UNIT-V

Wave propagation

W/P ① ~~rough propagation~~

① **Concept of propagation of Radio waves**

→ In 1864, maxwell discovered that em waves are traveling in space with velocity of light

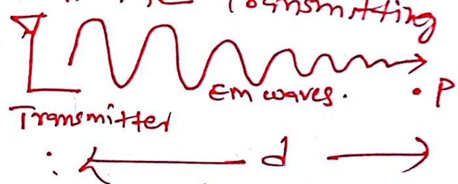
→ Later Hertz explained that em radio waves are traveled from tr to Rr in straight line

→ In general

× when the antenna radiates a radio signal, it spreads in all the direction.

→ when the signal propagates through the space, the amplitude (strength) of the signal decreases rapidly as the distance at a point from the transmitting antenna increases.

Ex:



If d increases, the field strength ↓

→ The electromagnetic signal can travel in different paths because of operating frequencies and atmospheric conditions.

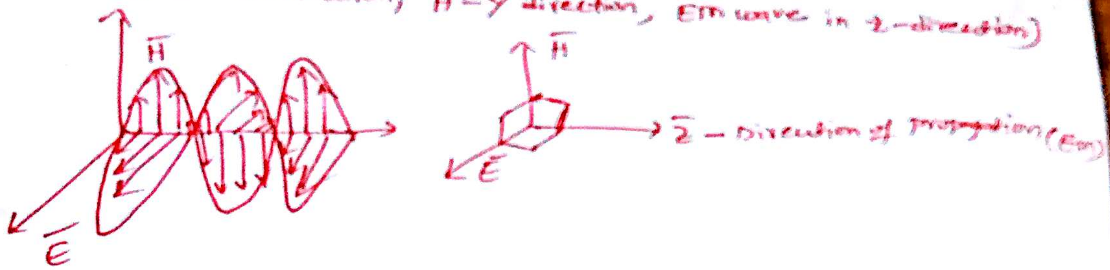
→ There are three different paths for radio signals.

(i) Ground wave propagation (ii) space wave propagation

(iii) sky wave propagation.

→ The radio waves is also called as electro magnetic wave, which is consisting of electric field $\bar{E}$ and magnetic field $\bar{H}$ and these are perpendicular to each other.

→ The direction in which the the electromagnetic wave travels is perpendicular to both the fields simultaneously
i.e (E - x direction, H - y direction, EM wave in z-direction)



→ If the antenna is considered as point source, then point source radiates an electromagnetic waves in all directions uniformly, thus giving a spherical wavefront.

→ An electromagnetic wave traveling in the free space may be of different frequencies but all travel with same velocity (with light speed)

→ The different parts of the electromagnetic wave spectrum are utilized for various purposes.

Freq Range		Applications
Below 30 MHz	—	Broadcasting & worldwide radio Communication
30 - 300 MHz	—	Radar, point-to-point radio communication
300 - 3 GHz	—	Mobile & TV
3 - 30 GHz	—	Satellite, Radar communications
30 - 300 GHz	—	Radio astronomy.

→ The region at height of 16 km is called Troposphere.

② Modes of propagation

→ There are different paths of propagation by which the transmitted signal can reach the receiving antenna.

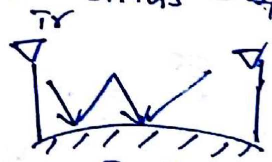
→ The most important propagation paths can be described as follows.

→ The radio waves transmitted by the transmitting antenna may reach to the receiving antenna through any of the following modes.

→ The modes of propagation depending on the practical factors such as distance between the transmitter and the receiver, frequency of operation i.e (i) Ground wave. (ii) Space wave (iii) Sky wave propagations.

Ground wave propagation / surface

→ The wave which are propagating near/along the earth's surface is called ground wave propagation.



→ It is important at broadcast and lower frequencies.

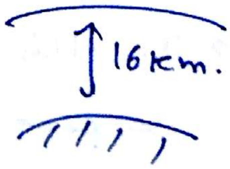
→ In this mode of propagation the transmitting & Receiving antennas are placed close to the surface of the earth.

→ when the vertical antennas are used, the ground waves are produced.

→ The electric field of Em waves are vertical w.r.t ground.

Space wave propagation

→ The wave which are propagating within 16 km range from the earth is called space wave propagation



→ The region at height of 16 km is called Trophosphere.

→ In the Space wave propagation the waves are reached to receiving antenna in 2 ways

i.e (i) via Direct ray (ii) via Ground Reflected Ray.

→ It is applicable for 30 MHz to 300 MHz frequencies (FM, TV).

