POSTAL Book Package 2023

ESE

Electronics Engineering

Conventional Practice Sets

Advanced Communication

Contents

MADE EASY Publications

1 CHAPTER Microwave Communication

Q.1 **What is "skip distance"? Why there is better high frequency reception during night time? A long distance microwave link consists of a chain of repeaters at 40 km intervals. What must be the minimum height of transmitting and receiving antennas above ground level? (The antennas are identical to each other in order to ensure line of sight communication).**

Solution:

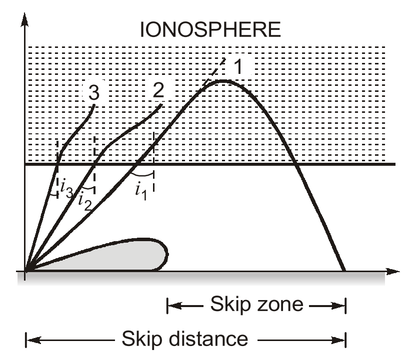
Skip distance can be defined as:

1. The minimum distance from the transmitter at which a sky wave of given frequency is returned to earth by ionospheric layer.
2. The minimum distance from the transmitter to a point where sky wave of a given frequency is received.
3. The minimum distance within which a sky wave of given frequency fails to reflect back.

There is a zone which is not covered by any wave (surface or sky wave) called skip zone.

During night time layer F_1 and F_2 combines and form one layer called F layer and D-region vanishes altogether. Thus in night time only two principal layer exits i.e. E & F layer.

So there is better high frequency reception during night time.



Distance between repeaters d = 40 km,

when there is no atmosphere.

$$d(\text{km}) = 3.57\left[\sqrt{h_t} + \sqrt{h_r}\right]$$

$$40 = 3.57\left[2\sqrt{h}\right] \qquad \text{given } [h_t = h_r]$$

where, h_t = height of transmitter in antenna in meters and h_r = height of receiving antenna in meter

$$h_t = h_r = 31.38 \text{ m}$$

When atmosphere is present,

$$d = 4.12\left[\sqrt{h_t} + \sqrt{h_r}\right]$$

$$40 = 4.12\left[2\sqrt{h}\right]$$

$$h_t = h_r = 23.56 \text{ m}$$

Q.2 **The critical frequencies at an instant observed for E, F_1 and F_2 layers were found to be 3, 5 and 9 MHz. Find the corresponding concentration of electrons in these layers.**

Solution:

Given: Critical frequencies for E layer = 3 MHz, critical frequencies for F_1 layer = 5 MHz, critical frequencies for F_2 layer = 9 MHz.

To be calculated: Concentration of electrons.

$$f_c = 9\sqrt{N_{\max}} \qquad \Rightarrow N_{\max} = \frac{f_c^2}{81}$$

For E layer, f_c = 3 MHz

$$\Rightarrow N_{\max} = \frac{f_c^2}{81} = 9\times\frac{10^{12}}{81} = 0.111\times 10^{12} \text{ Electrons/m}^3$$

For F_1 layer, f_c = 5 MHz $\Rightarrow N_{max} = \frac{f_c^2}{81} = 25 \times \frac{10^{12}}{81} = 0.3086 \times 10^{12}$ Electrons/m^3

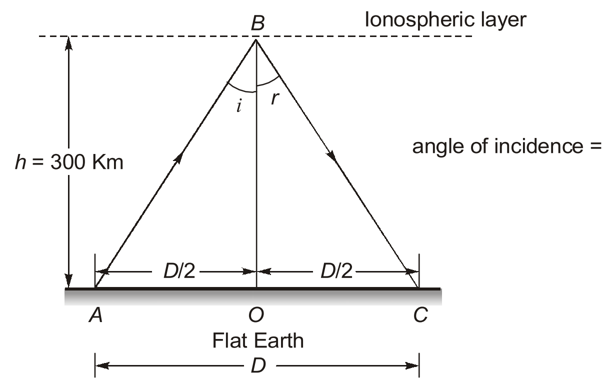
For F_2 layer, f_c = 9 MHz $\Rightarrow N_{max} = \frac{f_c^2}{81} = 81 \times \frac{10^{12}}{81} = 10^{12}$ Electrons/m^3

