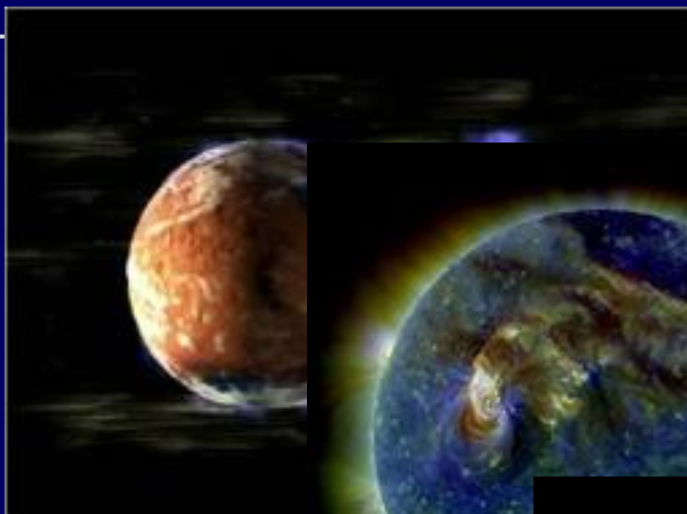
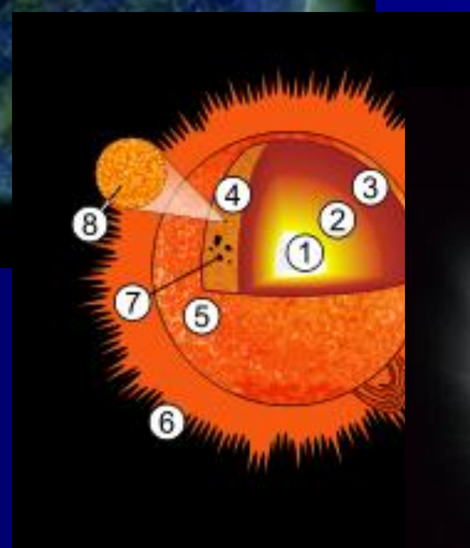
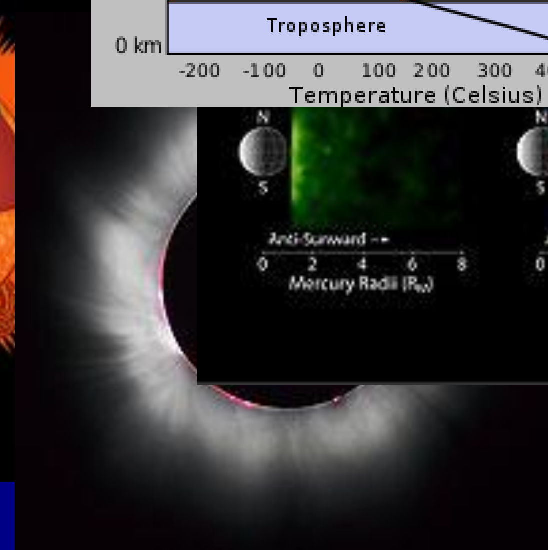
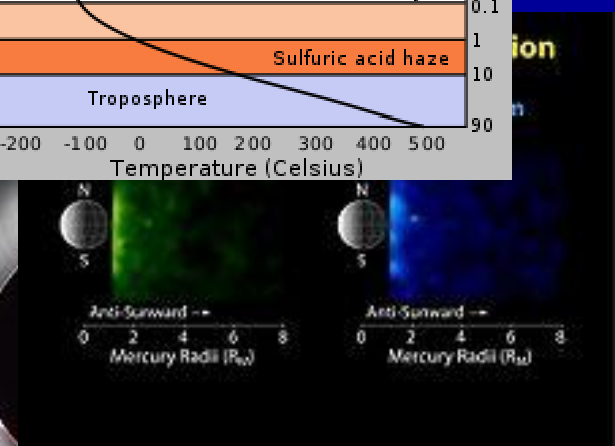
Space Physics

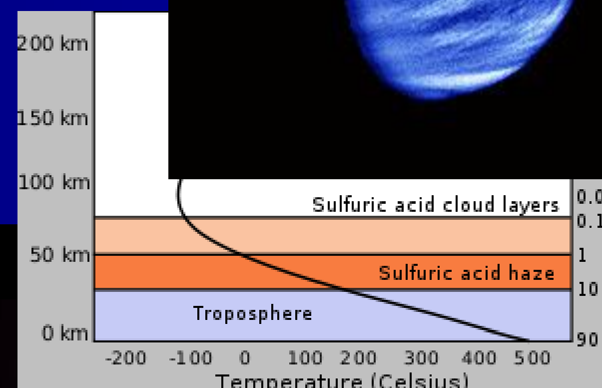
Space Physics

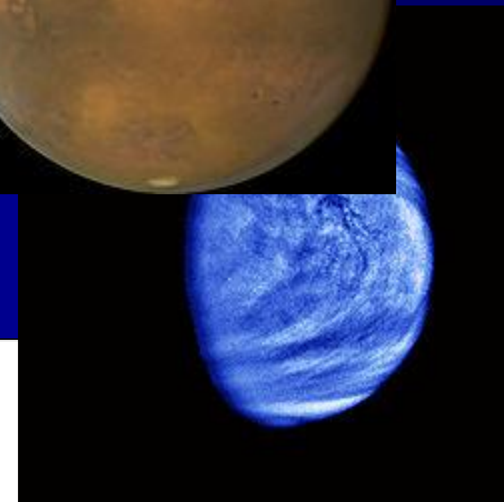


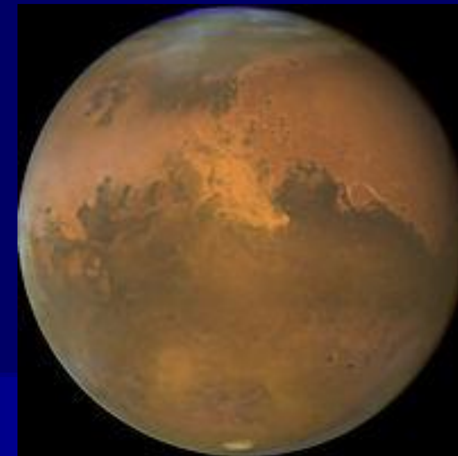






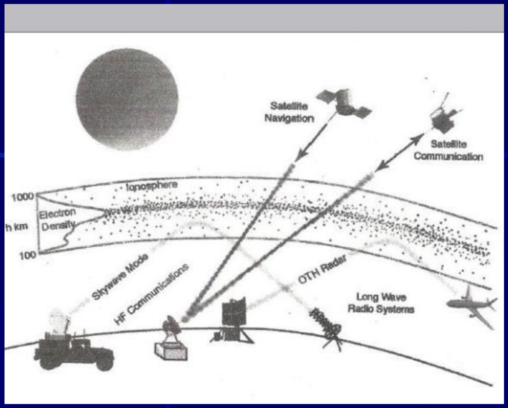






Lecture – 14&15
Reference

Radio Wave Communication



Reflection of Radio Waves
Absorption of Radio Waves
Complex Refractive Index
Reflection Heights
Deviating Region Absorption, Non- Deviating Region Absorption
Ionosphere – Sounding Techniques
Pulse Reflection Methods

Complex Refractive Index

If the radio wave going through the ionosphere, **refractive index n is always a complex number**. (As we discussed in the ionosphere chapter) That means **n = α + i β** and n is complex. Therefore, we can use **n → n***. i.e.;

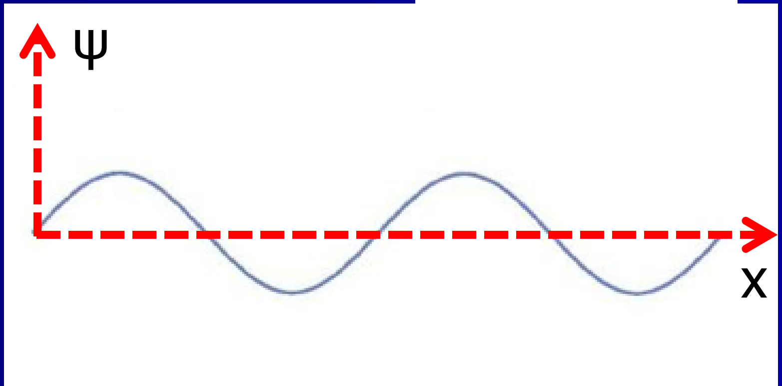
$$n^* = \alpha + i\,\beta$$

Where **α** and **β** are positive constants. And $i = \sqrt{-1}$

.: Equation of the motion of the radio wave can be express as the following form;

$$\beta \rightarrow small$$

$$\psi = \psi_o e^{i\,n\,x}$$



Complex Refractive Index

$$\psi = \psi_o e^{i\,n\,x}$$

Now we can substitute, **n = n* = α + i β** to the above equation.

$$\therefore \psi = \psi_o e^{i(\alpha + i\beta)x}$$

$$\Rightarrow \psi = \psi_o e^{i\alpha x} e^{-\beta x}$$

$$\Rightarrow \psi = \left(\psi_o e^{-\beta x}\right) e^{i\alpha x}$$

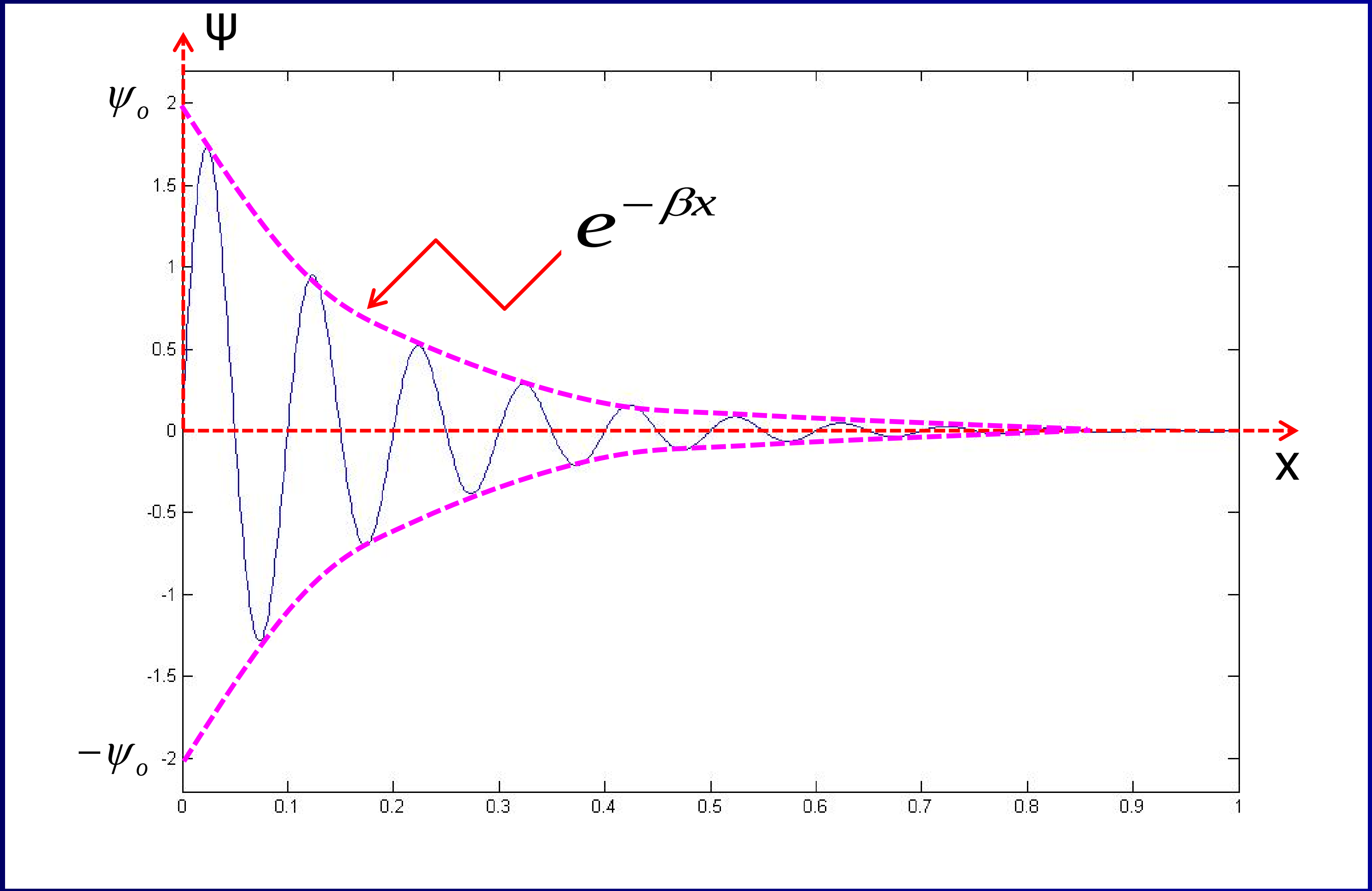
$$\Rightarrow \psi = \psi_o^1 \, e^{i\alpha x}$$ and $$\psi_o^1 = \psi_o e^{-\beta x}$$

Where $\psi_o^1 = \psi_o e^{-\beta x}$ is the new amplitude of the Radio Wave.

