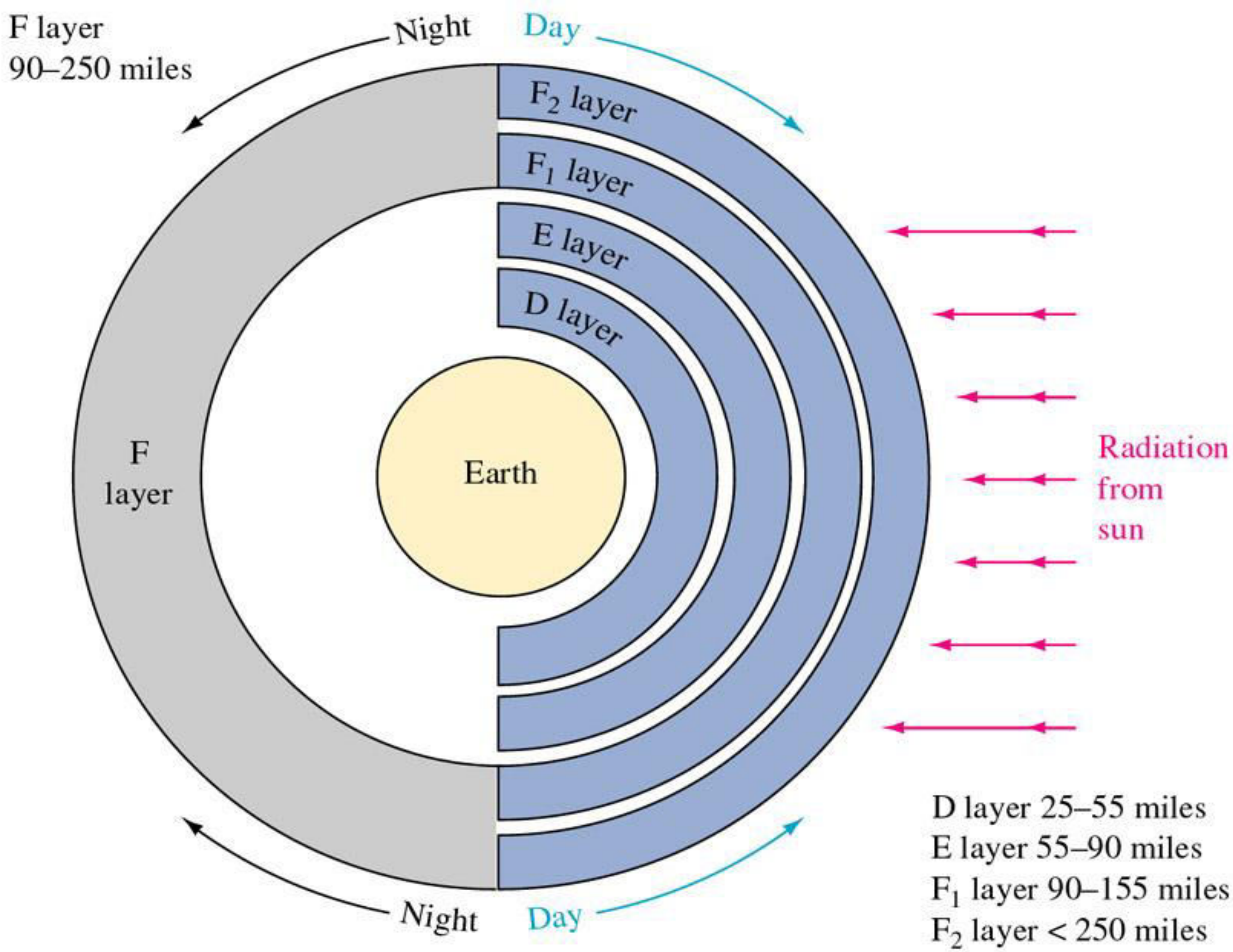
ANTENNA AND WAVE PROPAGATION

Ionospheric Layers

- ✓ Each region is subdivided into layers called the D, E, F1, and F2 layers, also according to height and ion distribution.
- ✓ These are not distinctly separated layers, but rather overlapping regions of ionisation that vary in thickness from a few kilometres to hundreds of kilometres.
- ✓ The number of layers, their heights, and their ionisation (electron) density vary both geographically and with time.
- ✓ At HF all the regions are important & must be considered in predicting the operational parameters of radio communication circuits.

