PROPAGATION

- Radio waves-used for both indoor and outdoor communications because of their ability to pass through buildings and travel long distances.
- key features:
  - **Omni directional** in nature
  - frequency of the radio wave determines many of the characteristics of the transmission.
  - At low frequencies, the waves can pass through obstacles easily.
  - higher frequency waves are more prone to absorption by rain drops and they get reflected by obstacles.
  - Due to the long transmission range of the radio waves, interference between transmissions is a problem that needs to be addressed.

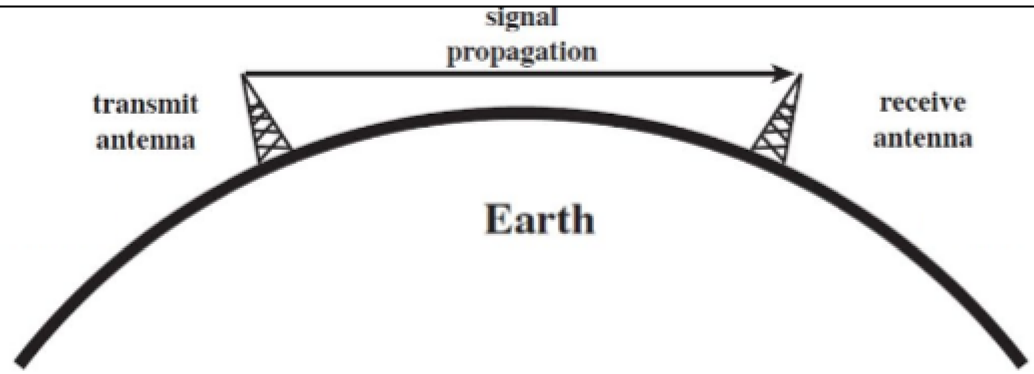
- VLF, LF and MF bands the propagation of waves, also called as **ground waves** follow the curvature of the earth.
- used for low bandwidth transmissions such as Amplitude Modulation (AM) radio broadcasting.
- A powerful sky wave may be reflected several times between the Earth and the ionosphere.
- Sky waves are used by amateur ham radio operators and for military communication.

Radio Wave Propagation

- we use wireless electromagnetic waves as the channel.
- The antennas of different specifications can be used for these purposes.
- The sizes of these antennas depend upon the bandwidth and frequency of the signal to be transmitted.
- The mode of propagation of electromagnetic waves in the atmosphere and in free space may be divided in to the following three categories:
  - Line of sight (LOS) propagation
  - Ground wave propagation
  - Sky wave propagation

Line of Sight (LOS) Propagation

- the wave travels a minimum distance of sight.
- Which means it travels to the distance up to which a naked eye can see.



Line-of-sight (LOS) propagation (above 30 MHz)

- The line-of-sight propagation will not be smooth if there any obstacle occurs in its transmission path.
- As the signal can travel only to lesser distances in this mode, this transmission is used for **infrared** or **microwave transmissions**.
- Above 30 MHz neither ground nor sky wave propagation operates.
- Transmitting and receiving antennas must be within line of sight.

Line-of-Sight Equations

Line-of-Sight Equations

- Optical line of sight

$$d = 3.57\sqrt{h}$$

- Effective, or radio, line of sight

$$d = 3.57\sqrt{Kh}$$

  - d = distance between antenna and horizon (km)
  - h = antenna height (m) (altitude relative to a receiver at the sea level)
  - K = adjustment factor to account for refraction caused by atmospherics layers; rule of thumb K = 4/3

Maximum distance between two antennas for LOS propagation:

$$3.57\left(\sqrt{Kh_1}+\sqrt{Kh_2}\right)$$

- h_1 = height of antenna one
- h_2 = height of antenna two

Ground Wave Propagation

- wave follows the contour of earth.
- Such a wave is called as direct wave.
- The wave sometimes bends due to the Earth's magnetic field and gets reflected to the receiver.
- Such a wave can be termed as reflected wave.
- The wave when propagates through the Earth's atmosphere is known as **Ground Wave**.