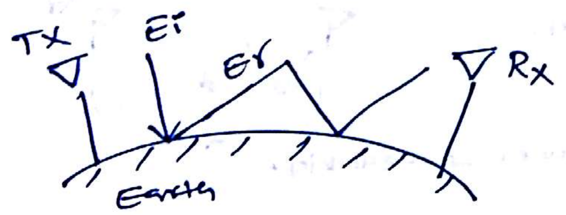
Sky wave / Ionospheric propagation

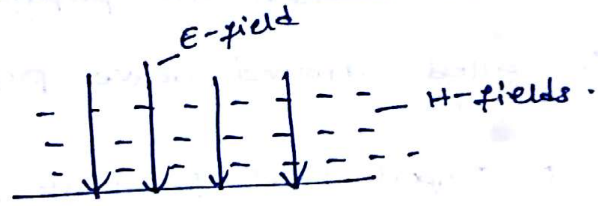
→ The Ionosphere is located at above the earth's surface about 50km–400km height.

→ It is used for long radio communications.

→ The frequencies of sky wave is about 2MHz to 30MHz.

③ Ground wave propagation (— plane Earth Reflection)





→ The wave which are propagating near (or) along the earth's surface is called Ground wave propagations.

→ It is used for broad casting of low frequencies

→ In this mode the transmitting & Receiving antennas closed to surface vertically. (vertically polarized)

→ In this case the charges are induced on the earth's surface which travel along the wave and thus current In

→ The behaviour of the earth as conductor can be realized in terms of conductivity and the dielectric constant.

(3) → If the earth is considered as a perfect conductor with infinite conductivity, then the transmitted & reflected waves have the same amplitudes.

→ If the surface of the earth is considered as the smooth plane with finite conductivity, then the amplitude and the phase of the reflected wave can be obtained by using concept of the reflection.

→ But if the surface of the earth is rough, then the scattering of the reflected wave takes place.

→ with the scattering of the wave, the amplitude of the reflected wave reduces considerably as compared to that reflected from the smooth surface.

→ This roughness of the surface responsible for the scattering of the reflected wave can be obtained by using Rayleigh criterion.

– The Rayleigh criterion is given by

$$R = \frac{4\pi\sigma\sin\phi}{\lambda}, \quad R = \text{measure of Roughness}$$

σ = standard deviation of surface, ϕ = angle of incidence,

→ Depending on the value of R, the surface can be considered as either smooth or rough.

→ If the R is less than 0.1, then surface is considered as smooth surface which gives well-defined reflection of the waves.

→ If the value of R is greater than 1, then the surface is considered as rough surface which leads to the scattering of the reflected wave.

→ Basically the earth is neither a perfect conductor nor a perfect dielectric

→ The ground is acting as leakage capacitance in carrying induced current

→ The wave is attenuated as its propagate due to the imperfect nature of the earth.

→ The attenuation is mainly result of absorption & reflection of electromagnetic energy by the earth.

→ The characteristic of earth described by constant permitivity & conductivity.

→ According to the Somar field analysis, the ground field strength has a field strength as.

→ Earth constants

$$E = \frac{A E_0}{d}$$

E ⇒ Field strength at point

E_0 = Field strength at unit distance from Tx

A = factor of ground loss.

d = distance from Tx.

→ (The ~~characteristic of~~ earth ~~described by~~ constant permitivity, ~~conductivity~~).

→ E_0 is depends upon the power radiated by transmitting antenna & directivity of the antenna,

(c) Space & surface wave

Space wave

→ The waves which are travel from the transmitter to receiver directly without any reflection are called space waves.

→ The space wave expression is as follows.

$$E_{\substack{Total \\ (space)}} = j\,30\beta I\,dL \cos\psi \left(\frac{e^{-j\beta R_1}}{R_1} + R_v \frac{e^{-j\beta R_2}}{R_2} \right)$$

→ The first term inside bracket indicates a spherical wave at position of dipole, where $e^{-j\beta R_1}$ is phase factor, $\frac{1}{R_1}$ - inverse distance

→ The second term inside bracket indicates a spherical wave at the position of image of dipole.

Surface wave

→ The waves which propagate to the receiving antenna through the reflections from the earth's surface is called surface wave.

→ Let us consider the dipole is at the surface of the earth, then the expression of surface wave of this field is

$$E_{surface} = j\,30\beta I\,dL\,(1-R_v).F.\left(\frac{e^{j\beta R}}{R}\right) \times$$

$$\left[(1-u^2)\,\hat{k} + \cos\psi \left(1+\frac{\sin^2\psi}{2}\right) u\sqrt{1-u^2\cos^2\psi}\;\hat{\gamma} \right]$$

Attenuation function $F = \left[1 - j\sqrt{\pi\omega}\, e^{-\omega} \left(erfc\,(j\sqrt{\omega}) \right) \right]$, ③ S Wave tilt of of surface wave

→ → Generaly there is forward tilt in a vertically polarized wave at the surface of the earth.