THE IONOSPHERIC LAYERS CONT'D



THE IONOSPHERIC LAYERS CONT'D

D layer:

- is the **innermost layer**, **50 km to 90 km** above the surface of the Earth. when the sun is active with 50 or more sunspots, During the night cosmic rays produce a residual amount of ionization as a result high-frequency (HF) radio waves aren't reflected by the D layer.

- **The D layer is mainly responsible for absorption of HF radio waves**, particularly at 10 MHz and below, with progressively smaller absorption as the frequency gets higher. The **absorption is small at night** and **greatest about midday**. The layer reduces greatly after sunset. A common example of the D layer in action is the **disappearance of distant AM broadcast band stations in the daytime.**

THE IONOSPHERIC LAYERS CONT'D

D layer

- Because of the low electron density, the D region does not reflect useful transmissions in the frequency range above 1 MHz.
- The electron density is relatively small compared with that of the other regions, but, because of collisions between the molecules of the atmosphere and free electrons excited by the presence of an electromagnetic wave, pronounced energy loss occurs.
- This energy loss, dissipated in the form of thermal energy of the electrons or thermal (electromagnetic) noise, is termed absorption.

THE IONOSPHERIC LAYERS(Contd.)

<u>The E layer:</u>

- is the middle layer, 90 km to 120 km above the surface of the Earth.
- can only reflect radio waves having frequencies less than about 10 MHz.
- has a negative effect on frequencies above 10 MHz due to its partial absorption of these waves.
- At night the <u>E layer begins to disappear because the primary source of ionization is no longer present</u>. The <u>increase in the height</u> of the E layer maximum <u>increases the range to which radio waves can</u> travel by reflection from the layer.
- Maximum Electron density occurs at 110 Km.

THE IONOSPHERIC LAYERS

The F layer:

- is **120 km to 400 km** above the surface of the Earth.
- is top most layer of the ionosphere (Imp. For HF Comm.)
- Extreme ultraviolet (UV) (10-100 nm) solar radiation ionizes atomic oxygen (O).
- The **F layer combines into one layer at night**, and in the presence of sunlight (during daytime), it divides