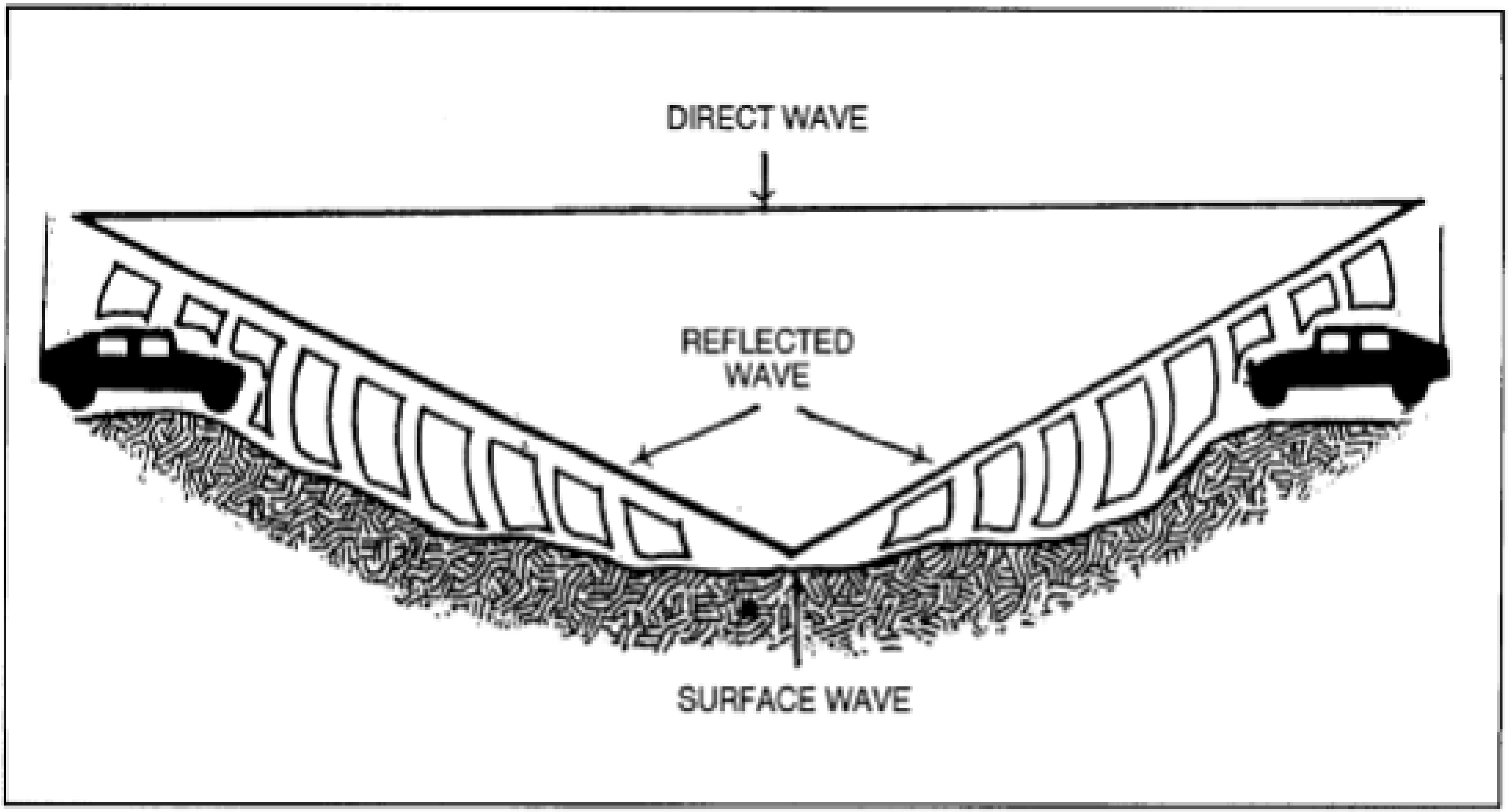
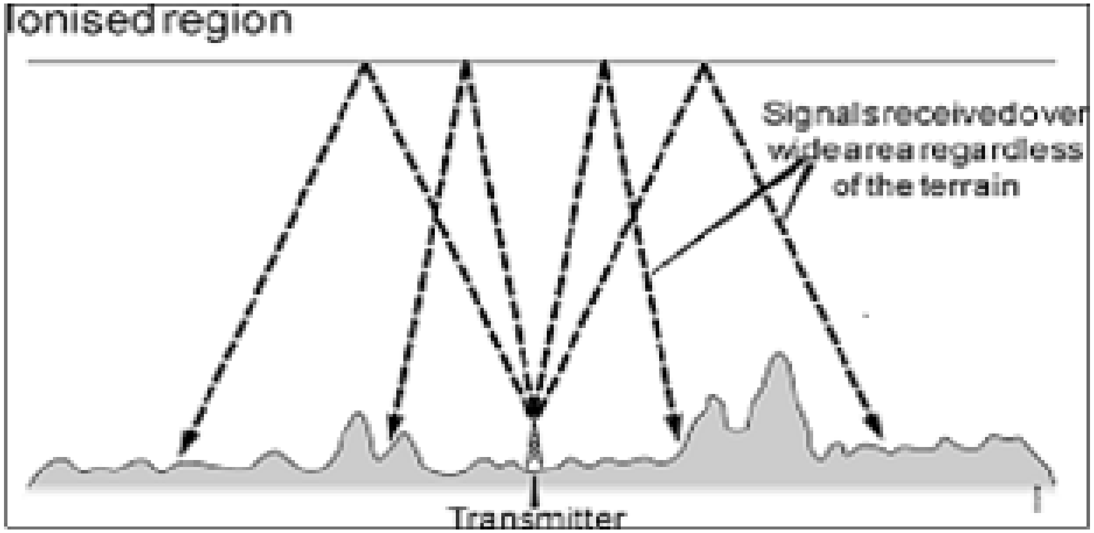


