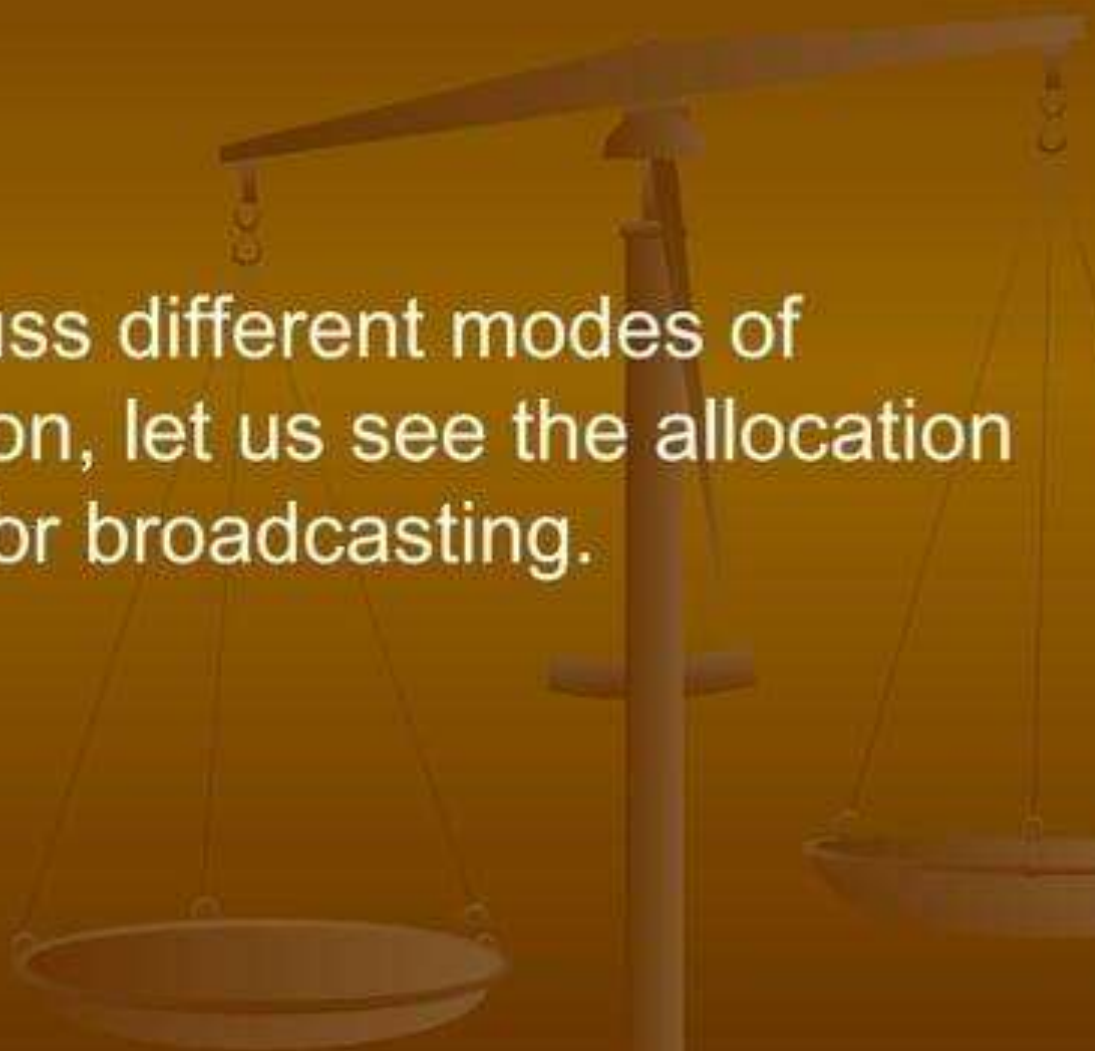# Module 5: WAVE PROPAGATION

Introduction, Modes of wave propagation, Ground wave propagation, Space wave propagation- Introduction, field strength variation with distance and height, effect of earth's curvature, absorption; Super refraction, M-curves and duct propagation, troposphere propagation. Sky wave propagation - Introduction, structure of Ionosphere, refraction and reflection of sky waves by Ionosphere, Ray path, Critical frequency, MUF, LUF, OF, Virtual height and Skip distance, Relation between MUF and Skip distance.