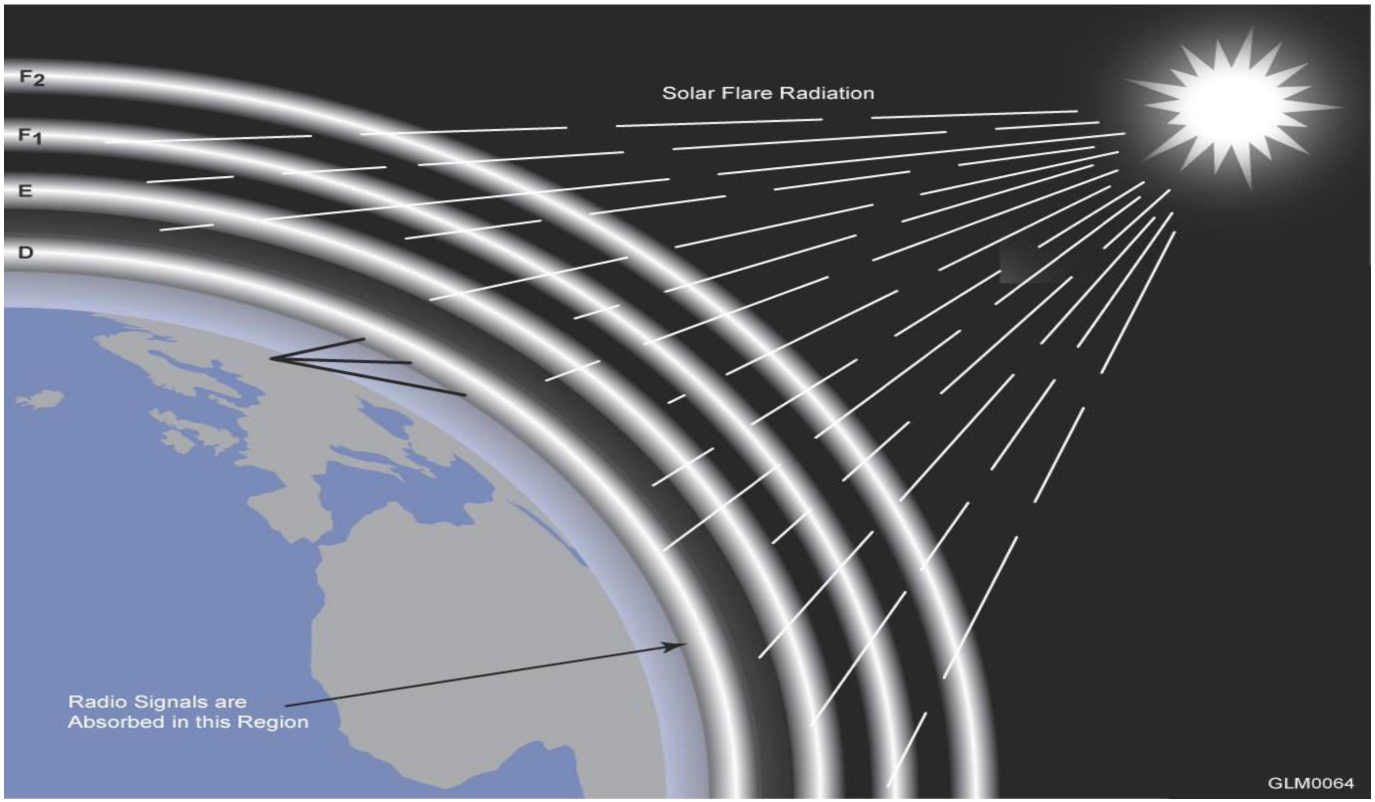
into two layers, the F1 and F2. The F layers are responsible for most skywave propagation of radio waves, and are thickest and most reflective of radio on the side of the Earth facing the sun.

THE IONOSPHERIC LAYERS(Contd.)

- The F1 layer is of importance to communication only during daylight hours. It lies in the height range of about 200 to 250 km and undergoes both seasonal and solar cycle variations, which are more pronounced during the summer and in high sunspot periods.

- The F2 layer is located between 250 to 350 km above the earth's surface. During the night the F1 and F2 layers combine into a single layer

Effect of Solar Flare Radiation on the Ionospheric layers



Effects of the Ionosphere on the Sky wave

If we consider a wave of frequency , *f* is incident on an ionospheric layer whose maximum density is *N*, then the refractive index of the layer is given by

$$n = \sqrt{1 - \frac{81N}{f^2}}$$

Critical Frequency

If the frequency of a wave transmitted vertically is increased, a point will be reached where the wave will not be refracted sufficiently to curve back to earth and if this frequency is high enough then the wave will penetrate the ionosphere and continue on to outer space. The highest frequency that will be returned to earth when transmitted vertically under given atmospheric conditions is called the *CRITICAL FREQUENCY.*

$$f_c = 9\sqrt{N}$$

Maximum Usable frequency (MUF)

There is a best frequency for communication between any two points under specific ionospheric conditions. The highest frequency that is returned to earth at a given distance is called the Maximum Usable Frequency (MUF).

