Introduction

Communication Systems
Lecture 1
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What We are Going to Learn?

Discuss about

- RF/ Microwave Links
- Microwave Communication
- Different Communication Systems
  - Satellite Communication System
  - Analog/ Digital Broadcast System

- Link Budget Calculations

What is Microwave?

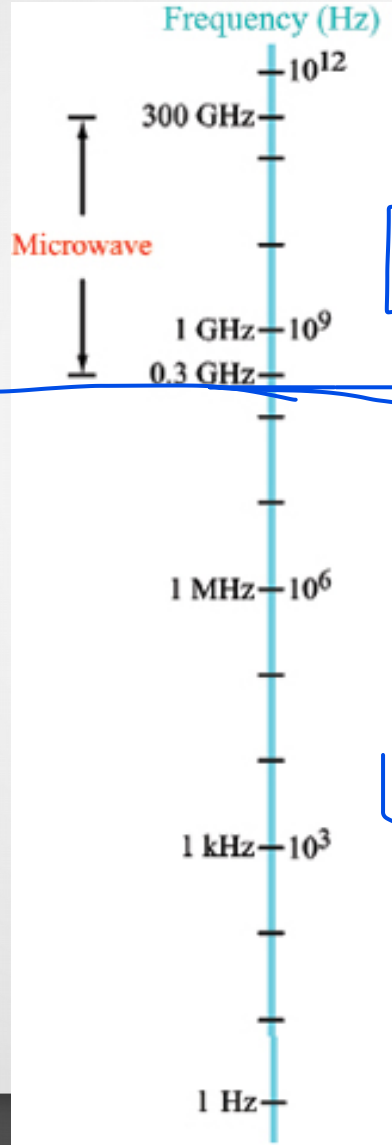
Radio waves of very short wavelength.

Frequency Band	Frequency Range	Wavelength Range
Extra Low Frequency (ELF)	<3 KHz	>100,000m
Very Low Frequency (VLF)	3-30KHz	100,000-10,000m
Low Frequency (LF)	30-300KHz	10,000-1,000m
Medium Frequency (MF)	300-3000MHz	1,000-100m
High Frequency (HF)	3-30MHz	100-10m
Very High Frequency (VHF)	30-300MHz	10-1m
Ultra High Frequency (UHF)	300-3000MHz	100-10cm
Super High Frequency (SHF) or Microwave	3-30GHz	10-1cm
Extra High Frequency (EHF) or Millimeterwave	30-300GHz	10-1mm

Microwave Band

Frequency Band	Frequency Range
L	1-2GHz
S	2-4GHz
C	4-8GHz
X	8-12GHz
Ku	12-18GHz
K	18-26.5GHz
Ka	26.5-40GHz

