19L406-ANTENNA AND WAVE PROPAGATION

ASSIGNMENT PRESENTATION

WAVE PROPAGATION

BATCH 7

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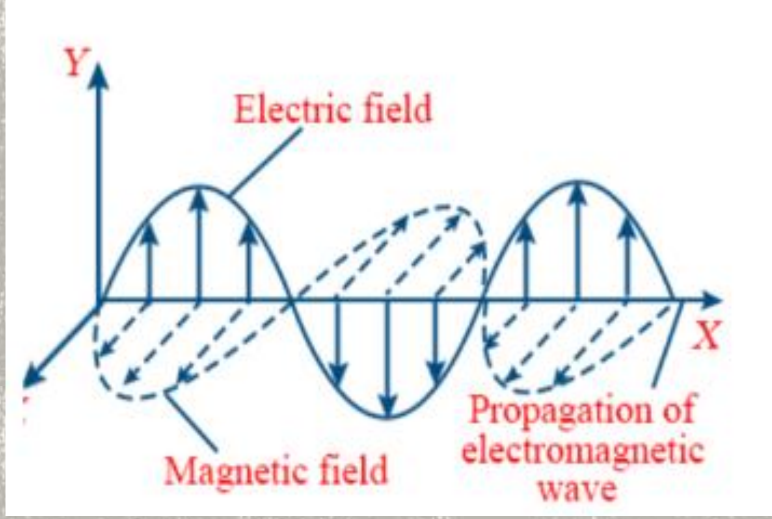
WAVE PROPAGATION

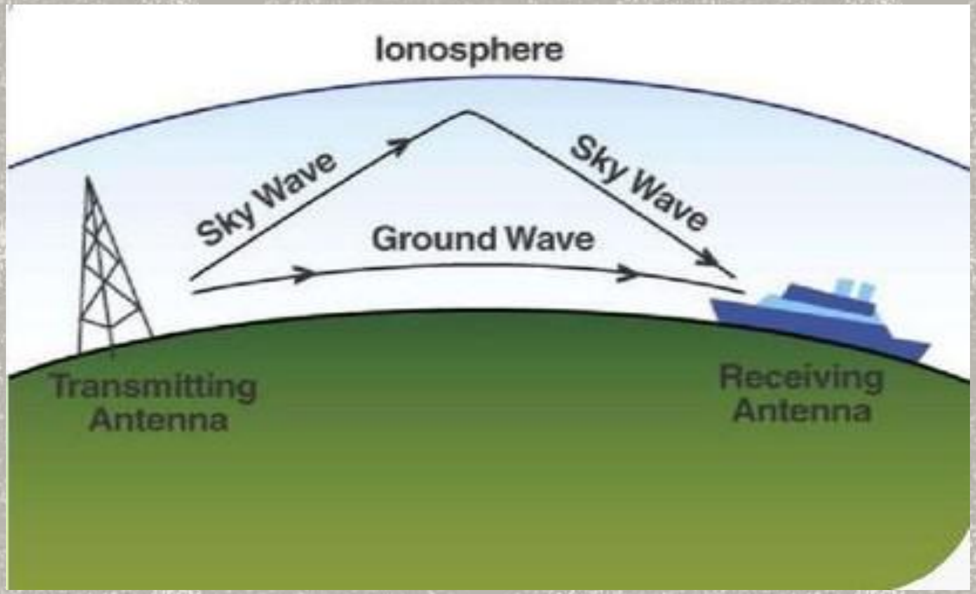
- The path taken by the wave to travel from the transmitter and to the receiver is known as **wave propagation.**
- The electromagnetic waves are of transverse in nature and they propagate in free space with the velocity of light(3×10^8 ms^{-1}).



MODES OF PROPAGATION

There are three types of modes of propagation of electromagnetic waves:

- Ground wave propagation
- Space wave propagation
- Skywave propagation



SURFACE WAVE

- Ground wave propagation is a type of radio propagation which is also known as a surface wave.
- These waves propagate over the earth’s surface in low and medium frequencies(up to 2MHz).
- These are mainly used for transmission between the surface of the earth and the ionosphere.
- These are made up of the number of constituent waves.
- Example: AM radio

STRUCTURE OF IONOSPHERE

- The traditional view of the ionosphere indicates a number of distinct layers, each affecting HF radio communications in slightly different ways.
- Indeed, the early discoveries of the ionosphere indicated that a number of layers were present.
- The ionosphere is divided meteorologically into different regions (layers) and each layer exhibit different characteristics.
- The layers were designated the D, E and F layers of the ionosphere, and the concept of distinct layers with these names has remained for many years.
- **Topside Layer:** This part of the Ionosphere starts at the height of the maximum density of the F2 layer of the Ionosphere and extends upward with decreasing density to a transition height where O+ ions become less numerous than H+ and He+.
- The transition height varies but seldom drops below 500km at night or 800km in the daytime, although it may lie as high as 1100km. Above the transition height, the weak ionization has little influence on radio signals.

MAIN LAYERS OF IONOSPHERE

- **D-Region:** The region between about 75 and 95km above the Earth in which the (relatively weak) ionization is mainly responsible for absorption of high-frequency radio waves
- **E-Region:** The region between about 95 and 150km above the Earth that marks the height of the regular daytime E-layer. Other subdivisions, isolating separate layers of irregular occurrence within this region, are also labeled with an E prefix, such as the thick layer, E2, and a highly variable thin layer, Sporadic E. Ions in this region are mainly O2+.
- **F-Region:** The region above about 150km in which the important reflecting layer, F2, is found. Other layers in this region are also described using the prefix F, such as a temperate-latitude regular stratification, F1, and a low-latitude, semi-regular stratification, F1.5. Ions in the lower part of the F-layer are mainly NO+ and are predominantly O+ in the upper part. The F-layer is the region of primary interest to radio communications.

CRITICAL FREQUENCY

- Critical frequency is the highest magnitude of frequency above which the waves penetrate the ionosphere and below which the waves are reflected back from the ionosphere. It is denoted by "f_c". Its value is not fixed and it depends upon the electron density of the ionosphere.
- It changes with time of day, atmospheric conditions and angle of fire of the radio waves by antenna. The existence of the critical frequency is the result of electron limitation, i.e., the inadequacy of the existing number of free electrons to support reflection at higher frequencies.
- It can be computed either using the electron density or using the maximum usable frequency as follows.

$$f_c = 8.979\sqrt{N_{\max}} \approx 9\sqrt{N_{\max}}$$

or

$$f_c = MUF/sec\theta$$

where f_c is critical frequency in Hz, N_{max} is maximum electron density per m^3, MUF is the maximum usable frequency in Hz, θ is the angle of incidence in degrees.