MUF depends on the layer that is responsible for refraction/reflection and so contact between two stations relying on skip will depend on the amount of <u>sunspot activity</u>, <u>the time of day, time of year, latitude of the two stations</u>, and <u>antenna transmission angle</u>. The MUF is not significantly affected by transmitter power and receiver sensitivity

$$f_{muf} = 9\sqrt{N}\sec\theta$$

OPTIMUM WORKING FREQUENCY (OWF)

- **The OWT is usually the most effective frequency for ionospheric reflection of radio waves between two specified points on Earth.**
- **The actual freq which provides the most satisfactory reception of the signal should be less than the MUF.**
- **OWT is the highest effective (i.e. working) frequency that is predicted to be usable for a specified path and time for 90% of the days of the month.**
- **An Optimum Frequency is predicted from MUF and is 85%of the MUF. This is also called as Freq. Of Optimum Transmission(FOT).**

For transmission using the F2 layer it is defined as $f_{owf} = 0.85 \times 9\sqrt{N}\sec\theta$

The Lowest Usable high Frequency (LHF)

- **The Lowest Usable high Frequency (LUF):**

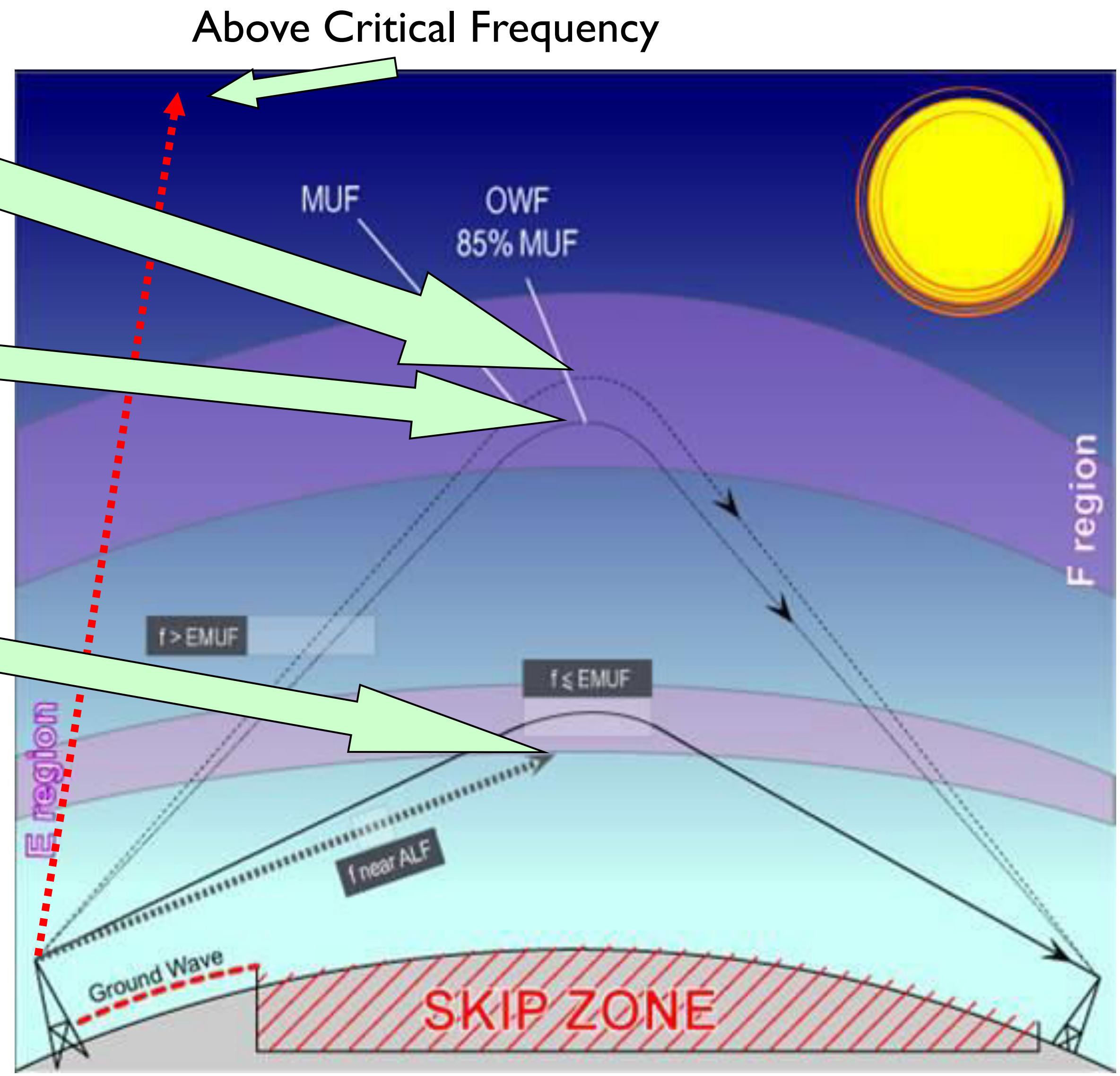
  The frequency in the HF band at which the received field intensity is sufficient to provide the required signal-to-noise ratio. The amount of energy absorbed by the lower regions of the ionosphere (D region, primarily) directly impacts the LUF