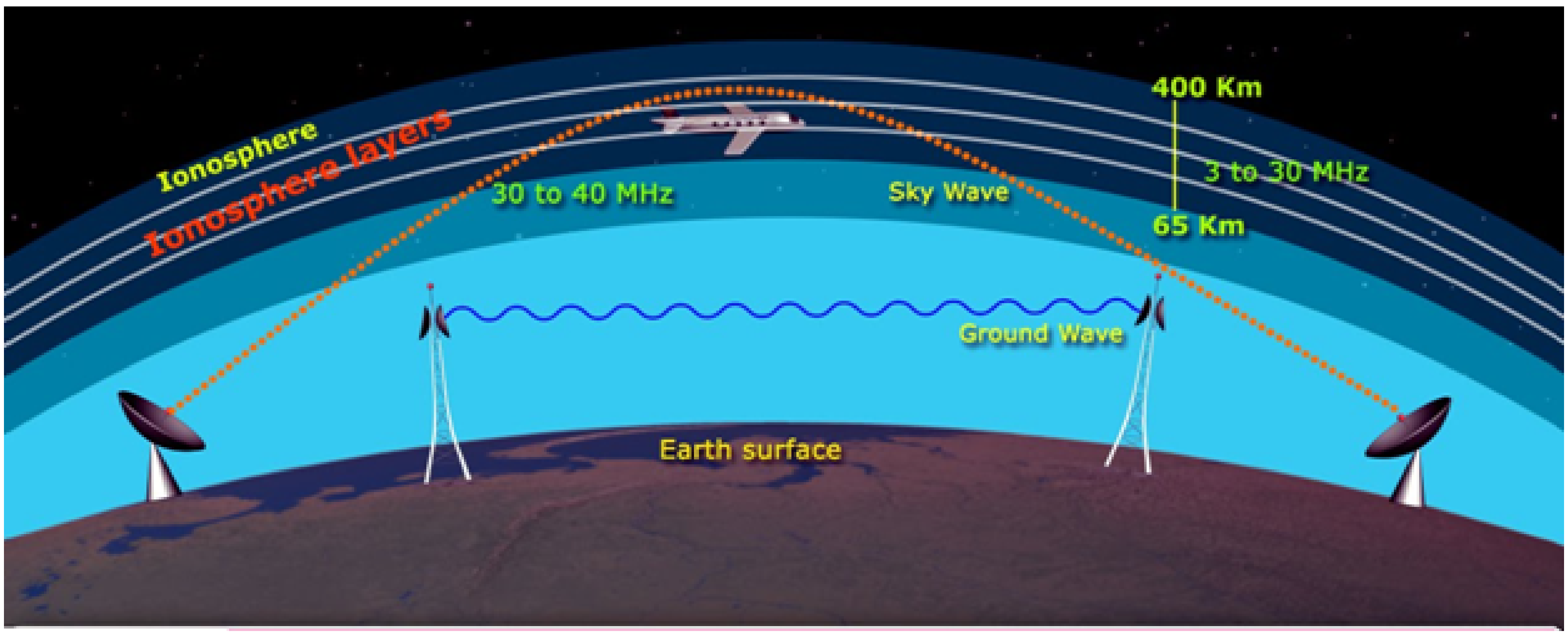
Figure D-2. Components of ground wave.