EFFECT OF EARTH'S MAGNETIC FIELD ON WAVE PROPAGATION

- The earth's magnetic field causes the electrons to trace complicated trajectories with cyclotron or gyrofrequency f_g = 1.4 MHz at H = 40 A/m.
- The earth's magnetic field (B) exerts a deflecting force on the moving electrons. The magnitude of this force on each electron is given by $\vec{F} = e^*(\vec{v} \times \vec{B})$

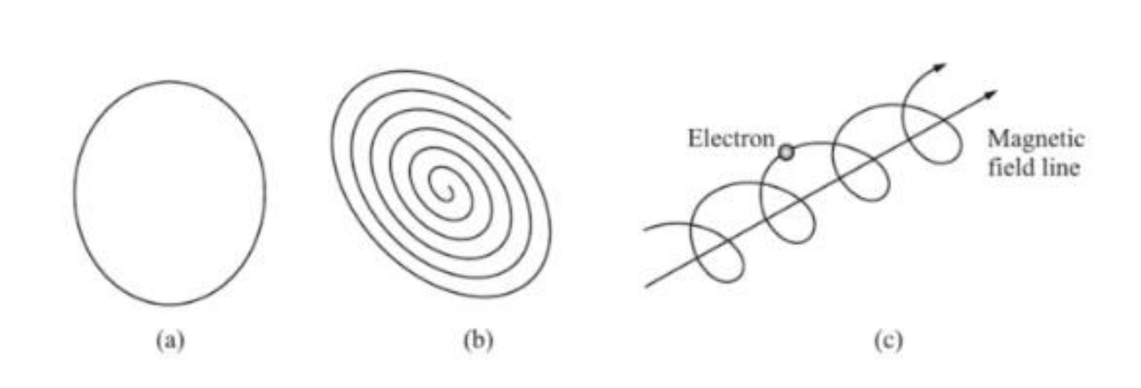
  where e is the charge of electron (C), F is the force on the electron in the ionosphere (N), v is the velocity of the electron (m/s), $B = \mu_o H$ is the magnetic flux density (Wb/m2) and H is the magnetic flux density of earth (A/m).
- Thus whenever radio wave enters into the ionosphere, a component of magnetic field which is perpendicular to the electric field of the incident radio waves cause oscillating electrons to follow an elliptical path.
- When the frequency of sky wave becomes equal to the natural frequency of revolution of free electrons due to resonance, the energy of radio waves is absorbed by the revolving electrons and they follow a spiral path. The frequency at which this phenomenon occurs is known as gyro or cyclotron frequency.

GYRO FREQUENCY

- The lowest natural frequency of a wave at which the charged particles spiral in a fixed magnetic field is known as the gyro or cyclotron frequency.
- If the frequency of the sky wave is less than the gyro frequency, the electrons move in an helical path. If the frequency of the sky wave is greater than the gyro frequency, the electrons move in an elliptical path.

$$f_g = (1/2\pi)(eB/m) = (1/2\pi)(\mu_o eH/m)$$

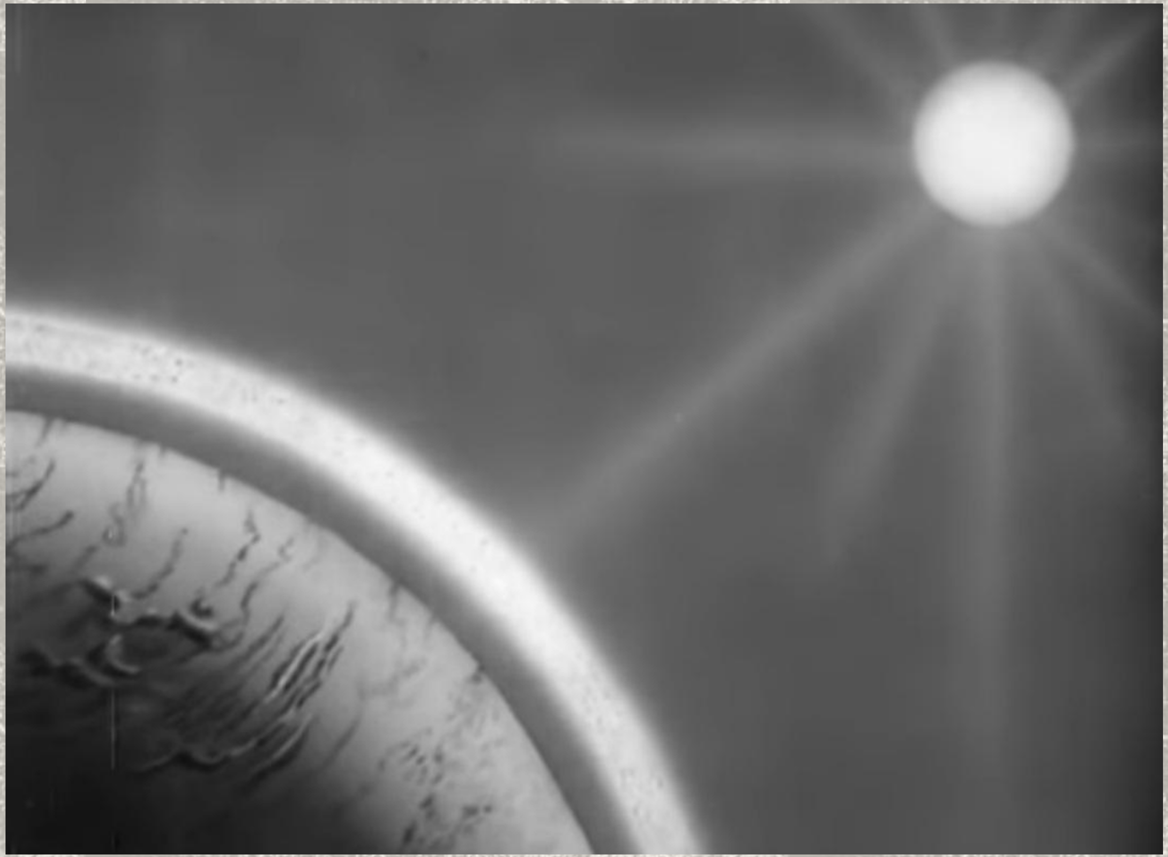
where e is the charge of the electron (C), B is the magnetic flux density (Wb/M2), m is the mass of the particle (kg), μ_o is the permeability of ionosphere (H/m), H is the magnetic field density (A/m)