Complex Refractive Index

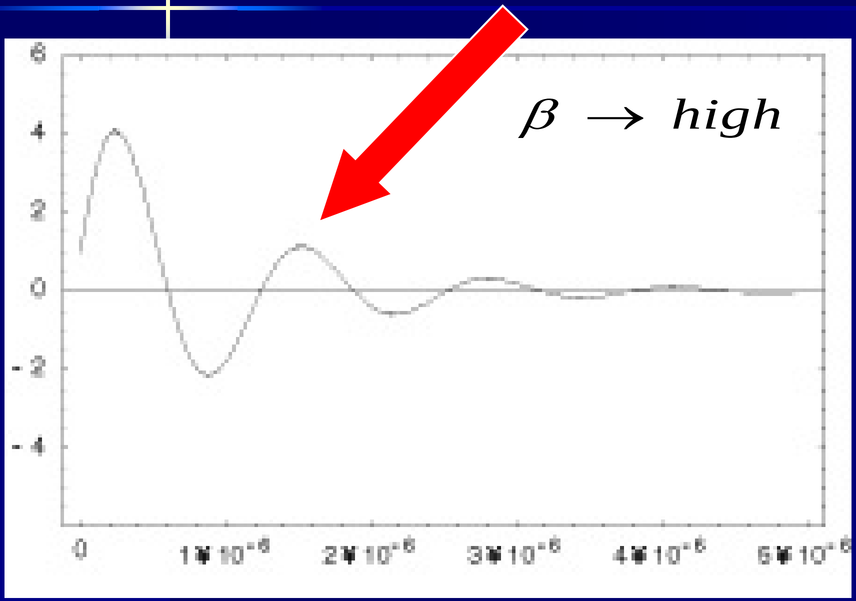
$$\psi_o^1 = \psi_o e^{-\beta x}$$

means that the new amplitude is attenuated from the ionosphere.

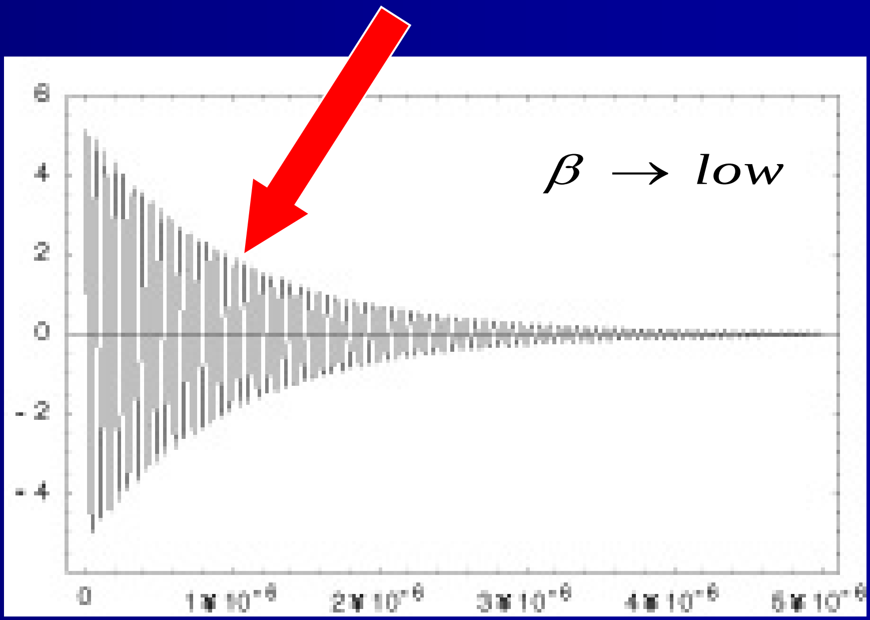


Complex Refractive Index

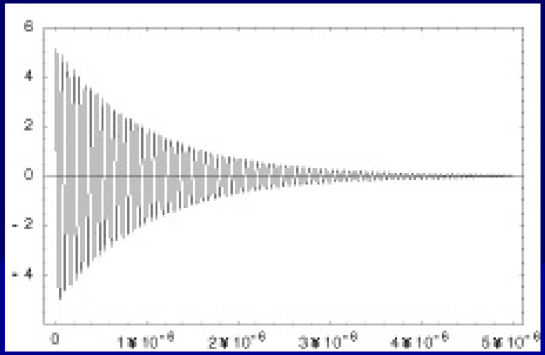
$$n = \alpha + i\,\beta$$



Attenuation



Complex Refractive Index



The wave is attenuated. That means the wave is decaying. Because, the wave is absorbed from the ionosphere.

$$Ab \quad \alpha \quad \frac{1}{c + f}$$

- If the **frequency of the radio wave is very high, the absorption from the ionosphere is very low**. That means the **attenuation of the radio wave is small**. That means **Exp[-βx]** is **approximately equal to one**.

$$e^{-\beta x} \approx 1$$

$$\beta \to 0$$

That means complex part of the refractive index ($n^* = \alpha + i\,\beta$) is negligible. It is going through the ionosphere.

Complex Refractive Index

- If the **frequency of the radio wave is very small, the absorption from the ionosphere is very high**. That means the **attenuation of the radio wave is high**. That means **Exp[-βx]** is **going to zero**.

$$e^{-\beta x} \approx 0$$

→ **β is very large !**

That means complex part of the refractive index ($n^* = \alpha + i\beta$) is very large. It is reflected back from the ionosphere to the Earth surface.

Plasma frequency of the ionosphere: $f_p = 8.97 \times N^{1/2}$

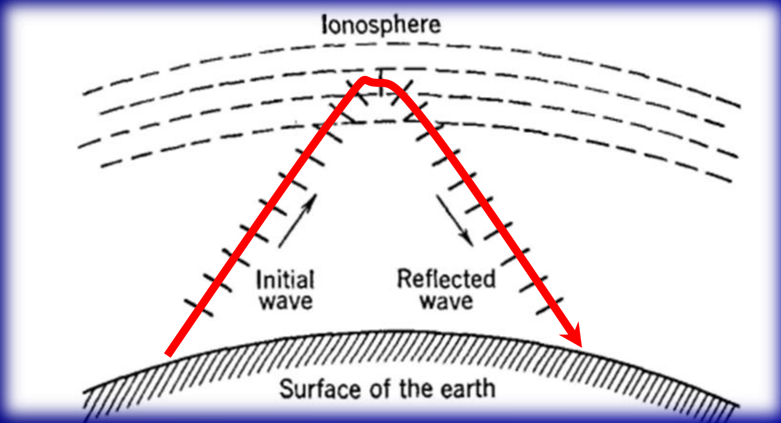
If the electron density of the ionosphere is 10^{12} e^n/cm^3,

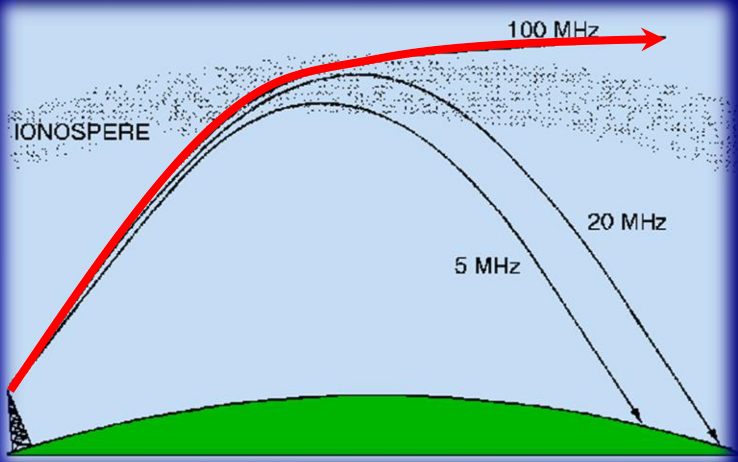
$$f_p = 8.97 \times \left(10^{12}\right)^{1/2} \quad \rightarrow \quad f_p \approx 9MHz$$

Complex Refractive Index

- That means, if we send a **Radio Wave** to the ionosphere with frequency **9 MHz** (or lower value), it is **reflected from the region of the ionosphere** whose electron density is 10^{12} e^n/cm^3.

That means **VLF** (3-30 kHz), **LF** (30-300 kHz), **MF** (300-3000 kHz), and **HF** (some short waves in the region 3 MHz - **9** MHz) are **reflected from the ionosphere** !

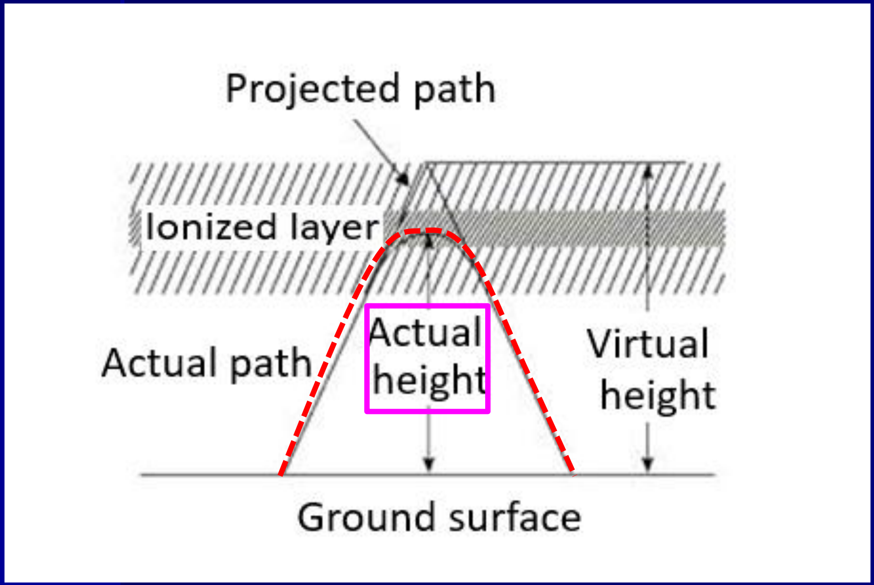


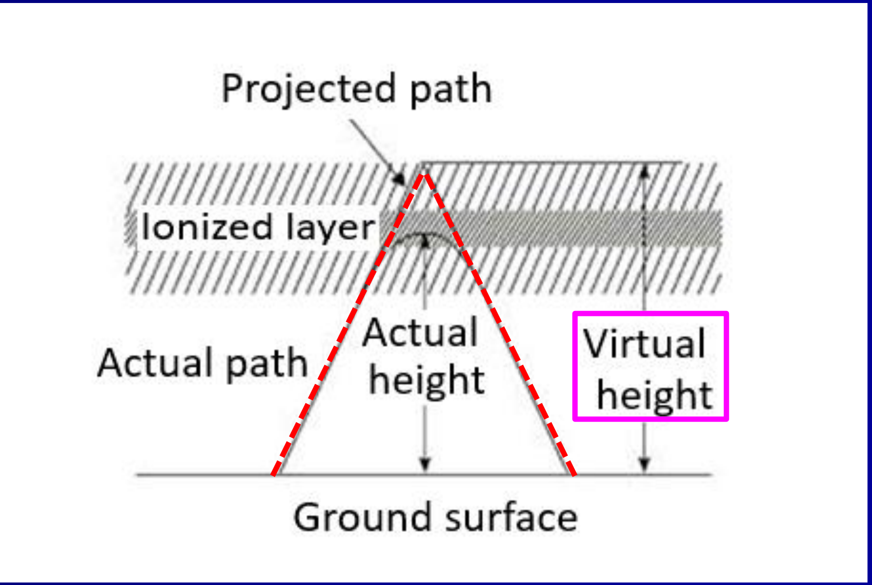


But, if we send **UHF** (>30 MHz) and **VHF** (>300 MHz) signal to the ionosphere, both signals are **going through ionosphere** to the space without reflection back!

Reflection Heights

A radio wave transmitted towards the ionosphere is subject to be reflected. The process of this reflection shows an exciting feature which is, that the position it reflects from the ionosphere is varying with corresponding to the frequency of a particular radio wave. This particular position of reflection is expressed in terms of heights and it is known as **reflection height** for the particular radio wave.