- The direct wave and reflected wave together contribute the signal at the receiver station.
- When the wave finally reaches the receiver, the lags are cancelled out.
- In addition, the signal is filtered to avoid distortion and amplified for clear output.

Sky Wave Propagation

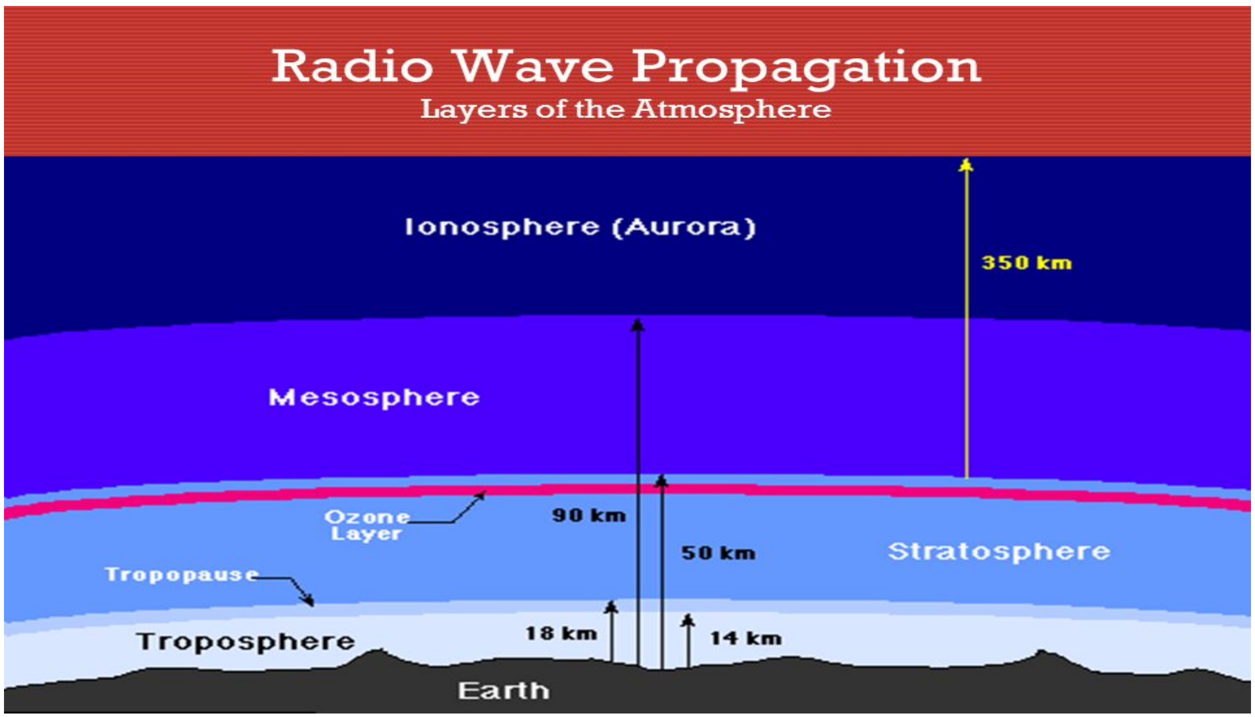
- when the wave has to travel a longer distance.
- Here the wave is projected onto the sky and it is again reflected back onto the earth.
- Here the waves are shown to be transmitted from one place and where it is received by many receivers.
- Hence, it is an example of broadcasting.