MUF,LUF AND CRITICAL FREQUENCIES

Maximum Useful Frequency (MUF)

Frequency of optimum transmission (FOT) /Optimal Working Frequency (OWF)

Lower Absorption Frequency (ALF) / The lowest Usable frequency (LUF):



Effect of Earth’s Geomagnetic Fields

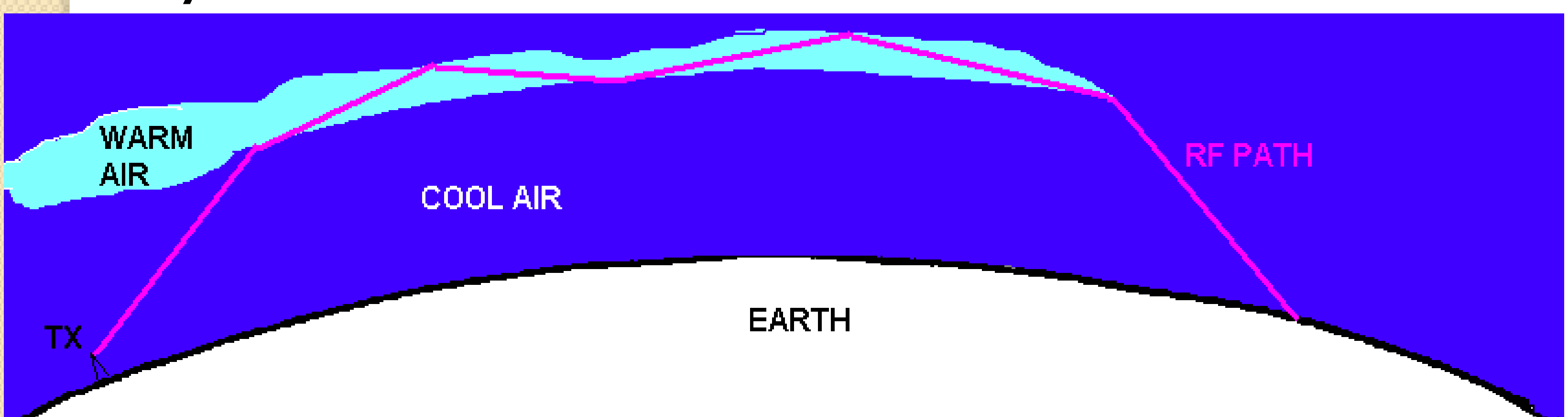
- The EM waves propagation depends not only on its own properties but is dictated by the environment itself.

<u>Earth's Geomagnetic Fields:</u> Activity in this field caused by interaction with charged particles from the sun.