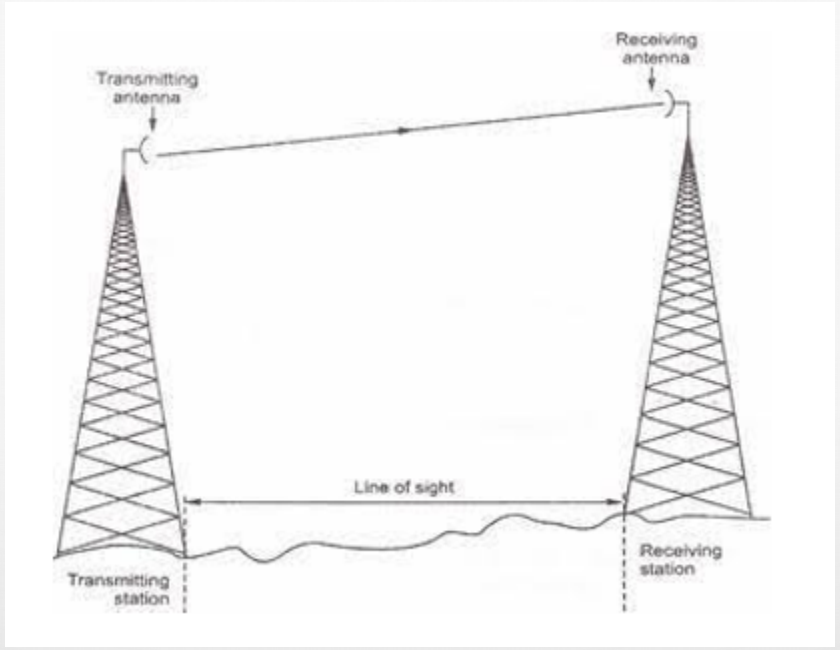
Frequency Ranges and their Applications

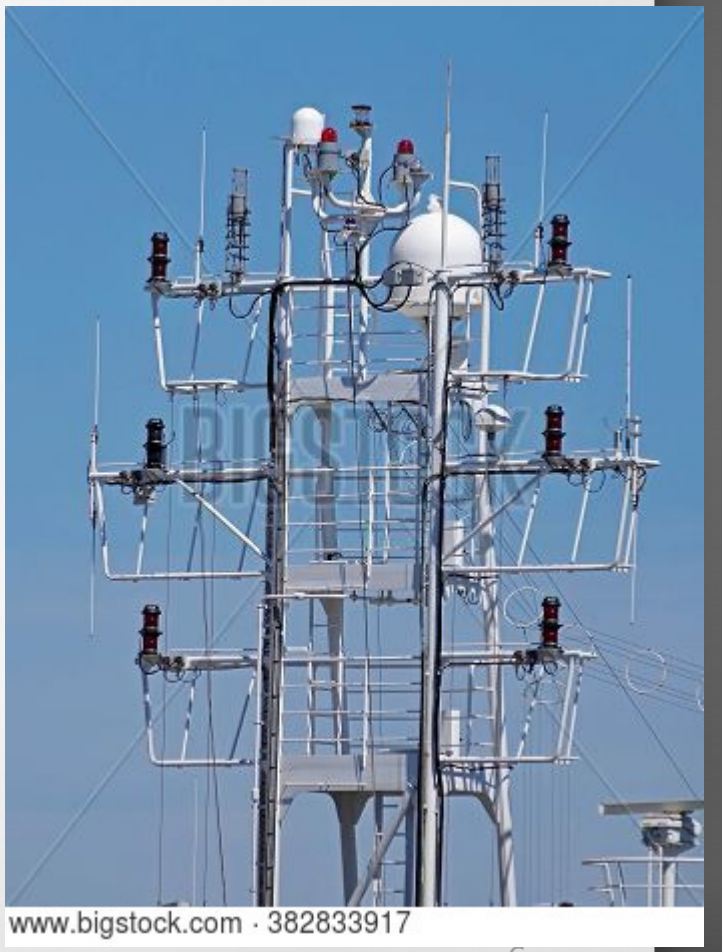


Band	Applications
Extremely High Frequency (30–300 GHz)	Radar, advanced communication systems, remote sensing, radio astronomy
Super High Frequency (3–30 GHz)	Radar, satellite communication systems, aircraft navigation, radio astronomy, remote sensing
Ultra High Frequency (300 MHz – 3 GHz)	TV broadcasting, radar, radio astronomy, microwave ovens, cellular telephone
Very High Frequency (30–300 MHz)	TV and FM broadcasting, mobile radio communication, air traffic control
High Frequency (3–30 MHz)	Shortwave broadcasting
Medium Frequency (300 kHz – 3 MHz)	AM broadcasting
Low Frequency (30–300 kHz)	Radio beacons, weather broadcast stations for air navigation
Very Low Frequency (3–30 kHz)	Navigation and position location
Ultra Low Frequency (300 Hz – 3 kHz)	Audio signals on telephone
Super Low Frequency (30–300 Hz)	Ionospheric sensing, electric power distribution, submarine communication
Extremely Low Frequency (3–30 Hz)	Detection of buried metal objects
	Magnetotelluric sensing of the Earth's structure

Applications of Microwave in Communication

- For Radar communication in Navigation.
- Ground based line of sight communication.
- Satellite Communication.





