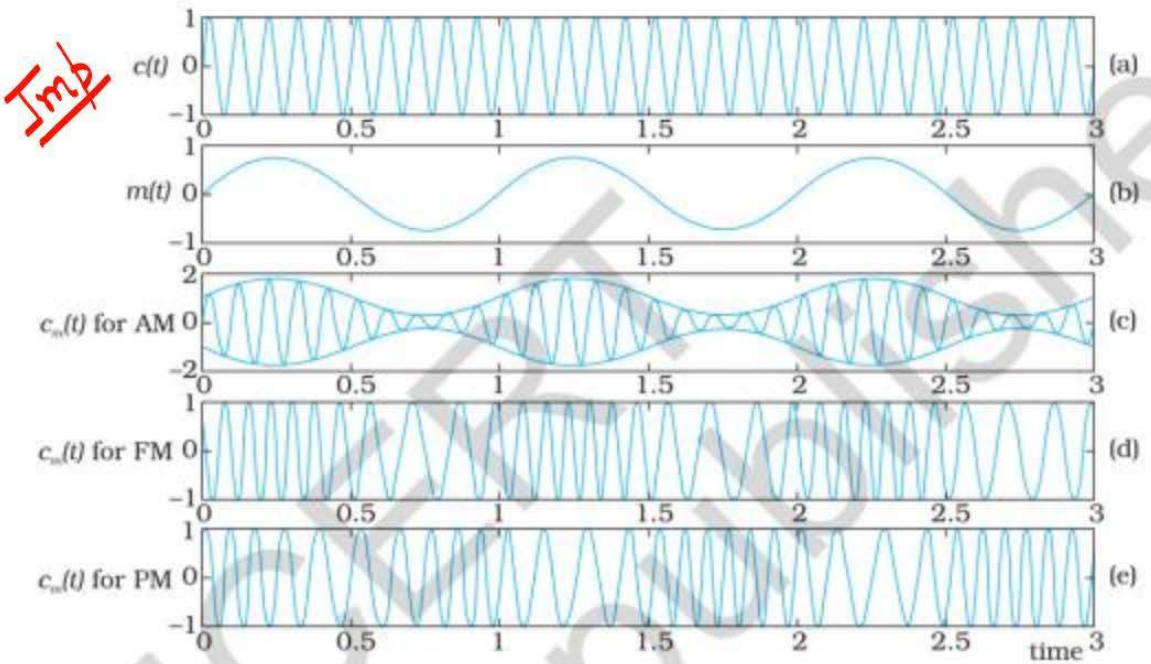
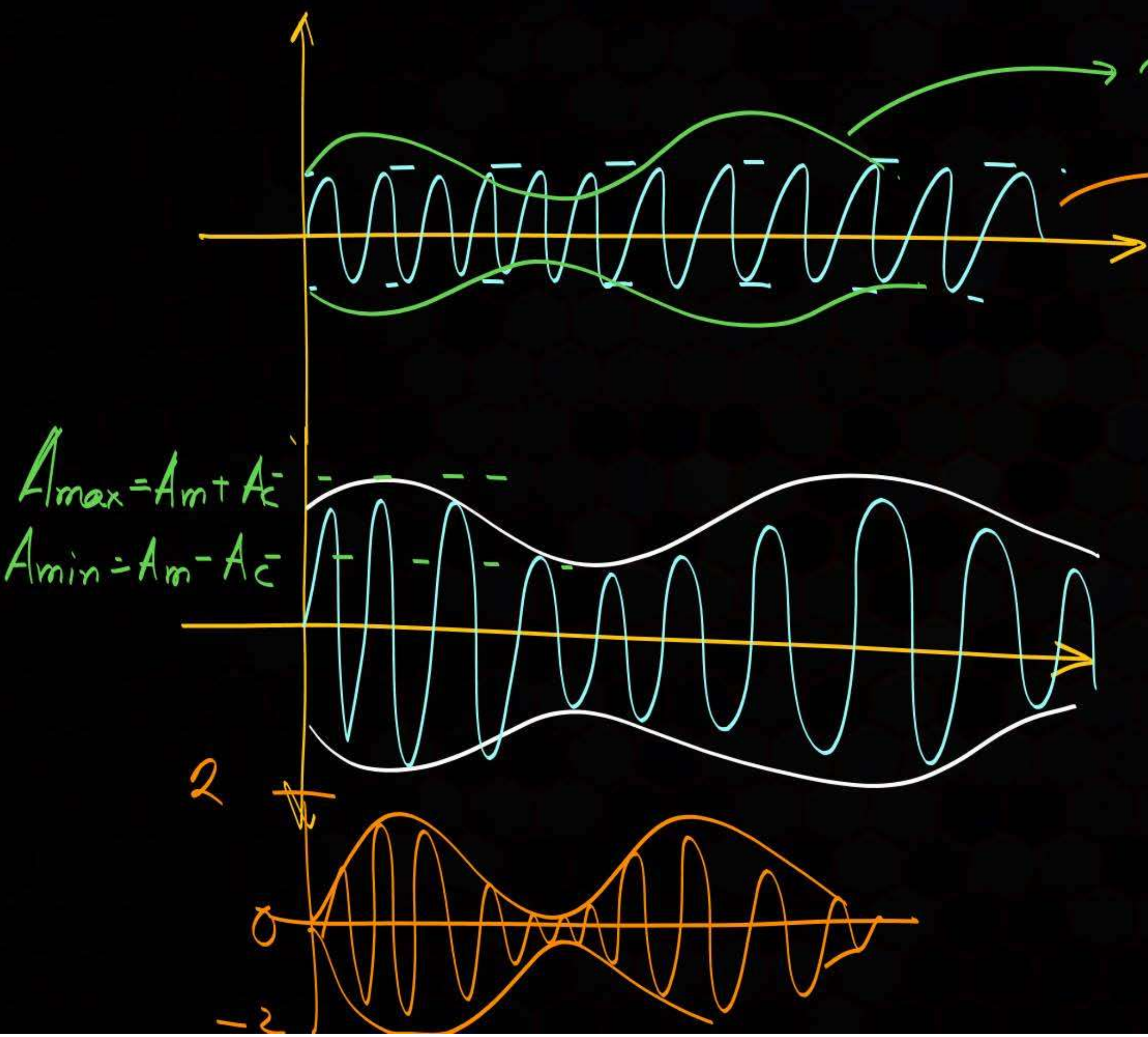