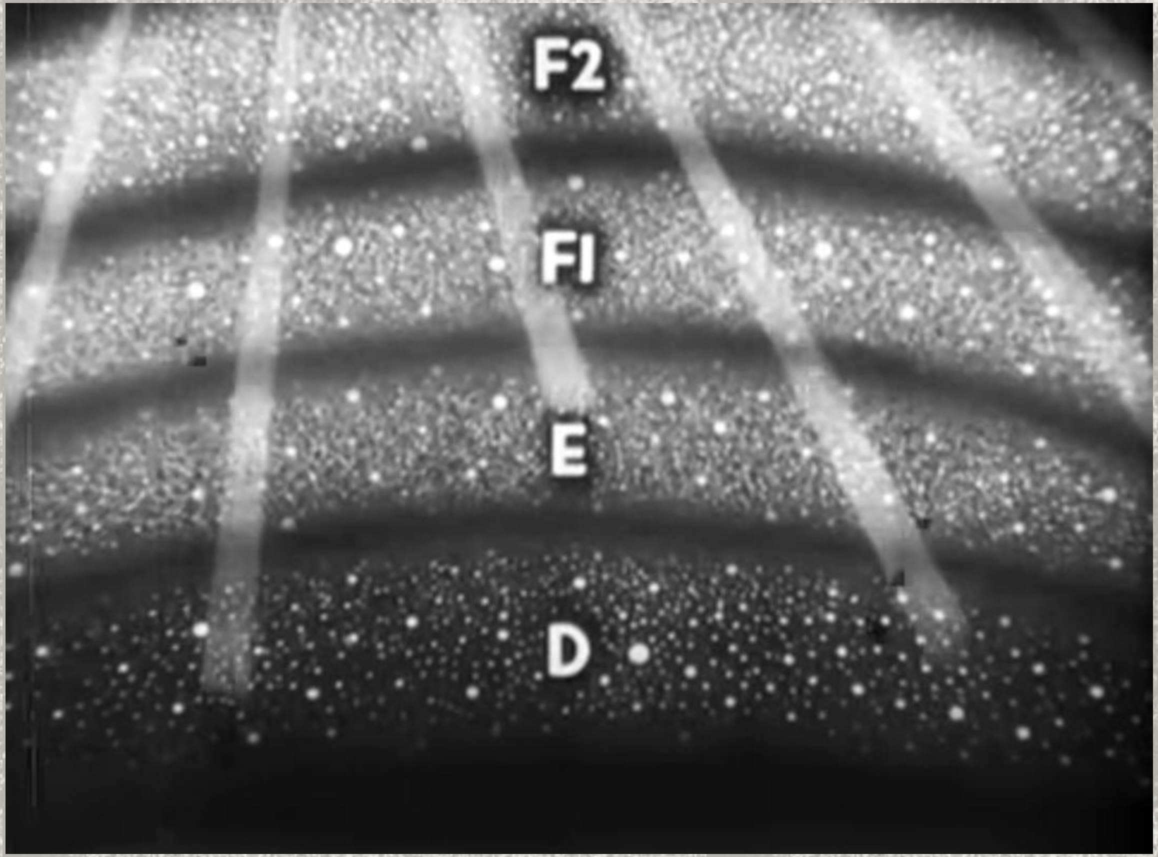
Motion of electrons under geomagnetic field