Advantages of Microwave in Communication

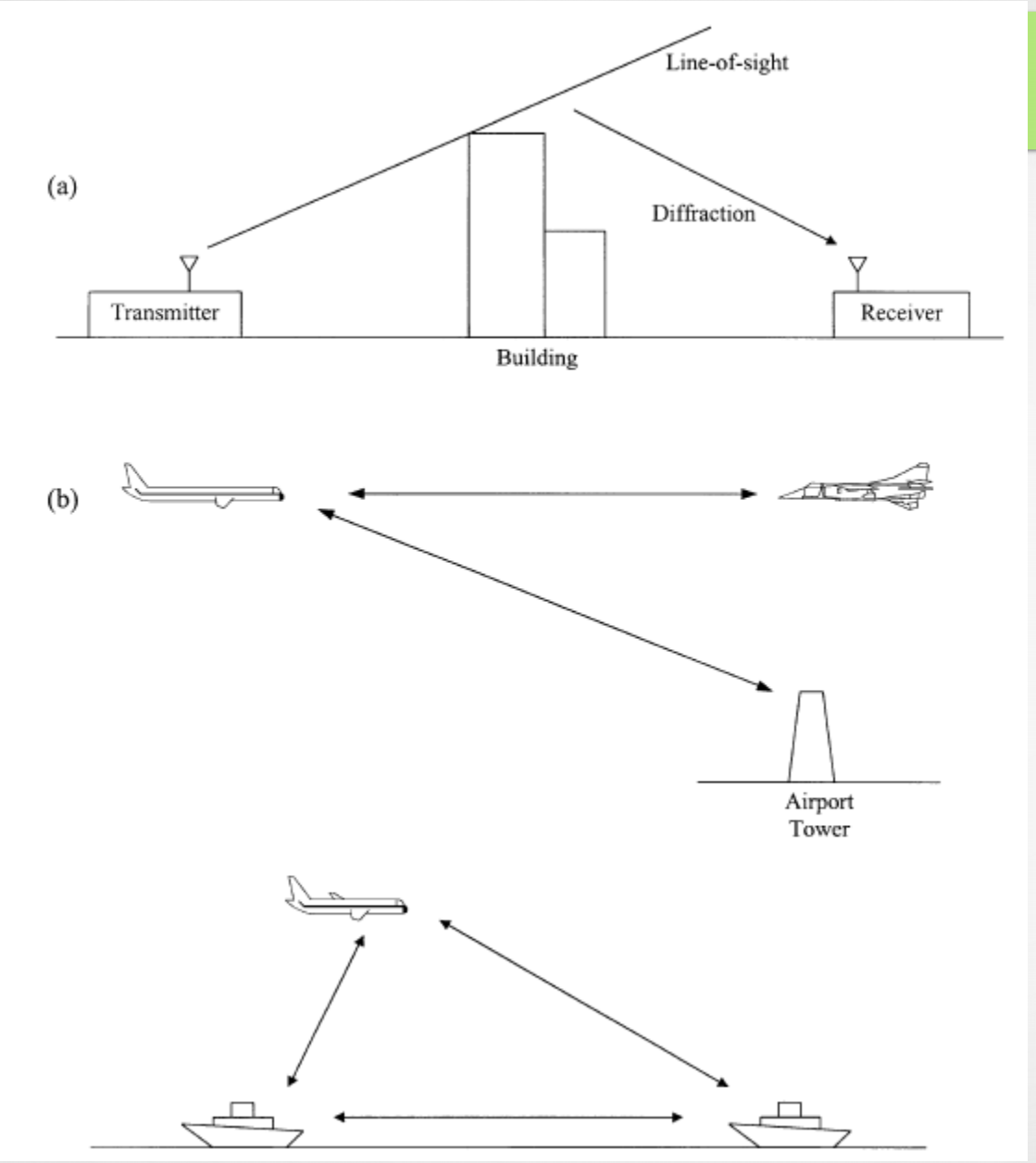
- Broader Bandwidth.
  - Can be used as the backbone of many communication systems.

- Improved Directivity and Gain of the Antennae
  - At microwave frequencies the size of the dipole is very small. Hence by adding many dipoles the antenna directivity and gain can be improved.

Advantages of Microwave in Communication

- Reliability.
  freznel zone clearance is low
  less prone to scaterring and abosrption
  - Higher reliability with the weather conditions compared to MF/ HF.