FIGURE 15.8 Modulation of a carrier wave: (a) a sinusoidal carrier wave; (b) a modulating signal; (c) amplitude modulation; (d) frequency modulation; and (e) phase modulation.



$m(t)$ is Superimposed on Amp of $c(t)$

$A_m = 1$

$A_c = 1$

$A_{max} = 2$

$A_{min} = 0$.

15.8 Amplitude Modulation

In amplitude modulation the amplitude of the carrier is varied in accordance with the information signal. Here we explain amplitude modulation process using a sinusoidal signal as the modulating 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

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

$$= A_c \left(1 + \frac{A_m}{A_c} \sin\omega_m t\right) \sin\omega_c t \qquad (15.3)$$

Note that the modulated signal now contains the message signal. This can also be seen from Fig. 15.8(c). From Eq. (15.3), we can write,

$$c_m(t) = A_c \sin\omega_c t + \mu A_c \sin\omega_m t \sin\omega_c t \qquad (15.4)$$

$= A_c[1 + \mu \sin\omega_m t] \sin\omega_c t.$

$= A_c \sin\omega_c t + A_c \mu \sin\omega_m t \sin\omega_c t$

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

$c(t) = A_c \sin\omega_c t.$

AM wave

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

$= A_c\left[1 + \frac{A_m}{A_c} \sin\omega_m t\right] \sin\omega_c t$

$\Downarrow$

μ = Modulation Index

$\boxed{\mu \leq 1}$

Here $\mu = A_m/A_c$ is the *modulation index;* in practice, μ is kept ≤ 1 to avoid distortion.

Using the trignomatric relation $\sin A \sin B = ½\,(\cos(A-B) - \cos(A+B))$, we can write $c_m(t)$ of Eq. (15.4) as

$$\boxed{c_m(t) = A_c \sin\omega_c t + \frac{\mu A_c}{2}\cos(\omega_c - \omega_m)\,t - \frac{\mu A_c}{2}\cos(\omega_c + \omega_m)t} \qquad (15.5)$$

Here $\omega_c - \omega_m$ and $\omega_c + \omega_m$ are respectively called the lower side and upper side frequencies. The modulated signal now consists of the carrier wave of frequency ω_c plus two sinusoidal waves each with a frequency slightly different from, known as side bands. The frequency spectrum of the amplitude modulated signal is shown in Fig. 15.9.

