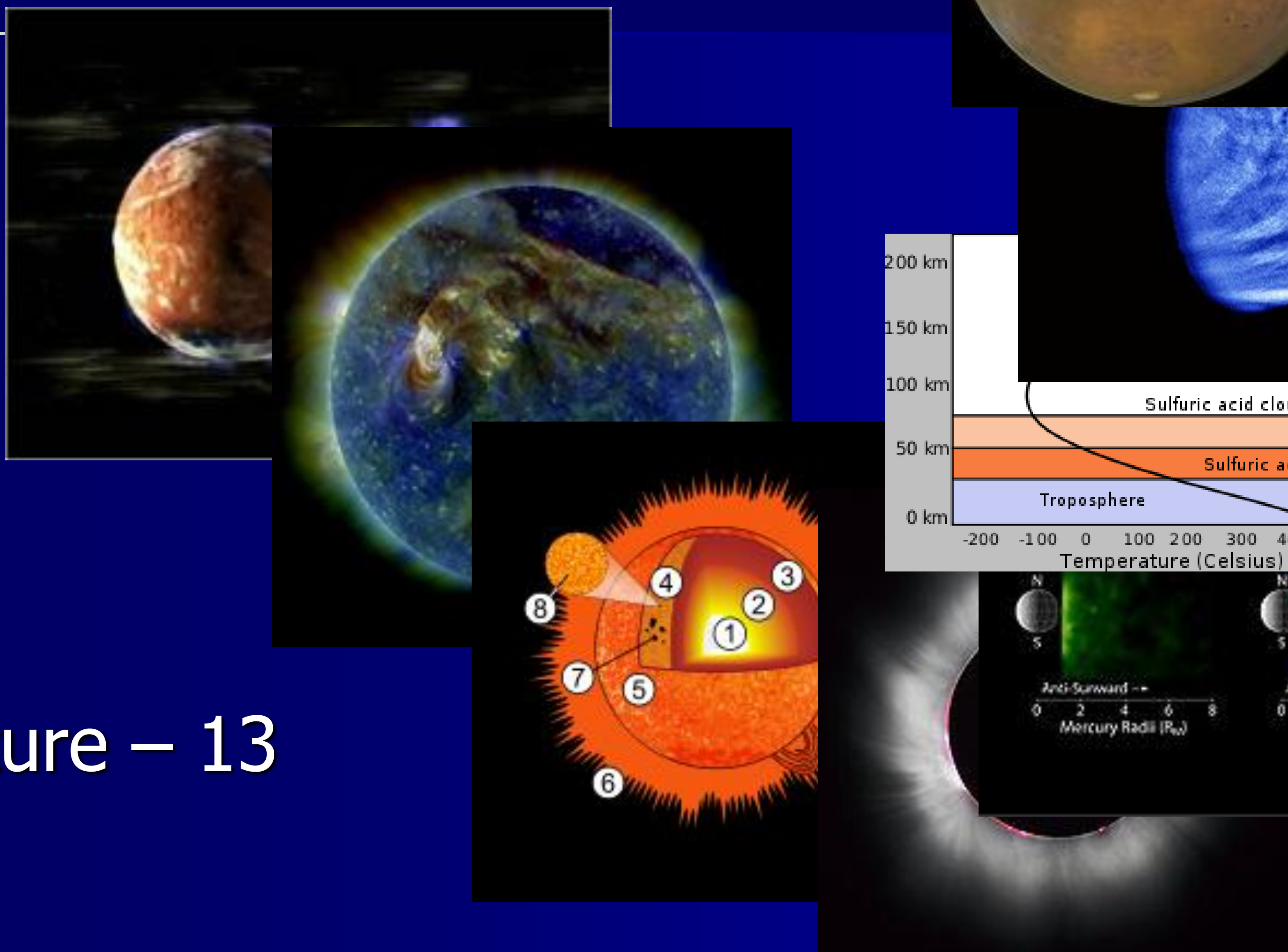
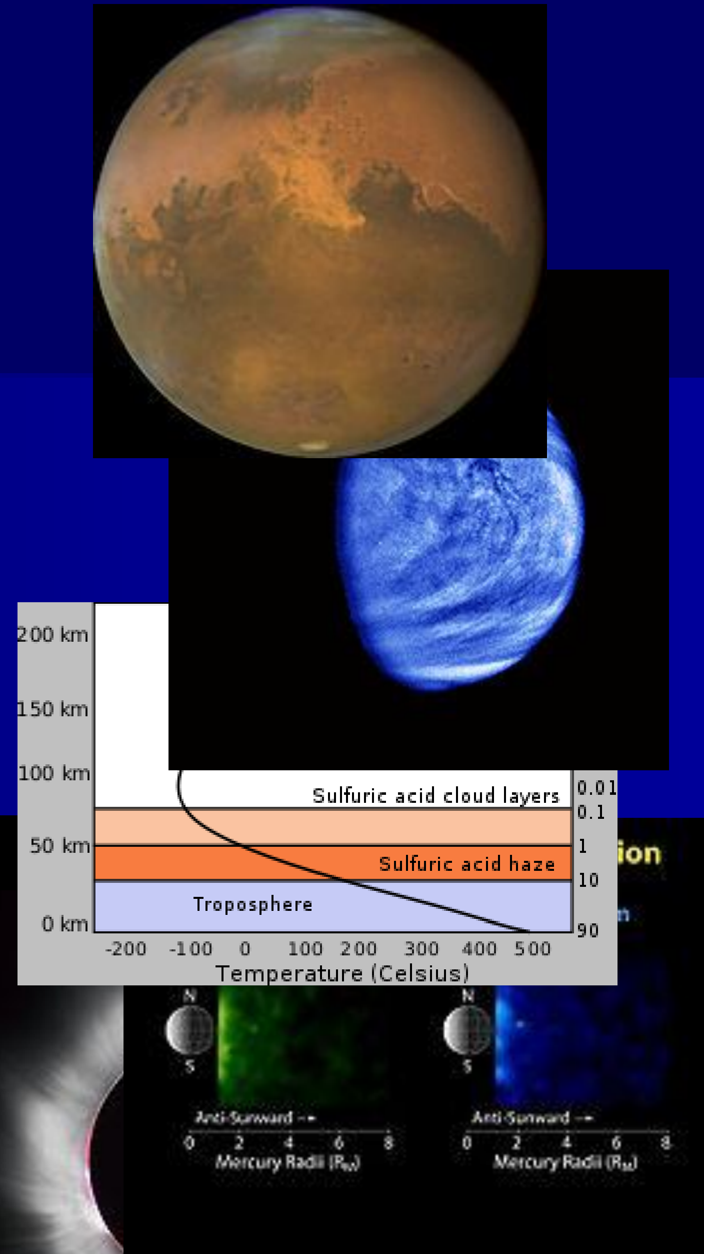
Space Physics

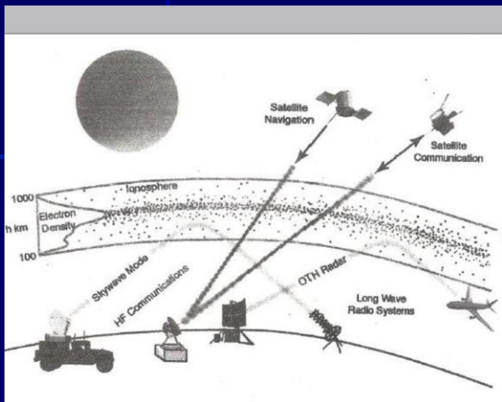
Space Physics





Lecture – 13

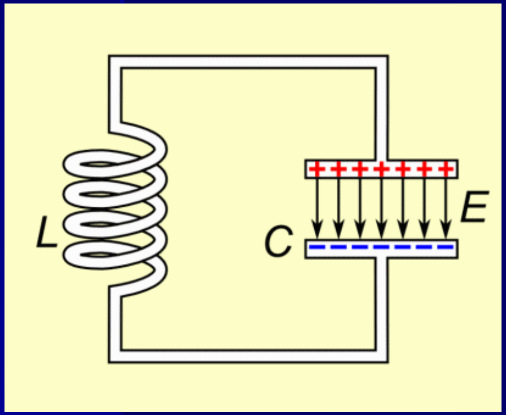
Radio Wave Communication



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

Radio Communication

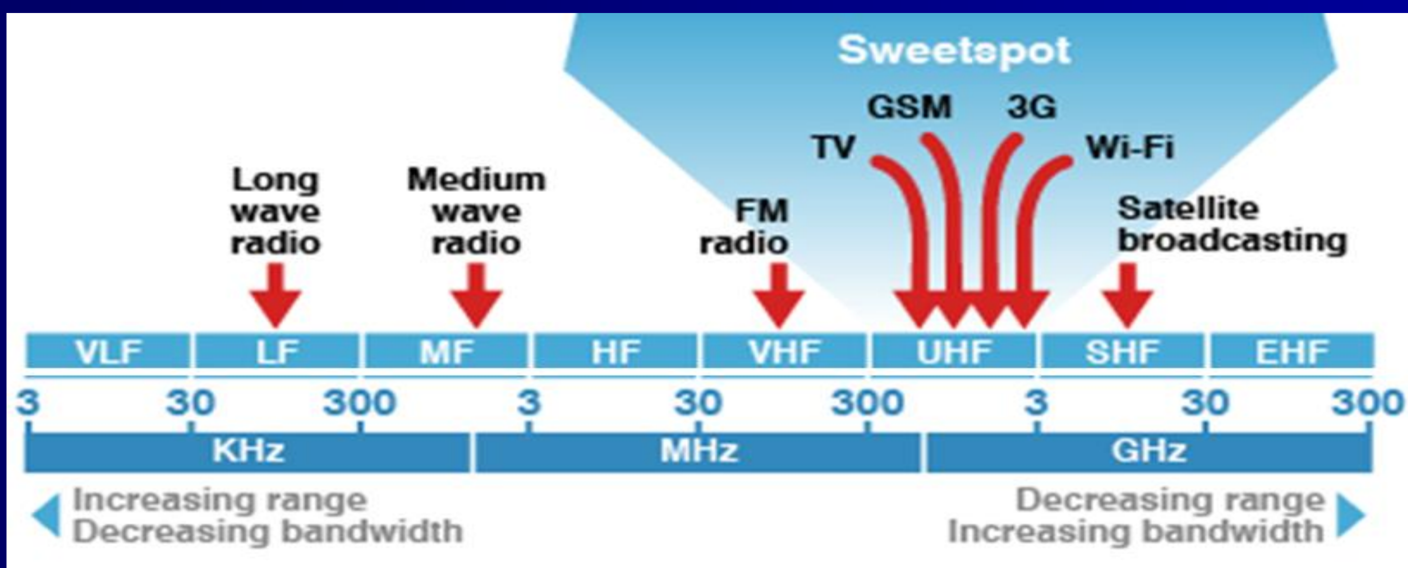
In order to receive radio signals, for instance from AM / FM radio stations, a radio antenna must be used. However, since the antenna will pickup thousands of radio signals at a time, a **radio tuner** is necessary to tune in to a particular frequency (or frequency range).



This is typically done via a **resonator** (in **the simplest form, a circuit with a capacitor and an inductor**). The resonator is configured to resonate at a particular frequency (or frequency band), thus amplifying since waves at that radio frequency, while ignoring other **sine waves**. Usually, either the inductor or the capacitor of the resonator is adjustable, allowing the user to change the frequency at which it resonates.

Radio Spectrum

Band	Frequency range	Wavelength range
Extremely low frequency (ELF)	< 3 kHz	>100 km
Very low frequency (VLF)	3 - 30 Hz	10 - 100 krn
Low frequency(LF)	30 - 300 kHz	1 - 10 km
Medium frequency (MF)	300 kHz - 3 MHz	100m - 1km
High frequency (HF)	3 - 30 MHz	10 - 100m
Very high frequency (VHF)	30 - 300 MHz	1 - 10m
Ultra high frequency (UHF)	300 MHz - 3 GHz	10cm - 1m
Super high frequency (SHF)	3 - 30 GHz	1 - 10cm
Extremely high frequency (EHF)	30 - 300 GHz	1mm - 1cm



How Radio Communication Works ?

Radio **FM waves** are used because they can travel **very large distance** through the atmosphere **without** greatly **attenuated** due to scattering or **absorption**.

Your Radio Receives the radio waves decodes this information , and uses a speaker to change it back into a sound wave. An picture illustration of this process is given below.

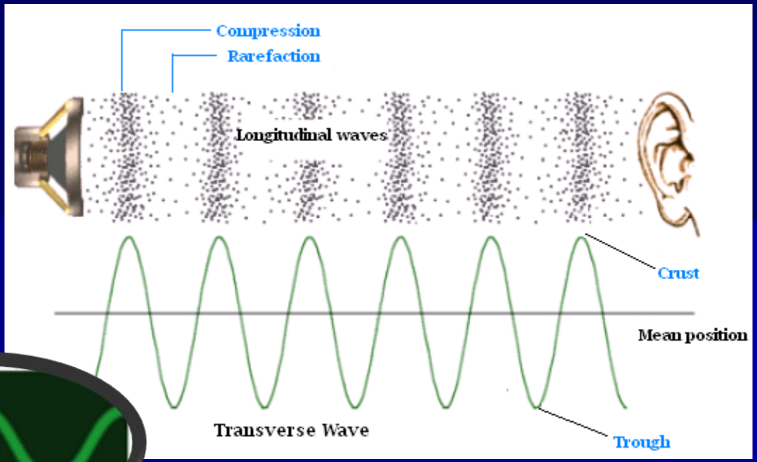
Step – 01

A sound wave produced with a frequency of 5 Hz – ~20 kHz

How Radio Communication Works ?