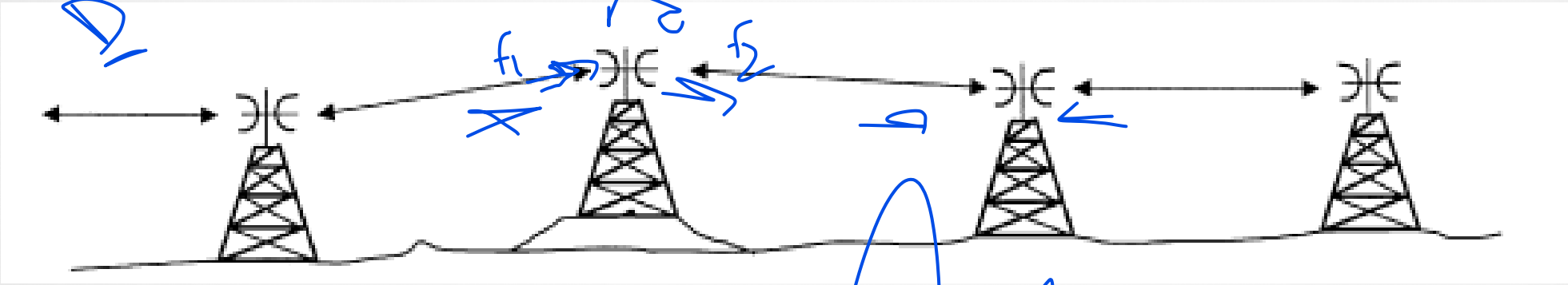
- Power Requirement
  - Power requirement is lower compared to MF/ HF due to the high gain of the microwave antennae.


(a)
Line-of-sight
Diffraction
Transmitter
Receiver
Building
(b)
Airport
Tower

Relay Systems → long distance

coverage

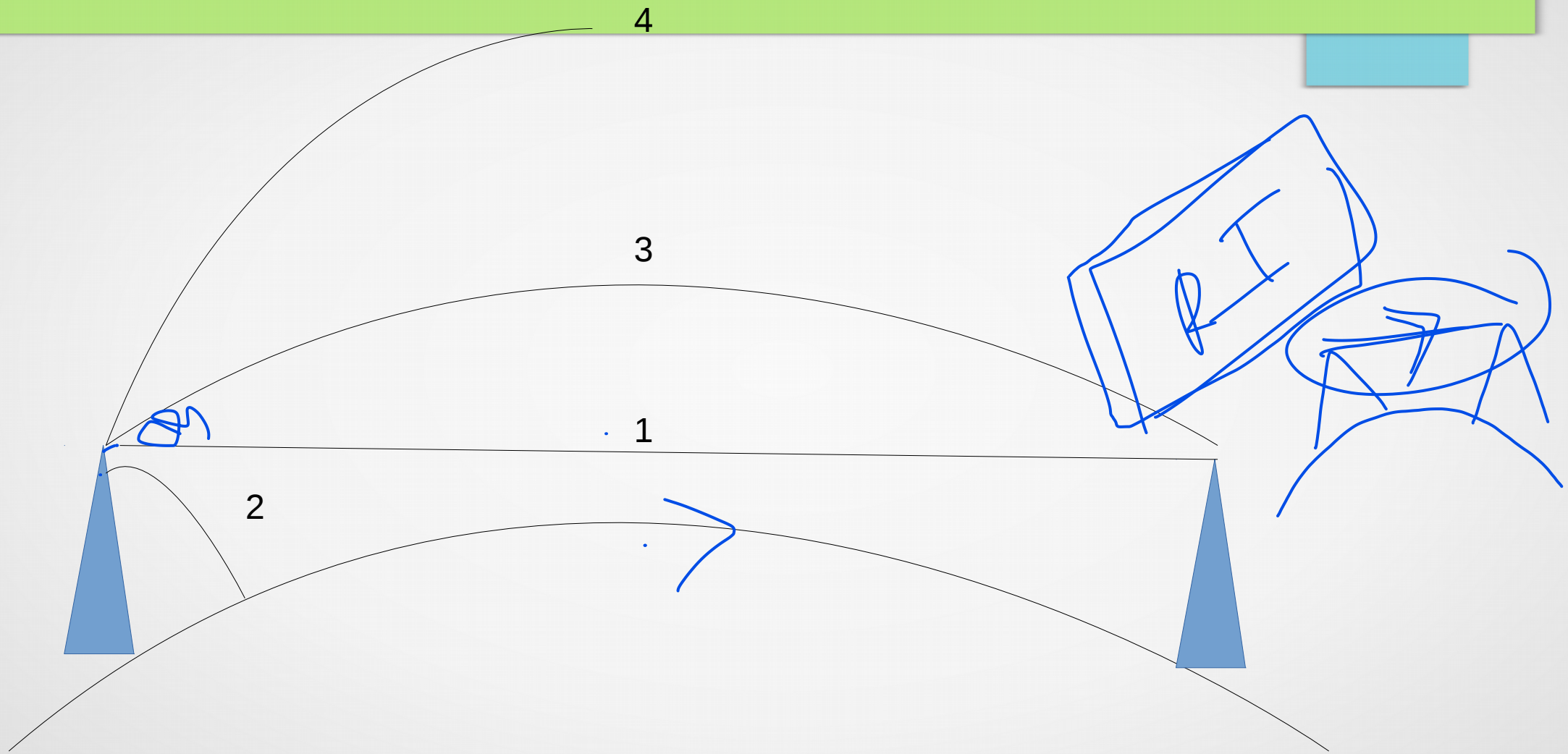
extend the transmission range and overcome signal attenuation caused by the propagation losses over long distances. A repeater system acts as a regenerator, receiving weak incoming signals, amplifying them, and retransmitting them at a higher power level to maintain signal strength and quality.