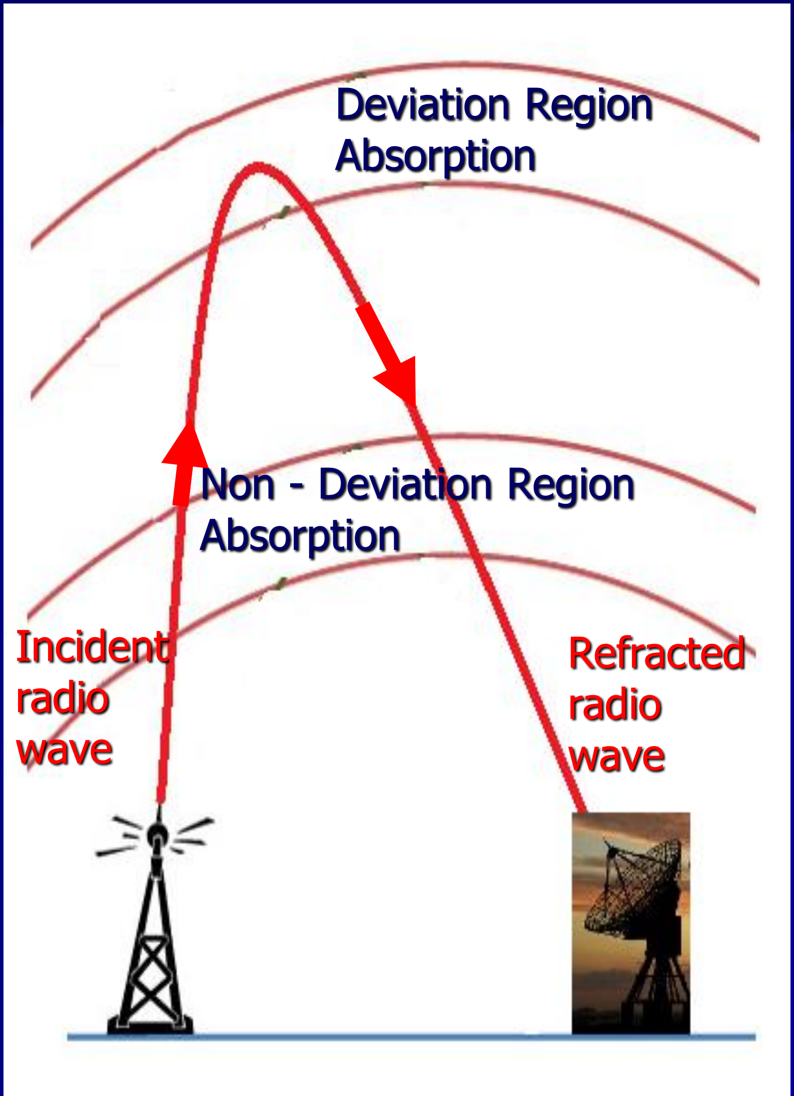
Deviation Region Absorption & Non-Deviation Region Absorption

There are many different type of phenomena that attenuate or reduce the signal strength of propagating radio waves. Those phenomena types extract energy from the radio wave by converting its energy to **heat** and **electro-magnetic noise** and are associated with the term absorption.

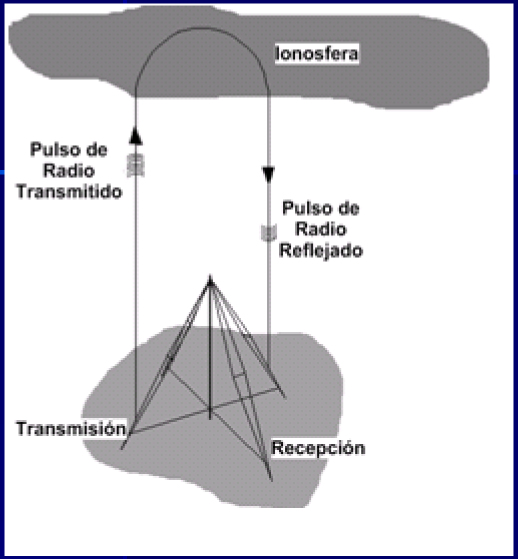
When referring to the actual propagation of a radio wave through the ionosphere, we have **principally two types of ionospheric absorption**.

01. Deviating Absorption

02. Non - Deviating Absorption



Ionospheric Sounding Technique



In telecommunication and radio science, an ionospheric sounding is a technique that provides real-time data on high frequency ionospheric-dependent radio propagation, using a basic system consisting of a **synchronized transmitter** and a **receiver**.

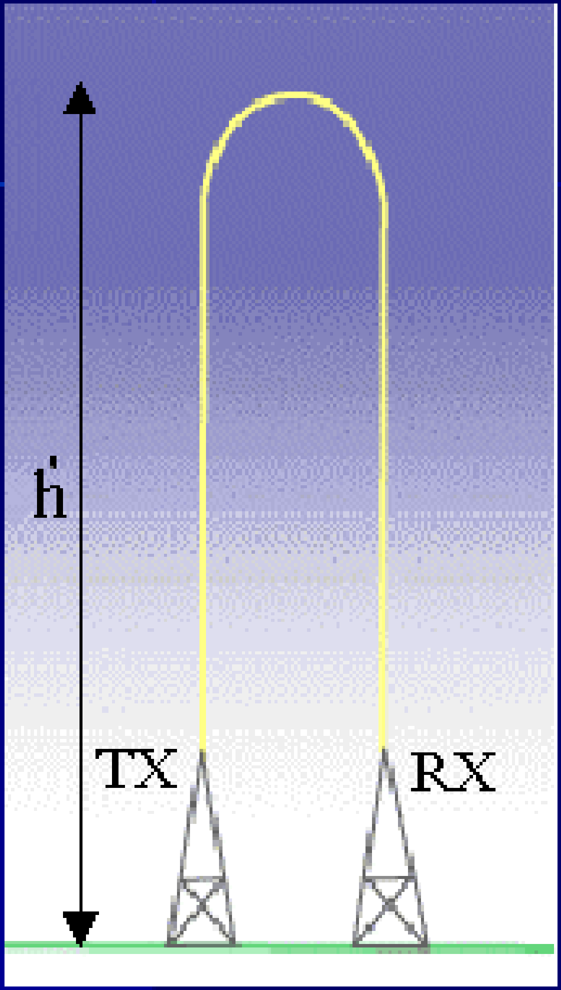
The time delay between transmission and reception is translated into effective ionospheric layer altitude. Vertical incident sounding uses a collocated (arrange) transmitter and receiver and involving directing a range of frequencies vertically to the ionosphere and measuring the values of the reflected returned signals to determine the effective ionospheric layer altitude. This technique is also used to determine the critical frequency.

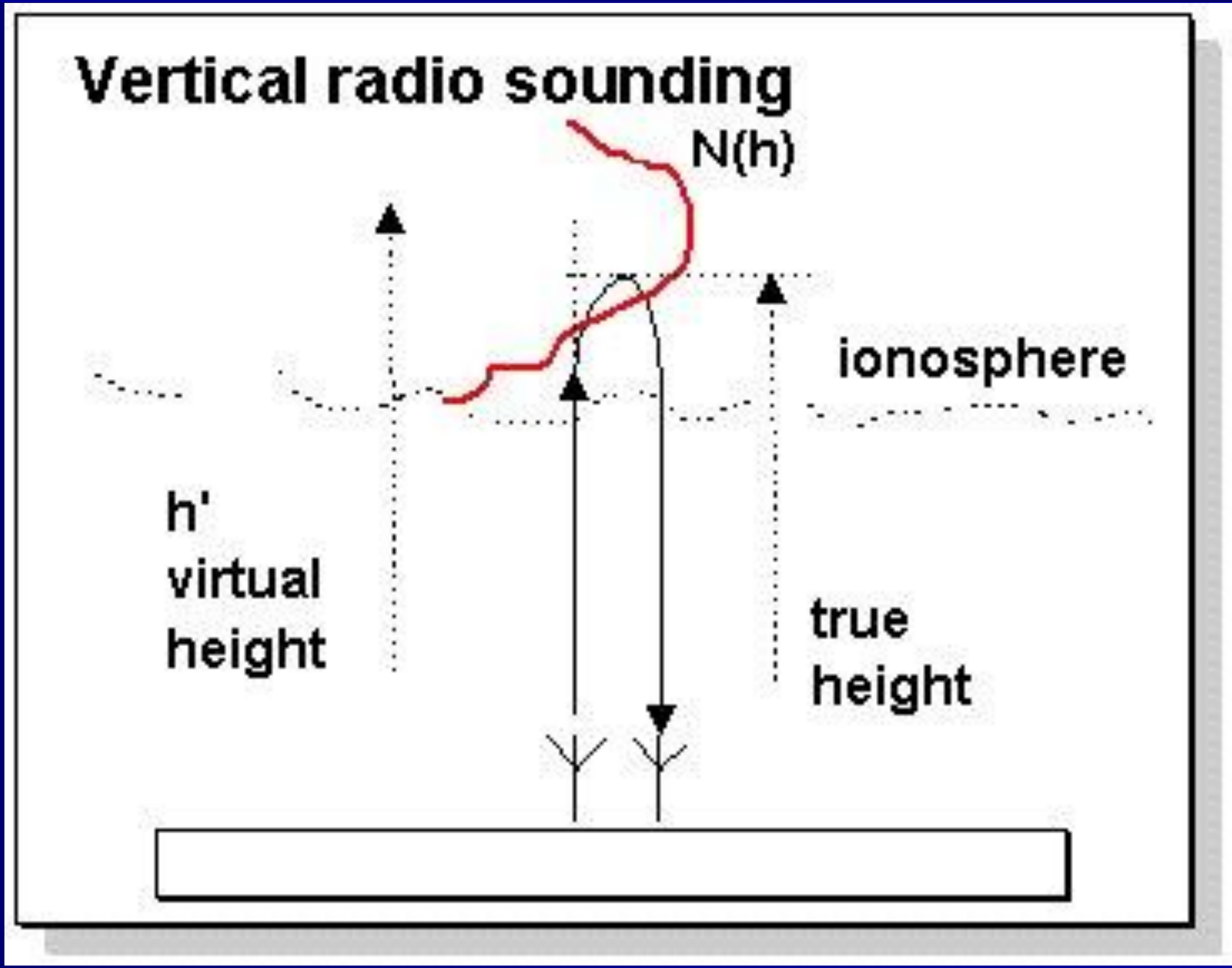
Ionospheric Sounding Technique

Oblique (indirect) sounders use a transmitter at one end of a given propagation path, and a synchronized receiver, usually with an oscilloscope type display (ionogram), at the other end.

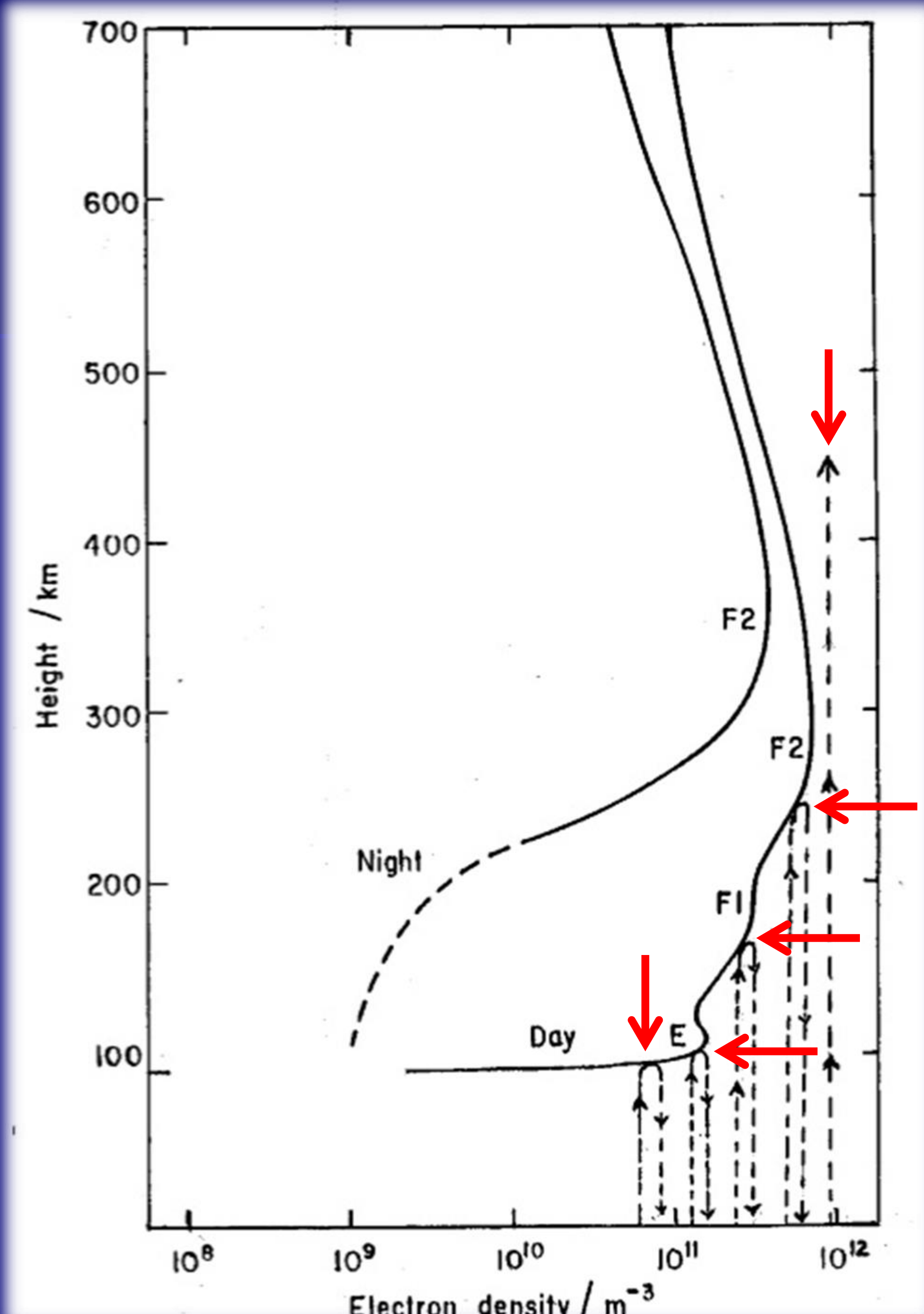
The transmitter emits a stepped (incident) or swept (sweep) frequency signal which is displayed or measured at the receiver. The measurement converts **time delay** to effective altitude of the ionospheric layer. The ionogram display shows the **effective altitude of the ionospheric layer** as a function of frequency.