- Substituting all these values, we get **f_g = 1.4 MHz.**

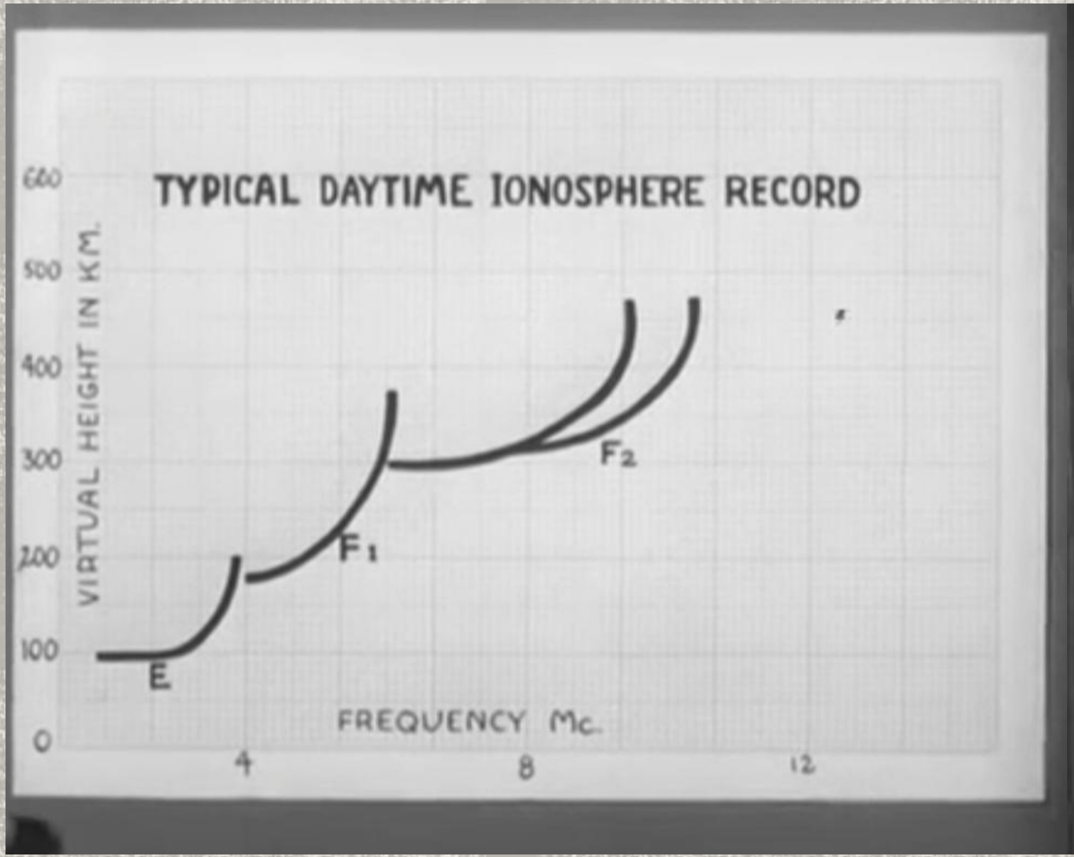
FORMATION OF IONOSPHERE



DIFFERENT LAYERS OF IONOSPHERE

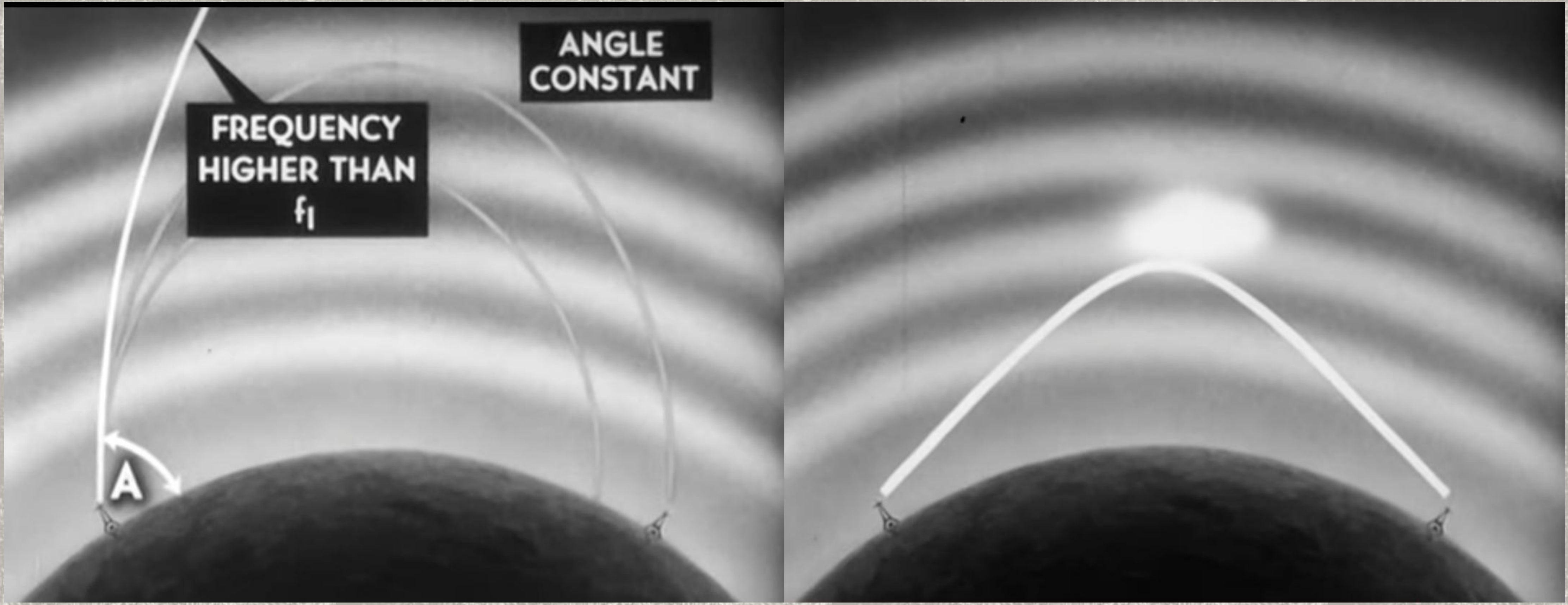


IONOSPHERE RECORD

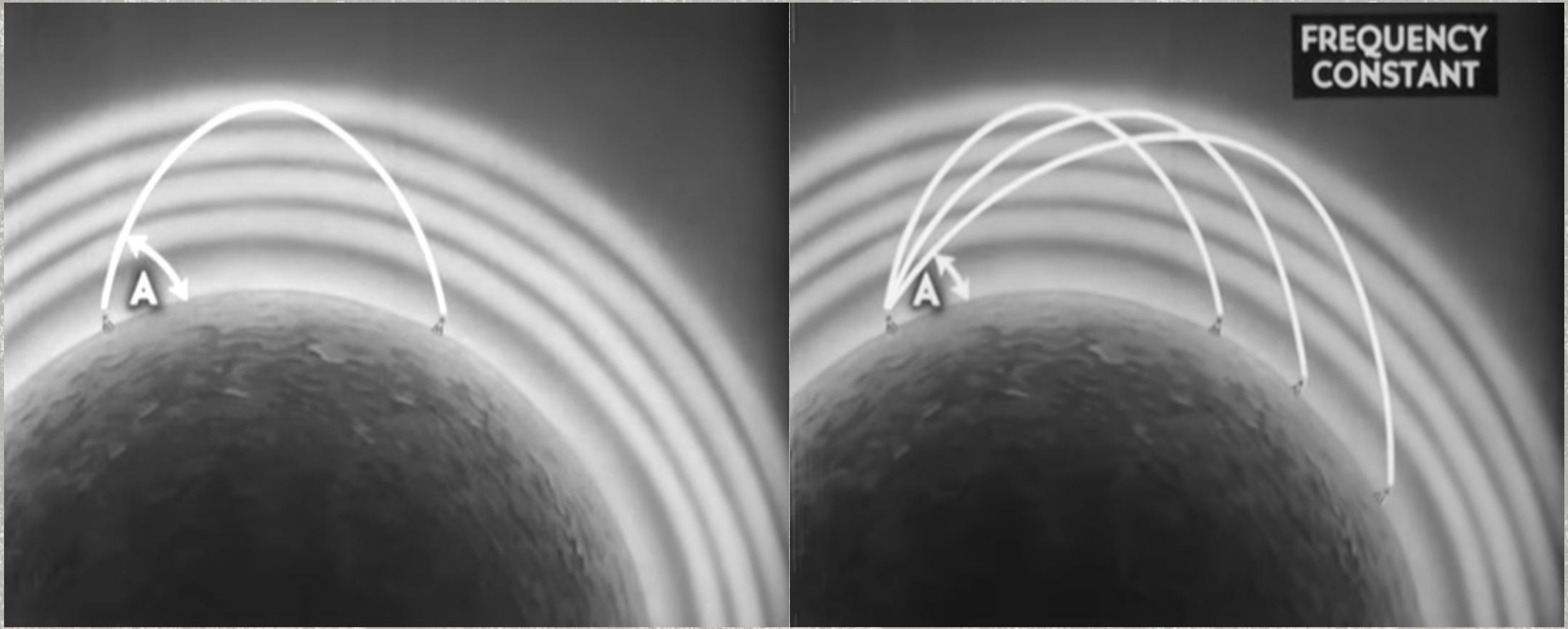


FREQUENCY RANGE	NAME OF FREQUENCY	ABBREVIATION
Below 30 kc	Very Low Frequencies	VLF
30-300 kc	Low Frequencies	LF
300-3000 kc	Medium Frequencies	MF
3 mc - 30 mc	**High Frequencies**	**HF**
30-300 mc	Very High Frequencies	VHF
300-3000 mc	Ultra High Frequencies	UHF
3000-30,000 mc	Super High Frequencies	SHF