Q.3 **For an ionospheric layer at a height of 300 km, having electron concentration of 5 × 10^{11} per m^3. Find the maximum permissible frequency at an angle of incidence of 60°. Calculate the critical frequency and skip distances, under flat earth assumptions.**

Solution:

Under Flat Earth assumptions we have,

From ΔAOB,



$$\cos i = \frac{BO}{AB} = \frac{h}{\sqrt{h^2 + D^2/4}}$$

$$= \frac{2h}{\sqrt{4h^2 + D^2}}$$

$$\Rightarrow \quad \cos 60° = \frac{2 \times 300}{\sqrt{4 \times (300)^2 + D^2}}$$

$$\Rightarrow \quad 4 \times (300)^2 + D^2 = (1200)^2$$

$$\Rightarrow \quad D^2 = 1080{,}000$$

$\Rightarrow \quad D$ = Propagation distance AC = 1039.23 km = Skip – distance

Also, ionization density (electrons per cubic meter) = $N_{max} = 5 \times 10^{11}$ / m^3

$\therefore \quad f_c$ = Critical frequency for the layer

$$= 9\sqrt{N_{max}} = 9\sqrt{5 \times 10^{11}} = 6{,}36{,}3961.03 \text{ Hz} = 6.36 \times 10^6 \text{ Hz} = 6.36 \text{ MHz}$$

Now, maximum permissible frequency under flat earth assumptions is,

$$f_{muf} = f_c\sqrt{1 + \left(\frac{D}{2h}\right)^2} = 6.36 \times 10^6 \sqrt{1 + \left(\frac{1039.23}{600}\right)^2} = 12.719 \times 10^6 \text{ Hz}$$

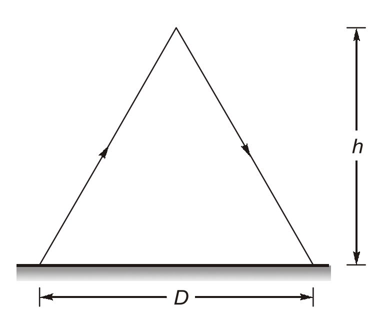
$$\approx 12.72 \text{ MHz}$$

Q.4 **A high frequency radio link has to be established between two points at a distance of 2500 km on the earth's surface. Considering ionospheric height to be 200 km and its critical frequency 5 MHz, calculate the maximum usable frequency for the given path.**

Solution:

Given: D = 2500 km, h = 200 km and f_c = 5 MHz

Maximum Usable frequency is,



$$f_{muf} = f_c\sqrt{1 + \left(\frac{D}{2h}\right)^2}$$

$$\Rightarrow \quad f_{muf} = 5\sqrt{1 + \left(\frac{2500}{2 \times 200}\right)^2} = 31.65 \text{ MHz}$$

Q.5 Calculate the skip distance for flat earth with MUF of 10 MHz if the wave is reflected from a height of 300 km where the maximum value of refractive index (n) is 0.9.

Solution:

Given: MUF = 10 MHz, height (h) = 300 km and n = 0.9.

To be calculated: Skip distance.

$$n^2 = 0.81 = (1 - 81N/f^2)$$

$$N_{max} = (1 - n^2)\, f^2/81 = [(1 - 0.81) \times 10^{14}]/81 = (19/81) \times 10^{12}$$

$$= 23.45 \times 10^{10} \text{ Electrons/m}^3$$

$$f_c = 9\sqrt{N_{max}} = 9\sqrt{(23.45 \times 10^{10})} = 9 \times 4.8425 \times 10^5 = 4.36 \text{ MHz}$$

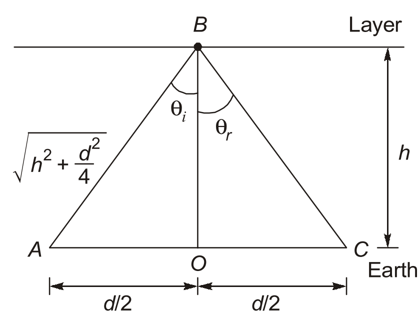
$$d_{skip} = 2h\sqrt{[(f_{MUF}/f_c)^2 - 1]} = 2 \times 300\sqrt{\left[(10/4.36)^2 - 1\right]} = 600 \times 2.06$$

$$= 1236 \text{ km}$$

Q.6 Calculate the maximum single hop distance for D, E, F_1 and F_2 layers if their heights are assumed to be 70, 130, 230 and 350 km respectively above the earth and the angle of incidence is 10° in all cases.