Ionospheric Sounding Technique





Ionospheric Sounding Technique



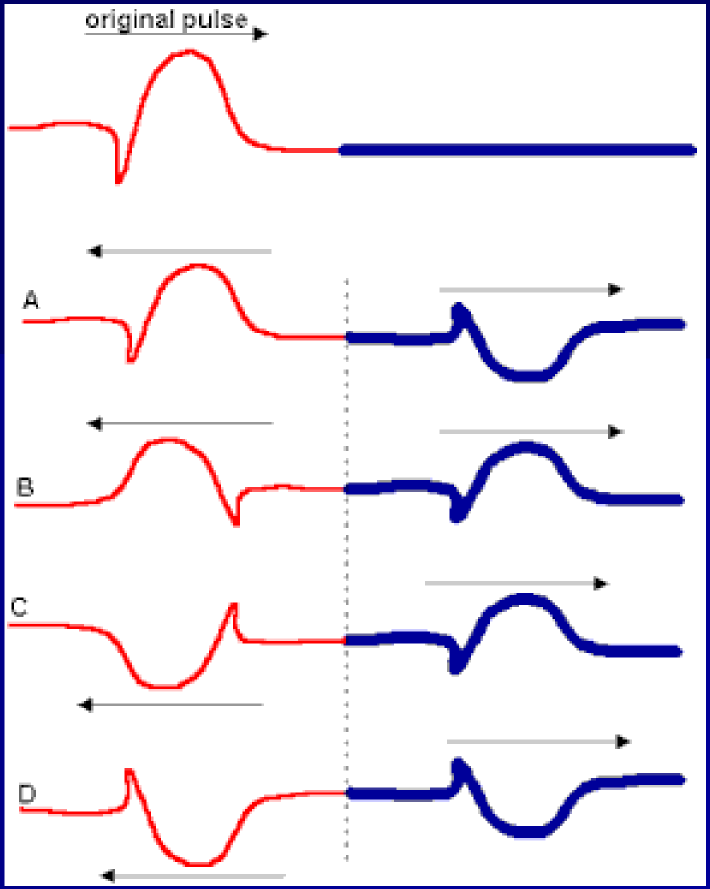
Pulse Reflection Method

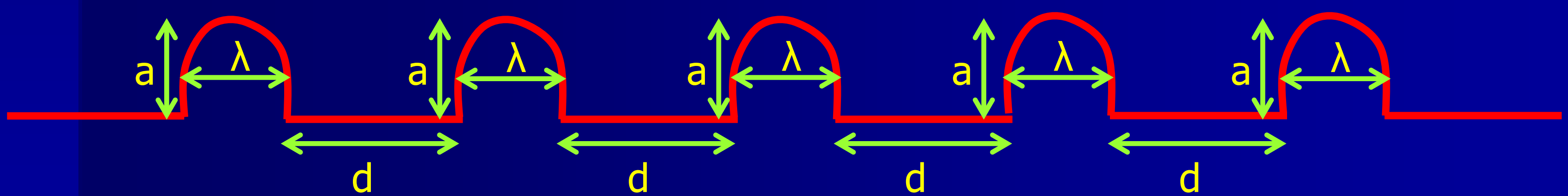
Pulse reflection method is widely used to study the characteristics of the upper atmosphere by sending pulses towards it. These pulses are sequential and having the,

1. **same gaps between each pulses**,
2. **same amplitude**

and

3. **same frequency**.





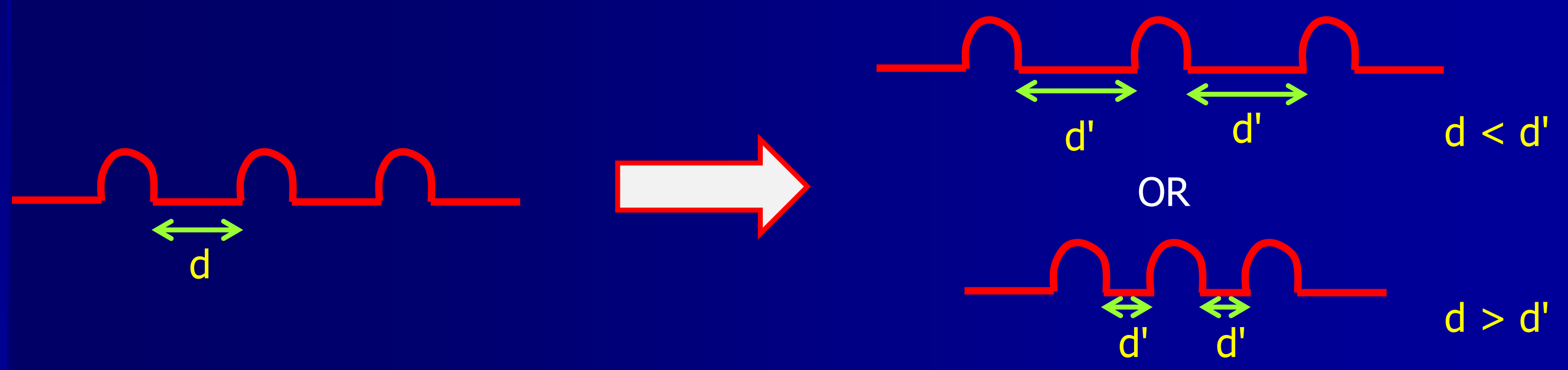
Where **$c = f\lambda$**

Pulse Reflection Method

Method :

These pulses are send towards the upper layers of the atmosphere and by observing the changes they shows at the step of direction, then can be used to make conclusion regarding the characteristics of those layers. Such differences between the incident and reflected signals can be depict as follows.

01. A difference can be observed between two consecutive gaps

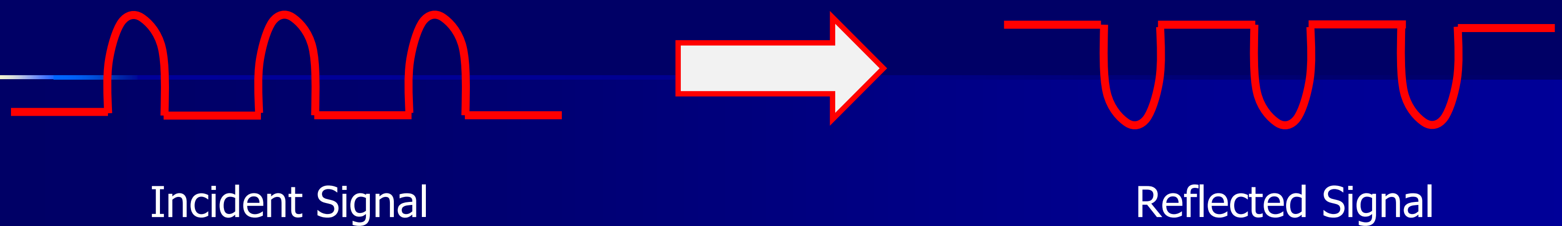


Incident Signal

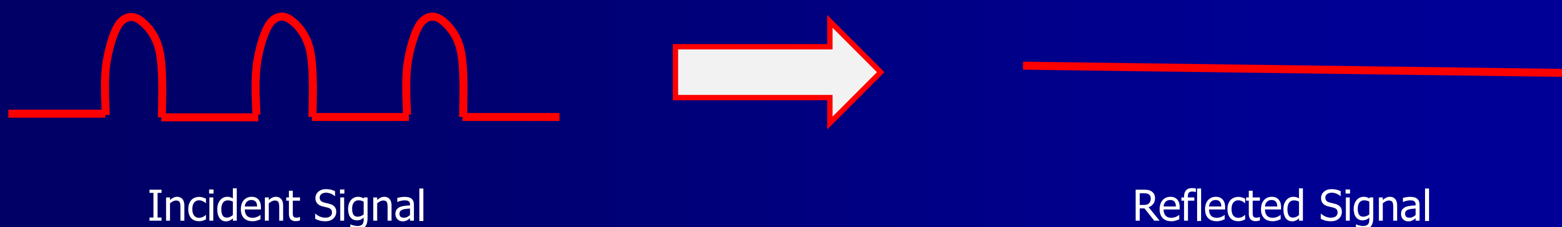
Reflected Signal

Pulse Reflection Method

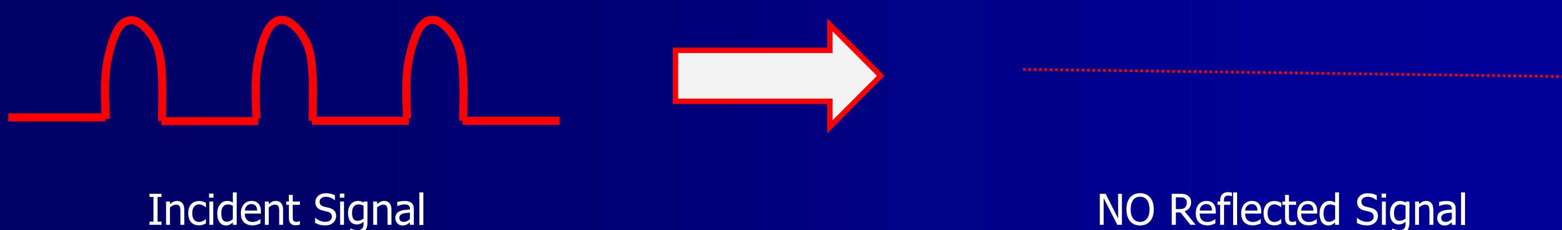
02. The wave form can be inverted during the step of reflection