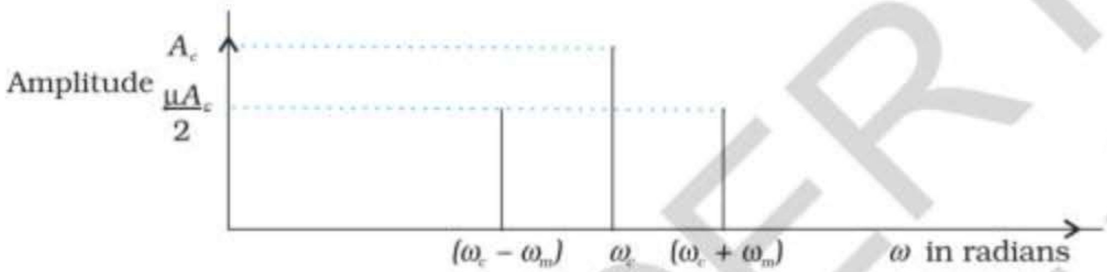


FIGURE 15.9 A plot of amplitude versus ω for an amplitude modulated signal.

FM.

95MHz

Carrier freq

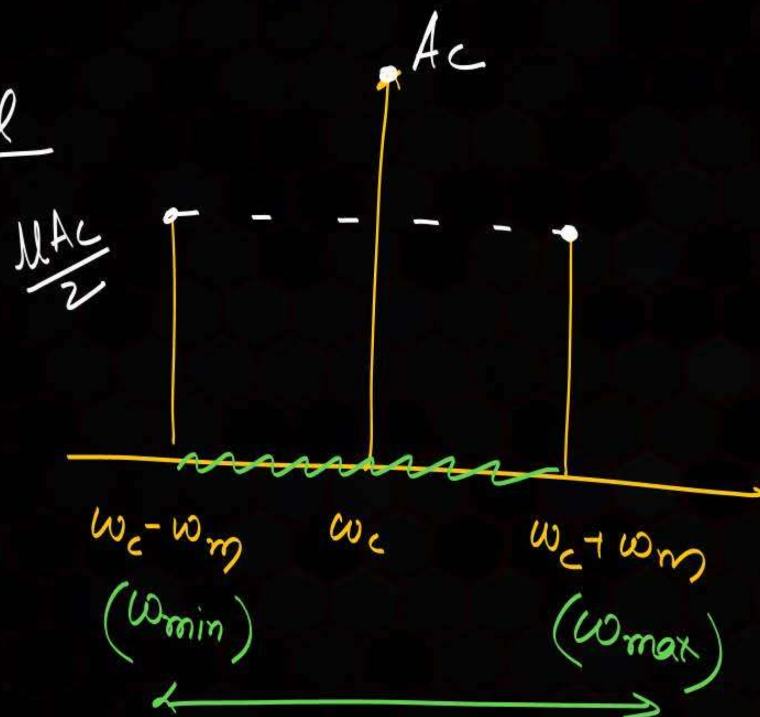
94.7MHz

95.2MHz

Range of freq

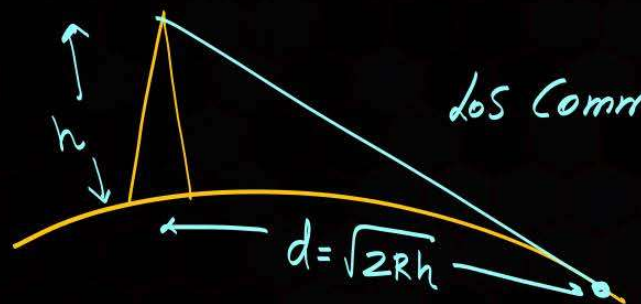
Bandwidth.

Final Signal

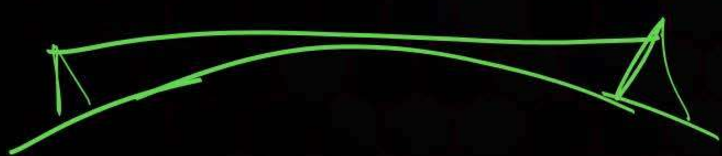


$$\boxed{\text{Bandwidth} = 2\omega_m}$$

Summary.