LOS

Bending of Ray Due to Atmospheric Refractive Gradient

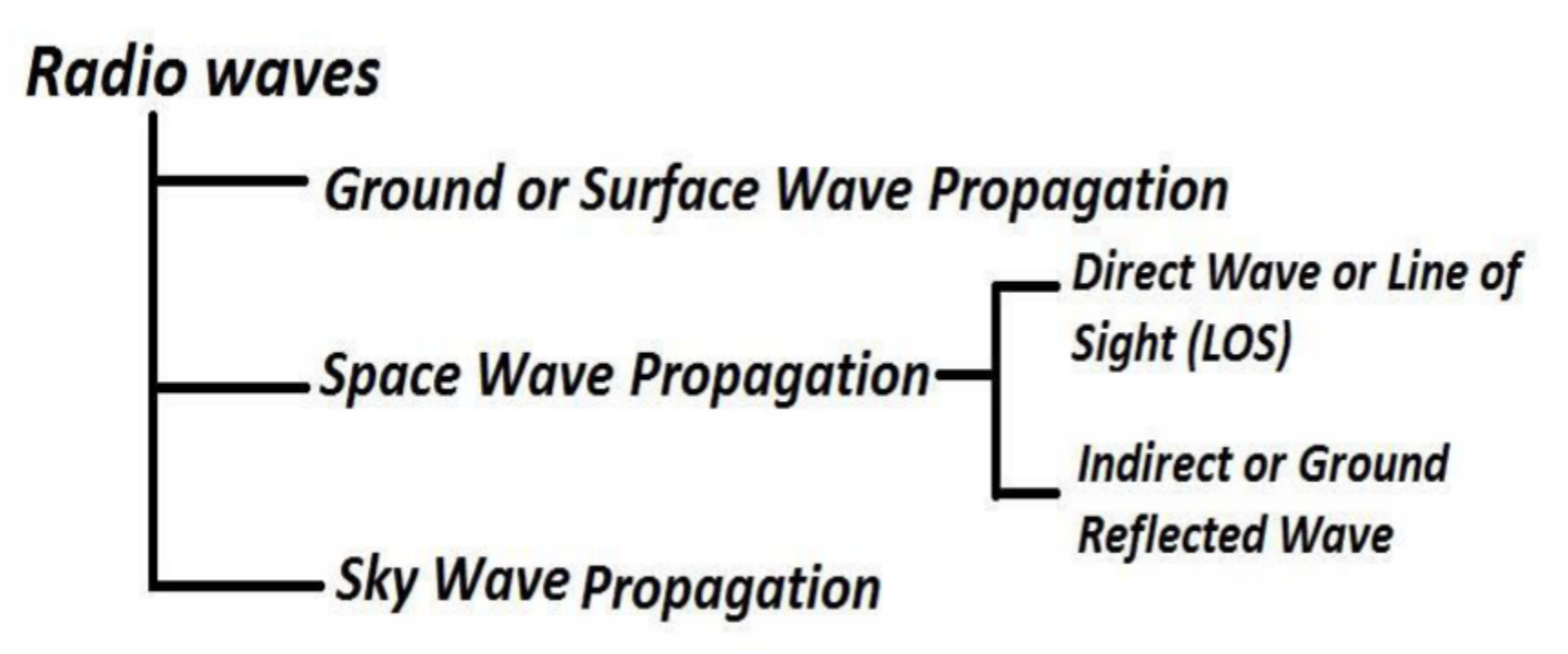
- Refraction occurs for LOS microwave links due to atmospheric refractive resulting bent ray path.
- The density of the atmosphere decreases exponentially with height.
- If the gradient is such that the curvature of the ray path is equal to the earth's surface, then the ray and the surface will be parallel.
- A beam with higher elevation angle is used to have the link operative.