03. The wave form can be vanished during the step of reflection

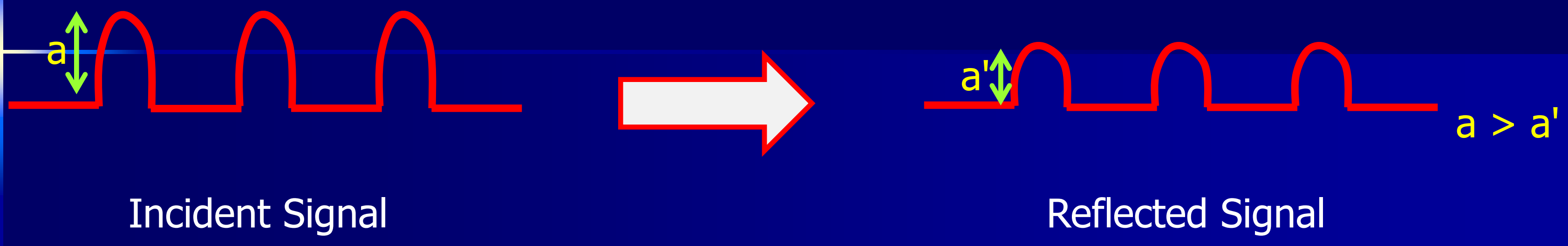


04. There is no reflected signal

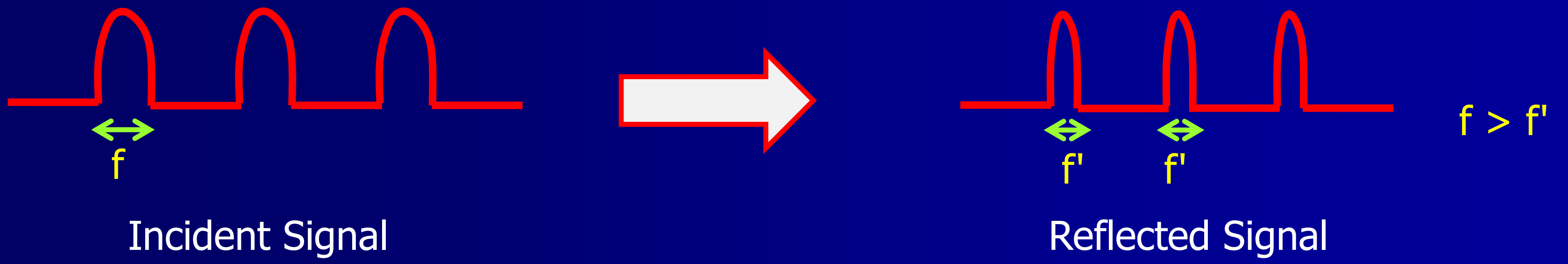


Pulse Reflection Method

05. Amplitude is tends to be reduced during the step of reflection



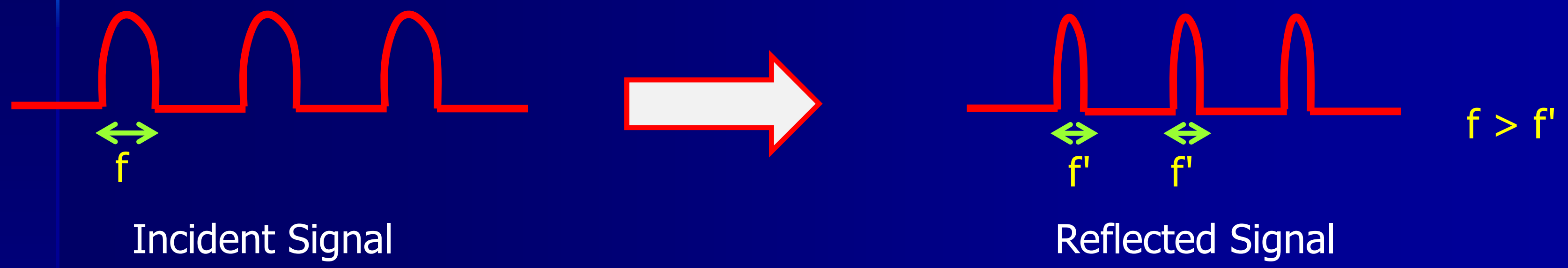
06. Frequency of the reflected pulse can be observed to be vary according to the prevailing circumstances in the upper atmosphere



Here the gap between two consecutive pulses wont get affected.

Pulse Reflection Method

06. Frequency of the reflected pulse can be observed to be vary according to the prevailing circumstances in the upper atmosphere



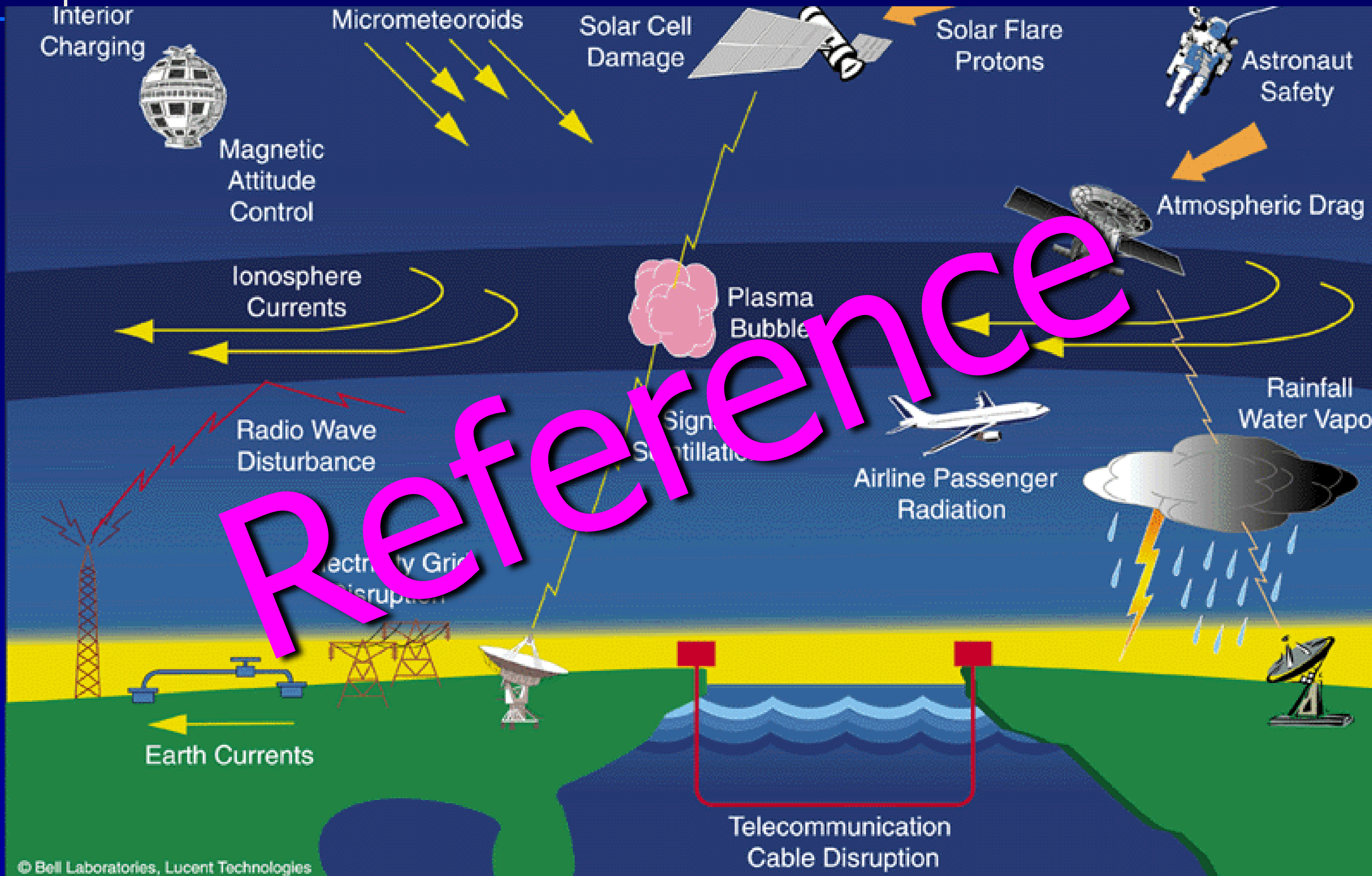
Here the gap between two consecutive pulses wont get affected.

Time that would take to detect after the reflection can be use to study the regions where these pulses being reflected from. **As the time vary**, it indicate that the **pulses are reflecting from different sections of the upper atmosphere !**

Expectable Crisis of Radio Wave Communication

Reference

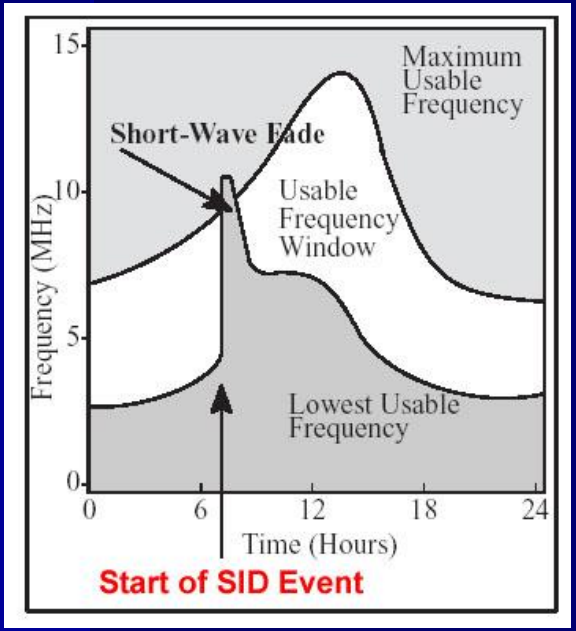
Expectable Crisis of Radio Wave Communication

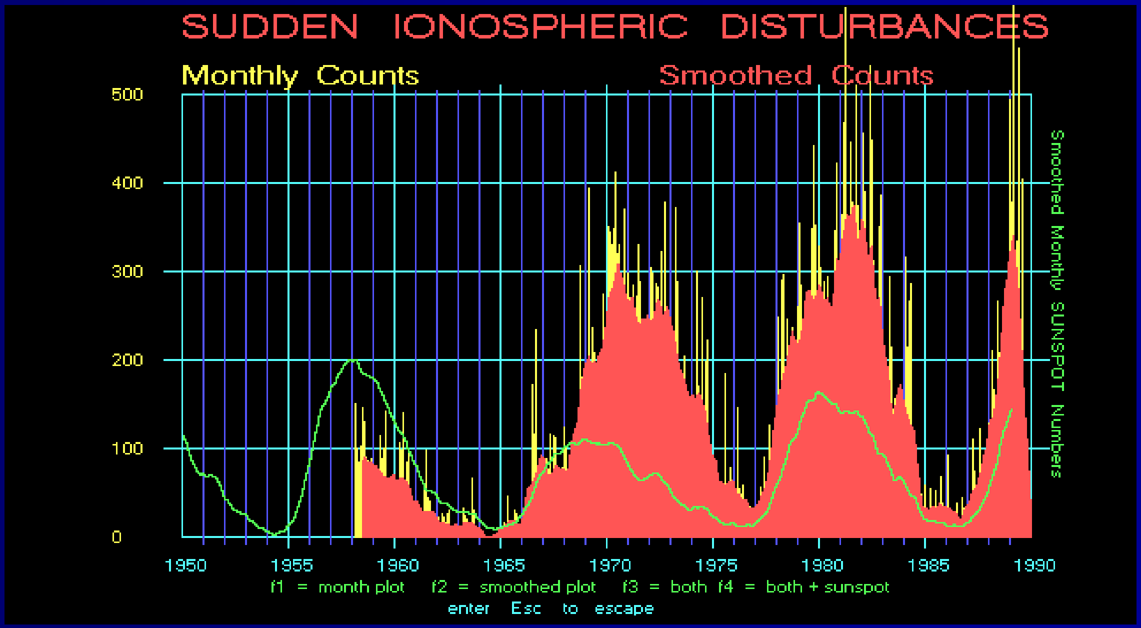


Expectable Crisis of Radio Wave Communication

∆ Sudden Ionospheric Disturbances (SID)

A solar flare transmits UV and X-ray radiation that rapidly reaches the Earth (this is take about 8.5 min). This produces abnormally high ionization in the D-region causing increased absorption of MF, HF and VHF frequencies and also increased reflection of LF and VLF. It can cause a complete and sudden loss of HF propagation. This can only occur on the sunlit side of the Earth and is most frequent at the maximum of the sunspot cycle.

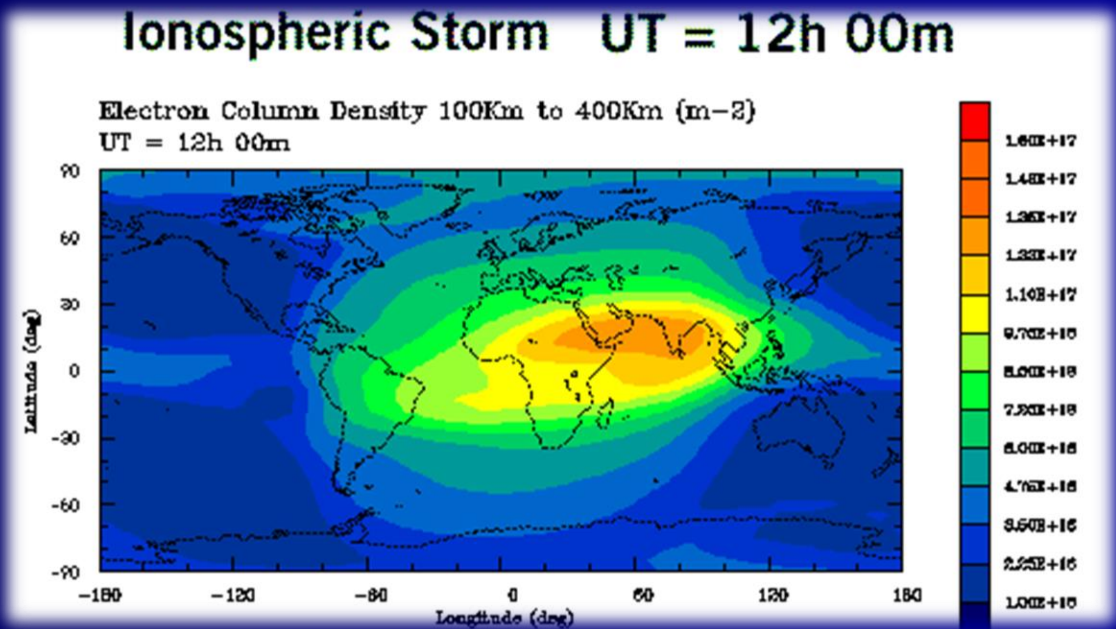




Expectable Crisis of Radio Wave Communication

∆ Ionospheric Storms

These may last for several days and are caused by terms of charged particles (protons and electrons). They may take one or two days to reach the Earth and are deflected by the Earth's magnetic field towards the **auroral zones**. The cause increased ionization in the D-region and an expansion and diffusion of the F_2-layer, causing decreased critical frequencies and higher heights.