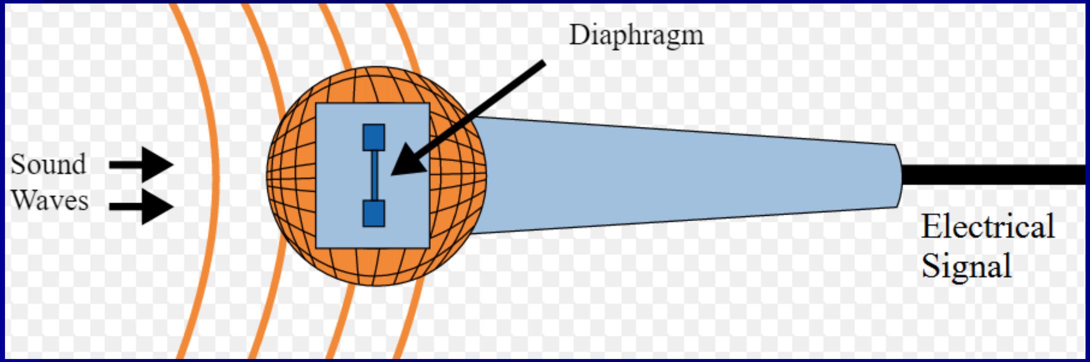
Step – 02

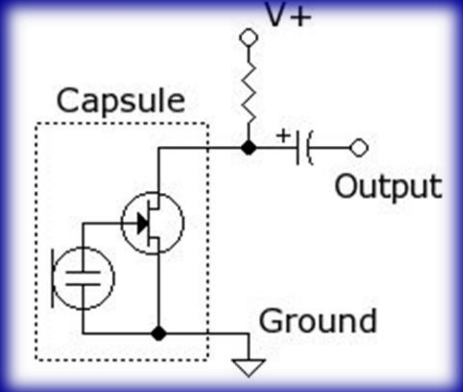
The sound wave is equivalent to pressure wave travelling through the air.



Step – 03

A microphone converts the sound wave into an electrical signal

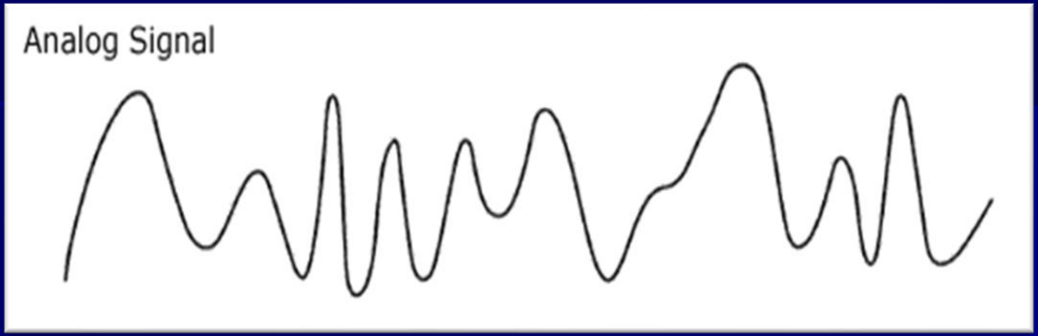




How Radio Communication Works ?

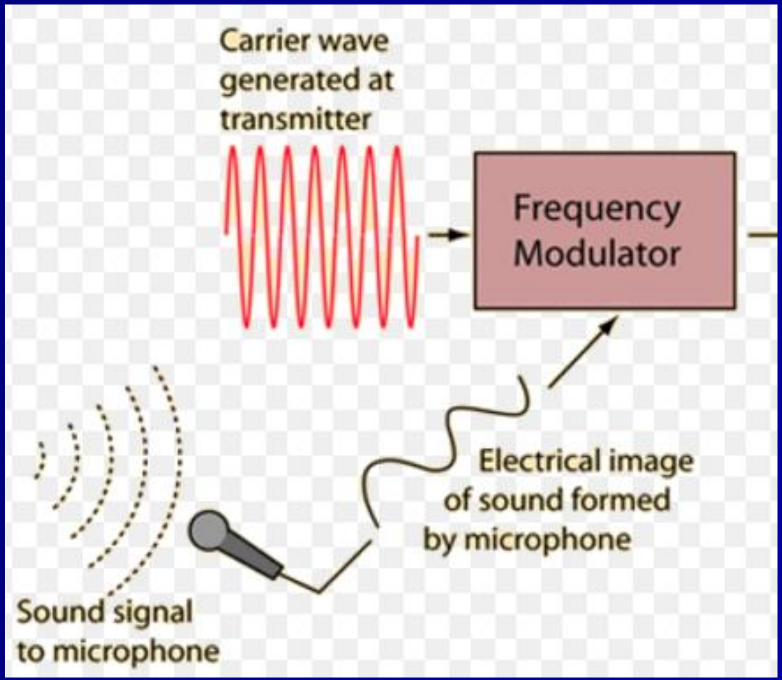
Step – 04

The electrical wave travelling through the microphone wire is analogous to the original sound wave.



Step – 05

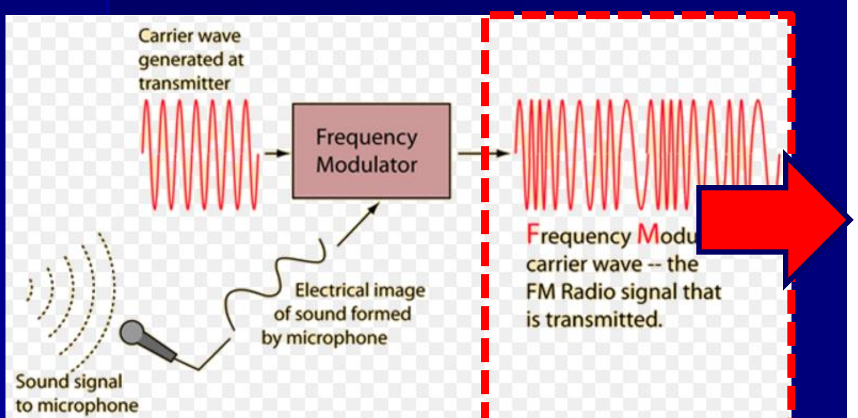
The electrical wave is used to encode or modulate a high-frequency "carrier" radio wave. The carrier wave itself does not include any of the sound information until it has been modulated.

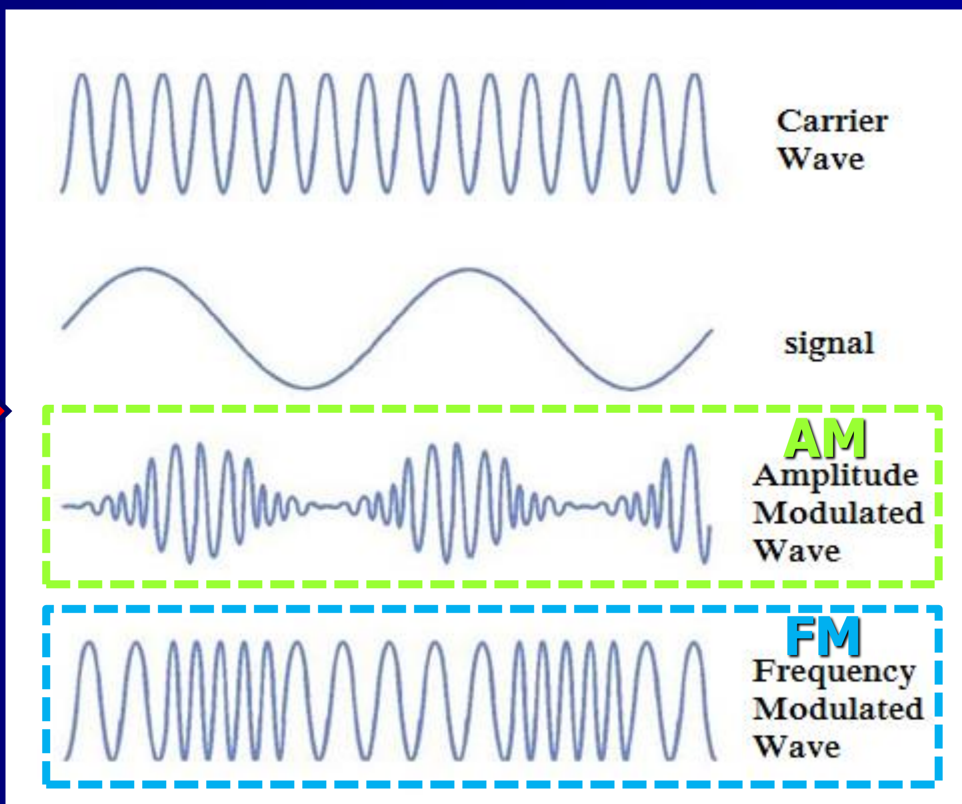


How Radio Communication Works ?

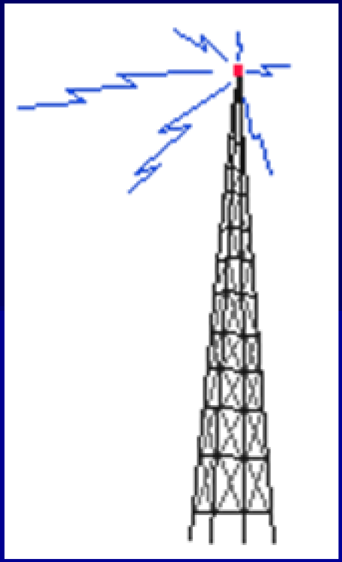
Step – 06

The carrier wave can either be amplitude modulated (AM, top) by the electrical signal, or frequency modulated (FM, bottom).





How Radio Communication Works ?



Step – 07

The signal is transmitted by a radio broadcast tower.

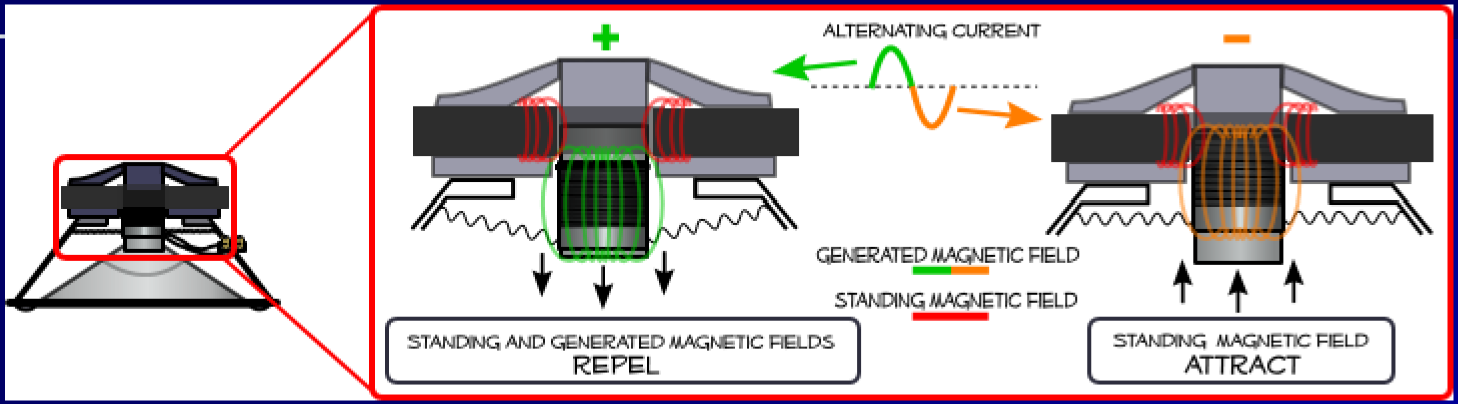
Step – 08

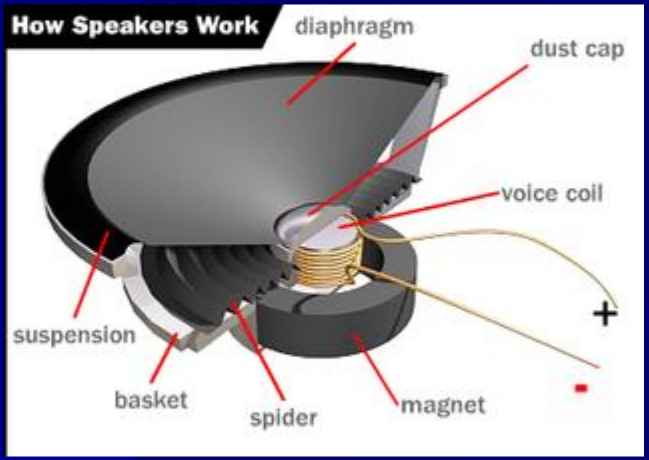
Your radio contains an antenna to detect the transmitted signal,
a tuner to pick out the desired frequency,
a demodulator to extract the original sound wave from the transmitted signal, and
an amplifier which sends the signal to the speakers.