Ionised region
Signals received over wide area regardless of the terrain
Transmitter


Ionosphere
Ionosphere layers
30 to 40 MHz
Sky Wave
400 Km
3 to 30 MHz
65 Km
Ground Wave
Earth surface

- waves, which are transmitted from the transmitter antenna, are reflected from the ionosphere.
- It consists of several layers of charged particles ranging in altitude from 30- 250 miles above the surface of the earth.
- Such a travel of the wave from transmitter to the ionosphere and from there to the receiver on Earth is known as **Sky Wave Propagation**.
- Ionosphere is the ionized layer around the Earth's atmosphere, which is suitable for sky wave propagation.

- Earth’s atmosphere has several layers.
- These layers play an important role in the wireless communication.
- These are mainly classified into three layers.



- **Troposphere**
  - This is the layer of the earth,
  - which lies just above the ground.
  - The ground wave propagation and LOS propagation take place here.
- **Stratosphere**
  - This is the layer of the earth, which lies above Troposphere.
  - The birds fly in this region.
  - The airplanes travel in this region.
  - Ozone layer is also present in this region.
  - The ground wave propagation and LOS propagation takes place here.
- **Ionosphere**
  - This is the upper layer of the Earth's atmosphere, where ionization is appreciable.
  - The energy radiated by the Sun, not only heats this region, but also produces positive and negative ions.
  - Since the Sun constantly radiates UV rays and air pressure is low, this layer encourages ionization of particles.

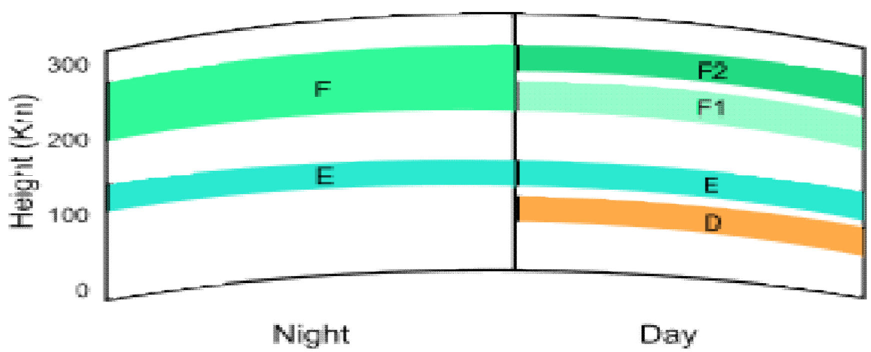
Importance of Ionosphere

- The ionosphere layer is a very important consideration in the phase of wave propagation because of the following reasons:
  - The layer below ionosphere has higher amount of air particles and lower UV radiation. Due to this, more collisions occur and ionization of particles is minimum and not constant.
  - The layer above ionosphere has very low amount of air particles and density of ionization is also quite low. Hence, ionization is not proper.
  - The ionosphere has good composition of UV radiation and average air density that does not affect the ionization. Hence, this layer has most influence on the Sky wave propagation.