DIFFERENT MODES OF WAVE PROPAGTION

- **Propagation of Radio waves takes place by different modes, the mechanism being different in each case. Based on that, it can be classified as:**
  - 1. Ground (Surface) waves
  - 2. Space (Tropospheric) waves
  - 3. Sky (Ionospheric) waves

- Before we discuss different modes of wave propagation, let us see the allocation of frequencies for broadcasting.

Allocation of frequencies for Broadcasting

- **Long Wave Band**
  - *(This is not used in India.)*
- **Medium Wave (MW) Band**
  - MF - 300 - 3000 kHz
    - 531 kHz to 1602 kHz
    - With a Channel spacing - 9 kHz
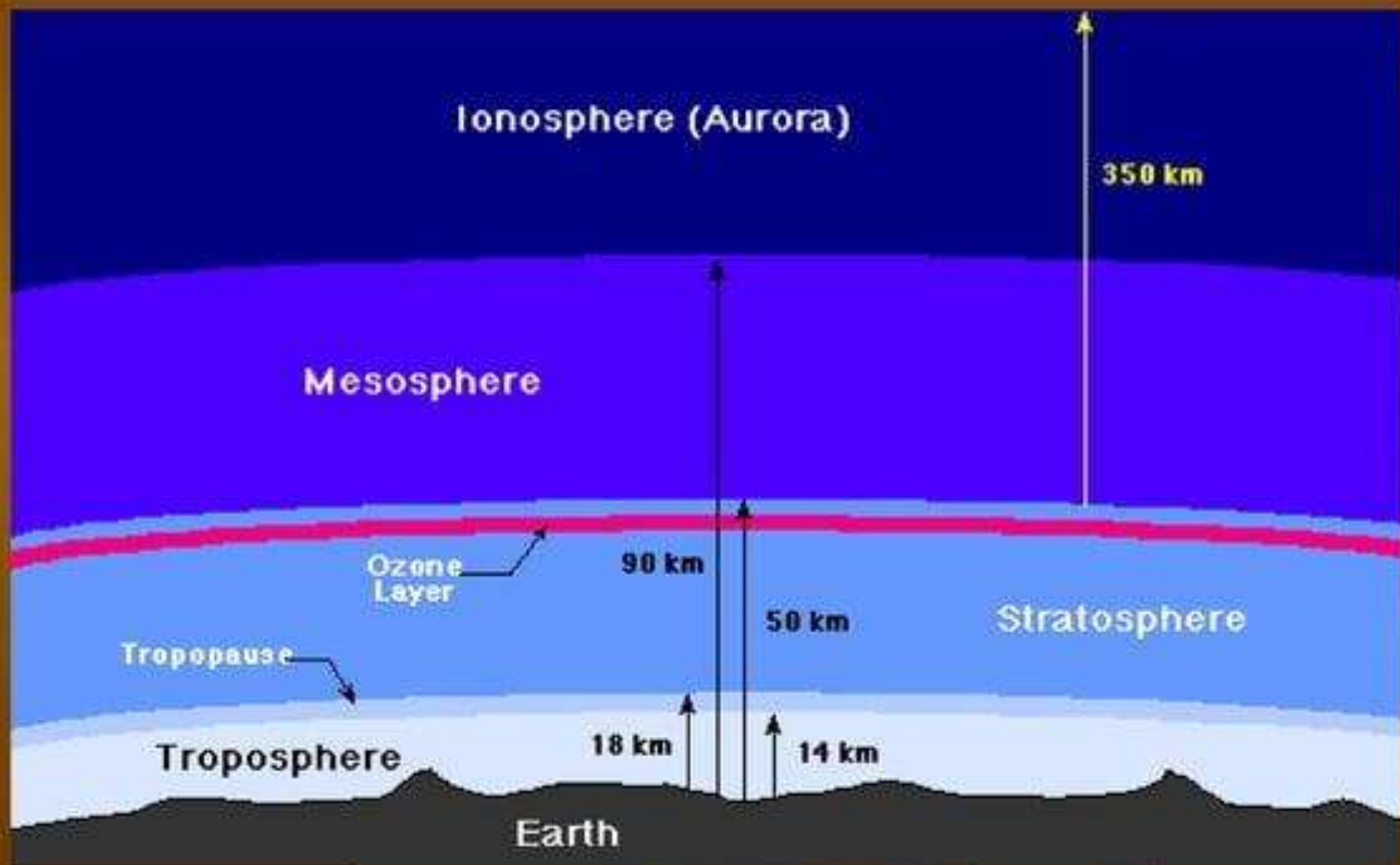
Short Wave (SW) Band

HF - 3 - 30 MHz

VHF
30 –300 MHz

UHF
300 – 3000 MHz

SHF
3 – 30 GHz

Different Layers on Earth

Ground (Surface) Waves

▶ Medium wave (MW) propagates along the surface of the earth.