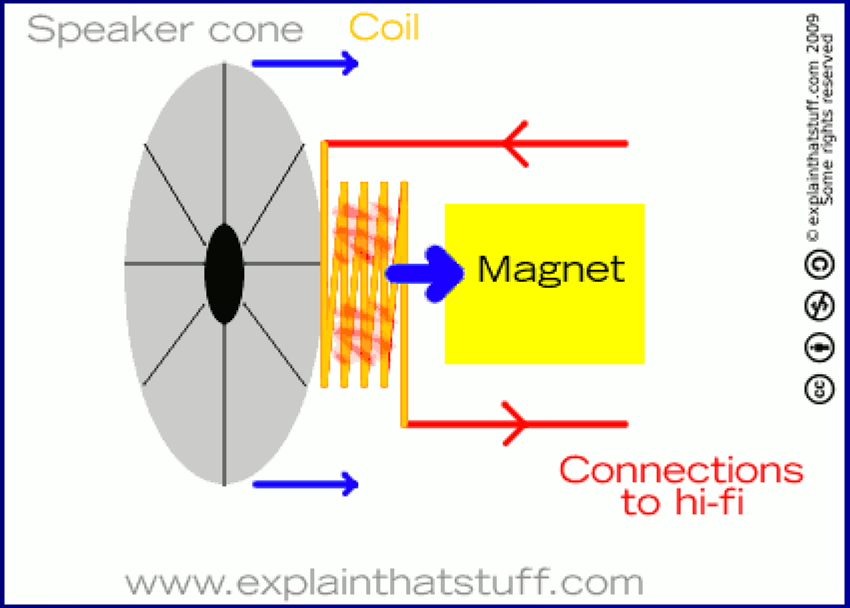
The speakers convert the electrical signal into physical vibrations (sound).

How Radio Communication Works ?

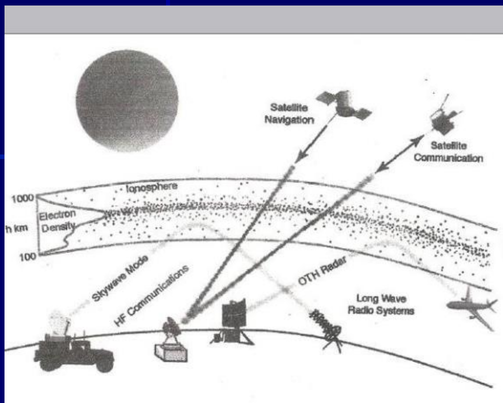
Step – 08 : How to a speaker works ?







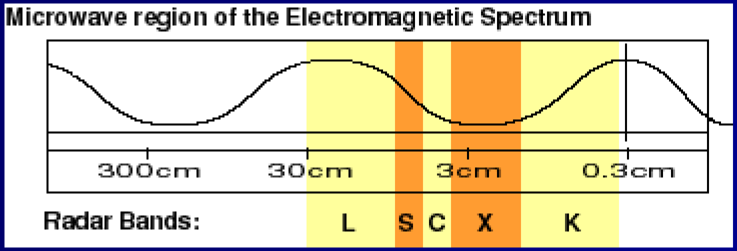
Radio Wave Communication



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

Microwave Transmission

Microwave Transmission refers to the technology of transmitting information by the use of the **radio waves** whose wavelengths are conveniently measured in small numbers of centimeters, by using various electronic technologies. These are called **microwaves**.

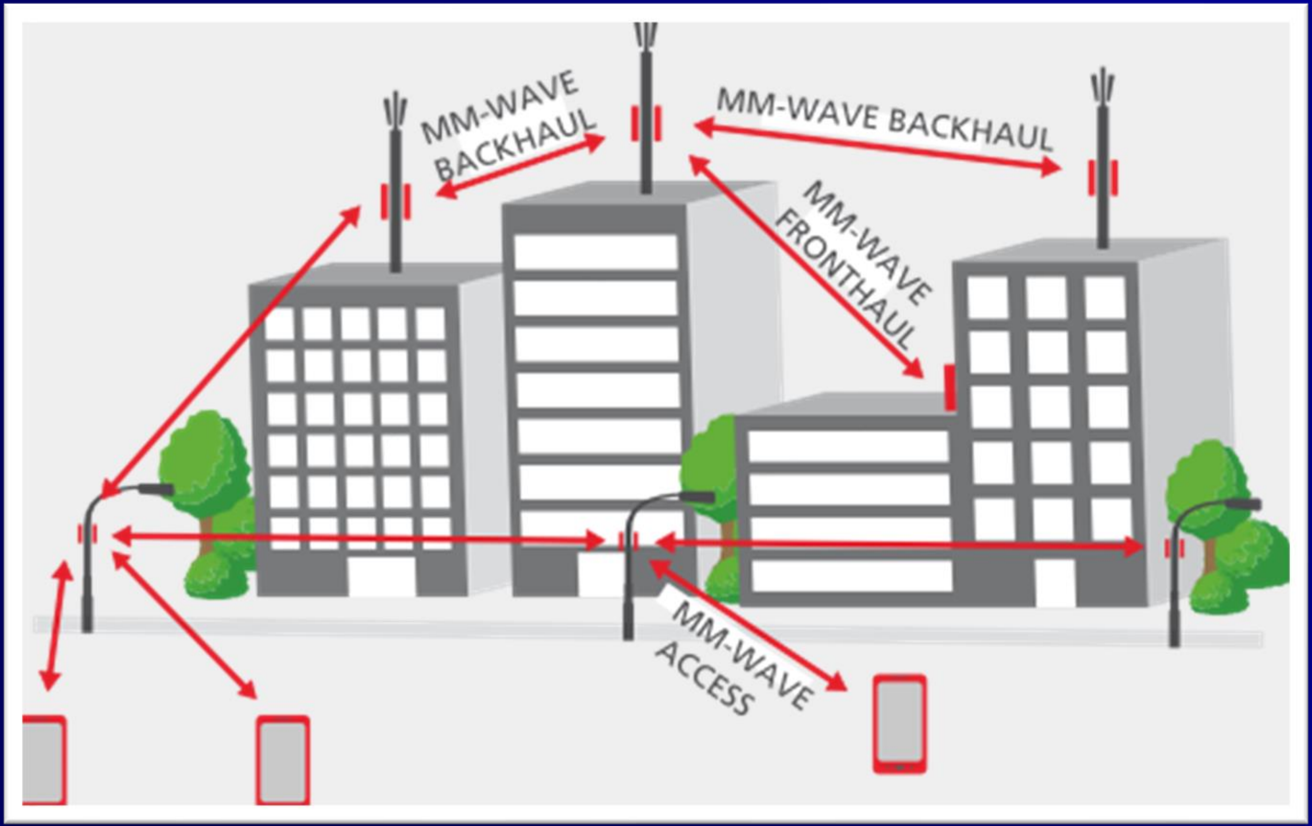


This part of the radio spectrum ranges across frequencies of roughly **1 GHz – 30 GHz**. Also by using the formula $c = f\lambda$, these correspond to wavelengths from **30 cm** down to **1 cm**.

In the microwave frequency band, **antennas** are usually of convenient sizes and shapes and also the use of **metal waveguides** for carrying the radio power works well.

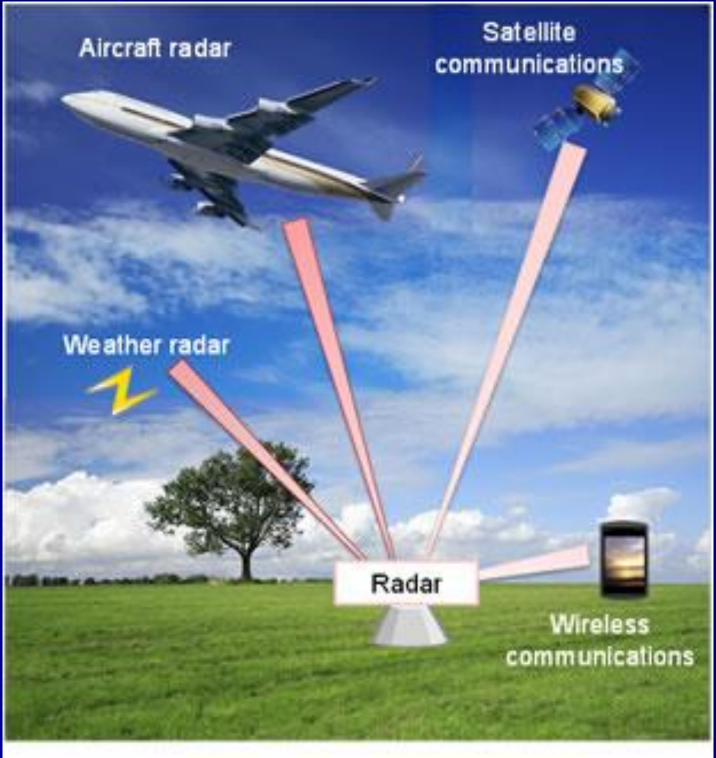
Radio Transmission – (MM Waves)

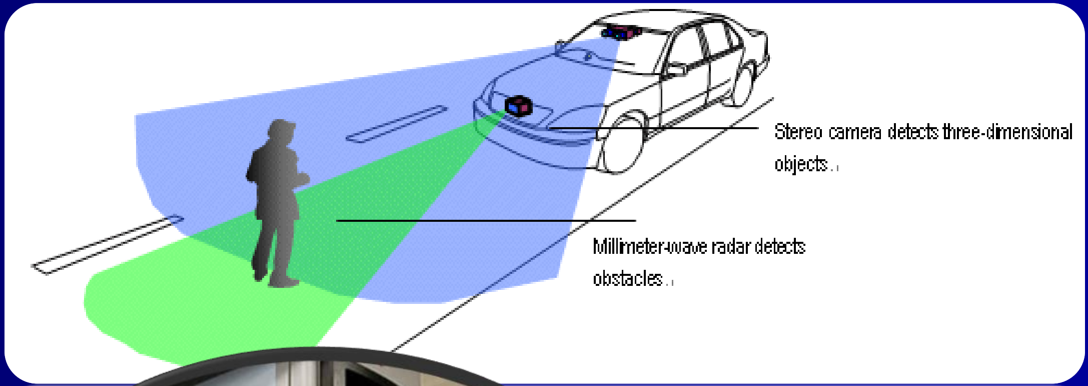
The next higher part of the radio electro magnetic spectrum, where the frequencies are **above 30 GHz** and **below 100 GHz** are called "**Milimeter Waves**" because their wavelengths are conveniently measured in milimeters, and their wavelengths range from **10 mm** down to **3 mm**.

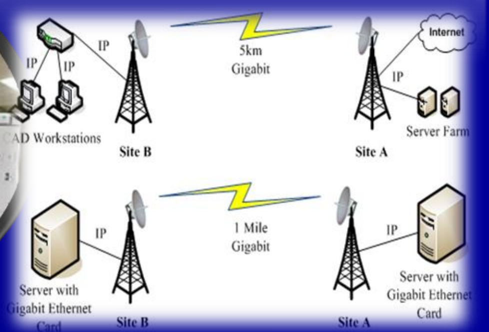


Radio Transmission – (MM Waves)

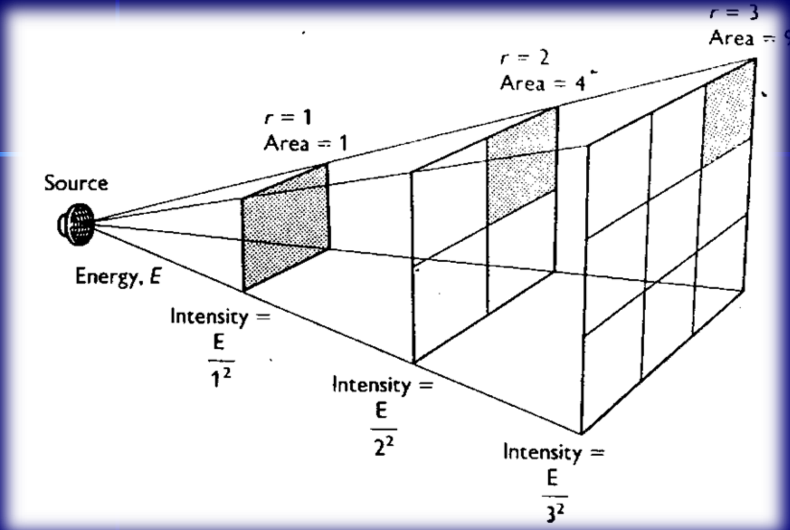
Radio waves in this band are usually strongly attenuated by the Earth atmosphere and particles contained in it, especially during wet weather. Also in wide band of frequencies around **60 GHz**, the radio wave are strongly attenuated by molecular oxygen in the atmosphere. The electronic technologies needed in the millimeter wave band are also much more difficult to utilize than those of the microwave band.





