UNIT 8

1. Derive the fundamental equation for free space propagation?

Ans:

Fundamental Equation for Free Space Propagation

Consider the transmitter power (P_t) radiated uniformly in all the directions (isotropic), the power received at a distance (r) from the isotropic source is given by,

$$P_r = P_t / 4\pi r^2 \text{ (W/m}^2\text{)} \quad \ldots (1)$$

Where,

P_t = Transmitter power (Watts)

P_r = Received power (Watts)

r = Distance between the transmitting (and) receiving antenna.

The power density (P_D) along the maximum radiation for the directive antenna is given by,

$$P_D = G_t \cdot P_r \quad \ldots (2)$$

Where,

G_t = Gain of the transmitting antenna

P_r = Received power

P_D = Power density.

For antenna with an effective aperture area (A_e), received power is given by,

$$P_r = P_D \times A_e \quad \ldots (3)$$

Substitute equations (1) and (2) in equation (3), we get,

$$P_r = P_D \times A_e$$

$$P_r = (G_t \cdot P_t / 4\pi r^2) \times A_e$$

$$P_r = (G_t \cdot P_t / 4\pi r^2) \times A_e \text{ (W/m}^2\text{)} \quad \ldots (4)$$

We know that, relation between gain and maximum effective aperture is given by,

$$G = (4\pi / \lambda^2) A_e$$

$$G_r = (4\pi / \lambda^2) A_e \quad \ldots (5)$$

Where,

G_r = Gain of the receiving antenna

A_e = Effective aperture area.

From equation (5),

$$A_e = (\lambda^2 / 4\pi)\, G_r$$

Substituting equation (6) in equation (4), we get,

$$P_r = (G_t \cdot P_t / 4\pi r^2) \times A_e$$

$$P_r = (G_t \cdot P_t / 4\pi r^2)(\lambda^2 / 4\pi)\, G_r$$

$$P_r = P_t G_t G_r \lambda^2 / (4\pi r)^2$$

The above equation is general expression for free space propagation.

Here,

P_r = Received power in watts

P_t = Transmitter power in Watts

G_t = Gain of transmitting antenna

G_r = Gain of receiving antenna

λ = Wave length (m)

r = Distance between the transmitting (and) receiving antenna.

The above equation written in another form is,

$$P_r = P_t G_t G_r / L_s$$

Where,

$$L_s = (4\pi r / \lambda)^2$$

Path loss represent in logarithmic form is given as,

$$10 \log_{10}\left(\frac{pr}{pt}\right) = 10 \log_{10} Gt + 10 \log_{10} Gr + 10 \log_{10} \left(\frac{\lambda}{4\pi r}\right) 2$$

$$P_r(\text{dBW}) = P_t(\text{dBW}) + G_t\,(\text{dB}) + G_r\,(\text{dB}) - L_s$$

2. What are the different paths used for propagating radio waves from 300 kHz and 300 MHz.

Ans:

The term radio propagation is used to explain how radio waves behave when they are transmitted, or propagated from one point on the earth to another. Like light waves, radio waves are affected by the phenomenon of reflection, refraction, diffraction, absorption and scattering.

Radio waves at different frequencies propagate in different paths. The different modes of propagation for frequencies from 300 KHz to 300 MHz are as follows,

1. **300 KHz to 3000 KHz**

   These frequencies have the property of following the curvature of the earth via ground wave propagation in the majority of occurrences. In this mode the radio wave propagates by interacting with the semi conductive surface of the earth. The wave sticks to the surface of the earth and thus follows the curvature of earth. Vertical polarization is used to reduce short circuiting the electric field through the conductivity of the ground, since the ground is not a perfect electrical conductor, ground waves are attenuated rapidly as they follow the earth's surface. Attenuation is proportional to the frequency making this mode mainly useful for LF and VLF.

2. **3MHz to 30 MHz**

   These range of frequency waves travel from transmitter to receiver through multiple reflections from the ionosphere. This mode of propagation is called as sky-wave or ionospheric wave propagation. The waves cover a maximum of 4000 km in a single reflection. This path of propagation is effective if counter techniques are developed at the receiver to eliminate fading, due to reflection.

3. **30 MHz to 300 MHz**

   These frequencies use direct path propagation. The signals reach receivers directly or after getting reflected from the earths bottom most layer troposphere. This mode of propagation is called as space wave propagation space wave has two components. They are

   (i) Direct component

   (ii) Reflected from ground component.

   In direct component, the wave travel directly from transmitter to receiver. In ground reflected component, the wave reaches the receiver after reflection from ground with a phase change of 180°.