▶ Medium wave induces current in the ground over which it passes, and thus, lose some energy by absorption.

▶ Range of such coverage depends on frequency, power of the transmitter, ground conditions like salinity and conductivity of the ground or water over which the waves propagate, and the water vapour content of the air.

Received signal strength

Received signal strength V $=$ $\dfrac{120\pi h_r h_t I}{\lambda d}$

120π $=$ Characteristic impedance of free space

h_t $=$ effective height of the transmitting antenna

h_r $=$ effective height of the receiving antenna

I $=$ Antenna current

d $=$ distance from the transmitting antenna

FADING OF SIGNAL

- When both ground wave and sky wave signals are received, fading occurs in those areas where the signals are of comparable strength and the area is called as 'fading zone'.

- This fading zone should be kept as far away as possible from the transmitter.

- The optimum antenna that achieves this objective is of height 0.55λ, where λ is the wavelength of the operating frequency.

Space (Tropospheric) Waves

- They travel more or less in straight lines. As they depend on line of sight conditions, they are limited in their propagation by the curvature of the earth

- Space wave can have two components: viz. Direct wave and reflected wave from the surface of earth. Direct wave will be steady and strong.

Line of sight (LOS)

$$LOS = \sqrt{2a}\left(\sqrt{h_t} + \sqrt{h_r}\right) m$$

Where

a = radius of earth = 6370 km = 6.37×10^6 m.

h_t = Transmitting antenna height in metres.

h_r = Receiving antenna height in metres.

Radio waves normally propagate in a curved path due to refraction in the troposphere. It can be noted that not only the transmitting antenna height, but also the receiving antenna height is equally important.

Fresnel Zone

- Propagation is not by single thread like ray. Certain volume around the line of sight called "**First Fresnel Zone**" is significant for propagation.

- This volume should be devoid of any surface, building, etc. causing reflections.

- Therefore, mere availability of line of sight alone is not sufficient, but the First Fresnel Zone must be clear.

Environment Effects

- **Effects of buildings**

   Built up area has little effect on low frequencies (few MHz). But above 30 MHz, obstruction loss and shadow loss become important. The attenuation by walls may be 2 - 5 dB at 30 MHz and increases to 10 - 40 dB at 3000 MHz.

- **Effects of trees and vegetation**

   The effect of thick vegetation is to absorb RF energy and it is particularly more dominant for vertical polarization than horizontal polarization.

- **Clutter losses**

   The loss due to natural and man made obstruction can only be statistically evaluated and a certain allowance made in the calculations of field strength. Such losses, in general, are grouped and referred to as "**Clutter losses**". This loss is dependent   on frequency of operation and the area surrounding the transmitter.

Effective Radiated Power (ERP)

- ERP is the product of Intrinsic power of the transmitter and the gain of the transmitting antenna over a dipole.

- ERP = Transmitter power in kW x antenna gain (In kW)

  (or alternatively)

- ERP = Transmitter power in dBm + antenna gain in dBm

Effective Isotropic Radiated Power (EIRP)

- It is similar to ERP, except that the gain is expressed relative to an isotropic antenna.

- Gain of a Isotrophic antenna = 1.64 times or 2.15 dB of that of a dipole.

- EIRP = ERP (dBW) + 2.15 dB (In dBW)
  or   EIRP = 1.64 x ERP

Isotropic Antenna

- It is an imaginary (non-existent) point (dimensionless) antenna, and radiates uniformly in all the three dimensions.

Field Strength

- Minimum signal requirement for satisfactory reception with receiving antenna at 10 m height are as follows:

Band 1*	48 dBµV/m
Band 3	55 dBµV/m
Band 4	65 dBµV/m
Band 5	70 dBµV/m

* However, Doordarshan has adopted 40 dBµV/m.

Field Strength

- Field strength = 134.8 + 10 log P

  $\qquad\qquad$ − 20 log d − F $\qquad$ dBμV/m

  Where

  $\qquad$ P = EIRP in Watts

  $\qquad$ d = distance of receiving point in m.

  $\qquad$ F = Loss experienced in propagation.

Protection Ratio

- The ratio of wanted to the unwanted field strength at a point 'P' is known as the **'Protection Ratio'** (PR).