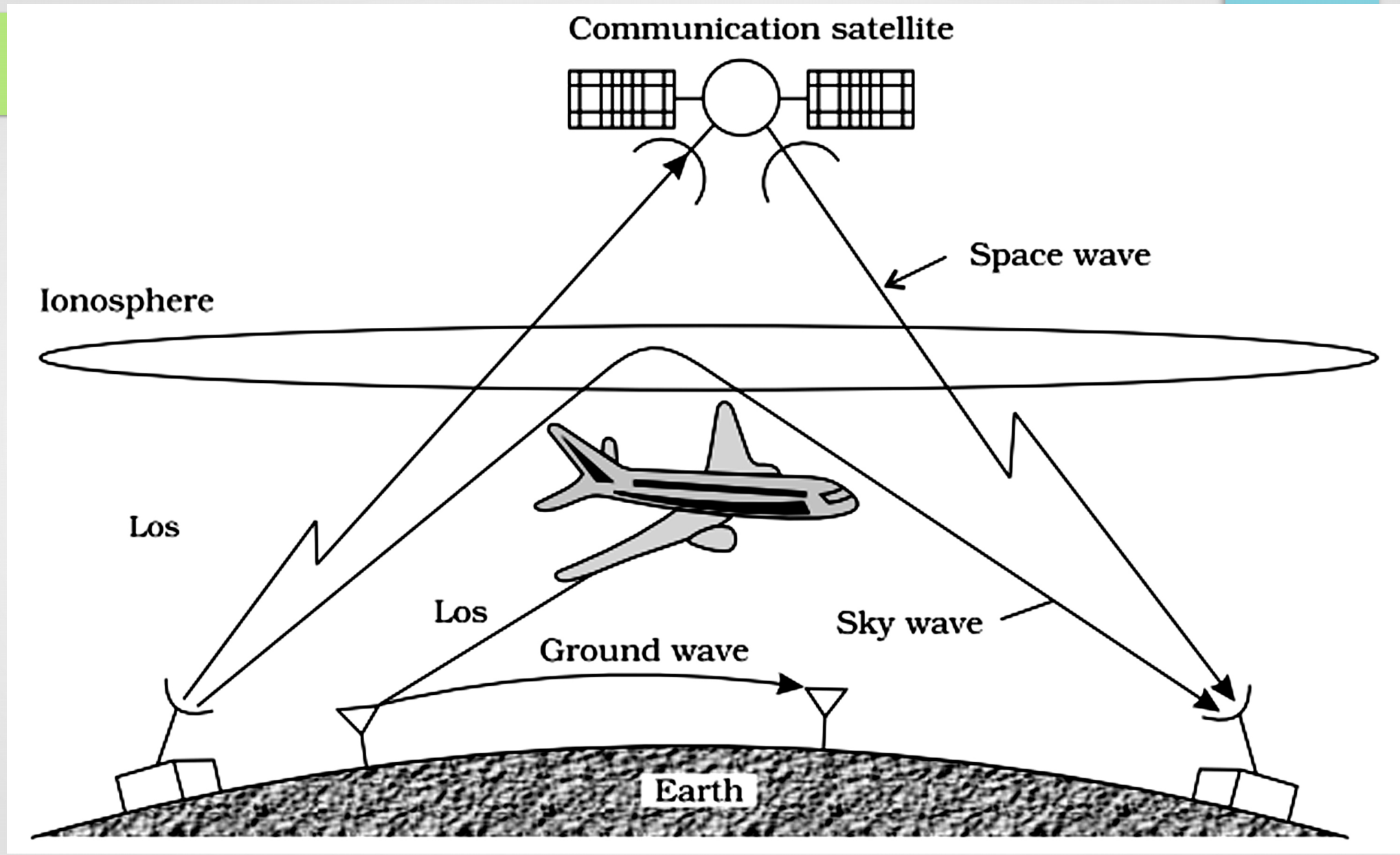

4
3
1
2

Why Antenna Beam Cannot be made very sharp?