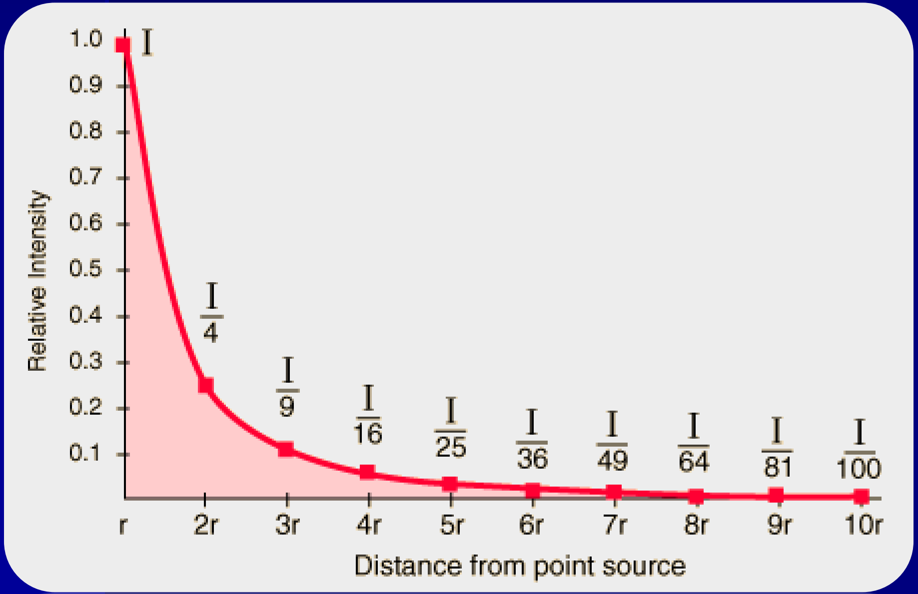


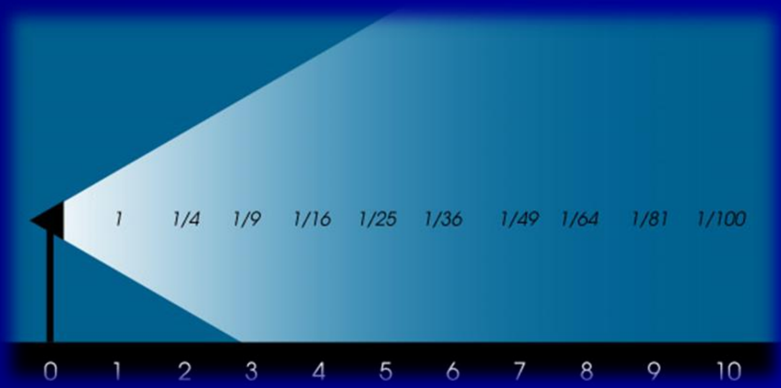
Free Space Propagation



In free space all EM waves obey the **Inverse Square law** which states that the **power density of an EM wave** is proportional to the **inverse of the square of the distance from the Source**.

$$\rho_p \quad \alpha \quad \frac{1}{r^2}$$

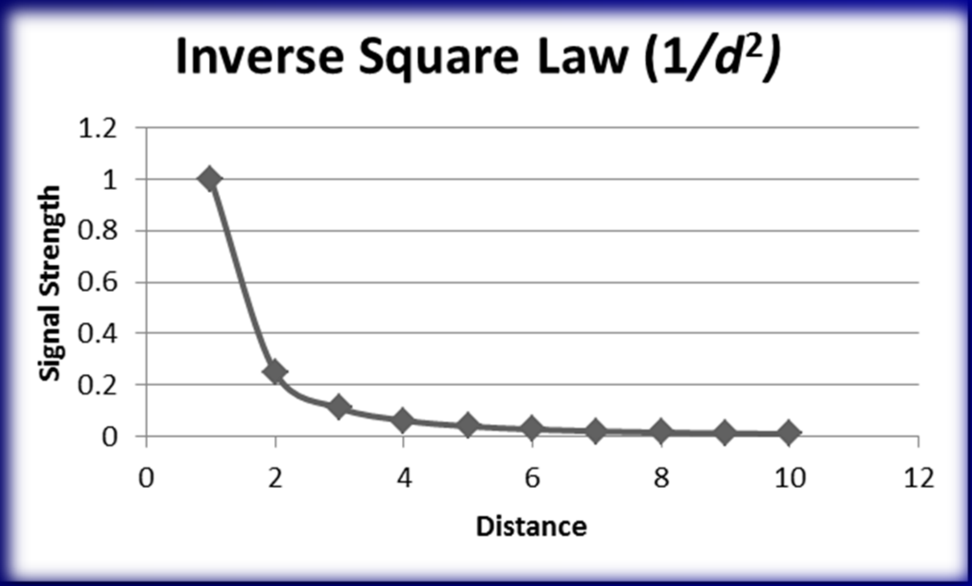




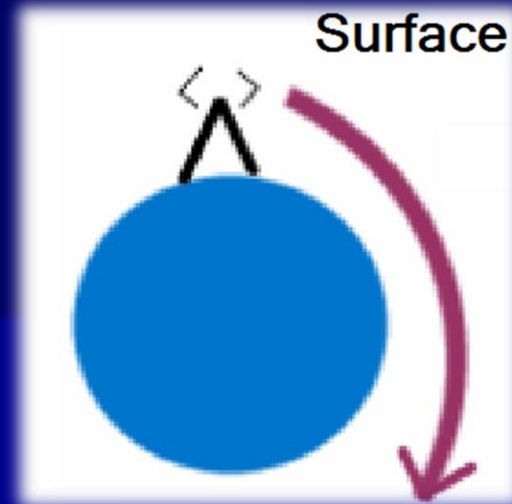
Free Space Propagation

Doubling the distance from a transmitter means that the power density of the radiated wave at that new location is reduced to one quarter of its previous value !

The power density per surface unit is proportional to the product of the electric and magnetic field strengths. Thus, **doubling the propagation path distance from the transmitter reduces each of their received field strengths over a free-space path by one half.**

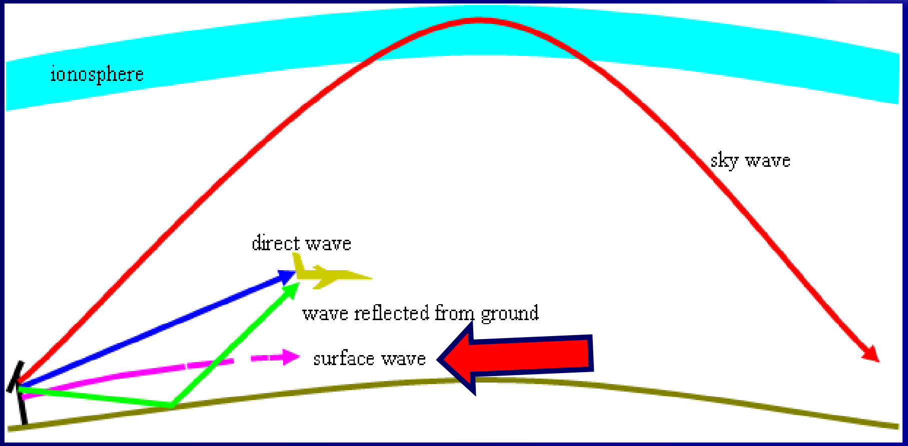


Propagation Modes



Surface Modes :

Lower frequencies (between 30 kHz – 3000 kHz) have the property of the curvature of the Earth via ground wave propagation in the majority of occurrences.

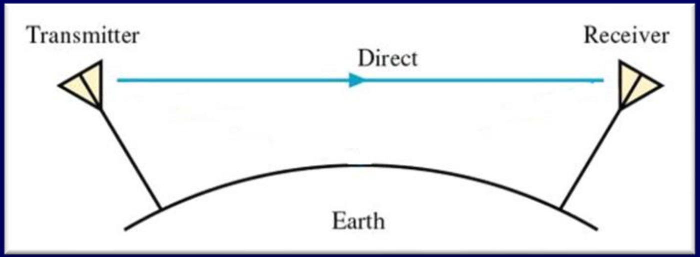


Ground waves are attenuated rapidly as they follow the Earth's surface. Attenuation is proportional to the frequency making this mode mainly useful for LF and VLF frequencies.

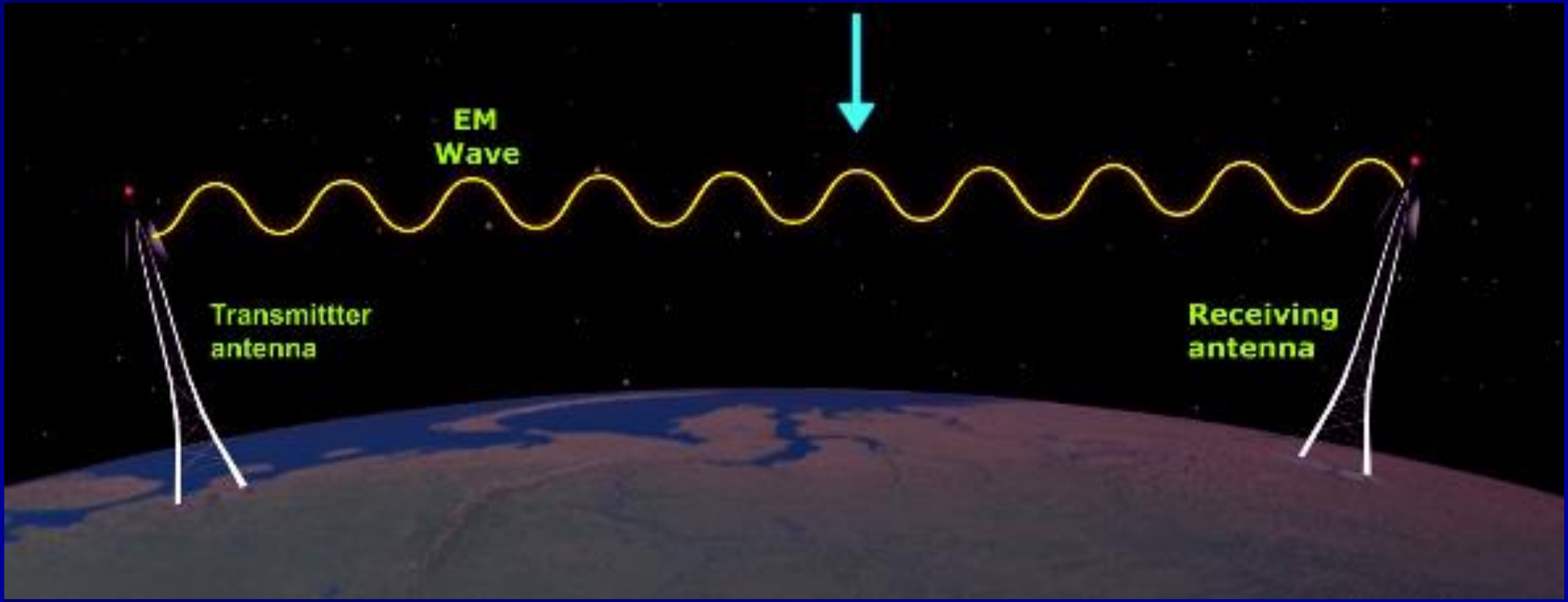
$$Attenuation \quad \alpha \quad f$$

Propagation Modes

Direct Modes : (line-of-sight)



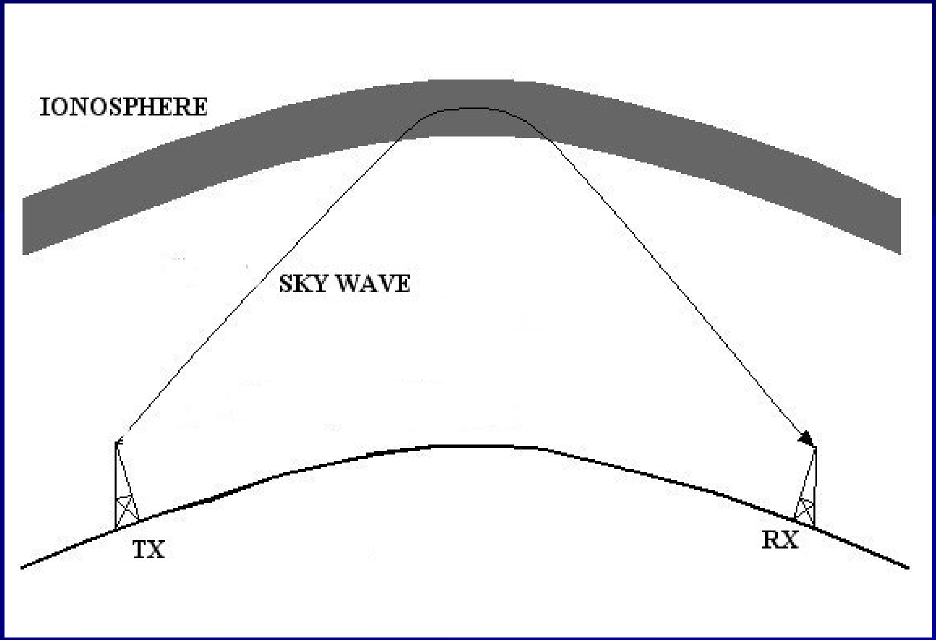
Line of sight is the **direct propagation of radio waves between antennas** that are visible to each other. This is probably the most common of the radio propagation modes **at VHF and higher frequencies**