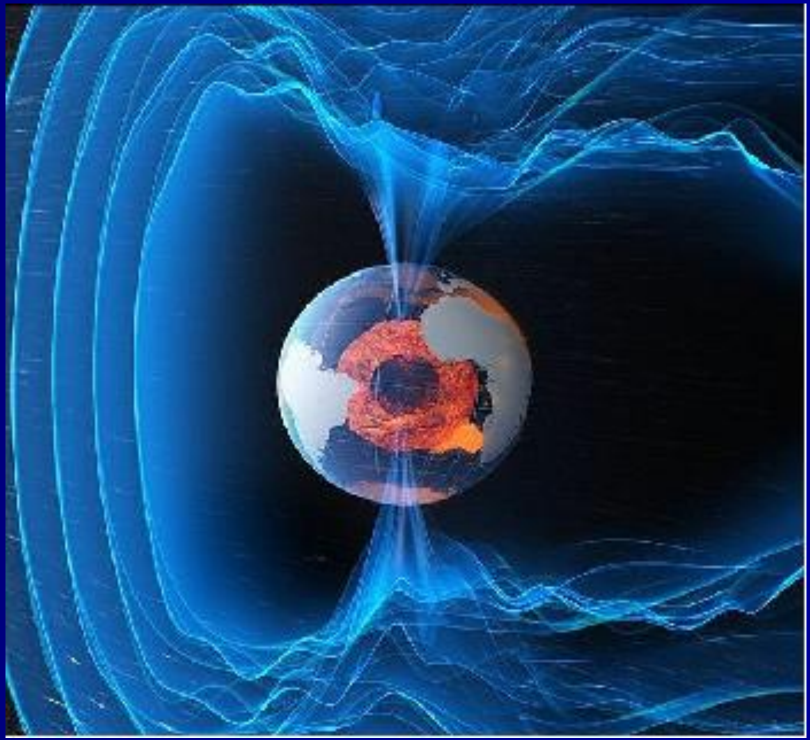


Expectable Crisis of Radio Wave Communication

∆ Polar Cap Absorption (CPA)

There are infrequent but major disturbances that occur throughout the polar regions. They are caused by high energy protons that are guided by the earth's magnetic field towards the polar regions. These may take from 15 minutes to 3 hours to reach the Earth from the Sun. These are called polar cap absorption events or solar proton events (SPE).

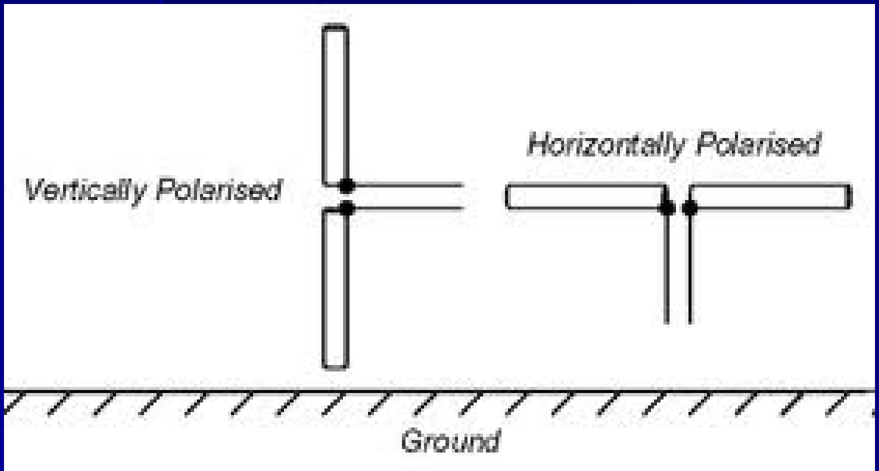
Image Credit: M. A. Shea, Geophysics Directorate, Philips Laboratory

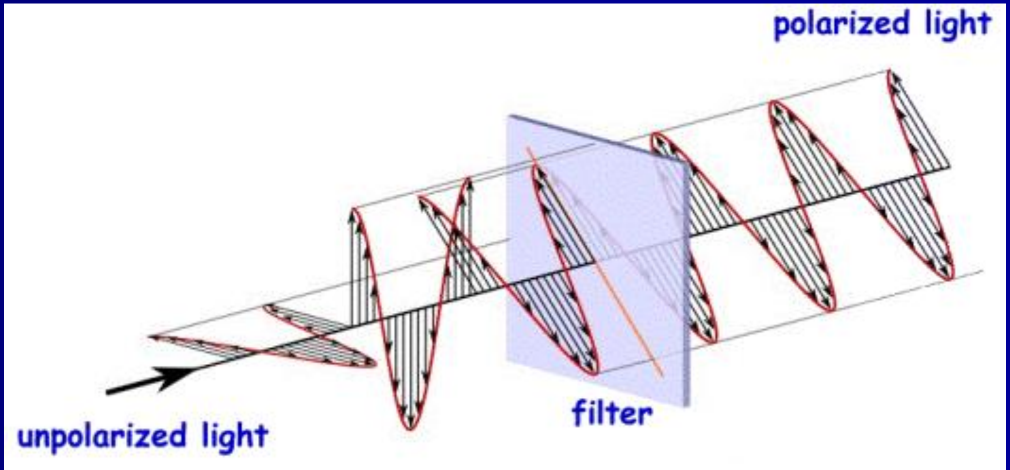


Expectable Crisis of Radio Wave Communication

Δ Polarization

When a radio wave travels through the ionosphere its Electric Field impacts an oscillatory motion on the electrons. These re-radiate modifying the velocity of the radio wave and if the electron concentration is changing, refracting the **wave back towards the Earth**, if its frequency is not too high. The Earth's magnetic field modifies the oscillatory motion of the electrons causing them to move in complicated orbits.



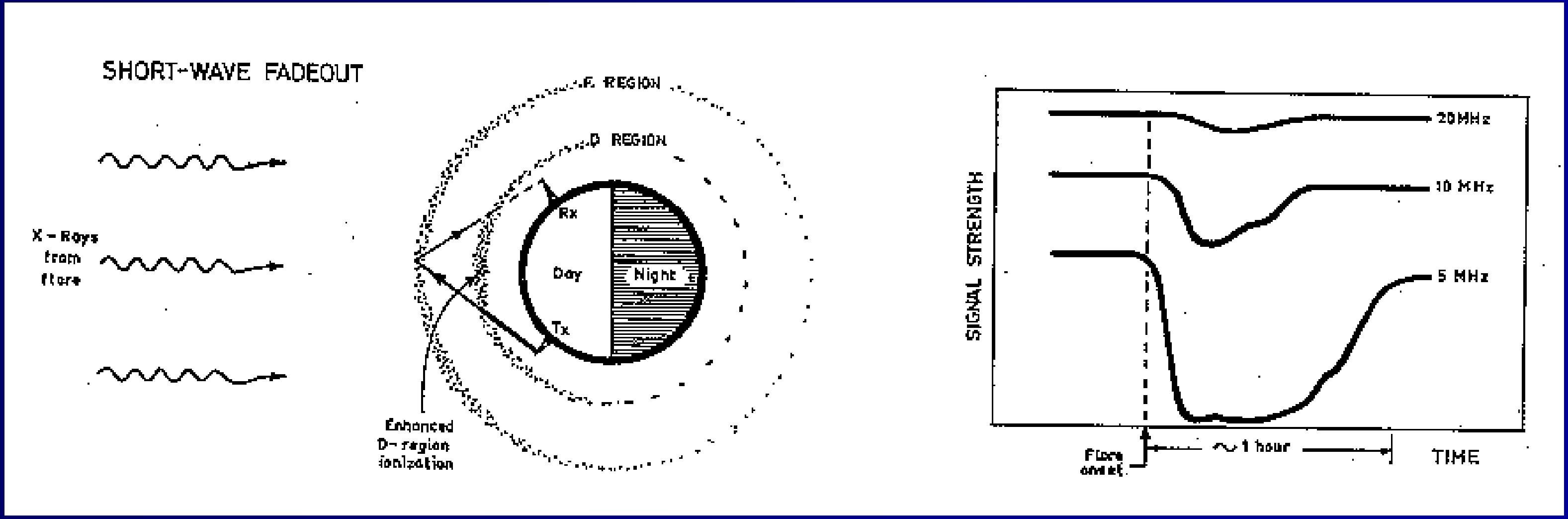


Expectable Crisis of Radio Wave Communication

∆ Short Wave Fadeout (SWF)

During a solar flare, absorption of short wave by the D-region starts to arise strongly. As a result of it, Short Wave transmission can be completely terminated. This is known as the "**SW fadeout**". Mainly the lower frequencies in the SW band are heavily affected.

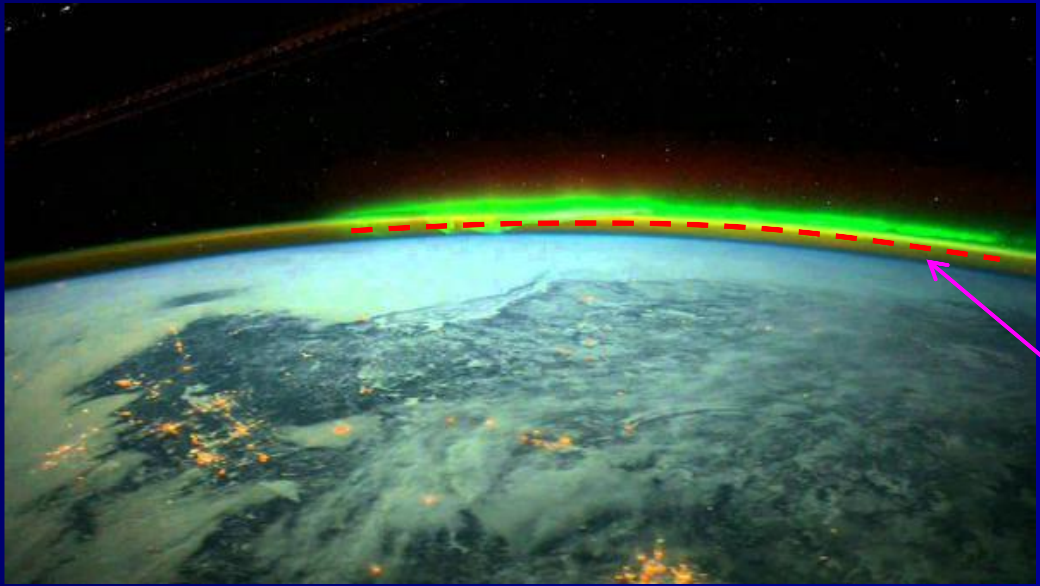
Reflection of SW during a SWF is expected to be completely vanished. But under any circumstance, ground waves are not being interrupted and received as usually by the receiver. This is called as the "Short wave Backout"



Expectable Crisis of Radio Wave Communication

∆ Sudden Enhancement of Atmosphere

Molecular density (ions and electrons) of the D-region is tends to be high during a solar flare. Thus, the lower frequency waves starts to reflect. Randomly this D-region can be expanded as well. In such situations, one can be recognize a lower layer of the D-region. This layer is known as the **Echo Surface**. An increasing trend of SW can seen as a result of the formation of this Echo Surface. This phenomena is known as Sudden Enhancement of Atmosphere.