- The ionosphere has different gases with different pressures.
- Different ionizing agents ionize these at different heights.
- The number of layers, their heights, and the amount of sky wave that can be bent will vary from day to day, month to month and year to year.
- For each such layer, there is a frequency, above which if the wave is sent upward vertically, it penetrates through the layer.

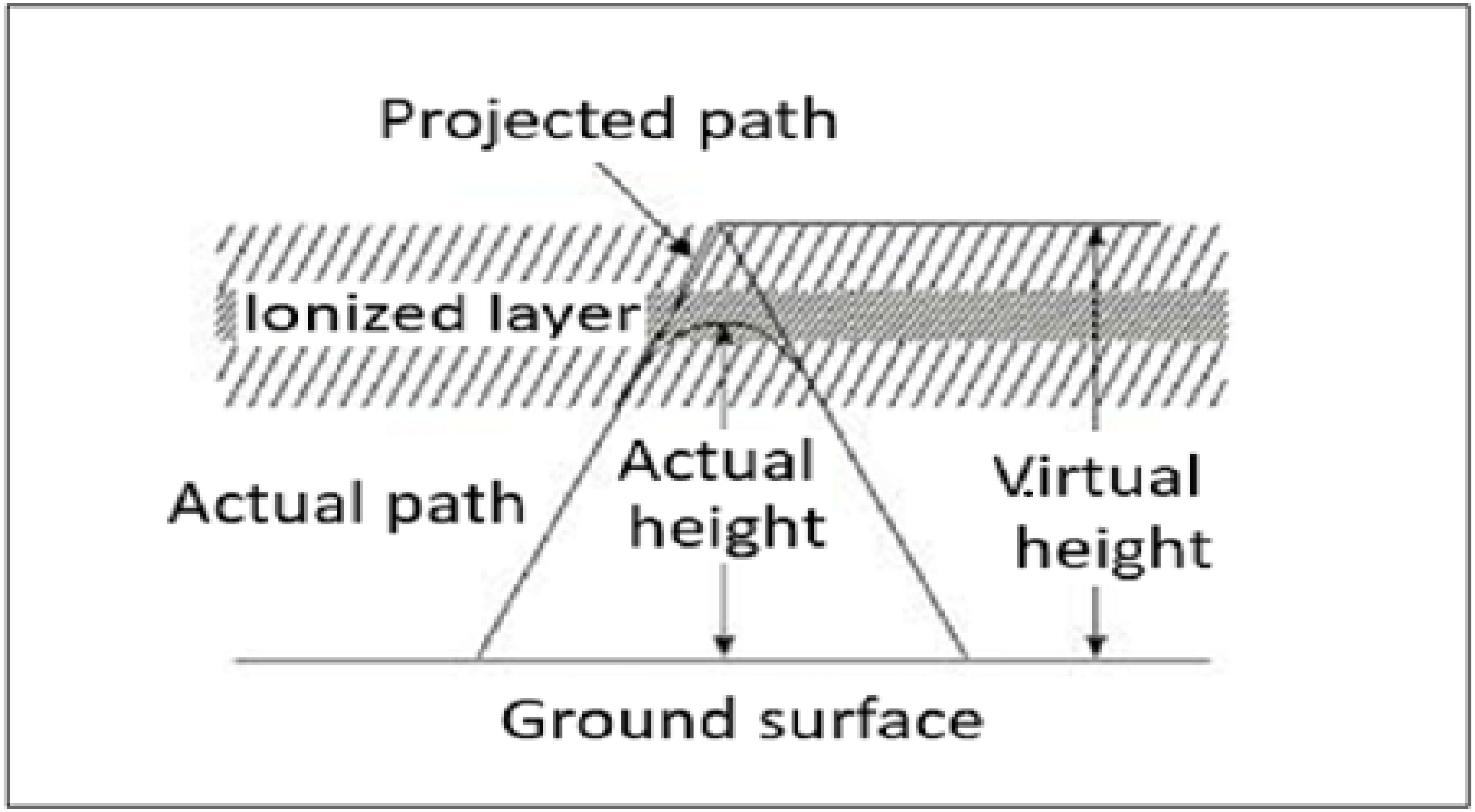
- The function of these layers depends upon the time of the day, i.e., day time and night time.
- There are three principal layers- E, F1 and F2 during day time.
- There is another layer called D layer, which lies below E layer.
- This layer is at 50 to 90kms above the troposphere.