Propagation Modes

Ionospheric Modes :

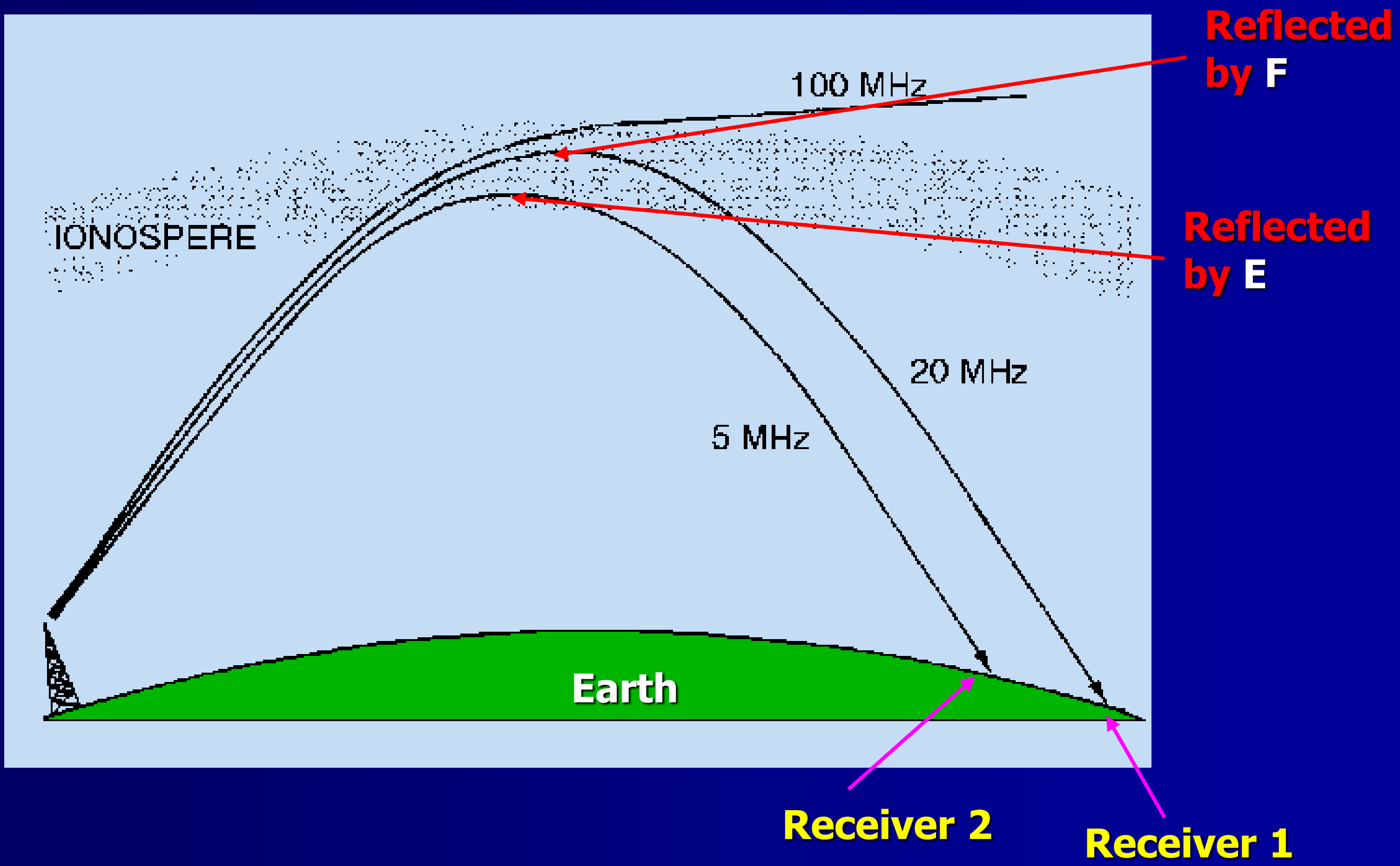
Sky wave propagation, also referred to as skip, is any of the modes that rely on **refraction** of radio waves in the **ionosphere**, which is made up of one or more ionized layers in the upper atmosphere



F_2 layer is the most important ionospheric layer for **HF** propagation, through **F_1**, **E** and **D** layers also play some role. These layers are directly affected by the Sun on a daily cycle, the reasons and the **11-year sunspot cycle** determines the utility of these modes. During **solar maxima**, the whole **HF range** up to **30 MHz** can be used and **F_2** propagation up to **50MHz** are observed frequently depending upon daily solar flux values. During **solar maxima**, **propagation of higher frequencies is generally worse**.

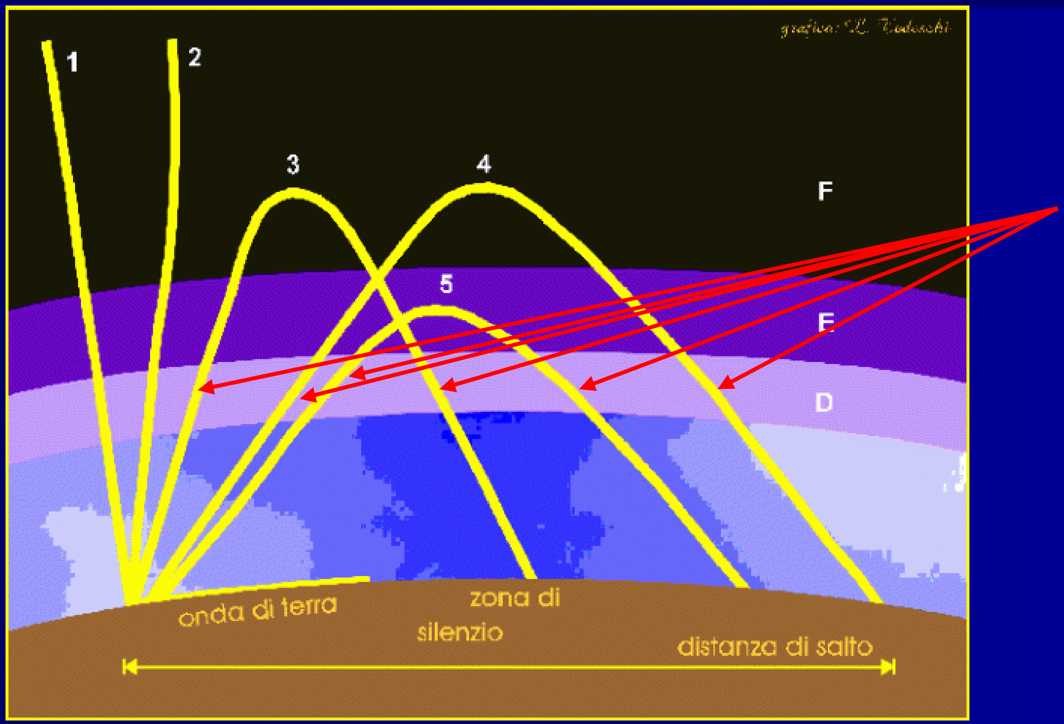
Reflection of Radio Waves

Generally, radio waves reflected by E and F regions, because that ionosphere E and F have more electron densities compared to the region D.



Reflection of Radio Waves

- Always radio waves **absorbed by the region D** in the ionosphere. That is a main problem of the radio communication.

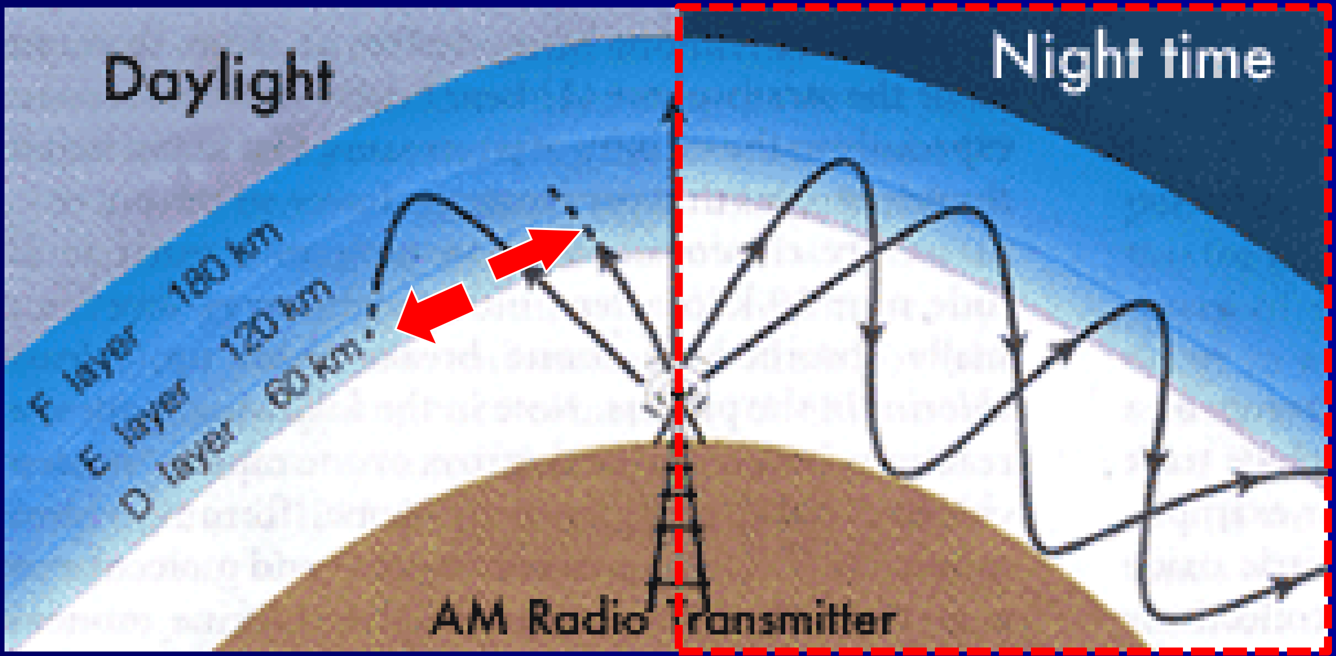


Absorbed by **D**

Because in the day time, radio waves reflected from the region E and F. But always the waves are going through the region D twice. (incident beam and reflected beam)

Reflection of Radio Waves

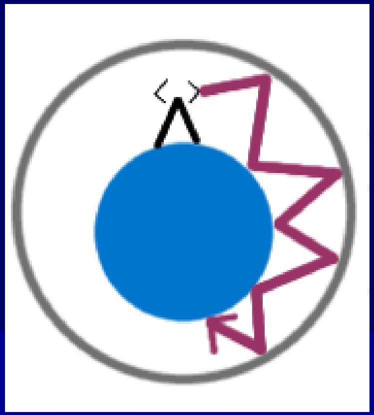
- In the Night time region **D** of the ionosphere vanishing suddenly, because the Sun goes down. But **E** and **F** regions are not destroying suddenly, specially the region **F** (F_2)

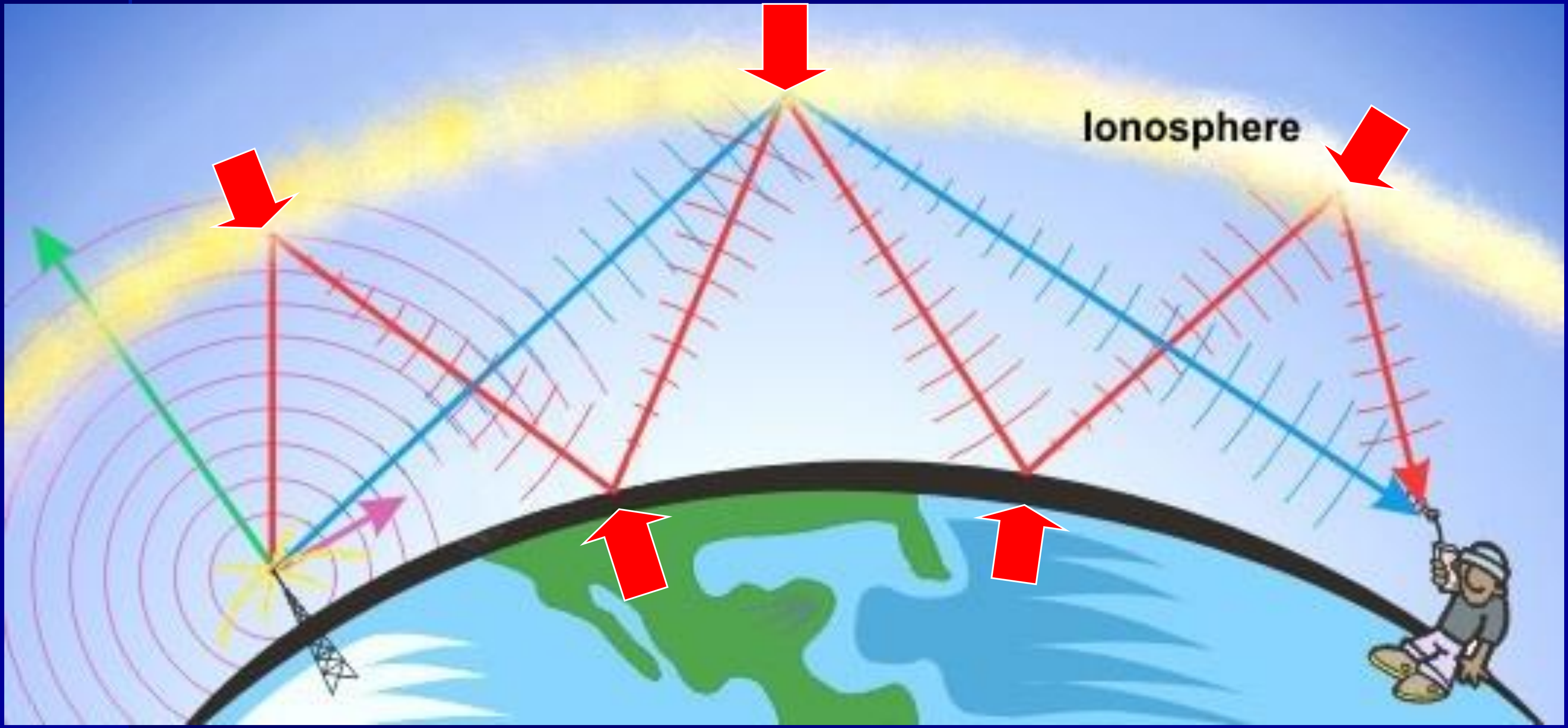


As a result SW radio broadcasting lines can listen very clearly at the night.
Eg: BBC Sandeshaya