- The refractive gradient of the atmosphere is subjected to variations from time to time resulting different curvatures of the ray path.
- Hence the there will be a loss of the beam alignment.

Classification of Radio Wave Propagation




Communication satellite
Space wave
Ionosphere
Los
Los
Sky wave
Ground wave
Earth

Ground Waves or Surface Waves

- Surface Wave propagates or travels close to the surface of the Earth. Follows the curvature of the earth and can travel at distances beyond the horizon (upto some km)
- Frequencies up to 2 MHz.
- Must have vertically polarized antennas.
- Strongest at the low- and medium-frequency ranges.
- AM broadcast signals are propagated primarily by ground waves during the day and by sky waves at night.

Ground Waves or Surface Waves

- Requires relatively high transmission power.
- They are limited to very low, low and medium frequencies which require large antennas.
- Losses on the ground vary considerably with surface material.
- Ground Wave get attenuated due to earth imperfection, absorption and reflection by earth surface and attenuation increases with frequency.

Advantages of Ground Waves

- Given enough power they can be used to communicate between any two points in the world.
- These waves are more efficient and also these are not affected by the change in atmospheric conditions, due to the bending around the corners or obstructions during propagation.
- They are relatively unaffected by changing atmospheric conditions like sky waves.
- Interference occurs due to atmospheric noise only.

Why ground waves are not suitable for high frequency?

The degree of attenuation is mainly dependent on the frequency of the wave and is directly proportional to it. So, ground wave propagation is not suitable for high frequency as the losses are high. Ground wave propagation

Attenuation refers to the loss of signal strength as the wave travels through a medium, such as the Earth's surfac

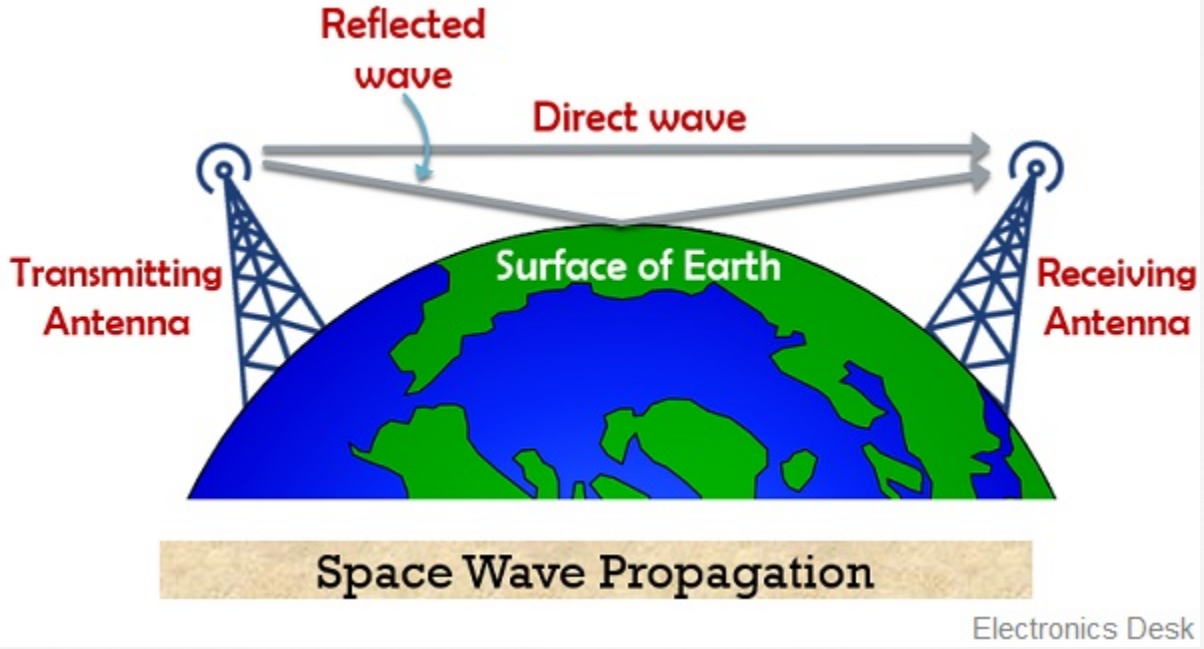
absorption and scattering by the Earth's surface

Applications of Ground Wave?