Solution :

To be calculated: Skip distance (d)



$$\cos\theta_i = \frac{OB}{AB}$$

$$\cos\theta_i = \frac{h}{\sqrt{h^2 + d^2/4}} = \frac{2h}{\sqrt{4h^2 + d^2}}$$

$$\cos^2\theta_i = \frac{4h^2}{4h^2 + d^2}$$

$$4h^2(\cos^2\theta_i - 1) = -d^2\cos^2\theta_i$$

$$d^2\cos^2\theta_i = 4h^2(1 - \cos^2\theta)$$

$$d^2 = 4h^2(\sec^2\theta_i - 1)$$

$$\boxed{d = 2h\sqrt{(\sec^2\theta_i - 1}}$$

$$d = 2h\sqrt{(\sec 10)^2 - 1} = 2h \times 0.176 = 0.352h$$

For D layer, $d = 0.352h = 0.352 \times 70 = 24.64$ km

For E layer, $d = 0.352h = 0.352 \times 130 = 45.76$ km

For F_1 layer, $d = 0.352h = 0.352 \times 230 = 80.96$ km

For F_2 layer, $d = 0.352h = 0.352 \times 350 = 123.2$ km

Q.7 In a microwave communication link operating at 100 MHz, the respective heights of transmitting and receiving antennas are 49 m and 25 m respectively. If the transmitted power is 100 W, then determine:

(i) The line of sight (LOS) distance.

(ii) The electric field strength received at LOS distance.

Solution:

Operating frequency, f = 100 MHz

Transmitted power, P_t = 100 W

Height of transmitting antenna, h_t = 49 m

Height of receiving antenna, h_r = 25 m

(i) Calculating the LOS distance:

$$\text{LOS distance} = 4.12\left(\sqrt{h_t} + \sqrt{h_r}\right) \text{ km}$$

Here, h_t and h_r must be represented in meters to get the value of LOS distance in kilometers.

So, $$\text{LOS distance} = 4.12\left(\sqrt{49} + \sqrt{25}\right) \text{ km} = 49.44 \text{ km}$$

(ii) Calculating the electric field strength received at LOS distance:

Electric field strength received (E_r) at a distance "d" from the transmitter can be given by,

$$E_r = \frac{88\sqrt{P_t}}{\lambda d^2} h_t h_r$$

Here, $$\lambda = \text{wavelength} = \frac{c}{f} = \frac{3\times 10^8}{100\times 10^6} \text{ m} = 3 \text{ m}$$

$$d = \text{LOS distance} = 49.44 \text{ km}$$

So, $$E_r = \frac{88\sqrt{100}}{(3)(49.44\times 10^3)^2}(49\times 25) \text{ V/m} = 147\ \mu\text{V/m}$$

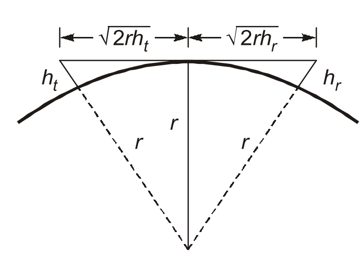
Q.8 Distinguish between radio horizon and optical horizon.

Solution:

Radio Horizon	Optical Horizon
1. Microwaves do not bend or refract beyond the radio horizon.	1. Microwaves 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.	2. This horizon is visible to our eyes.
3. The distance to radio horizon varies with the atmospheric refractive changes.	3. The optical horizon is independent of atmospheric refractive changes.
4. The distance to the radio horizon is given by $d_r = 0.49$ h km where h = height of tower	4. The distance to the optical horizon is given by $d_r = 0.49\sqrt{h}$ km where h = Height of tower
5. Radio horizon distance can also be calculated as $d_r = \frac{d_o}{K}$ where K = Correction factor	5. Optical horizon distance can also be calculated as $d_o = Kd_r$ where K = Correction factor
6. If $K < 1$, the radio horizon is further away from optical horizon.	6. If $K > 1$, optical horizon is further away from radio horizon.