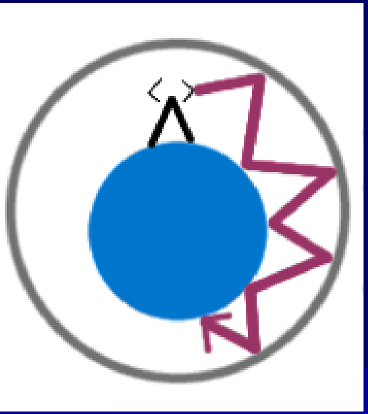
Multi - Reflection

- In the Night there are high possibilities for multi reflection too.





Multi - Reflection



Then the Sun is rising in the morning, all communications reflected from F-region going to weak. Because again D-region is creating !

In the night MW (medium waves) also reflected from the region F. As a result, we can listen some MW channels from India.

For long distance communication it is very useful SW reflection broadcast method. (But the problem is D-region in the day)

We can not use surface waves communication for long distance communications. There are two reasons:

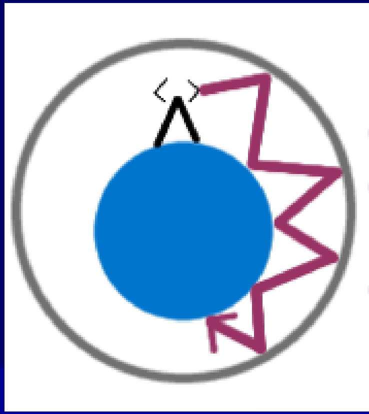
01. The problem from the curvature of the earth.

02. The surface waves dies more quickly as the frequency increases;

$$Range\ (km) = \frac{200}{\sqrt{Frequency\ (MHz)}}$$

Multi - Reflection

$$Range\ (km) = \frac{200}{\sqrt{Frequency\ (MHz)}}$$



If **f** increases the range of the propagation, **R** decreases rapidly. But **f** is decreases the range of the propagation, **R** increases.

Eg: A 100 kHz low frequency radio wave use for the surface propagation to long distance. Find the maximum range of the propagation of the of the wave.

f = 100 kHz → f = 0.1 MHz

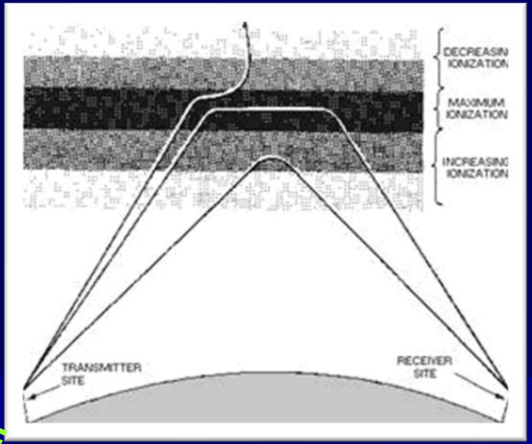
Using, $R\ (km) = \frac{200}{\sqrt{f\ (MHz)}}$ → $R\ (km) = \frac{200}{\sqrt{0.1}}$

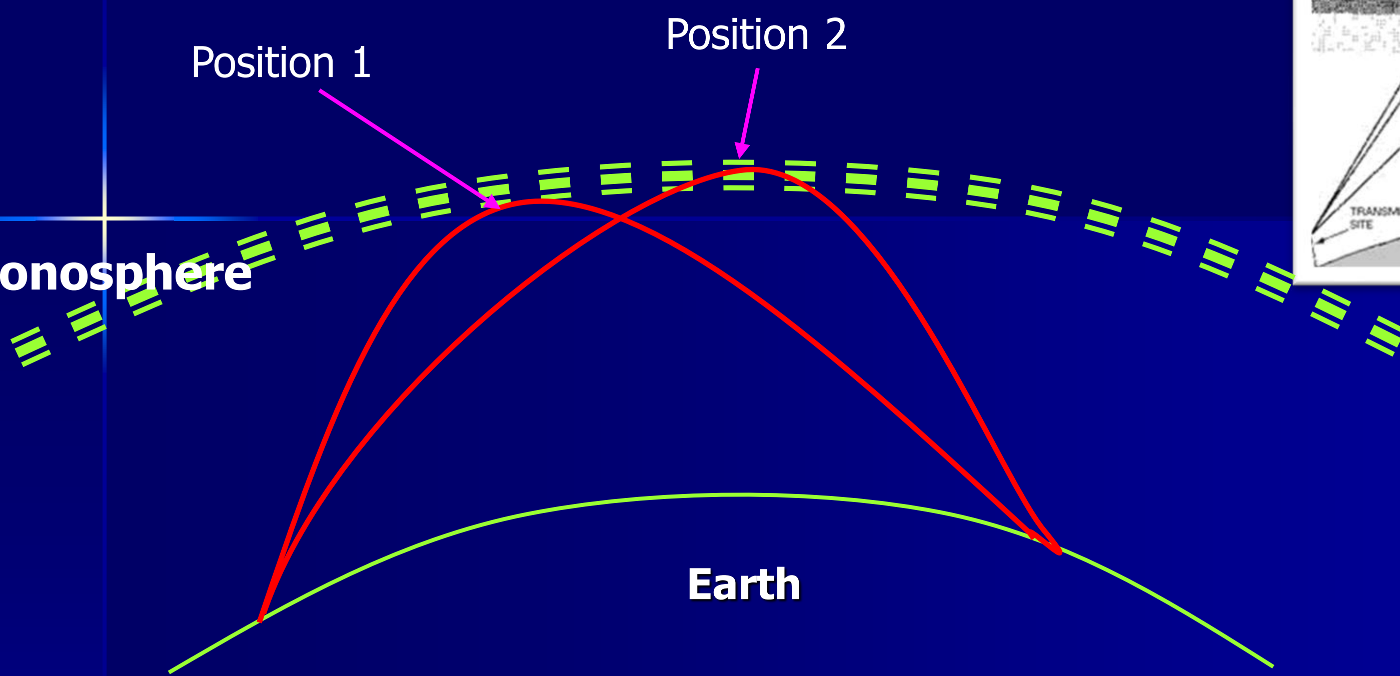
→ $R = 632.456\,km$

→ $R \approx 600\,km$

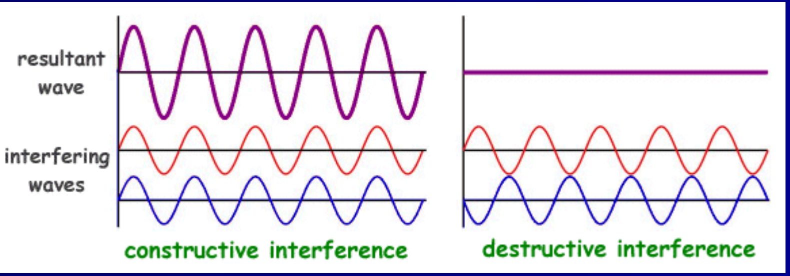
After that range it is dying more quickly !

Multi – Position Reflection

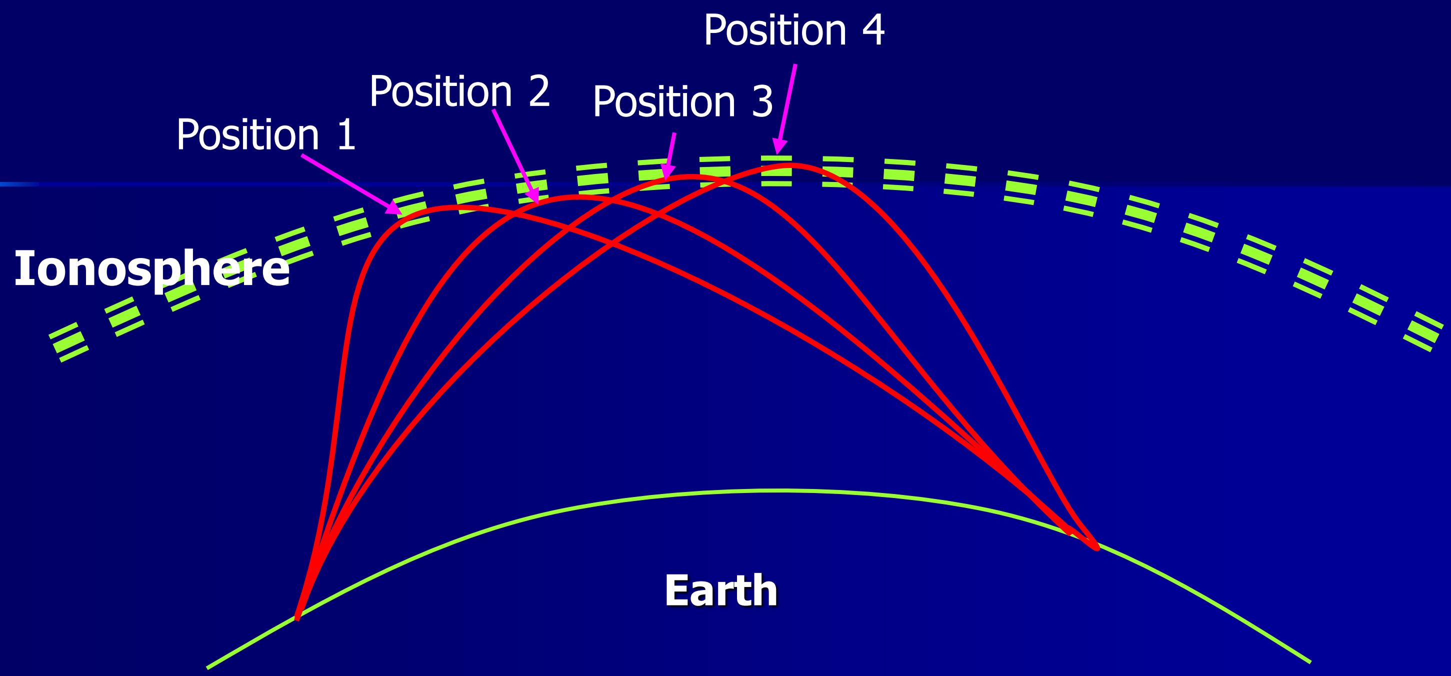




This is a possible situation. That means multi position of the ionosphere is supported to reflected the radio wave to the same receiver. **As a result the strength of the signal may be very strong**. But sometimes it may be very weak, because the **result of interference** final wave may be cancelled.