Echo Surface

Expectable Crisis of Radio Wave Communication

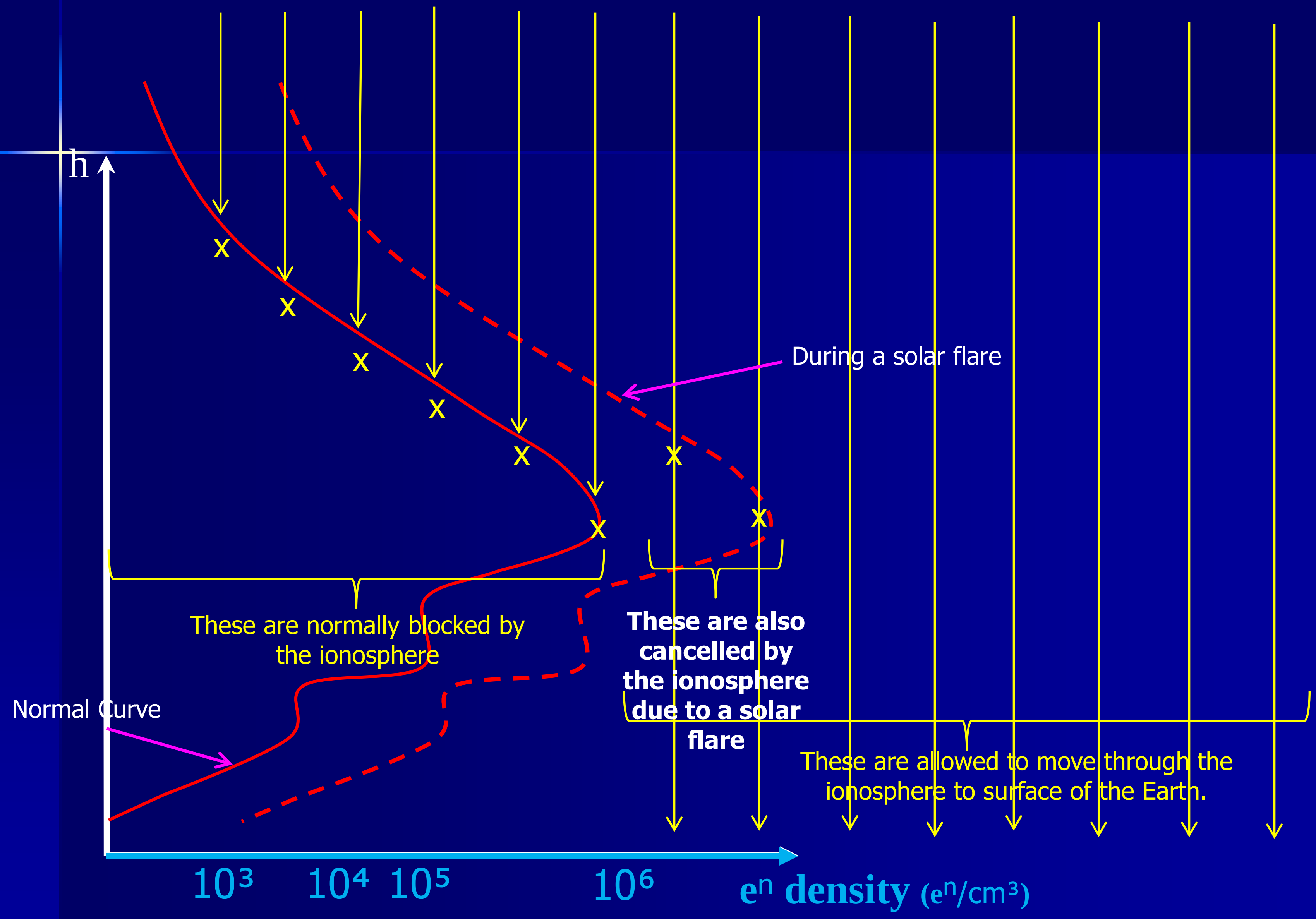
Δ Sudden Cosmic Noise Absorption

Noises added by the atmosphere for the SW high frequency radio waves, during a solar flare are absorbed by the peaks of the atmosphere. This is known as the **sudden cosmic noise absorption**.

In generally, we send high frequency short waves from the top side of the ionosphere towards the surface of the Earth, such waves are suppose to exhibit following properties,

1. wave should be strong enough,
2. it should focused towards the corresponding receiver.

Noises added by the atmosphere for the SW high frequency radio waves; absorbed by the peaks of the atmosphere! (**Noises are high frequencies**)



Expectable Crisis of Radio Wave Communication

∆ Sudden Cosmic Noise Absorption

In generally, we send high frequency short waves from the top side of the ionosphere towards the surface of the Earth, such waves are suppose to exhibit following properties,

1. wave should be strong enough,
2. it should focused towards the corresponding receiver.

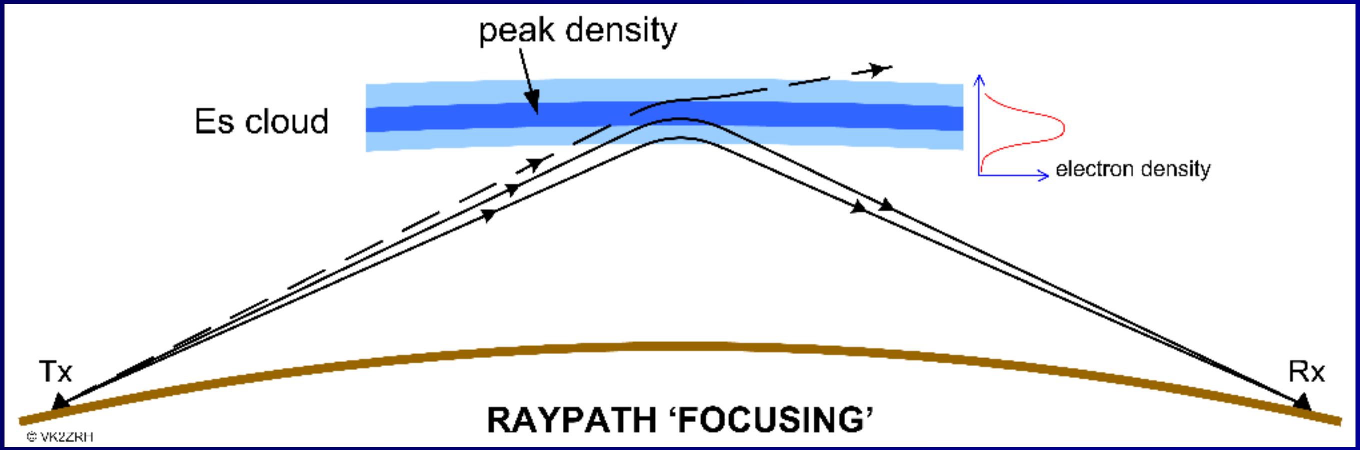
Basically **two main advantages** can be observed with **such focusing antennas**.

- Due to the gain of the antenna, station can receive signals with extra strength.
- The chances of affecting the signal by the background noise is essentially small as the signal is focused in to a narrow direction.

Expectable Crisis of Radio Wave Communication

- **Sporadic – E (Es) Propagation**

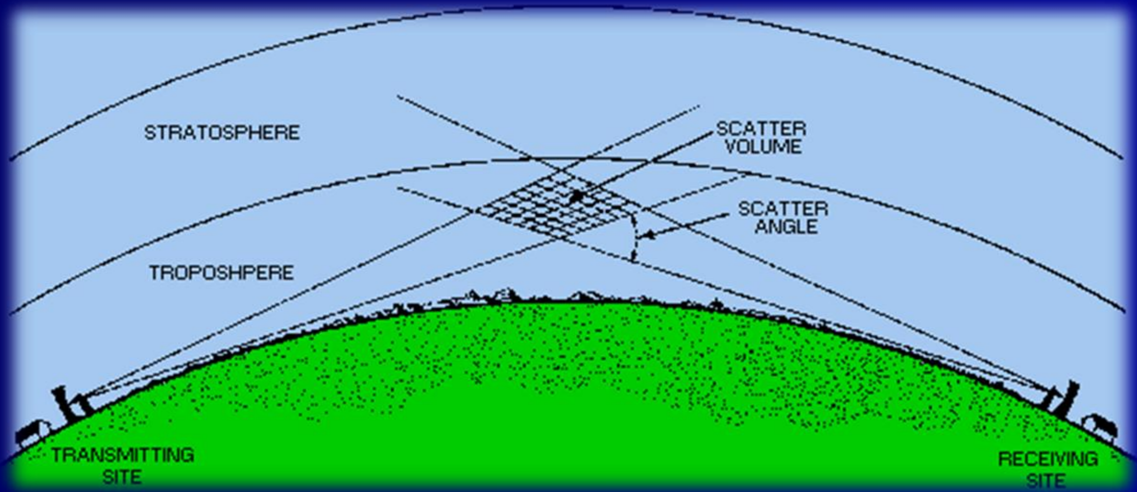
Sporadic – E Propagation can be observed on **HF** and **VHF** bands. It must not be confused with **ordinary HF** with **E-layer** propagation. Sporadic – E at mid latitudes occurs mostly during summer season, from May to August in the northern hemisphere and from November to February in the southern hemisphere. There is no signal cause for this **mysterious propagation mode**. The reflection takes place in a thin sheet of ionization around 90 km height. The ionization patches drift westwards at a speed of few thousand kilo meters per hour.



Expectable Crisis of Radio Wave Communication

- **Tropospheric Scattering**

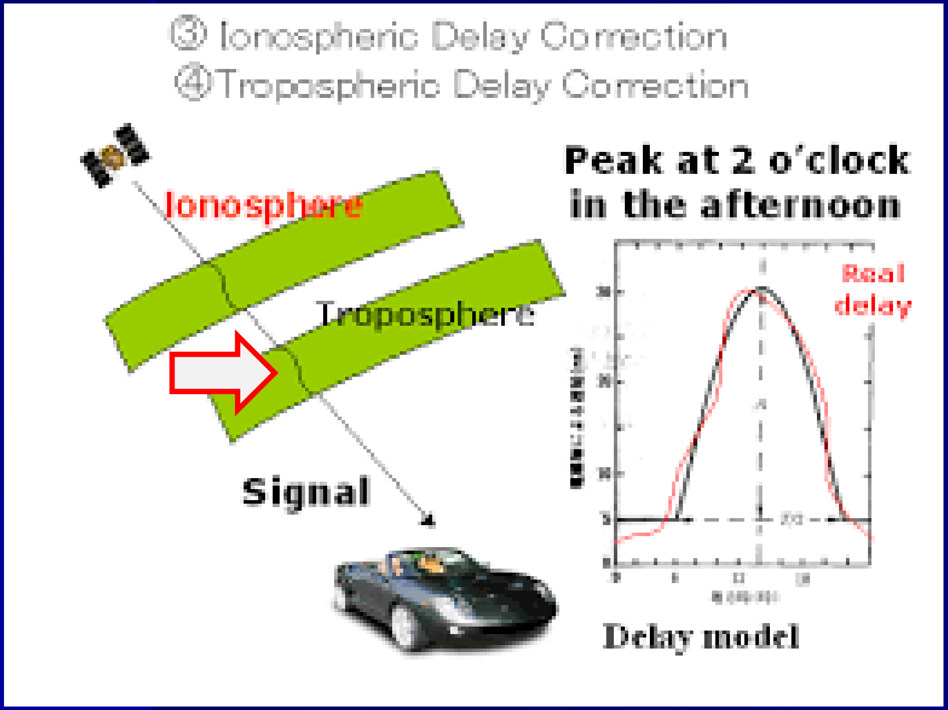
At VHF and higher frequencies, small variations (turbulence) in the density of the atmosphere at a height of around **10 km** can scatter some of the normally line-of-sight beam of radio frequency energy back toward the ground, allowing over-the-horizon communication between stations as far as 800 km apart. The military developed the White Alice Communication System covering all of Alaska, using this Tropospheric Scattering principle.