- This **D layer is responsible for the day time attenuation of HF waves**.
- During night time, this D layer almost vanishes out and the F1 and F2 layers combine together to form F layer.
- Hence, there are **only two layers E and F present at the night time**.



Virtual Height

- When a wave is refracted, it is bent down gradually, but not sharply.
- However, the path of incident wave and reflected wave are same if it is reflected from a surface located at a greater height of this layer.
- Such a greater height is termed as virtual height.
- the **virtual height** (height of wave, supposed to be reflected) and **actual height** (the refracted height).
- If the virtual height is known, the angle of incidence can be found.

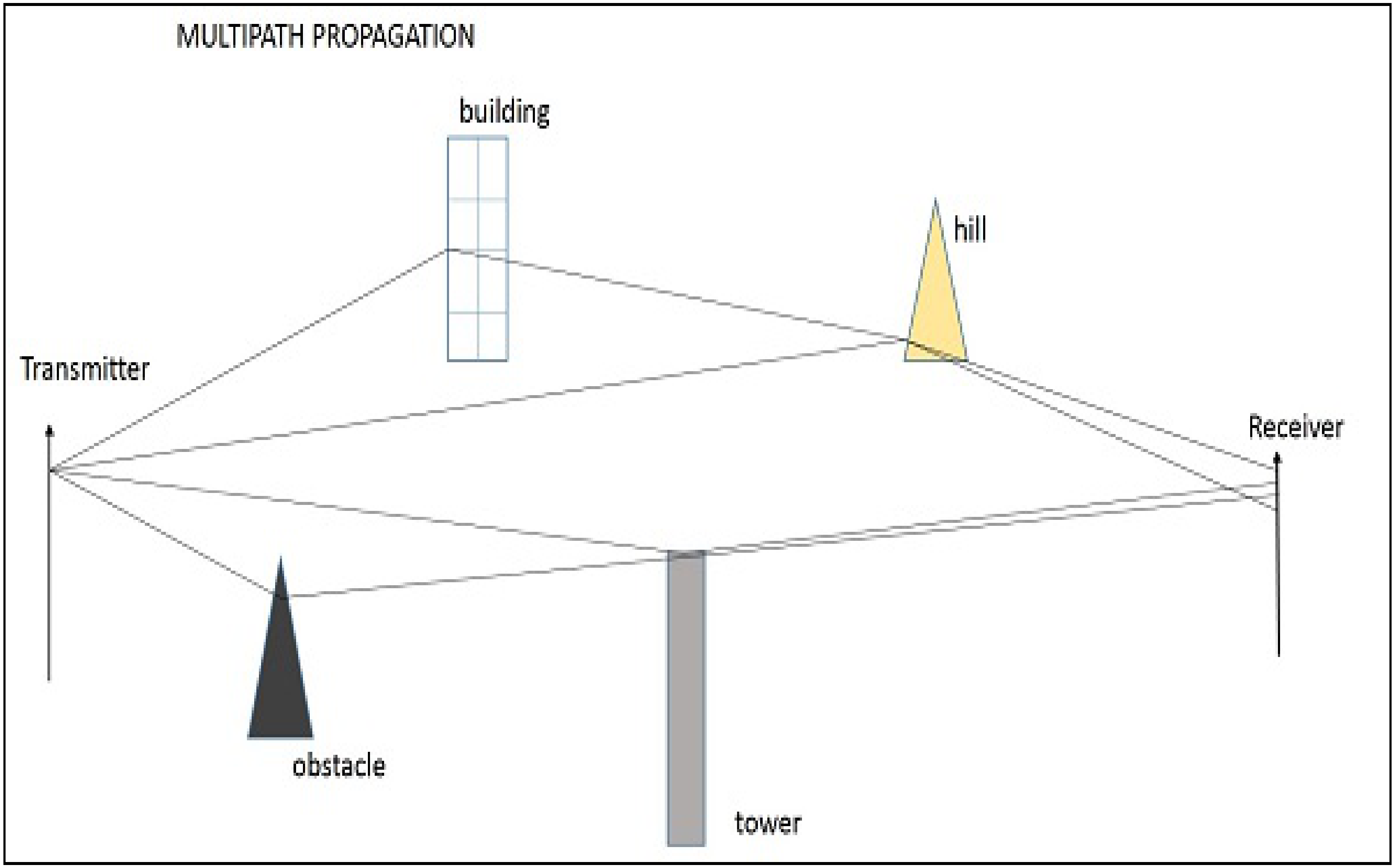

Projected path
Ionized layer
Actual path
Actual
height
Virtual
height
Ground surface

Critical Frequency (f_c)

- Critical frequency for a layer determines the highest frequency that will be returned down to the earth by that layer, after having been beamed by the transmitter, straight up into the sky.
- The rate of ionization density, when changed conveniently through the layers, the wave will be bent downwards.
- The maximum frequency that gets bent and reaches the receiver station with minimum attenuation can be termed as **critical frequency**. This is denoted by $\mathbf{f_c}$.

Multi-Path Propagation

- For the frequencies above 30 MHz, the sky wave propagation exists.
- Signal multipath is the common problem for the propagation of electromagnetic waves going through Sky wave.
- The wave, which is reflected from the ionosphere, can be called as a **hop** or **skip**.
- There can be a number of hops for the signal as it may move back and forth from the ionosphere and earth surface many times.