PROTECTION RATIO

- Let us say, that the wanted transmitter produces a field strength of Xw dBμV/m at a point P and an unwanted transmitter produces a field of strength Yuw dBμV/m at the same point. Then;

$$\text{Protection Ratio } P = \left(\frac{X_w}{Y_{uw}} \right)$$

Or

$$PR\ (dB) = 10\log\left(\frac{X_w}{Y_{uw}} \right)$$

Duct Propagation

- The refractivity 'n' of the troposphere, under normal weather conditions, gradually falls at the rate of -40 to –80 units per km with height above the earth.

- When the refractivity is – 157 N units/km or more, ducting mode exists.

- During ducting, the VHF/UHF radio waves are refracted (bent) very fast so as to bump against the ground and again reflected.

- This phenomena is called Duct Propagation.

Co-Channel Interference

- If the wanted TV signal exceeds the interfering signal by a voltage ratio of 55 dB or more, no interference will be noted.

- When the desired signal becomes weaker, "**Venetian blind**" interference occurs.

- This is seen as horizontal black and white bars super imposed on the picture and moving up or down.

Adjacent Channel Interference

- Adjacent channel interference may occur as the result of beats between any two of these carriers. The difference of 1.5 MHz produces a coarse beat pattern.

Fig. 1 Adjacent Channel Interference
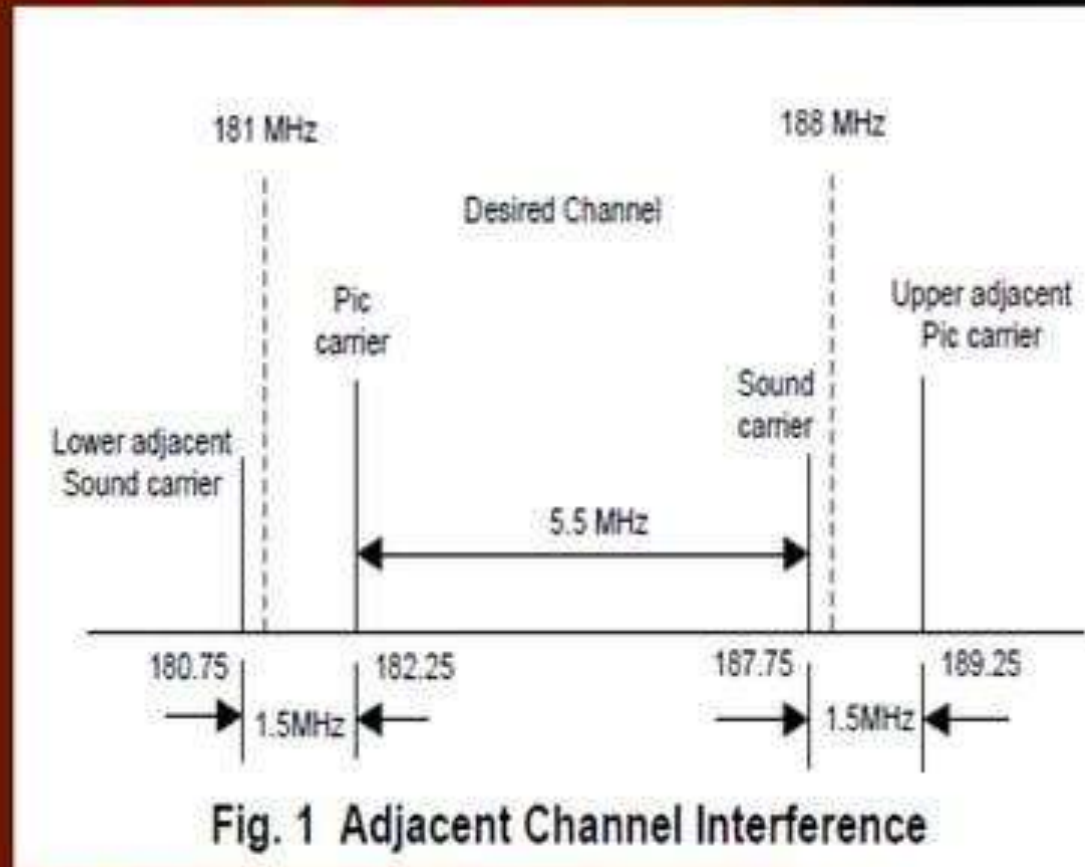
Ghost Interference

- This is due to reflection from tall obstructions. This is not only objectionable but most of the times reduces resolution. One way of reducing this interference is to shift the receiving antenna position so that it does not receive the reflected signals.