   The transmitter transmits both waves at the same time at the receiver both signals are added. The signal strength is high when direct and reflected components are in phase and low when they are out of phase. This is also called as tropospheric propagation.

3. Distinugish between radio and optical horizons. Give the reasons?

Ans:

Radio Horizon	Optical Horizon
1. Micro waves are not bent or refracted beyond the radio horizon.	Micro waves are usually bent or refracted beyond the optical horizon.
2. This horizon is not visible to our eyes, because generally these are further away from the optical horizon.	This horizon is visible to our eyes.
3. The distance to radio horizon is varies with the atmospheric refractive changes.	The optical horizon is independent of atmospheric refractive changes.
4. The distance to the radio horizon is given by, $d_r = 0.49h$ km where, h = Height of the tower (m).	The distance to the optical horizon is given by, $d_r = 0.49\sqrt{h}$ km where, h = Height of the tower (m).
5. Radio horizon distance can also be calculated as, $d_r = d_0/k$ where, k = Correction factor.	Optical horizon distance can also be calculated as, $d_0 = kd_r$ where, k = Correction factor.
6. If k < 1 ,the radio horizon is further away from optical horizon	If k > 1 optical horizon is further, away from radio horizon

4. What is LOS (Line Of Sight) propagation and explain it?

Ans:

Line of Sight Propagation (LOS)

Line of sight propagation is also known as space wave propagation. It is very important at higher frequency such as VHF, UHF and micro wave frequencies, i.e., 30 MHz to 300 MHz Consider two antennas, height of transmitting antennas is h_f and receiving antennas is h_r . The energy received at the receiving antenna can take two paths, one is direct from transmitting antenna to the receiving antenna and another is via ground.

Direct and indirect waves leave the transmitting antenna at the same time, but reach the receiving antenna at different times. The signal strength at receiving point is vector sum of direct and indirect waves. The field strength is greater, or less depending upon the two waves which are combining or opposing in phase.

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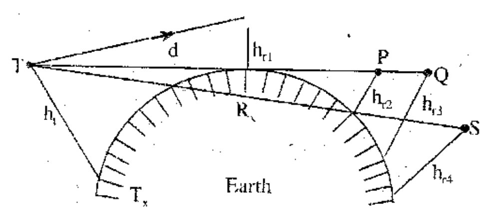

Fig 8.4.1 Line Of sight Propagation

Here the signal travels from the transmitting antenna to the receiving antenna through earth's tropospheric region, therefore, it is called as “Tropospheric propagation”. At higher frequency, space wave propagation is limited to the line of sight distance and earth curvature, so that line of sight propagation is useful at VHF and UHF. Sky wave and ground wave propagations are failing at these frequencies.

In figure the height of transmitting antenna is h_t and receiving antenna is h_r, and the distance between the two antennas is d. The signal path directly from transmitter to the receiver is denoted by ***TR***. As the receiving antenna is moved from point ***R*** to ***P***, the line of sight path from ***R*** to ***P*** crosses the surface of the earth.

Here,

TR = Direct path

TP = Line of sight distance

The line of sight distance can increased to ***TQ*** by increasing the height of the antenna to h_{r3}.

5. Write short note on tropospheric scatter propagation?

Ans:

Tropospheric Propagation or Tropospheric Scatter Propagation

Tropospheric scatter propagation is also known as forward scatter propagation, it is practically important at ultra high frequencies, VHF and micro wave frequencies. Tropospheric propagation provides communication in the range of 160 km to 1600 km.

Consider tropospheric scatter propagation shown in figure 8.5.1 below. Here the transmitter and receiver very close to each other.

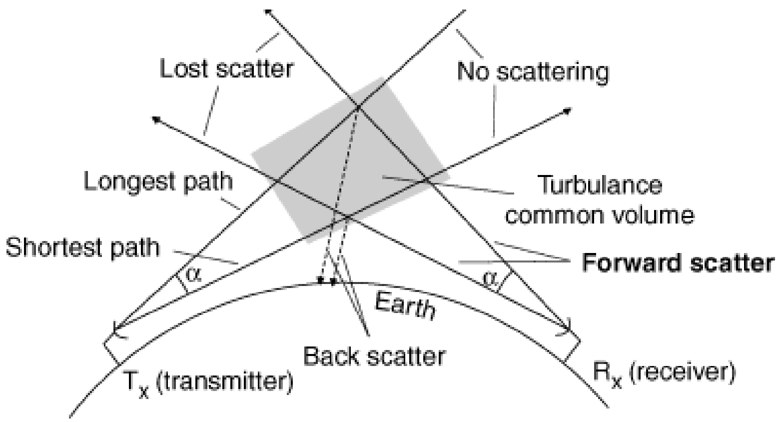

fig 8.5.1 Tropospheric Scattering

The principle of forward scattering involves,

1. Radio waves scattering from E layer of the ionosphere.
2. Radio waves scattering from either fine layer or blobs in the troposphere.