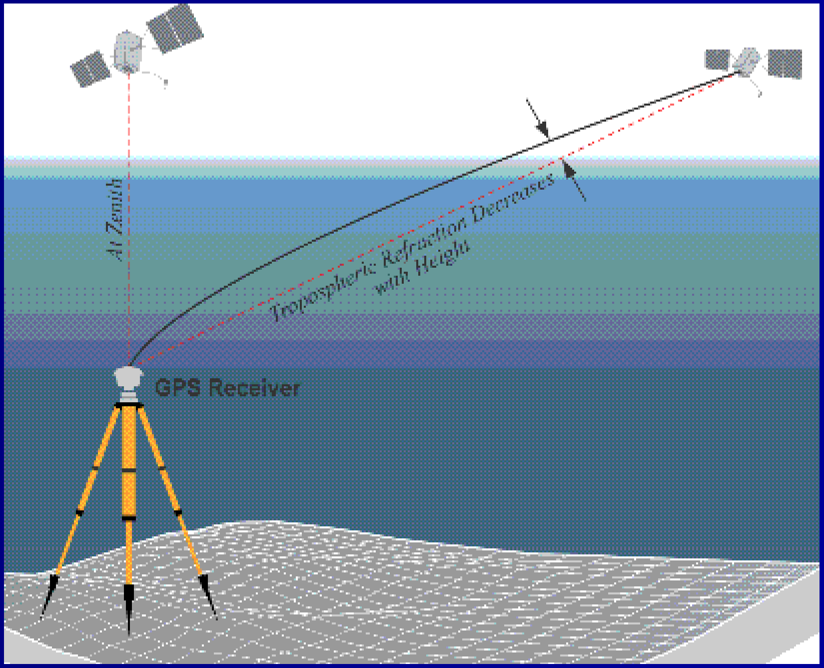


Expectable Crisis of Radio Wave Communication

- **Tropospheric Delay**

This is a **source of error in radio ranging techniques**, such as the **Global Positioning System** (**GPS**)

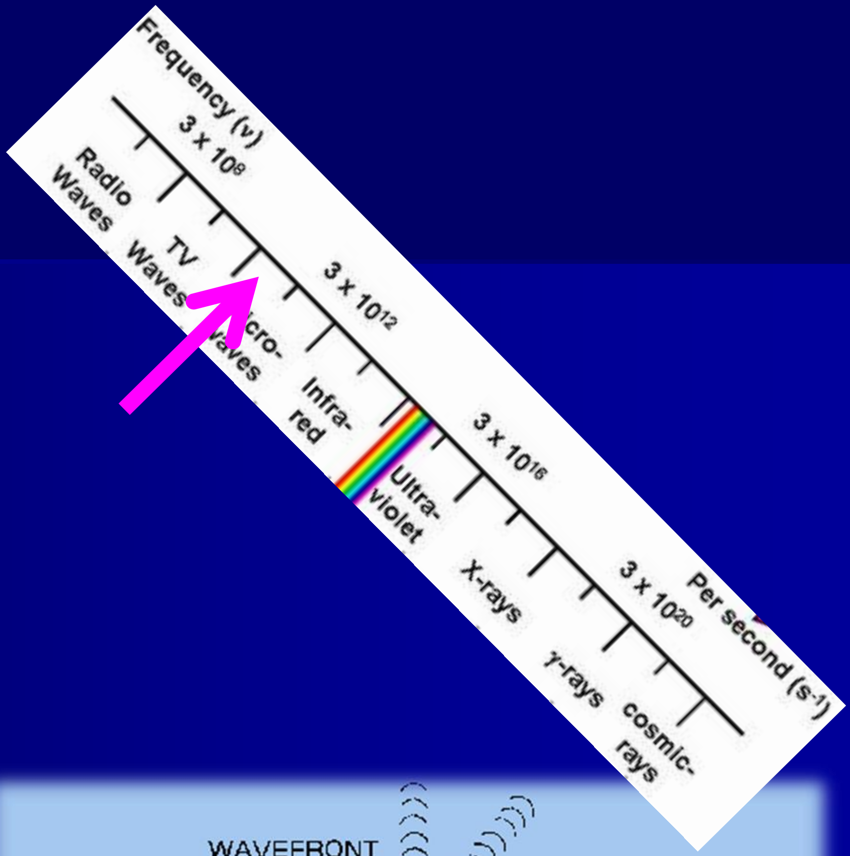


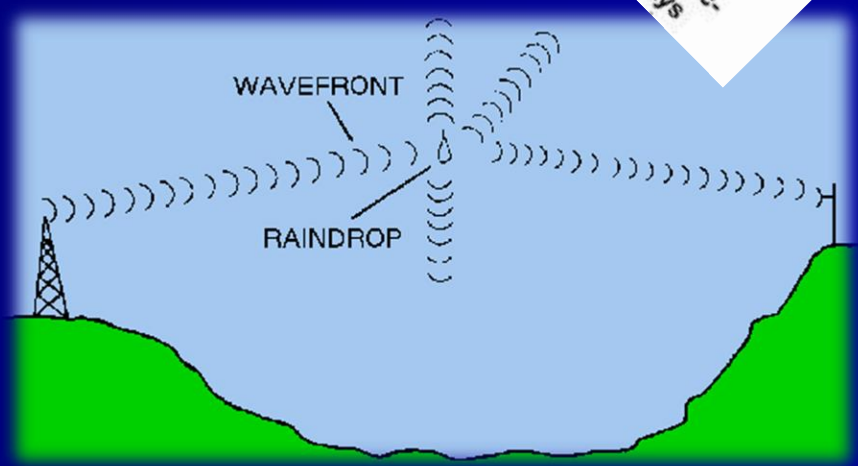


Expectable Crisis of Radio Wave Communication

- **Rain Scattering**

Rain Scattering is purely a microwave propagation mode and is best observed around 10 GHz, but extends down to a few gigahertz, the limit being the size of the scattering particle size vs. wavelength. This mode scatters signals mostly forwards and backwards when using horizontal polarization and side-scattering with vertical polarization. Forward-scattering typically yields (outputs) propagation range of 800 km. Scattering from snow flakes (chips) and ice pellets (pills) also occurs, but scattering from ice without watery surface is less effective.

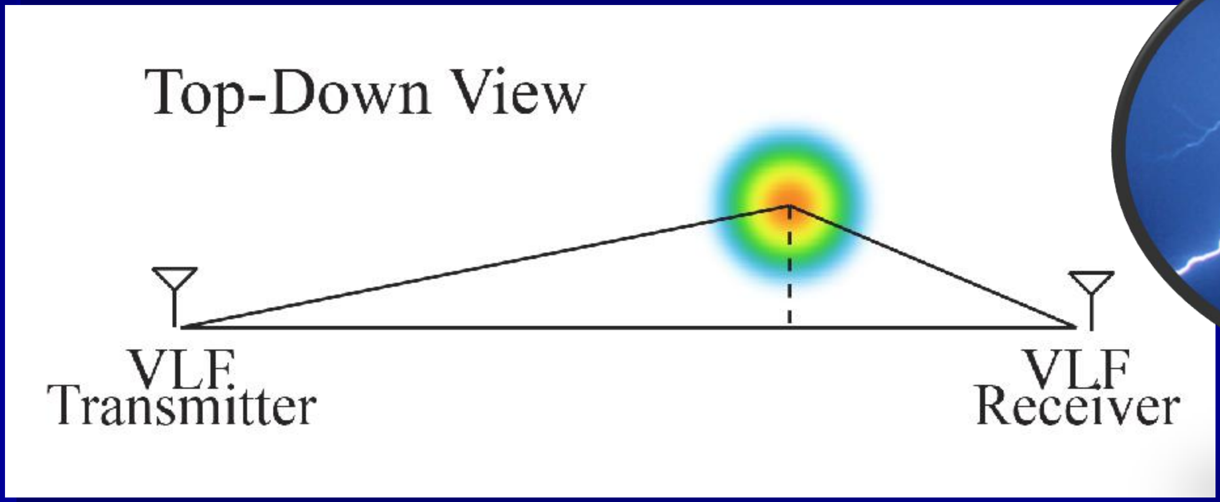




Expectable Crisis of Radio Wave Communication

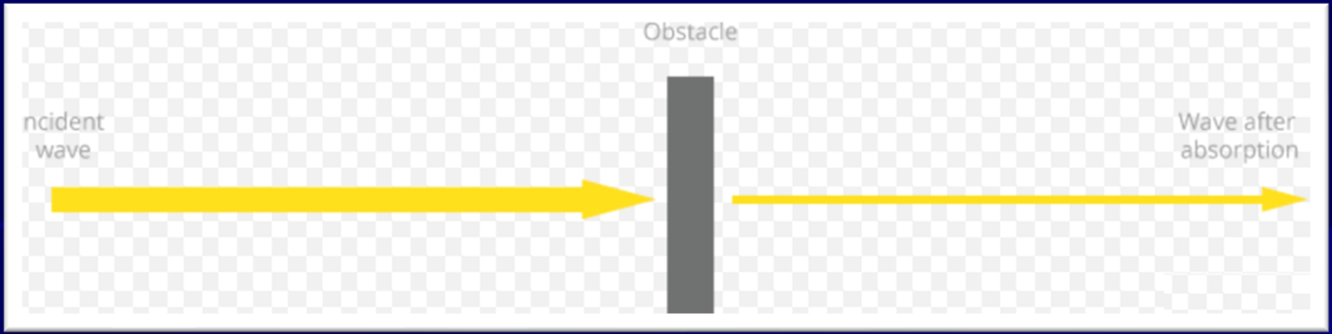
- **Lightning Scattering**

Lightning Scattering has sometimes been observed on VHF and UHF over distance of about 500 km. **The hot lightning channel scatters radio waves for a fraction of a second**. The **RF** noise burst (explosion) from the lightning makes the initial part of the open channel unusable and the ionization disappears soon because if combination at low altitude high atmospheric pressure. Although the hot lightning channel is briefly observable with microwave radar, **this mode has no practical use for communication**.



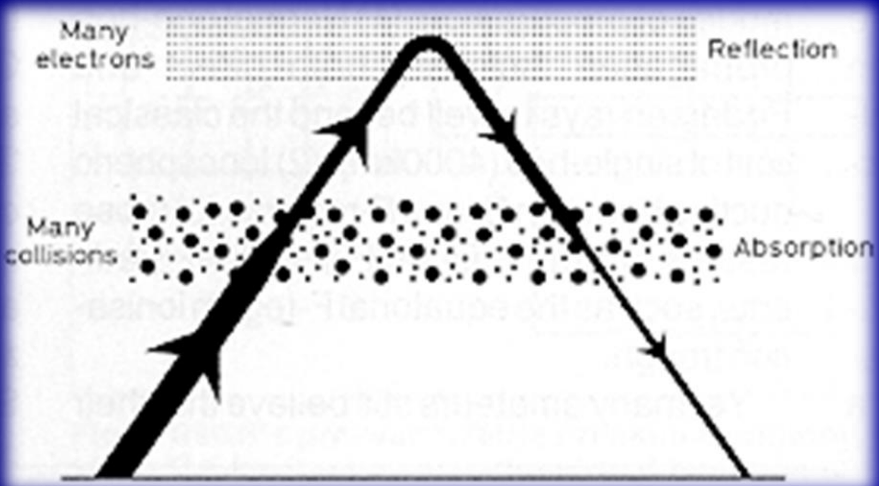
Expectable Crisis of Radio Wave Communication

Absorption



Low frequency radio waves travel easily through brick and stone and **VLF even penetrates sea-water**. As the frequency rises, absorption effects become more important. At micro-wave or higher frequencies , absorption by molecular resonance in the atmosphere (mostly water/water-vapor, and oxygen) is a major factor in radio propagation.

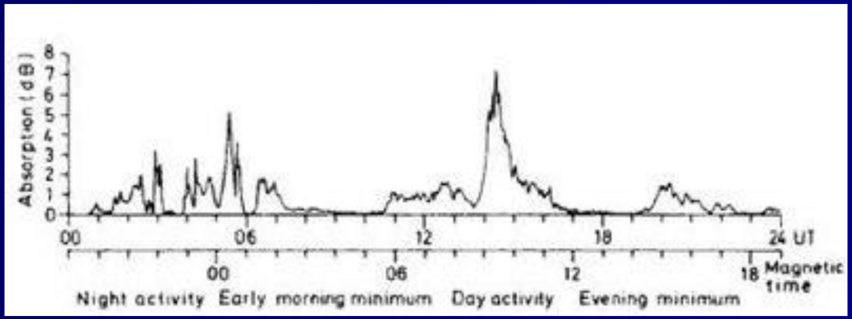
For example, in the 58 – 60 GHz band there is a **major absorption peak** which makes **this band useless for long distance use**. This phenomenon was first discovered during radar research in world war II.



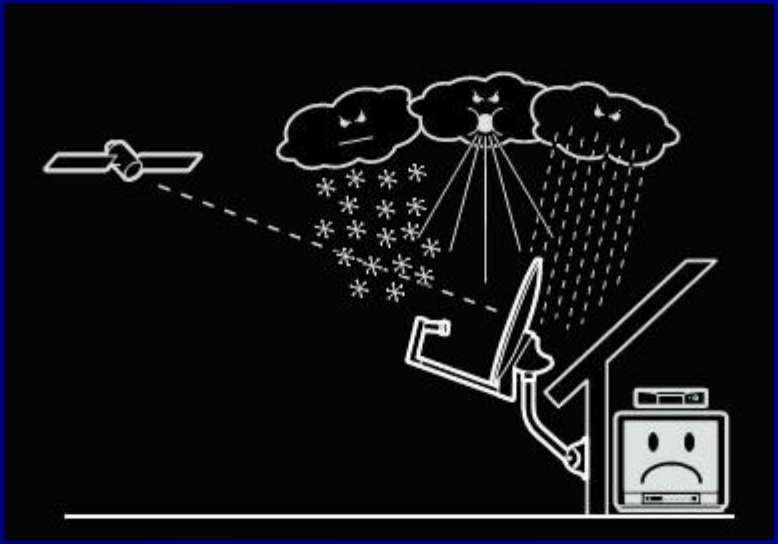
Expectable Crisis of Radio Wave Communication

Absorption

Beyond around 400 GHz, the Earth's atmosphere blocks some segments of spectra while still passes some this is true up to UV light, which is blocked by ozone, but Visible Light and some of near infrared is transmitted.



Heavy rain and snow also affect microwave reception.



Thank You !