Duct Propagation

Temperature Inversion / Troposphere Ducting:

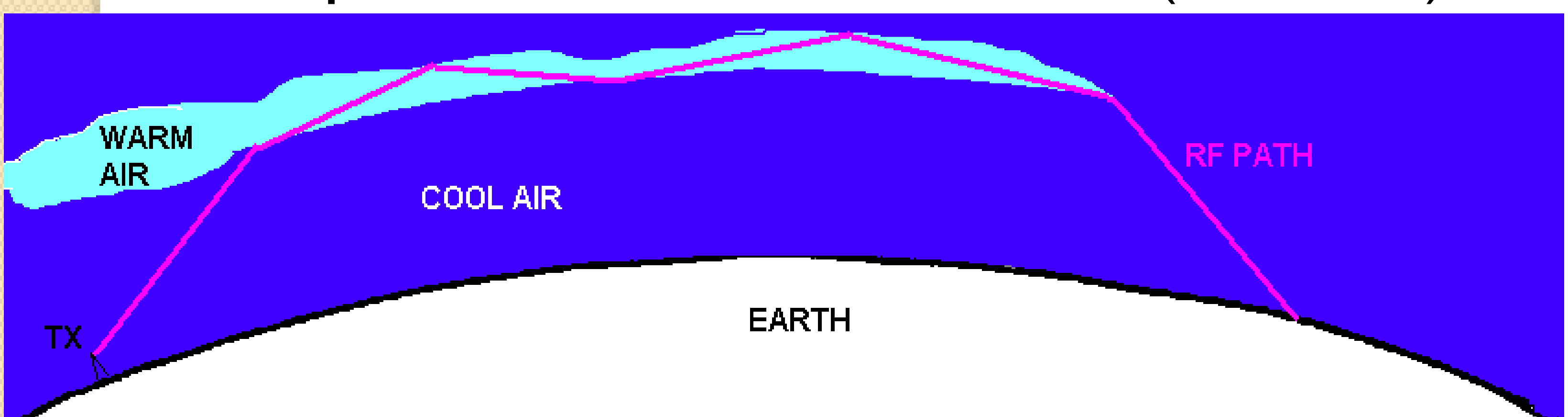
Certain weather conditions produce a layer of air in the Troposphere that will be at a higher temperature than the layers of air above and below it. Such a layer will provide a "**duct**" creating a path through the warmer layer of air which has less signal loss than cooler layers above and below.



Temperature Inversion / Troposphere Ducting (Contd.)

These ducts occur over relatively long distances and at varying heights from almost ground level to several hundred meters above the earth's surface.

This propagation takes place when hot days are followed by rapid cooling at night and affects propagation in the 50 MHz - 450 MHz range (6 meter, 2 meter, 1 1/4 meter and 70 centimeter bands). Signals can propagate hundreds of kilometers up to about 2,000 kilometers (1,300 mi).



SOLAR ACTIVITY AND SUN SPOTS

- The most critical factor affecting radio propagation is solar activity and the sunspot cycle. Sunspots are cooler regions where the temperature may drop to a frigid 4000K. Magnetic studies of the sun show that these are also regions of very high magnetic fields, up to 1000 times stronger than the regular magnetic field.
- Our Sun has sunspot cycle of about 22 years which reach both a minima and maxima (we refer to a 11 year low and high point or cycle). When the sunspots are at their maximum, propagation is at its best.

SOLAR ACTIVITY AND SUN SPOTS

- Ultraviolet radiation from the sun is the chief (though not the only) source of ionization in the upper atmosphere.
- During periods of low ultraviolet emission the ionization level of the ionosphere is low and radio signals with short wavelengths will pass through and be lost to space.
- During periods of high ultraviolet emission, higher levels of ionization reflect higher frequencies and shorter wavelengths will propagate much longer distances

SOLAR ACTIVITY AND SUN SPOTS CONT'D

Particle emissions are constituted **of high-energy protons** electrons forming solar cosmic rays when the sun releases huge amount of energy in Coronal Mass Ejections (CME).

These particles of protons and heavy nuclei propagate into space, **creating a shockwave.** The pressure created by the particles clouds is huge and **has a large effect on the ionosphere communications are interrupted**

Emission of larger amounts of ultraviolet radiation corresponds to increased surface activity on the sun.