1. 

R = Radius of Earth.



$d = \sqrt{2Rh_1} + \sqrt{2Rh_2}$

AM Modulated Wave.

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

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

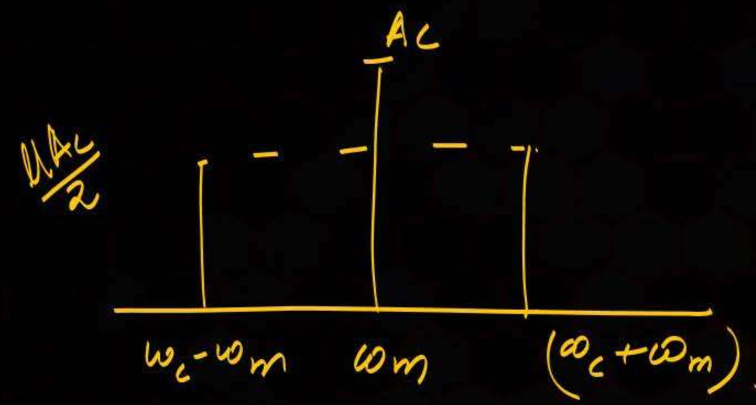
$\omega_m = 2\pi \nu_m$

$\omega_c = 2\pi \nu_m$

Final AM Wave $= (A_c + A_m \sin \omega_m t) \sin \omega_c t$

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

$\mu = \frac{A_m}{A_c}$ $\quad \mu \le 1$ Less distortion



freq in AM wave $\quad \omega_c, \ \omega_c + \omega_m, \ \omega_c - \omega_m$

$$B.W = 2\omega_m$$

2.X $\boxed{B.W = 2 \times n \times HF}$

Bandwidth of Signal

no of Transmitters

Highest freq.

$$A_{max} = A_c + A_m$$

$$A_{min} = A_c - A_m$$

$$A_c = \frac{A_{max} + A_{min}}{2}$$

$$A_m = \frac{A_m - A_{min}}{2}$$

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

Q. A carrier wave with amplitude of 250 V is amplitude modulated by a sinusoidal base band signal of amplitude 150 V. The ratio of minimum amplitude to maximum amplitude for the amplitude modulated wave is 50: x, then value of x is ______.

message signal

JEE Main 2021 (Online) 1st September Evening Shift

$A_c = 250$

$A_m = 150V.$

$A_{max} = A_m + A_c = 400$

$A_{min} = A_m - A_c = 100$

$$\frac{A_{min}}{A_{max}} = \frac{100}{400} = \frac{50}{x}$$

Q. A bandwidth of 6MHz is available for A.M. transmission. If the maximum audio signal frequency used for modulating the carrier wave is not to exceed 6kHz. The number of stations that can be broadcasted within this band simultaneously without interfering with each other will be ________.

JEE Main 2021 (Online) 31st August Evening Shift

x2

$$\boxed{\begin{array}{l} BW = 6\,MHz \\ MF = 6\,KHz \end{array}}$$

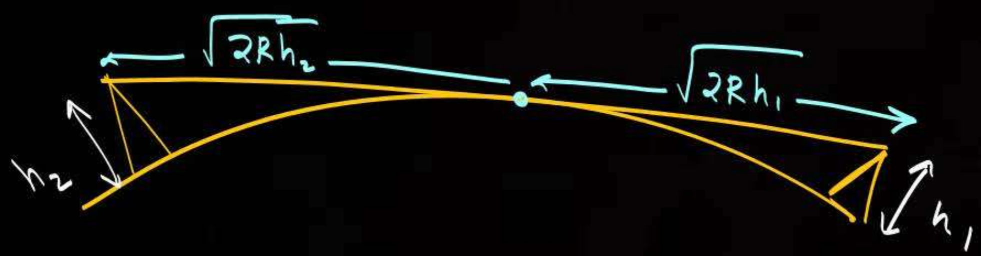
formula Not in NCERT.

$$\boxed{BW = 2n(\text{Max } F)}$$

$$n = \frac{BW}{2(MF)} = \frac{6\times 10^{6}\,Hz}{2\times 6\times 10^{3}}$$

Q. If the sum of the heights of transmitting and receiving antennas in the line of sight of communication is fixed at 160 m, then the maximum range of LOS communication is _______ km. (Take radius of Earth = 6400 km)