Layers during Day & Night
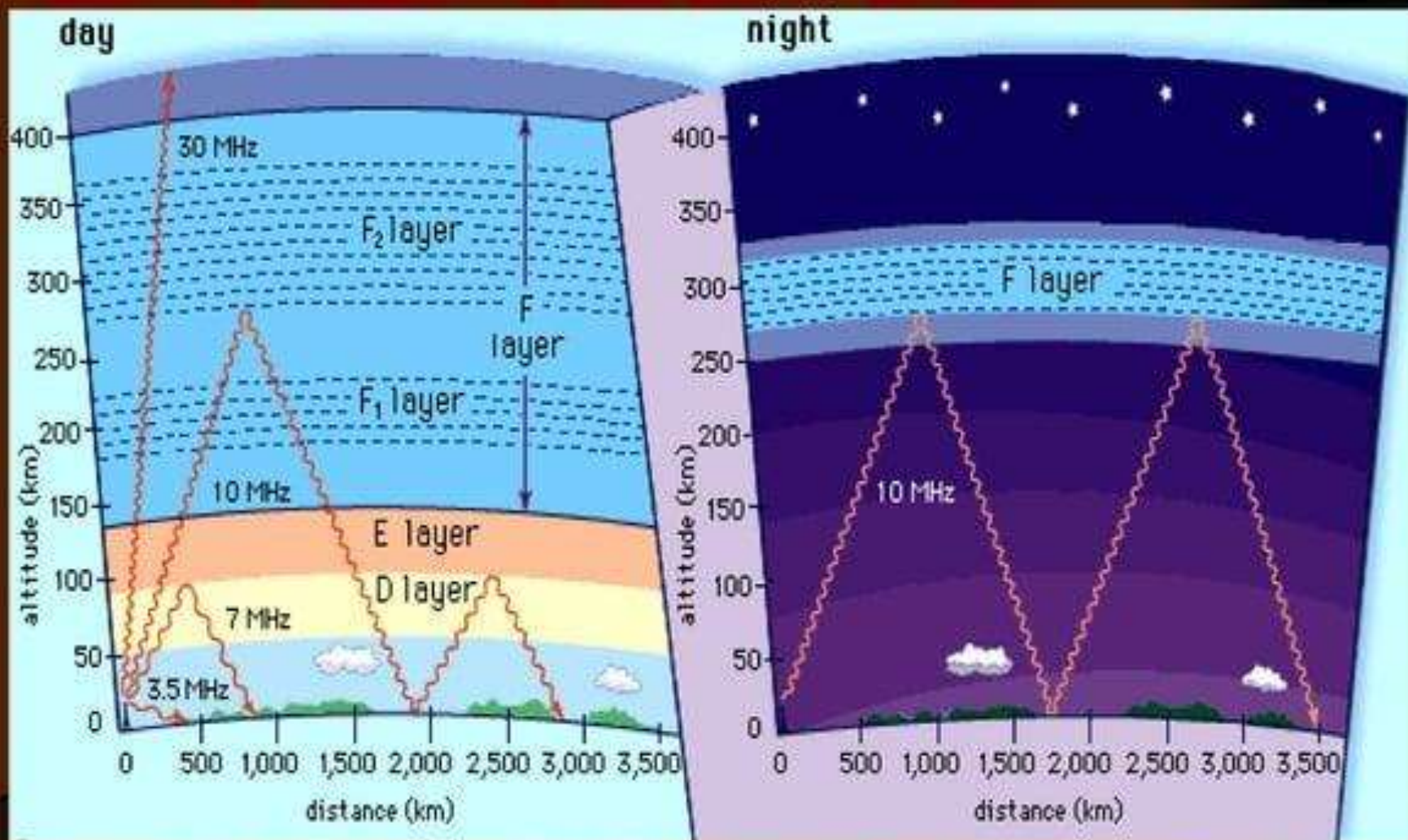
Sky (Ionospheric) Waves

- Short wave (SW) propagates as sky waves.

- Ionization of upper parts of the earth's atmosphere plays a part in the propagation of the high frequency waves.

- Due to the energy received from the sun, the atmospheric molecules split into positive and negative ions and remain ionized for a long period of time.

Ionospheric Layers

- Ionosphere extends from 50 to 400 km and has got ionized particles.

- When sunrays pass through this ionosphere, due to different densities, imaginary but distinct layers are formed like D, E, F1 and F2 layers.

D Layer

- It is the lowest layer of the ionosphere.