- Such a movement of signal can be termed as **multipath**.


MULTIPATH PROPAGATION
building
hill
Transmitter
Receiver
obstacle
tower

- Multipath propagation is a term, which describes the multiple paths a signal travels to reach the destination.
- These paths include a number of hops.
- The paths may be the results of reflection, refraction or even diffraction.
- Finally, when the signal from such different paths gets to the receiver, it carries propagation delay, additional noise, phase differences etc., which decrease the quality of the received output.

Fading

- The decrease in the quality of the signal can be termed as **fading**.
- This happens because of atmospheric effects or reflections due to multipath.
- Fading refers to the variation of the signal strength with respect to time/distance.
- It is widely prevalent in wireless transmissions.
- The most common causes of fading in the wireless environment are multipath propagation and mobility (of objects as well as the communicating devices).

Skip Distance

- The measurable distance on the surface of the Earth from transmitter to receiver, where the signal reflected from the ionosphere can reach the receiver with minimum hops or skips, is known as **skip distance**.

Maximum Usable Frequency (MUF)

- The **Maximum Usable Frequency (MUF)** is the highest frequency delivered by the transmitter regardless of the power of the transmitter.
- The highest frequency, which is reflected from the ionosphere to the receiver is called as **critical frequency, fc**.

$$\text{MUF} = \frac{\text{critical frequency}}{\cos\theta}$$

Where,

MUF = Maximum Usable Frequency

θ = Angle of Incidence