Multi – Position Reflection

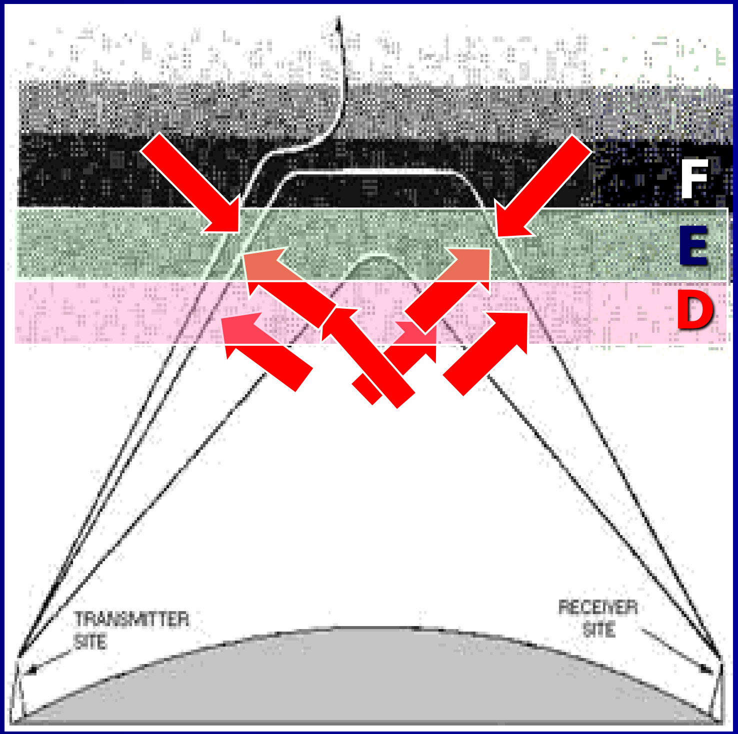


As **a result of reflection of multi position final wave may be destroyed**, because of the **attenuation of the carrier wave** of the radio signal. OR **final wave may be destroyed, because of anti-phase situation** (destructive interference)

Absorption of Radio Waves

Normally ions (electrons and positive ions) in the ionosphere interact with radio waves (EM wave). As a result, ions in the ionosphere are oscillating due to absorption energy from the radio waves. That means energy of the ions increases. Because, electric field of the radio wave transfer energy to ions. The temperature of the ionosphere is increases.

If we want to cancel this phenomena **we should use High Power radio waves** for this purpose. In the day time this phenomena is happening well, because, molecular density of the ionosphere is very high. Normally ions in the D-region are participated for this incident.



Absorption of Radio Waves

Oscillation frequency is the most important fact to absorb radio waves from the D-region. (**Oscillation frequency is no of oscillation per second of the electrons or positive ions**)
If **the radio wave frequency is equal to the oscillation frequency** of the D-region; the **wave is absorbed from the D-region**. Therefore, this oscillation frequency is the most important factor for the Radio Wave Propagation.

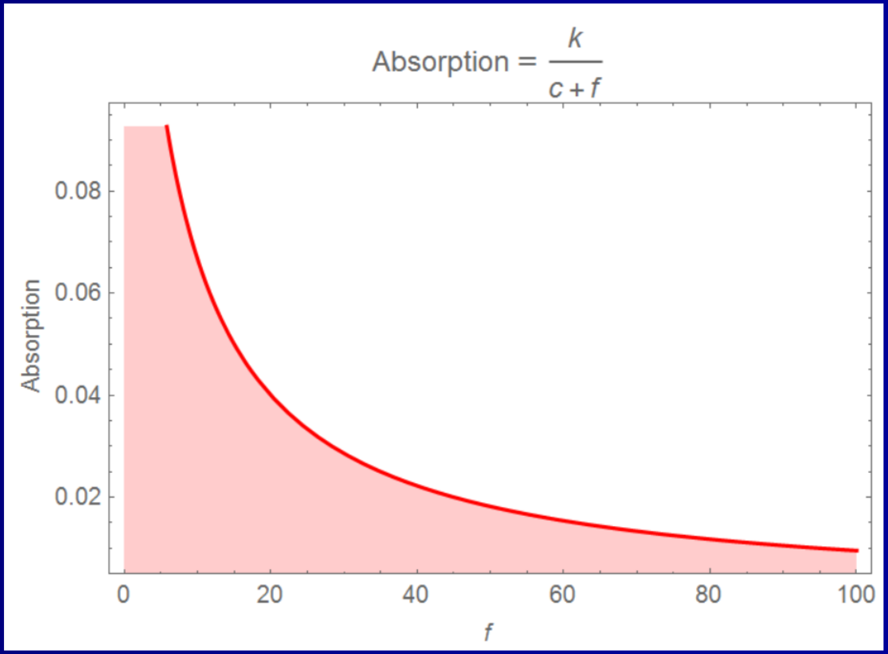
Normally, absorption is directly depend on the frequency of the Radio Wave.

$$Absorption \;\; \alpha \;\; \frac{1}{c + Frequncy\, of\, the\, wave}$$

Where, c is a constant.

$$Ab = \frac{k}{c + f}$$

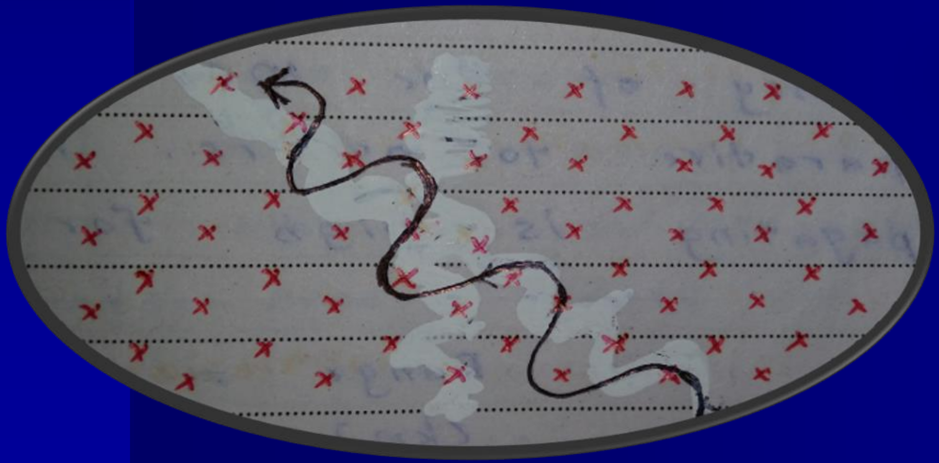
Where, k is proportional constant.



Absorption of Radio Waves

$$Absorption \quad \alpha \quad \frac{1}{c + Frequncy\, of\, the\, wave}$$

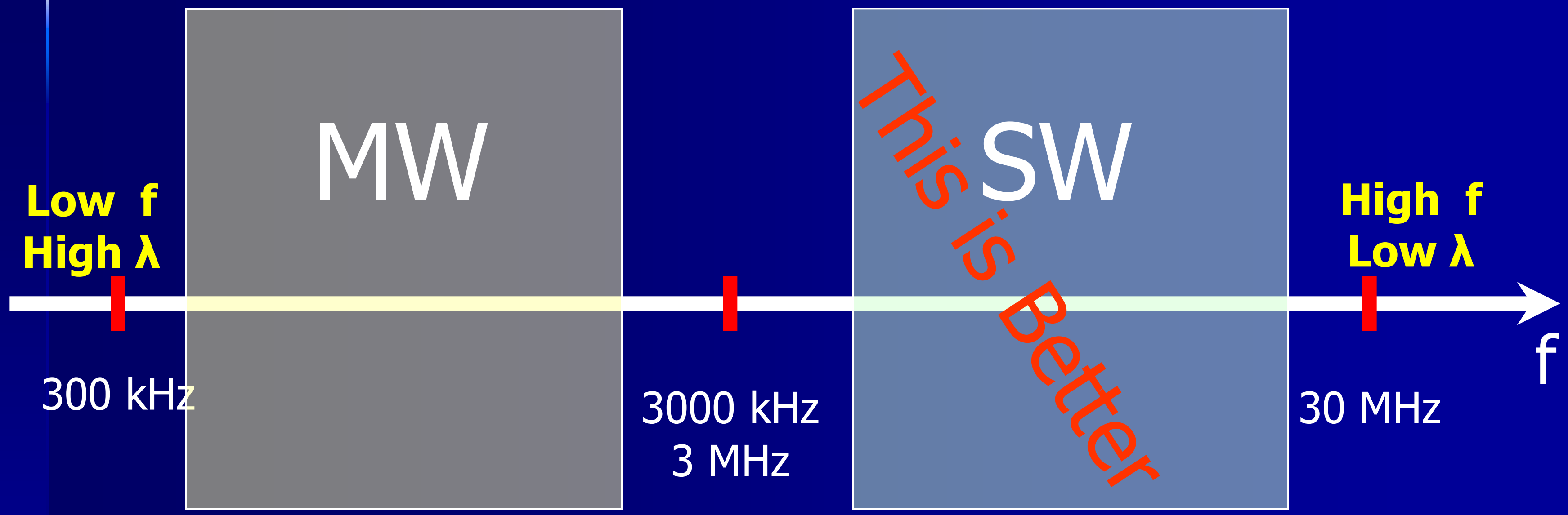
If **f** ↑ then **ab** ↓



If **f** ↓ **(λ ↑)** then **ab** ↑

Absorption of Radio Waves

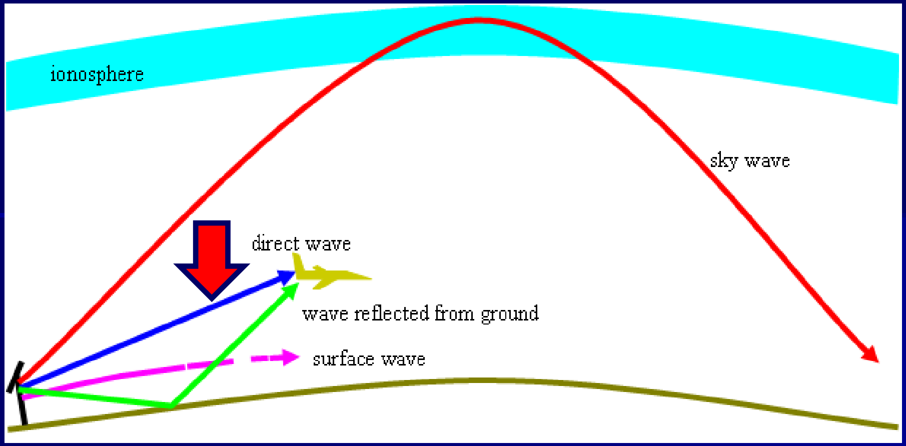
Generally, Short Waves (SW) are not much absorbed from the D-Region of the ionosphere. But, Medium Waves (MW) are normally absorbed from the ionosphere



In the day time, MW is almost absorbed from the D-Region of the ionosphere. But SW are not absorbed.

Therefore, we can use MW to direct communication without reflection from the ionosphere. That direct communication means use to communicate by direct ground waves.

Absorption of Radio Waves



But direct ground waves also face some practical problems due to **diffraction**. Because the wave is bending due to diffraction. **Therefore, we can not use ground waves to communicate to far**.

Frequency of the **MW** signal **very low** with comparative to others. As a result **range of propagating** is **high** for low frequency signals.

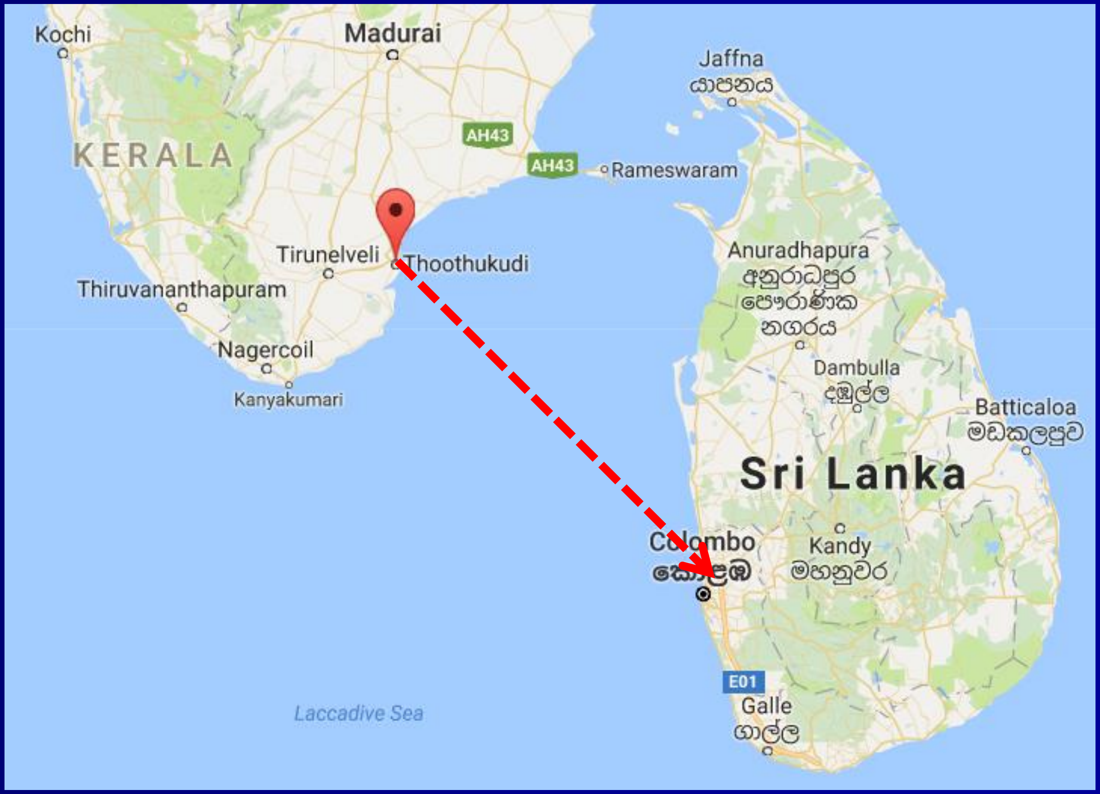
$$\because \; Range\ (km) = \frac{200}{\sqrt{f\ (MHz)}}$$

But the problem is **diffraction of the wave**.