The attenuation of ionospheric scatter propagation is greater than the tropospheric scattering. So that, at very high frequencies, tropospheric scattering is used. In above figure transmitting and receiving antennas are close, their beams intersect midway between them and above the horizon. The transmitting and receiving antennas are at ultra high frequencies. Here, cone angle (α) depends upon the wave length. The value of α is very small.

Tropospheric scatter propagation suffers from noise and fading which can be reduced by employing diversity reception.

6. Discuss the salient features of space wave propagation?

Ans:

Space Wave Propagation

Space wave propagation is useful in long distance about 30 MHz. The space wave propagation is known as tropospheric propagation, because the electromagnetic waves travelling from transmitter may reach the receiver either directly or after reflections from tropospheric region. Tropospheric region is just 16 km away from the earth's surface.

Space wave propagation consists of two ray paths. They are,

1. Direct path
2. Indirect path.

The signal from transmitter to the receiver is known as direct path and signal after reflections from the ground is known as indirect path. Due to the reflections from ground, the phase 180° is introduced in the received signal. The signal at the receiver is a combination of direct and indirect ray paths. The propagation of electromagnetic waves at higher frequencies is done by space wave propagation, because the ground wave and sky wave propagation are fail at these frequencies.

Space wave propagation is also known as line at sight propagation, because at higher frequencies, electromagnetic wave propagation is limited to the curvature of earth and line of sight distance. The range can be increased with the help of transmitting and receiving antenna heights. Space wave propagation is practically important at frequencies above 30 MHz. it is also known as tropospheric wave propagation, because the waves reach the receiving point after reflections from tropospheric region.

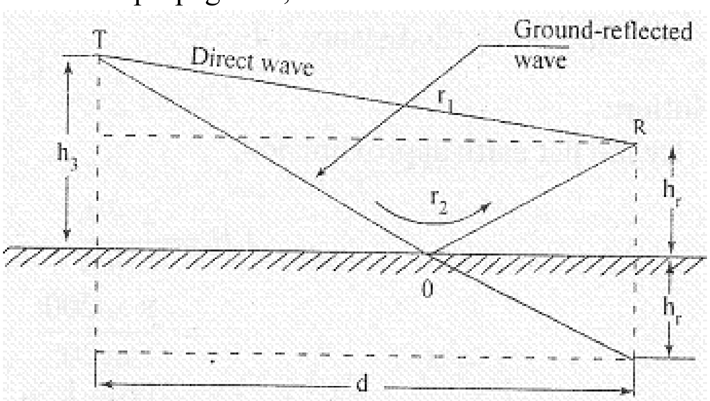

Fig 6.1.1 Space Wave Propagation - Flat Earth

In space wave propagation, signal at the receiving point is a combination of direct and indirect rays. It provides communication over long distances with VHF, UHF and microwave frequencies, space wave propagation is also known as "line of sight propagation".

Applications

1. Space wave propagation used in satellite communication.
2. Controls radio traffic between a ground station and a satellite.

7. Write short notes on “M-curves and their characteristics”?

Ans:

M-curves and their Characteristics

M-curves are known as modified index curves. These curves show the variations of refractive index with height. In order to account for the curvature of earth, the actual index of refraction modified to another refractive index. Due to the change in index of refraction, the straight rays are converted into curved rays above flat earth. The effects of non standard atmospheric conditions can be estimated easily by transforming temperature data, meteorological data into M-curves. M-curves are used to predict the type of transmission path for propagation of electromagnetic waves.

Characteristics of M-curve

1. Standard propagation occurs, when the modified index of refraction linearly varies with height. M-curve is a straight line having positive slope.
2. The slope of M-curve decreases near the surface of earth which results in standard propagation.
3. In order to achieve greater coverage, the slope of M-curve increases near the surface of the earth.
4. Greater coverage can be achieved when the rays over flat earth are straight and actual rays have the same curvature as that of the earth.
5. Duct propagation occurs when the rays are curved downward over the flat earth and the wave tends to be guided along the duct.
6. If the inverted portion of M-curve is elevated above the surface of earth then the duct is an "elevated duct".