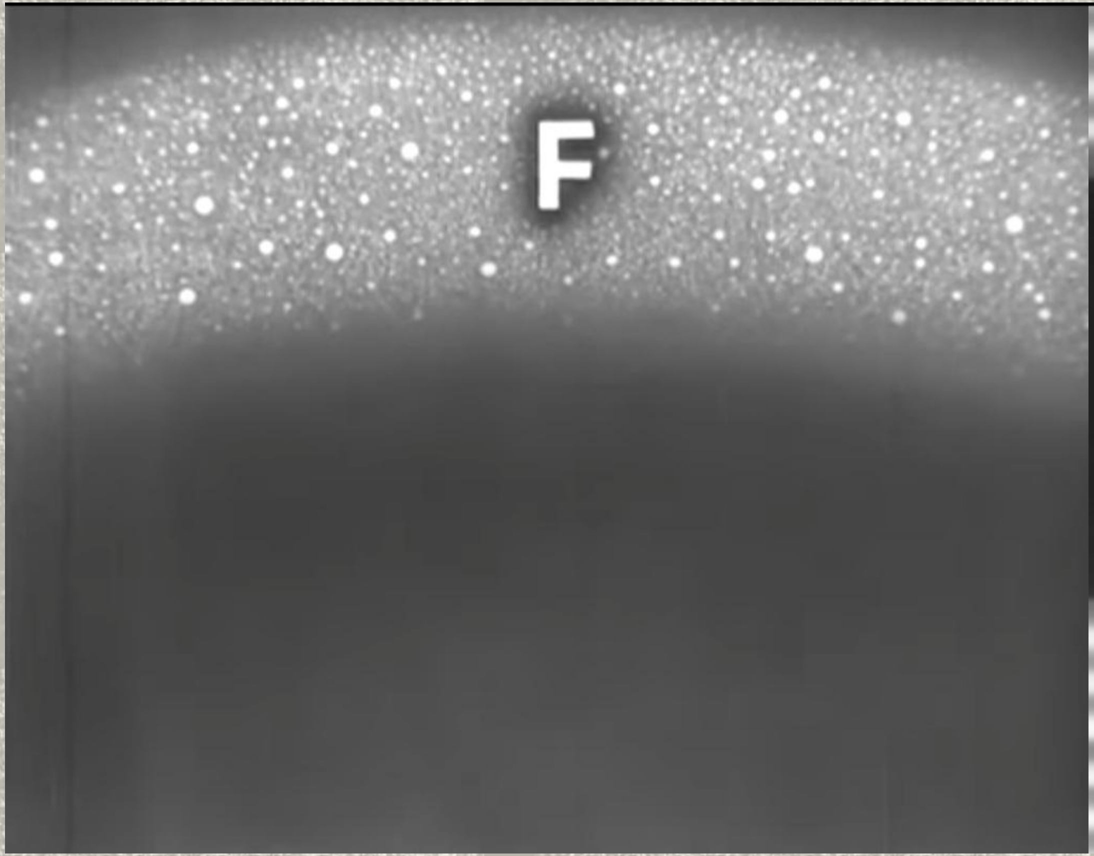
MAXIMUM USABLE FREQUENCY

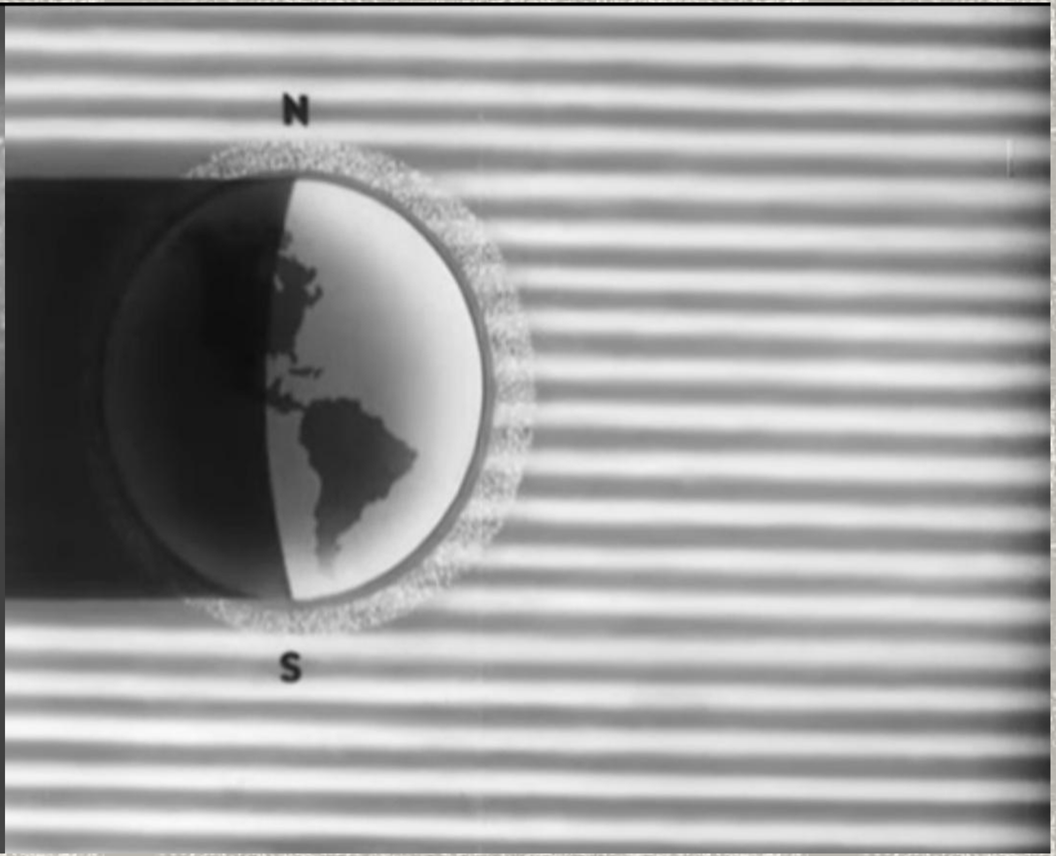


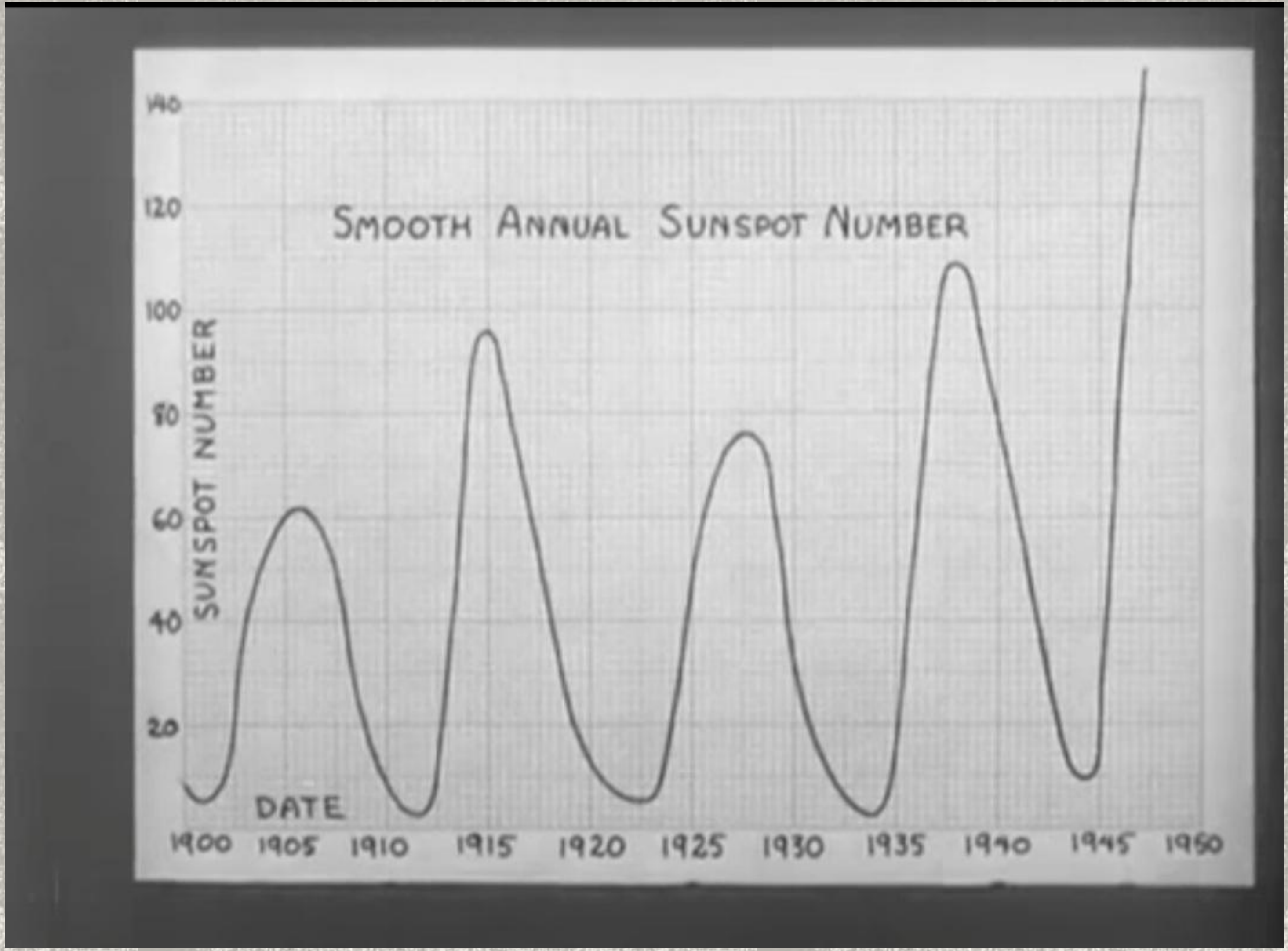
VARIATION IN SKIP DISTANCE



IONOSPHERE VARIATIONS





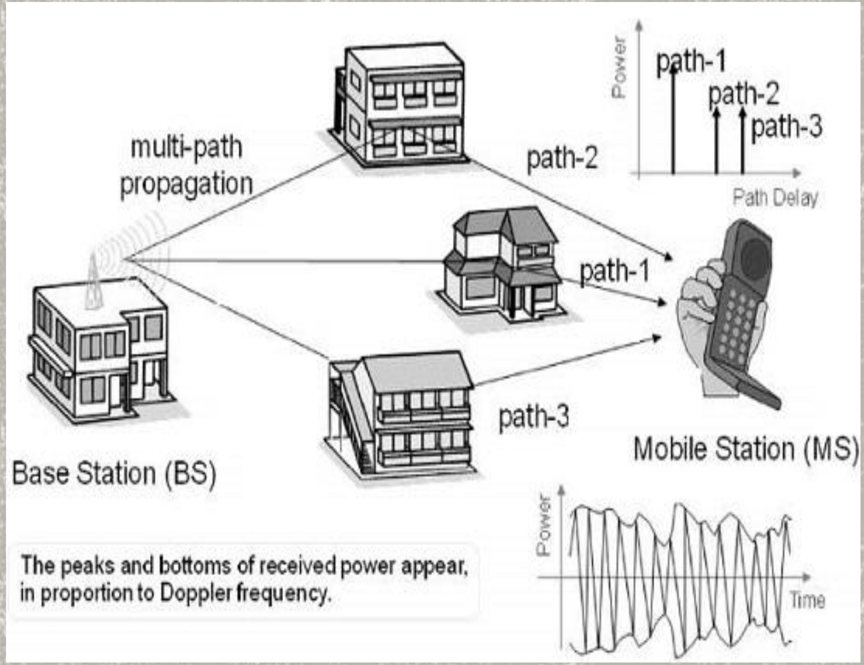


SMOOTH ANNUAL SUNSPOT NUMBER
SUNSPOT NUMBER
140
120
100
80
60
40
20
DATE
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950

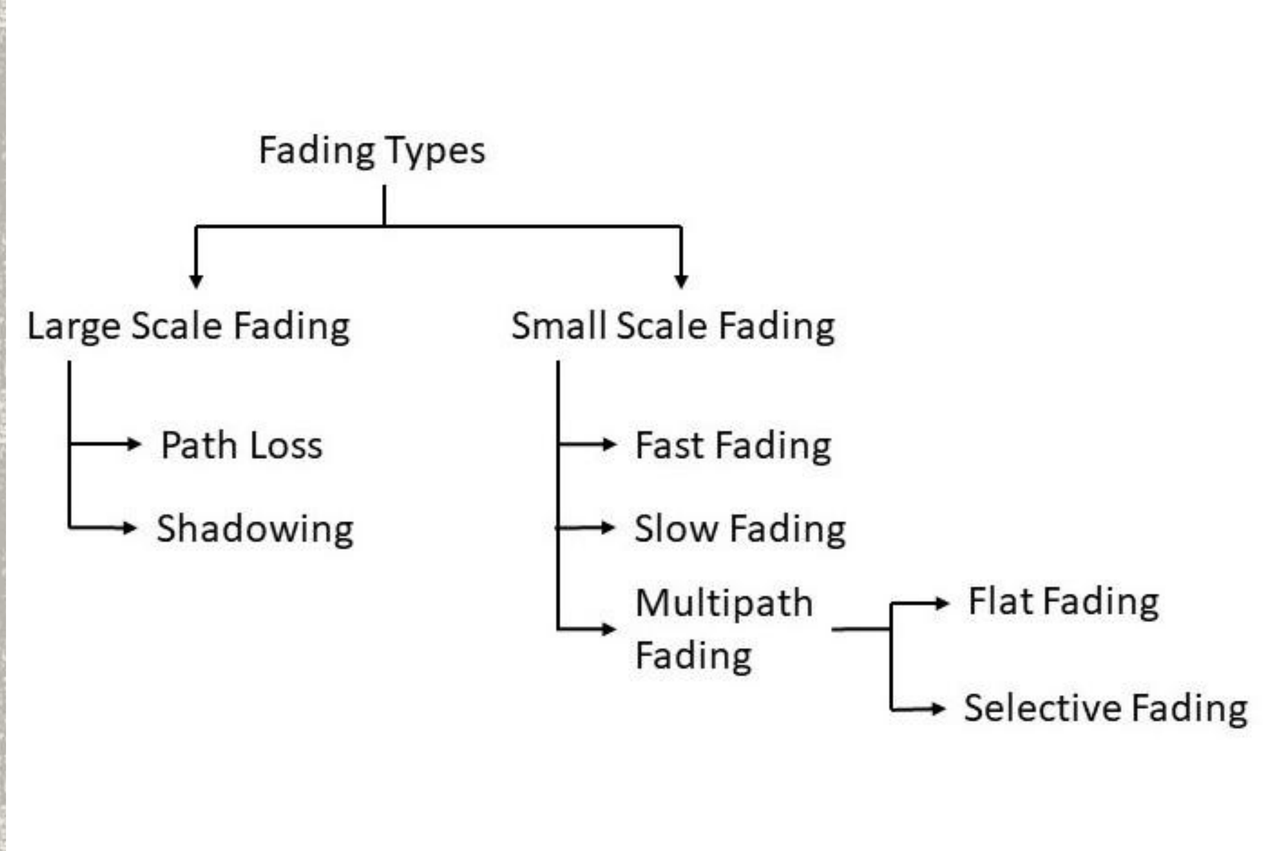
FADING

In Wireless Communication, fading refers to the attenuation of the transmitted signal power due to various variables during wireless propagation. These variables can be atmospheric conditions such as rainfall and lightning, geographical position, time, radio frequency etc.

The channel between transmitter and receiver can also be time varying or fixed depending upon whether the transmitter/receiver are fixed or moving with respect to each other which can cause fading to occur.