JEE Main 2021 (Online) 31st August Morning Shift



$$h_1 + h_2 = 160$$

$$l = \sqrt{2Rh_2} + \sqrt{2Rh_1}$$

$$h_1 = x$$

$$h_2 = 160 - x$$

Max. $\Leftarrow$ $l = \sqrt{2R}\left[\sqrt{x} + \sqrt{160 - x}\right]$

Los Max Range.

$$l = \sqrt{2R}\left[\sqrt{x} + \sqrt{160 - x}\right]$$

$$0 = \frac{dl}{dx} = \sqrt{2R}\left[\frac{1}{2\sqrt{x}} - \frac{1}{2\sqrt{160 - x}}\right]$$

$$\sqrt{x} = \sqrt{160 - x}$$

$$2x = 160$$

$$\boxed{x = 80\,m}$$

$h_1 + h_2 = Const$

Max Range $h_1 = h_2 = \frac{(Const)}{2}$

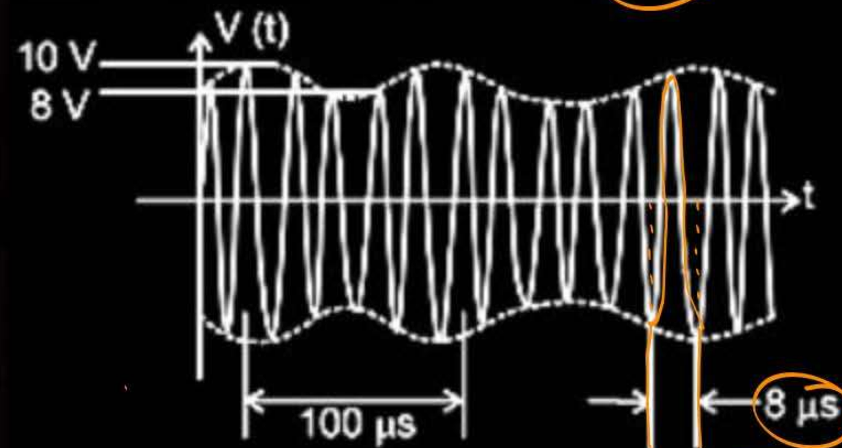
$$l_{max} = \sqrt{2R}\left[2\sqrt{80}\right]$$ Ans.

Q. An amplitude modulated signal is plotted below :
Which one of the following best describes the above signal ?

JEE Main 2019 (Online) 11th January Evening Slot

$\omega = \frac{2\pi}{T} = \frac{2\pi}{100\times10^{-6}}$ $(2\pi\times10^{4})$

$100\,\mu s = T_m$ ν_m



$T_c = 8\,\mu s$

$\nu_c =$

(A) A_c A_m
$\left(1 + 9\sin\left(2\pi \times 10^{4}t\right)\right)\sin\left(2.5\pi \times 10^{5}t\right)V$

(B) $\left(9 + \sin\left(4\pi \times 10^{4}t\right)\right)\sin\left(5\pi \times 10^{5}t\right)V$

(C) $\left(9 + 1\sin\left(2\pi \times 10^{4}t\right)\right)\sin\left(2.5\pi \times 10^{5}t\right)V$ Ans
A_c A_m

(D) $\left(9 + \sin\left(2.5\pi \times 10^{4}t\right)\right)\sin\left(2\pi \times 10^{4}t\right)V$

$$A_{max} = A_c + A_m = 10$$

$$A_{min} = A_c - A_m = 8$$

$$2A_c = 18$$

$$A_c = 9$$

$$A_m = 1$$

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

Q. A transmitting antenna at top of a tower has a height of 50 m and the height of receiving antenna is 80 m. What is range of communication for Line of Sight (LoS) mode? [use radius of earth = 6400 km]