Q.9 A TV transmitting antenna has a height of 169 meters and receiving antenna has a height of 16 m. What is the maximum distance through which the TV signal could be received by space wave propagation? Also calculate the Radio horizon in this case.

Solution:



Given that, $H_T = 169$ m, $H_R = 16$ m

$\therefore$ Maximum distance of LOS (d) = $4.12\left(\sqrt{h_t} + \sqrt{h_r}\right)$km

$$\Rightarrow \quad d = 4.12\left(\sqrt{169} + \sqrt{16}\right) = 4.12 \times 17$$

$$\therefore \quad d = 70.04 \text{ km}$$

we know that the radio horizon is the distance at which direct rays from a radio transmitter become tangential to the earth's surface.

$$\text{Radio Horizon} = \sqrt{2r'h_t} \quad \text{...(i)}$$

where, r' = 4/3 R i.e. for a standard atmospheric refraction, the effective earth's radius is 4/3 times the actual radius of the earth (R).

Now from equation (i),

$$\text{Radio horizon} = \sqrt{2 \times \frac{4}{3} \times \frac{6370}{1000} \times 169} = 53.58 \text{ km}$$

Q.10 Write a short note on digital microwave systems.

Solution:

Currently, most of the microwave systems (terrestrial line of sight, satellite etc.) uses analog FM technologies. With, advancement in the field of computers and data communication digital microwave is preferred to analog microwave systems. It gives following advantages:

1. It is having high immunity for noise in case of transmission of data, voice or video signals.
2. For digital system, ability to accommodate a large number of signals is easy and economical.
3. Digital systems give high RF spectrum efficiency.
4. Reliability of digital system is more. Also, the quality is very high.
5. Design of digital system is easy because of advancement in VLSI design.
6. Time division multiplexing makes the system more reliable and error of the system reduces.

Block Diagram of Digital Microwave System

- It is also known as digital radio system or PCM radio system.

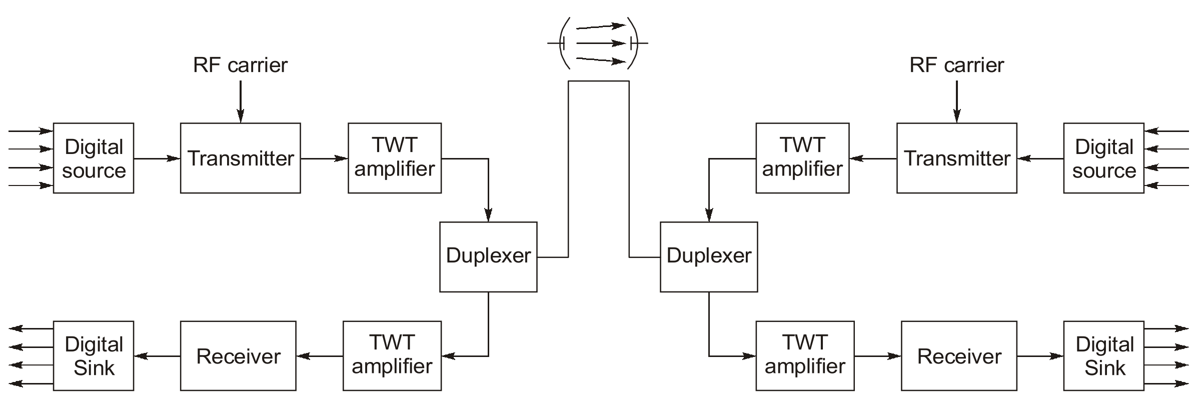


***Figure :** Digital microwave system*

- On transmitter side, transmitter block modulates the radio frequency carrier digitally by bit streams from digital source.
- After modulation, the power level is raised by amplification and then radiated by an antenna.
- Duplexer is used to have same antenna for transmitting and receiving signal.
- On the receiver side, the receiver demodulates the received signal and gives the digital data and from which original data is recovered by the help of *D* to *A* converters.