→ → The magnitude of the tilt depends on the permitivity and conductivity of the earth.

→ → The slight forward tilt of the electric field strength makes a small vertically downward component of the poynting vector.

→ → Thus, the electric field strength has 2 components, one parallel

→ to earth and other parallel to earth, are not in phase.

→ So that the electric field above the surface becomes elliptically polarized.

→ → The surface impedance of the earth is given by

$$Z_s \approx \sqrt{\frac{\omega \mu}{\sigma^2 + \omega^2 \varepsilon^2}} \angle \frac{1}{2} \tan^{-1}\left(\frac{\sigma}{\omega \varepsilon}\right)$$

→ The ratio of the horizontal component of the electric field to that vertical component is given by.

$$\frac{E_h}{E_v} = \frac{J_s Z_s}{H \eta_v} = \frac{Z_s}{\eta_v} = \frac{1}{377} \sqrt{\frac{\omega \mu}{\sqrt{\sigma^2 + \omega^2 \varepsilon^2}}} //$$

③ Space wave propagation

→ The em wave is transmitting from transmitter to the receiver in the Trophosphere region is called space wave propagation.

→ Trophosphere is the region of the atmosphere within the 16 km above the surface of the earth.

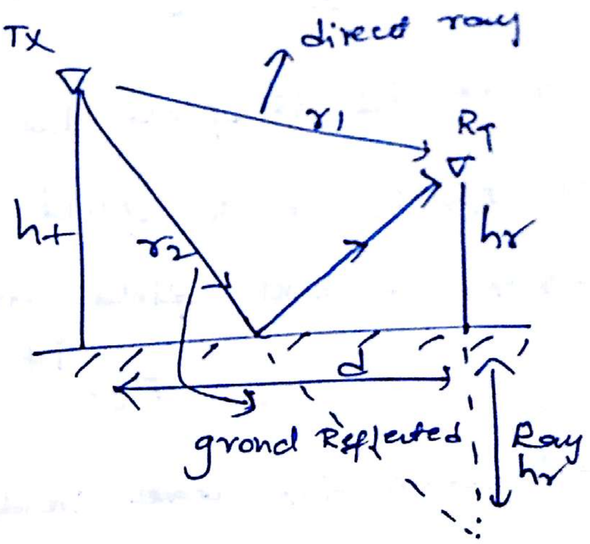
→ The space wave propagation is useful at frequency about 30–300 MHz (FM, TV).

→ It is also used for VHF & UHF

→ The space wave can be reaches the receiving antenna through (i) via direct ray (ii) via ground reflected ray.

→

Field strength of free space (distance-varying)



→ Field strength at Receiver is mostly contributed by direct and ground reflected waves.

h_t & h_r → height of Tr & Rr antennas

→ d ' distance b/w Tr & Rr antennas.

r_1 → direct ray path.

r_2 → grond reflected-ray path.

$$r_1^2 = (h_t - h_r)^2 + d^2$$

$$r_1 = d\left[\left(1 + \left(\frac{h_t - h_r}{d}\right)^2\right]^{1/2}$$

from binomial eqn

$r_1 = d\left[1+\frac{1}{2}\left(\frac{h_t-h_r}{d}\right)^2\right] \Rightarrow \boxed{r_1 = d + \frac{(h_t-h_r)^2}{2d}}$

→ $r_2^2 = (h_t+h_r)^2 + d^2 = d\{$

$r_2 = d\left[1+\left(\frac{h_t+h_r}{d}\right)^2\right]^{1/2}$

from binomial eqn

$r_2 = d\left(1+\frac{1}{2}\left(\frac{h_t+h_r}{2}\right)^2\right) \Rightarrow \boxed{r_2 = d + \frac{(h_t+h_r)^2}{2d}}$

→ The path difference is $r_2 - r_1$ is

$\boxed{r_2 - r_1 = \frac{2h_th_r}{d}}$

→ The phase difference b/w the due to the path difference

$\alpha = \frac{2\pi}{\lambda} \times$ path difference

$\alpha = \frac{2\pi}{\lambda} \cdot \frac{2h_th_r}{d} \Rightarrow \boxed{\alpha = \frac{4\pi \cdot h_th_r}{\lambda d}}$

→ Let E_d is field due to direct-ray

→ E_r is with field due to reflected ray.

→ The resultant field at the receiver is

$E_R = E_d + E_r e^{-j\psi}$, $E_d = E_r = E_s$.

→ when the wave incident on the earth, it is reflected with same amplitude but with phase reversal

Total phase $\psi = 180 + \alpha$.