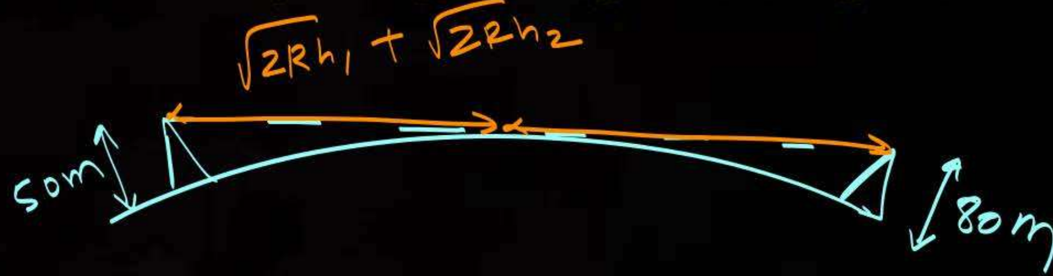
JEE Main 2021 (Online) 26th August Evening Shift

A 45.5 km

B 80.2 km

C 144.1 km

D 57.28 km



$$Ans = \sqrt{2R}\left[\sqrt{h_1} + \sqrt{h_2}\right]$$

Q. An amplitude modulated wave is represented by $C_m(t) = 10(1 + 0.2\cos \underbrace{12560t}_{\omega_m})\sin(\underbrace{111 \times 10^4 t}_{\omega_c})$ volts. The modulating frequency in kHz will be ....

JEE Main 2021 (Online) 26th August Morning Shift

A_c μ

modulating freq = Carrier freq.

$\omega_m = 111 \times 10^4 = 2\pi \nu_c$

Q. The maximum amplitude for an amplitude modulated wave is found to be 12 V while the minimum amplitude is found to be 3V. The modulation index is 0.6x where x is ________. JEE Main 2021 (Online) 27th July Evening Shift

$$A_{max} = 12V = A_m + A_c$$

$$A_{min} = 3V = A_m - A_c$$

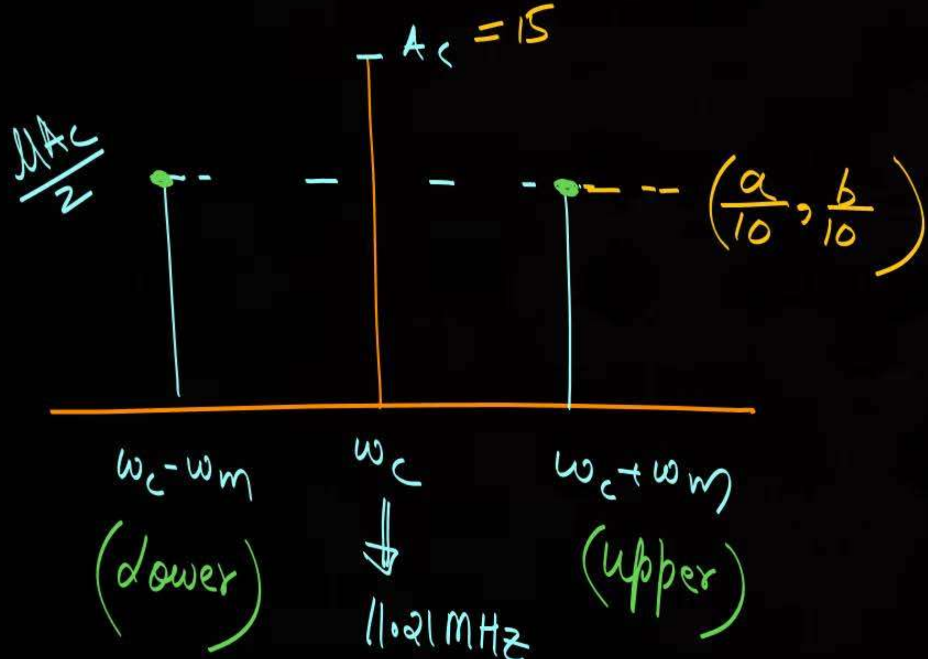
$$\mu = \frac{A_m}{A_c} = -$$

$A_m = ✓$

$A_c = ✓$

Q. The amplitude of upper and lower side bands of A.M. wave where a carrier signal with frequency 11.21MHz, peak voltage 15 V is amplitude modulated by a 7.7kHz (ω_m) sine wave of 5V amplitude are $\frac{a}{10}V$ and $\frac{b}{10}V$ respectively. Then the value of $\frac{a}{b}$ is ___1___.