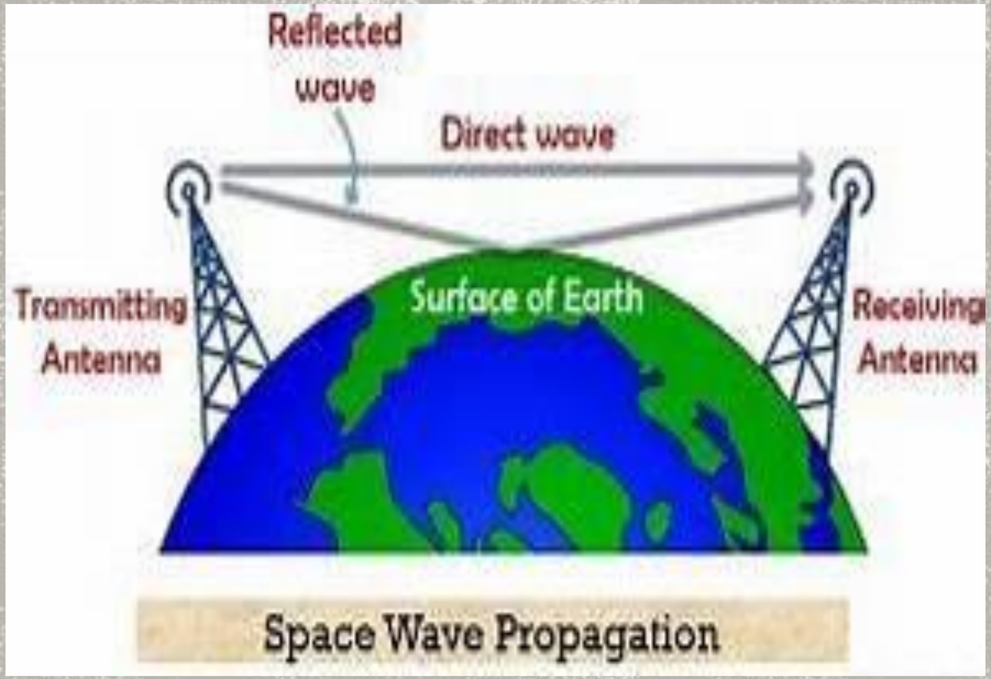


TYPES OF FADING



SPACE WAVE PROPAGATION

- Basically, space wave propagation has been adopted to overcome the disadvantages associated with ground wave propagation and sky wave propagation.
- Space wave propagation is the type of radio wave propagation in which the radio waves are propagated either directly from transmitting antenna to receiving antenna or by getting reflected from the ground.
- Basically in space wave propagation, direct transmission of the signal is achieved by line of sight communication.



- The transmission of a signal between transmitter and receiver is achieved in the tropospheric region of the atmosphere. Thus space wave propagation is sometimes referred as **tropospheric wave propagation**. Generally, the troposphere is extended up to 10 to 20 km above the surface of the earth. Thus space wave propagation occurs at about 20 km region in the atmospheric zone.

ORIENTATION OF ANTENNAS FOR SPACE WAVE PROPAGATION :

- To have a proper line of sight propagation above the surface of the earth, the orientation of the antennas must be such that the propagated wave must not interact with the curvature of the earth.
- However, for extremely low height antennas, the waves get reflected by the ground under certain conditions. And the reflected wave is received by the antenna at the other end. So, to have direct LOS communication between the two antennas, the antenna units must be placed with proper orientation on the ground.
- This type of radio wave propagation allows the transmission of signals having a very large range of frequencies. Usually, it permits the transmission of signals having a **frequency greater than 30 MHz.**

LIMITATIONS :

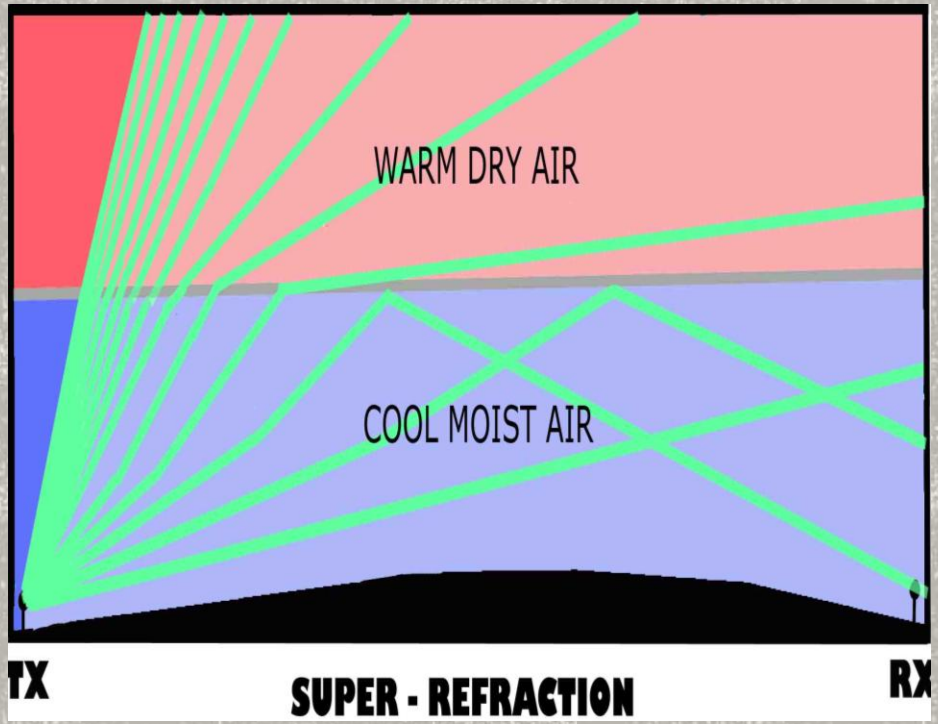
- These waves are limited to curvature of earth
- The propagation of the waves happens along the light of sight distance between the transmitting antenna and the receiving antenna which is also known as the range of communication.
- Also there should not be any obstacle for a wave to travel through the space.

APPLICATIONS :

- As, this type of propagation, permits large frequency operation, thus finds applications in
- Satellite communication
- Radar communication
- Television broadcast
- Microwave linking applications.

SUPER REFRACTION

- Super-refraction occurs when atmospheric conditions cause the radar beam to bend more than in the Standard Atmosphere.
- This happens when the atmosphere is stable relative to the Standard Atmosphere, and results in an extension in operational range.
- Radar coverage can be extended up to 150% of normal, especially if the super-refractive layer is surfaced-based.
- If the beam is not bent enough to intersect the Earth's surface, low altitude precipitation echoes that would ordinarily be below a standard refracted beam can be detected.