- Its average height is 70 km and average thickness is 10 km.

- Degree of ionization depends on the altitude of the sun above horizon.

- It disappears at night.

- It absorbs MF and HF waves to some extent and reflects some VLF and LF waves.

E Layer

- **This layer is above D-layer.**

- **Its average height is 100 km with a thickness of 25 km.**

- **It also disappears at night as the ions recombine into molecules. This is due to the absence of sun at night when radiation is no longer received.**

- **It aids MF surface wave propagation to some extent and reflects some HF waves in day time.**

Es-Layer

- It is a sporadic E-layer, a thin layer of very high density. Sometimes, it appears with E-layer.

- When Es layer occurs, it often persists during the night also. To say, it does not have an important part in long distance propagation, but sometimes permits unexpectedly good reception.

- Its causes are not well known.

What is sporadic E ?

- Irregular scattered patches of relatively dense ionization that develop seasonally within the E region and that reflect and scatter radio frequencies up to 150 MHz.

- Sporadic E is a regular daytime occurrence over the equatorial regions and is common in the temperate latitudes in late spring ,early summer and, to a lesser degree, in early winter.

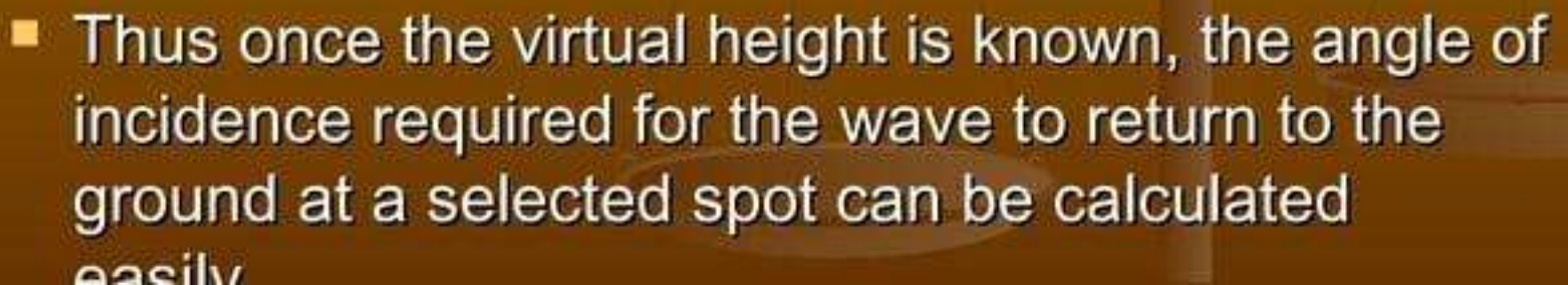- It can sometimes support reflections for distances up to 2,400 km

F1 Layer

- It exists at a height of 180 km in day time and gets combined with the F2 layer at nighttime.

- In day time, it's thickness is about 200 km.

- Although some HF waves are reflected from it, most passes through it to be reflected by the   F2 layer.

- The main effect of F1 layer is more absorption for HF waves.

- The absorption effect of F1 layer and any other layer is doubled because HF waves are absorbed on the way up
and also on the way down.

F2 Layer

- It is the most important reflecting medium for HF waves.

- Its approximate thickness can be upto 200 km and its height ranges from 290 to 400 km in day time.

- At night, it falls to about 300 km, when it combines with the F1 layer.

- Its height and ionization density vary tremendously depending upon the time of the day, the average ambient temperature and sunspot cycle.

Virtual Height

- As the electromagnetic wave is refracted, it is bent down gradually, rather than sharply.

- However, below the ionised layer, the path of the incident and the refracted rays is exactly same as if reflection has taken place from a surface located at a greater height called the virtual height of this layer.

φ₀

Vertical incidence path

Actual Height

Virtual height

T   β

R

β = take off angle

- Thus once the virtual height is known, the angle of incidence required for the wave to return to the ground at a selected spot can be calculated easily

Critical Frequency (fc)

- It is obtained by sending a signal pulse directly upwards. The pulse may be reflected back to earth, and the time is measured to give an indication of the height of the layer.

- As the frequency is increased a point is reached where the signal will pass right through the layer, and on to the next one, or into outer space. The frequency at which this occurs is called the critical frequency.

Maximum usable frequency

- MUF is defined as the highest frequency that can be used for sky wave communication between two given points on earth.

$$MUF = \frac{\text{Critical Frequency}}{\cos\theta} = f_c \sec\theta$$