JEE Main 2021 (Online) 27th July Morning Shift



$a = b$

$\frac{a}{b} = 1$

Q. A message signal of frequency 20kHz and peak voltage of 20 volt is used to modulate a carrier wave of frequency 1MHz and peak voltage of 20 volt. The modulation index will be : JEE Main 2021 (Online) 25th July Evening Shift

$\nu_m = 20\ kHz \quad A_m = 20V$

$\nu_c = 1\ MHz \quad A_c = 20V.$

$\mu = \frac{A_m}{A_c} = \frac{20}{20} = 1$

Q. In amplitude modulation, the message signal $V_m(t) = 10 \sin(2\pi \times 10^5 t)$ volts and Carrier signal $V_C(t) = 20\sin(2\pi \times 10^7 t)$ volts.

The modulated signal now contains the message signal with lower side band and upper side band frequency, therefore the bandwidth of modulated signal is α kHz. The value of α is :

JEE Main 2021 (Online) 25th July Morning Shift

A 200 kHz

B 50 kHz

C 100 kHz

D 0

Q. What should be the height of transmitting antenna and the population covered if the television telecast is to cover a radius of 150 km ? The average population density around the tower is $2000/\text{km}^2$ and the value of $R_e = 6.5 \times 10^6$ m

JEE Main 2021 (Online) 22nd July Evening Shift

(A) Height = 1241 m, Population covered = 7×10^5

(B) Height = 1731 m, Population covered = 1413×10^5

(C) Height = 1800 m, Population covered = 1413×10^8

(D) Height = 1600 m, Population covered = 2×10^5

Q.

A carrier wave $V_c(t) = 160\sin(2\pi \times 10^6 t)$ volts is made to vary between $V_{max} = 200$ V and $V_{min} = 120$ V by a message signal $V_m(t) = A_m \sin(2\pi \times 10^3 t)$ volts. The peak voltage A_m of the modulating signal is ________.

JEE Main 2021 (Online) 20th July Morning Shift

Q.

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 ________.

JEE Main 2021 (Online) 18th March Evening Shift

Q. 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 (Online) 17th March Evening Shift

(A) 50 MHz

(B) 8 GHz

(C) 1987.5 MHz

(D) 2.01 GHz

Q.

If the highest frequency modulating a carrier is 5kHz, then the number of AM broadcast stations accommodated in a 90kHz bandwidth are ________.

JEE Main 2021 (Online) 26th February Evening Shift

Q. Given below are two statements :

Statement I : A speech signal of 2kHz is used to modulate a carrier signal of 1MHz. The bandwidth requirement for the signal is 4kHz.

Statement II : The side band frequencies are 1002kHz and 998kHz.

In the light of the above statements, choose the correct answer from the options given below : JEE Main 2021 (Online) 25th February Morning Slot

(A) Statement I is false but Statement II is true

(B) Both Statement I and Statement II are false

(C) Statement I is true but Statement II is false

(D) Both Statement I and Statement II are true

Q. 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 (Online) 12th April Evening Slot

A. 0.3 and 9kHz

B. 0.5 and 10kHz

C. 0.4 and 10kHz

D. 0.5 and 9kHz

Q. A message signal of frequency 100MHz 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 (Online) 10th April Morning Slot

(A) $0.25; 1 \times 10^8$ Hz

(B) $4; 2 \times 10^8$ Hz

(C) $4; 1 \times 10^8$ Hz

(D) $0.25; 2 \times 10^8$ Hz

Q. The physical sizes of the transmitter and receiver antenna in a communication system are :- JEE Main 2019 (Online) 9th April Evening Slot

(A) proportional to carrier frequency

(B) inversely proportional to carrier frequency

(C) inversely proportional to modulation frequency

(D) independent of both carrier and modulation frequency

Q. To double the covering range of a TV transmition tower, its height should be multiplied by :

JEE Main 2019 (Online) 12th January Evening Slot

(A) 4

(B) 2

(C) $\sqrt{2}$

(D) $\frac{1}{\sqrt{2}}$

Q. 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 (Online) 12^{th} January Morning Slot

(A) 0.5

(B) 0.6

(C) 0.4

(D) 0.3

Q. An amplitude modulated 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 sideband frequencies (in kHz) are, [Given $\pi = 22/7$] JEE Main 2019 (Online) 11th January Morning Slot

(A) 892.5 and 857.5

(B) 89.25 and 85.75

(C) 1785 and 1715

(D) 178.5 and 171.5