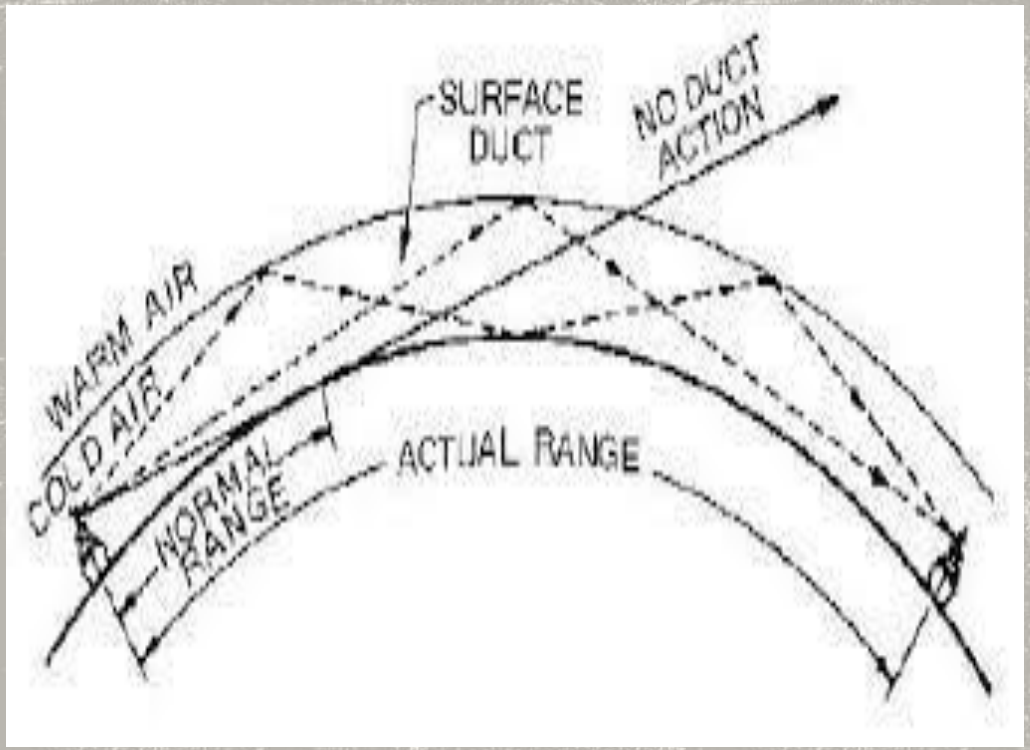


Several common situations/locations under which super refraction or beam trapping occurs are:

- The development of a low-level temperature inversion at night associated with a sharp decrease of moisture with height
- A flow of warm, dry air adverts over a cooler surface; this is most effective if the cooler surface is water – due to mixing, lower layers of the atmosphere are cooled and moistened.
- The development of a sea breeze with cool moist air moving inland beneath a warm dry continental air mass.
- Rain-cooled outflow from a thunderstorm forms a surface-based temperature inversion.
- Location of the tropopause, which denotes an area of significant decrease of lapse rate with height.

TROPOSPHERIC DUCTING

- In this propagation method, when the signal encounters a rise in temperature in the atmosphere instead of the normal decrease (known as a temperature inversion), the higher refractive index of the atmosphere there will cause the signal to be bent. Tropospheric ducting affects all frequencies, and signals enhanced this way tend to travel up to 800 miles
- Tropospheric ducting of radio and television signals is relatively common during the summer and autumn months, and is the result of change in the refractive index of the atmosphere at the boundary between air masses of different temperatures and humidity.



REFRACTIVE INDEX OF TROPOSPHERE

- It is found that the average value for the refractive index of air at ground level is around 1.0003, but it can easily vary from 1.00027 to 1.00035.
- The different gaseous particles in the air have different densities which then change the speed of light travelling through the air.
- The refractive index of atmospheric layers decreases with an increase in height above the earth's surface.
- The refractivity of the atmosphere decreases as you get higher into the atmosphere.
- This leads to a curved propagation path for rays that are incident to the atmosphere.

PROBLEMS

What is the critical frequency when a ray is incident normally in the ionosphere region with electron density 36x10^10/cm^3 ?

Solution:

Given,

$N_{max} = 36 \times 10^{10} / cm^3$

Critical frequency. $f_c = 9\sqrt{N_{max}}$

$f_c = 9\sqrt{36 \times 10^{10}}$

$= 54 \times 10^5$

$f_c = 5.4\ MHz$

What is the Maximum Usable Frequency(MUF) in F-region layer when the critical frequency is 60MHz and the angle of incidence is 70 deg ?

Solution:

Given,

$$f_c = 60\,\text{MHz}$$

$$\theta = 70^\circ$$

$$MUF = \frac{f_c}{\cos\theta}$$

$$= \frac{60 \times 10^6}{\cos 70}$$

$$MUF = 175.43\ \text{MHz}$$

PROBLEMS ON MAXIMUM USABLE FREQUENCY AND SKIP DISTANCE

PROBLEMS ON MAXIMUM USEABLE FREQUENCIES

1. Suppose a ray is incident normally in the ionosphere region with election density $36 \times 10^{10}/cm^3$. then the critical frequency is., ______

   a. 5 GHz
   b. 54 MHz.
   c. 5.4 MHz.
   d. 324 GHz

Answer:-

f_c (critical frequency) $= 9\sqrt{N_{max}}$ where $N_{max} = 36 \times 10^{10}$

$$f_c = 9\sqrt{36 \times 10^{10}} = 5.4 \text{ MHz}$$

2. What is the value of maximum usable frequency when the incident angle is $60°$ and the critical frequency is 4.5 MHz?

   a. 4.5 MHz.
   b. 2.25 MHz
   c. 9 MHz.
   d. 18 MHz.

MUF, $f_{MUF} = f_c \sec(\theta i) =$

$$\Rightarrow 4.5 \text{ MHz} \times \sec(60°) = 9 \text{ MHz.}$$

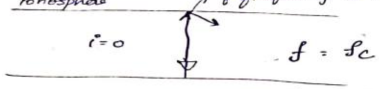
Problem on Skip Distance:-

Assume that reflection takes place at a height of 400 km and the maximum density in the ionosphere corresponds to a 0.8 refractive index at 15 MHz. What will be the range (assume flat earth) for which MUF is 20 MHz.

Refractive index of the ionosphere,

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

if frequency is high, it penetrates the ionosphere.



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

$$\text{Skip distance}, D = 2h\sqrt{\left(\frac{f_{muf}}{f_c}\right)^2 - 1}$$

Given,

$h = 400$ km.

refractive index = 0.8 (μ)

$f = 15$ MHz

$f_{muf} = 20$ MHz.

Now,

$\mu = \sqrt{1 - \frac{81N}{f^2}}$ → electron density in ionosphere.

$$0.8 = \sqrt{1 - \frac{81}{f^2}N}$$

$$0.8 = \sqrt{1 - \frac{81}{(15\,MHz)^2}N}$$

$$N = 10^{12}$$

$$D = 2h\sqrt{\frac{f_{muf}^2}{f_c^2} - 1}$$

Now,

$$f_c = 9\sqrt{N} = 9\times10^6$$

Skip distance, D.

$$D = 2h\sqrt{\frac{f_{muf}^2}{f_c^2} - 1}$$

$$= 2\times400\sqrt{\left(\frac{20}{9}\right)^2 - 1}$$

$$\boxed{D = 1567.673 \text{ km}}$$

REFRENCE

- https://electronicsdesk.com/space-wave-propagation.html
- www.byjus.com
- https://www.sanfoundry.com
- https://en.m.wikipedia.org/wiki/Critical_frequency
- https://buzztech.in/characteristics-of-different-ionospheric-layers/
- https://www.quora.com/What-is-difference-between-critical-frequency-and-maximum-usable-frequency

THANK YOU