Then, the $E_R = E_d + E_r e^{-j\psi}$

$$E_R = E_s + E_s e^{-j(180+\alpha)}$$

$$= E_s[1 + \cos(180+\alpha) - j\sin(180+\alpha)] = E_s[1 - \cos\alpha + j\sin\alpha]$$

$$E_R = E_s\sqrt{2(1-\cos\alpha)} = E_s\sqrt{4\sin^2\alpha/2} = 2E_s \sin\frac{\alpha}{2}$$

$$E_s = \frac{E_0}{d}$$

$$E_R = \frac{2E_0}{d}\sin\frac{\alpha}{2} = \frac{2E_0}{d}\sin\left(\frac{2\pi h_t h_r}{d\lambda}\right)$$

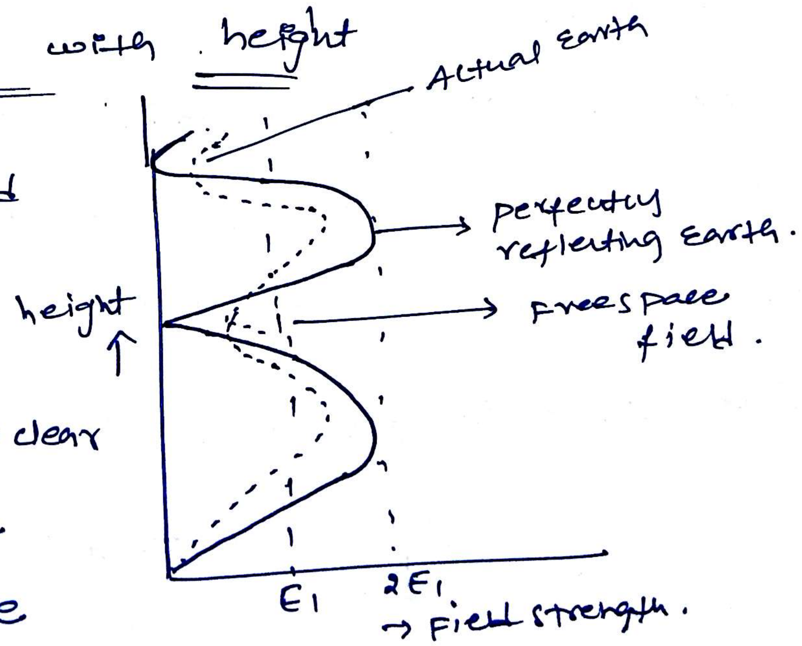
for $d \gg h_t h_r$

$$\boxed{E_R = \frac{2E_0}{d}\,\frac{2\pi h_t h_r}{d\lambda} \therefore = \frac{4E_0 \pi h_t h_r}{d^2\lambda}}$$

→ The space wave field strength is effected by curvature of the earth, earth imperfection, roughness, tall buildings and height above the earth.

Field strength variations with height

→ For a flat earth the field strength varies with height in the manner as shown in fig.



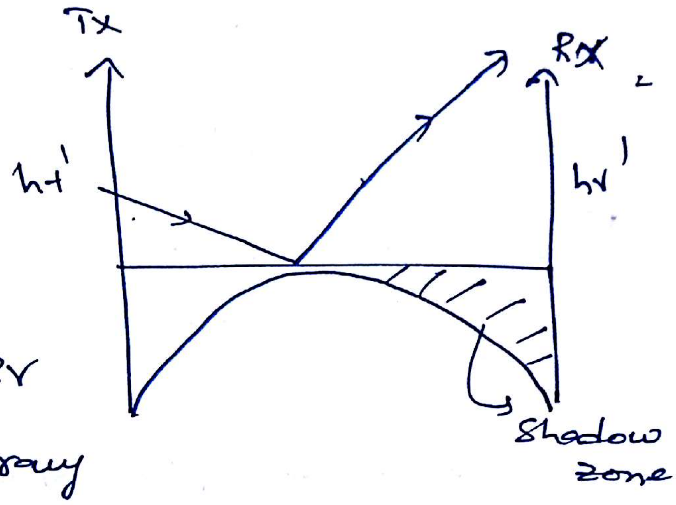
→ The curve has nulls that go clear to zero & maxima that are twice the free space field strength.

→ The positions of the maxima and nulls depend upon the frequency, the height of the transmitting antenna and distance involved.

→ This prevents the nulls from going to zero and also restricts the maxima to slightly less than twice the free space field strength, This is shown by dotted curves in fig.

Effect of curvature of the Ideal Earth

→ When the distance b/w Tr & Rr antenna is large then the curvature of the earth as effect on space wave propagation.



→ The field strength of the Rr become small as the direct ray may not be able to reach the receiving antenna

→ The earth reflection rays diverge after the incident on the earth.

→ The curvature of the earth create shadow zone.

→ These are the region where no signal reaches.

→ Shadow zone is also called as diffraction zone.

→ The field strength at the Rr

$$E = \frac{2E_0}{d} \frac{\sin 2\pi h_t' h_r'}{\lambda d}$$ //.