8. Write short notes on Duct propagation?

Ans:

Duct Propagation

The higher frequencies or microwaves are continuously reflected in the duct and re-flected by the ground. So that they propagate around the curvature for beyond the line of sight. This special refraction of

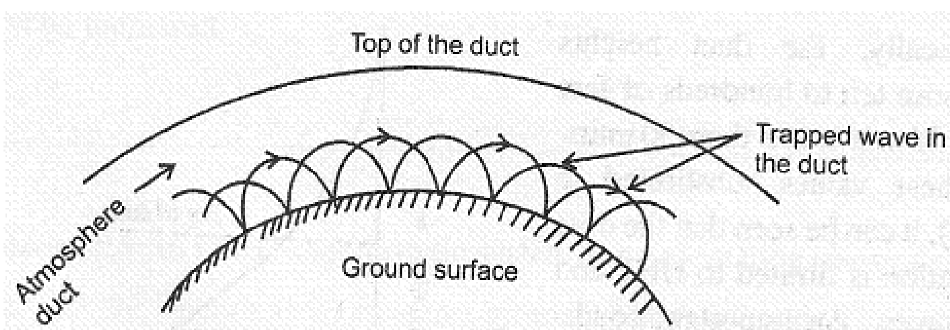

Fig 8.8.1 Duct Propagation

electromagnetic waves is called super refraction and the process is called duct propagation. Duct propagation is also known as super refraction. Consider the figure, Here, two boundary surfaces between layers of air form a duct or a sort of wave guide which guides the electromagnetic waves between the walls. Temperature inversion is one of the important factor for the formation of duct. For proper value of curvature, the refractive index (n) must be replaced by a modified refractive index *(N)*.

$$N = n + (h/r)$$

The term modified index of refractive modules (m) is related to N as

$$N = n + (h/r)$$

$$(N-1) = n-1+ h/r$$

$$(N-1) \times 10^6 = [n-1+ h/r] \times 10^6$$

$$m = (N-1) \times 10^6 = [n-1+ h/r] \times 10^6$$

Where,

n = Refractive index
h = Height above ground
r = Radius of the earth = 6370 km

Duct can be used at VHF, UHF and microwave frequencies. Because, these waves are neither reflected nor propagated along earth surface. So, the only possible way to transmit such signal is to utilize the phenomenon of refraction in the troposphere.

9. Discuss the advantages and disadvantages of communication at ultra high frequencies?

Ans:

Advantages of Ultra High Frequencies (UHF)

1. Ultra high frequencies range from 30 MHz to 3000 MHz, so that it is useful in space wave or line of sight propagation.
2. UHF is used in radio navigation and detection.
3. Ultra high frequencies are used for television and FM broadcasting stations.
4. Point-to-point communication and moving vehicle communication is possible at UHF.
5. Radio communication in aircraft.

6. Communication between the fixed station and many mobile stations situated in vehicles, ships and aircraft is possible in the frequency band of 30 to 470 MHz.

Disadvantages of UHF

1. Fading of signals, i.e., variation in intensity of signal with time, results due to change in tropospheric conditions and several different mechanisms involved at UHF.
2. The effect of earth imperfections and roughness causes field strength of direct wave to undergo a phase shift, and has a small effect on vertical polarization at ultra high frequency.
3. At UHF, it is not possible to communicate beyond line of sight distance.
4. At ultra high frequencies, radio horizon and heights of antennas are the limiting factors.

10. VHF communication is to be established with a 50 watt transmitter at 100 MHz. Calculate the LOS distance, if the heights of transmitting and receiving antennas are respectively 50 m and 10 m. Assuming the capture area of the transmitting antenna is 25 sqmts, calculate the field strength at the receiving neglecting ground reflected wave.

Ans:

Given that,

For a VHF communication,

Transmitted power, $P_t = 50$ watts

Operating frequency, $f = 100$ MHz

Height of the transmitting antenna, $h_t = 50$m

Height of the receiving antenna, hr = 10 m

Capture area of the transmitting antenna, $A = 25\text{m}^2$

Line of Sight (LOS) distance, d = ?

Field strength at the receiving end, E_R = ?

Then,

Operating wavelength,

$$\lambda = c/f = (3\times10^8)/(100\times10^6) = 3\text{m}$$

The Line Of Sight (LOS) distance is given by,

$$d = 4.12\,(\sqrt{ht} + \sqrt{hr}\,)$$

$$= 4.12\,(\sqrt{50} + \sqrt{10}\,)$$

$$= 4.12\,(10.233) = 42.16 \text{ km}$$

Then the field strength at the receiving end is given by,

$$E_R = (88\sqrt{Pt}\ h_t h_r)/ (\lambda d^2)$$

$$E_R = (88\sqrt{50} \text{ x } 50 \text{ x } 10) / (3 \text{ x } (42.16 \text{ x } 10^3)^2)$$

$$E_R = 58.347\ \mu V/m$$