Absorption and attenuation of Radio Waves

A significant atmosphere effect is that of **attenuation due to rain**. **Below about 10 GHz, rain fading is not very significant**, but at **higher microwave frequencies, it becomes the major factor limiting path length**, particularly in areas that experience high level of rainfall (eg: **Watawala town in Sri Lanka**). In addition to attenuation of EM waves, rain and other precipitation (dew,…) tend to cause depolarization of the wave.

There is a ULF (Ultra Low Frequency) radio frequency channel from **Thoothukudi** in India whose frequency range is **1020 Hz – 1070 Hz**. **We can listen to that channel in Sri Lanka** because they are using **Very High Power Transmitter** !

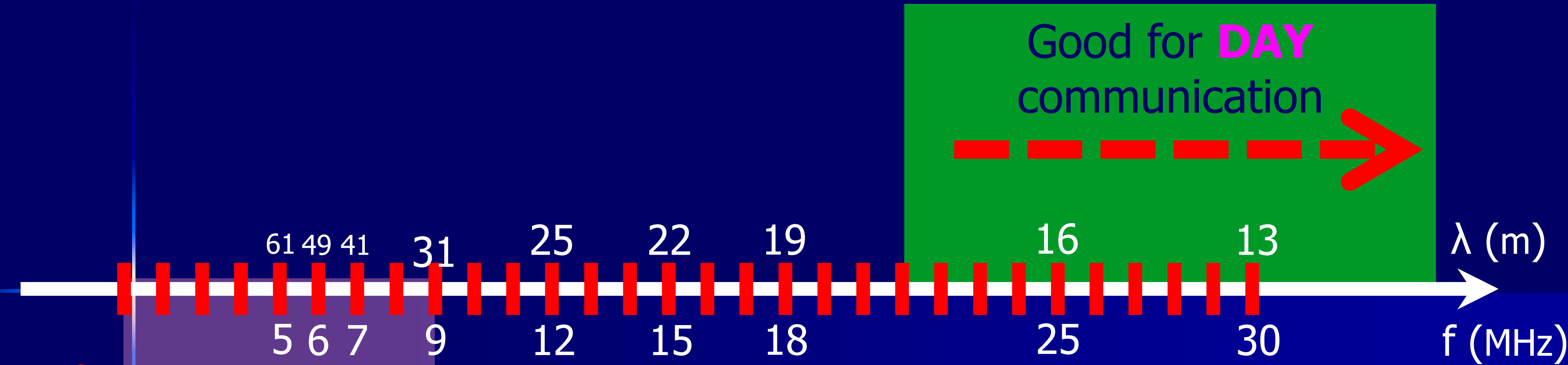


The specific amount of attenuation can be derived as a function of the inverse square law. The lower the frequency, the greater the attenuation.

In radio wave communication, the **Radio Broadcasting Center** should be change their carrier frequencies in the day and the night like the above diagram. Also this frequencies depend on the no of sunspots and activity of the Sun.

Eg: **BBC Sandeshaya**

(They used the transmission frequency **250 kHz** for the communication during the **DAY** and transmission frequency **100 kHz** for the **NIGHT**)



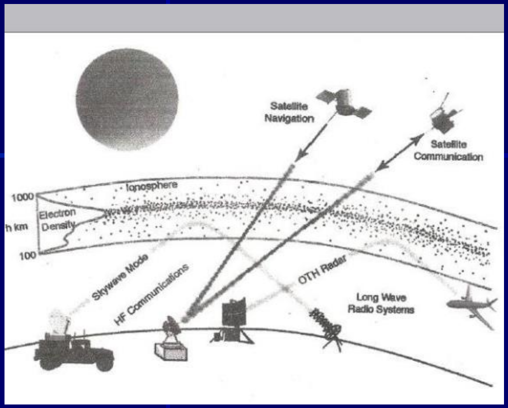
BBC Sandeshaya (NOW)

Daily **BBC Sandeshaya** program is broadcasting on SW 19 (15,690 kHz), SW 22 (13630 kHz) and SW 41 (7435 kHz) at 9:15 pm (night) on Sri Lankan time !

http://www.bbc.com/sinhala

Generally India using SW communication to broadcast their radio channels for all over the country !

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 **$n = \alpha + i\,\beta$** and n is complex. Therefore, we can use **$n \rightarrow n^*$**. i.e.;

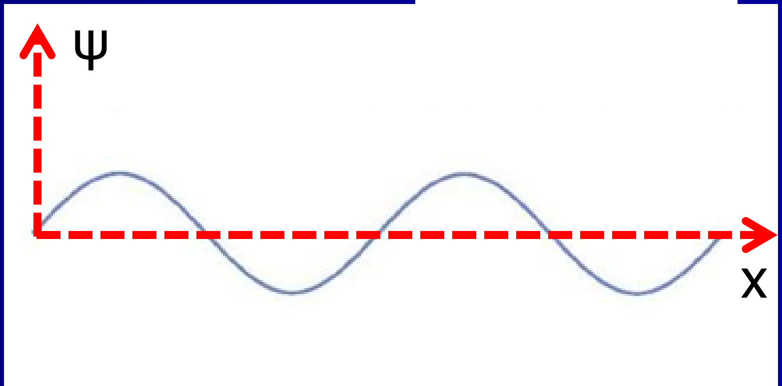
$$n^* = \alpha + i\,\beta$$

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;

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

$$\beta \rightarrow small$$



Complex Refractive Index

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

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

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

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

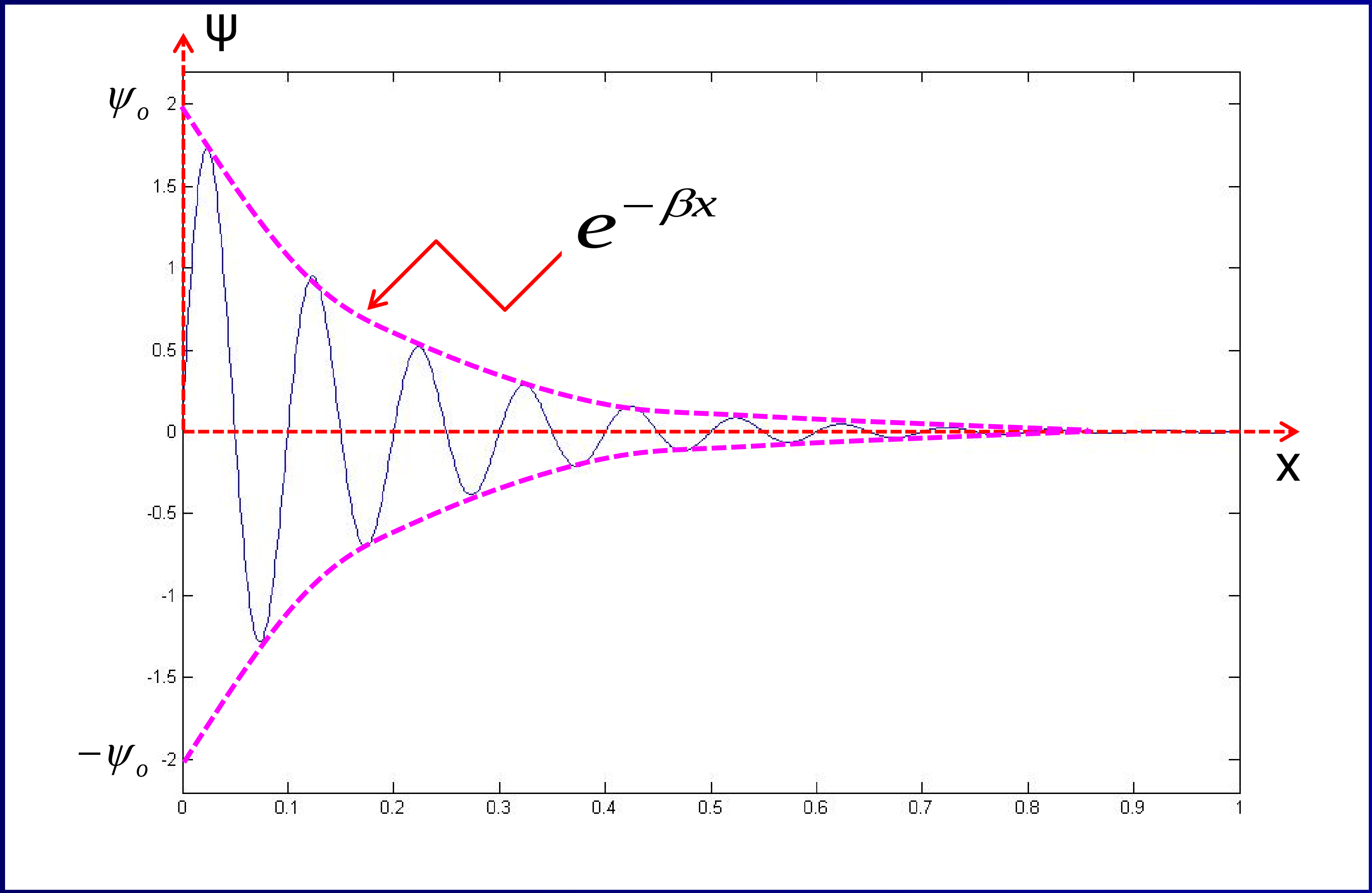
$$\Rightarrow \psi = \left(\psi_o e^{-\beta x}\right) e^{i\alpha x}$$

$$\Rightarrow \psi = \psi_o^1 \, e^{i\alpha x}$$ 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.

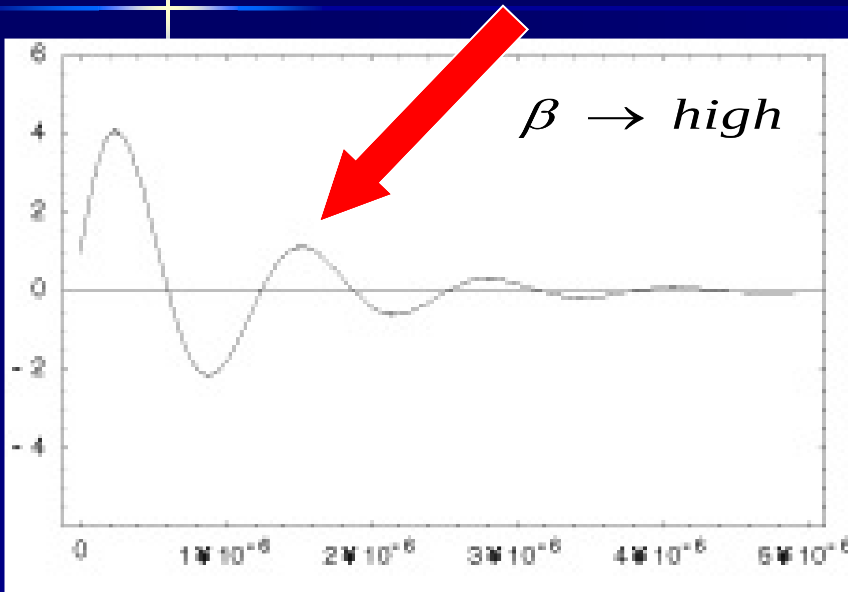
Complex Refractive Index

$$\psi_o^1 = \psi_o e^{-\beta x}$$ means that the new amplitude is attenuated from the ionosphere.

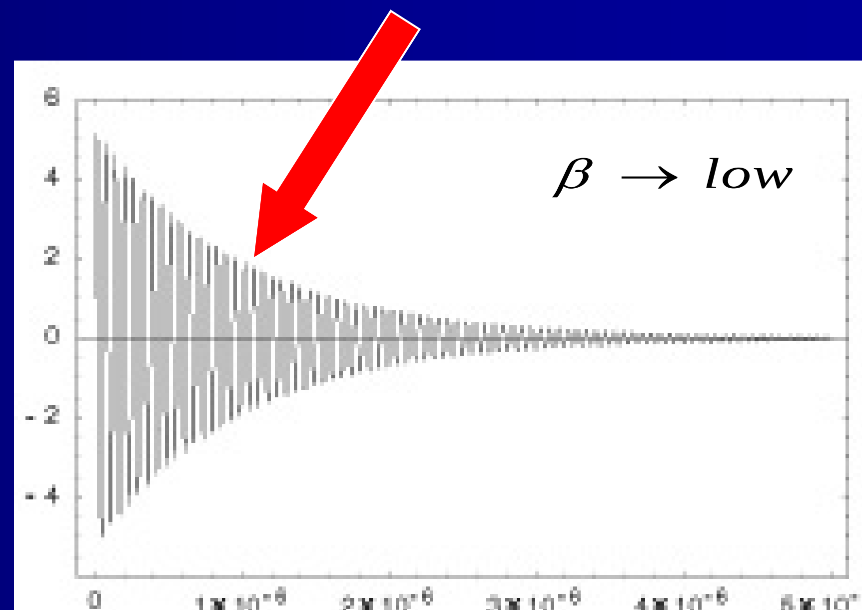


Complex Refractive Index

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



Attenuation



Thank You !