These can be used for one-way communication from the military to submerged submarines as they penetrate to a significant depth into seawater.

AM, FM and television broadcasting can be done with the help of ground waves

Space Waves



This type of radio waves include radiated energy that travels in the lower few miles of the earth's atmosphere. They include both direct and ground reflected waves.

Direct Waves

- A direct wave, travels in a straight line directly from the transmitting antenna to the receiving antenna.
- Direct-wave communication is often referred to as line-of-sight communication.
- Direct or space waves are not refracted, nor do they follow the curvature of the earth. These waves are deviated (reflected) by obstructions and cannot travel over the horizon or behind obstacles.

Effect of Imperfect Earth

- Attenuation and attenuation distortion
- Free space loss
- Noise
- Atmospheric absorption
- Multipath
- Refraction
- Thermal noise

Effect of the Earth on Space Wave Propagation

- Repeater stations extend the communication distance at VHF, UHF, and microwave frequencies.
- A repeater is a combination of a receiver and a transmitter operating on separate frequencies.
- The receiver picks up a signal from a remote transmitter, amplifies it, and retransmits it (on another frequency) to a remote receiver.
- Repeaters are widely used to increase the communication range for mobile and hand-held radio units.

Effect of the Earth on Space Wave Propagation

- In a **trunked repeater system**, multiple repeaters are under the control of a computer system that can transfer a user from an assigned but busy repeater to another, available repeater, thus spreading the communication load.
- Communication satellites act as fixed repeater stations.
- The receiver-transmitter combination within the satellite is known as a **transponder**.

Effect of the Earth on Space Wave Propagation

- Because of diffraction, a direct space wave can travel ~ 4/3 greater than line-of-sight. This distance is known as the radio horizon and can be approximated as:

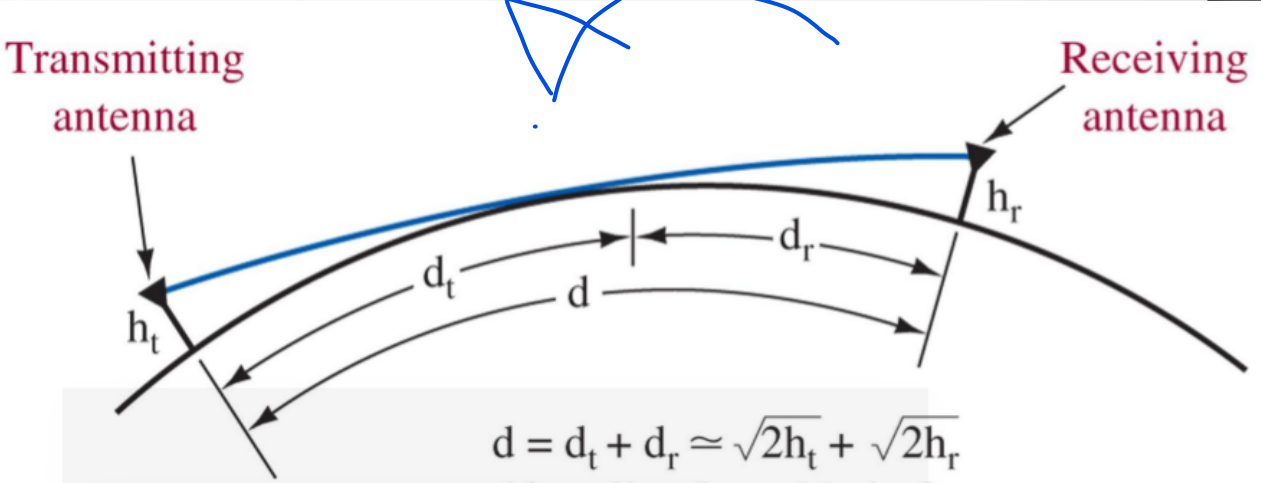
$$d \cong \sqrt{2h_t} + \sqrt{2h_r}$$

Where:

d = radio horizon (mi)

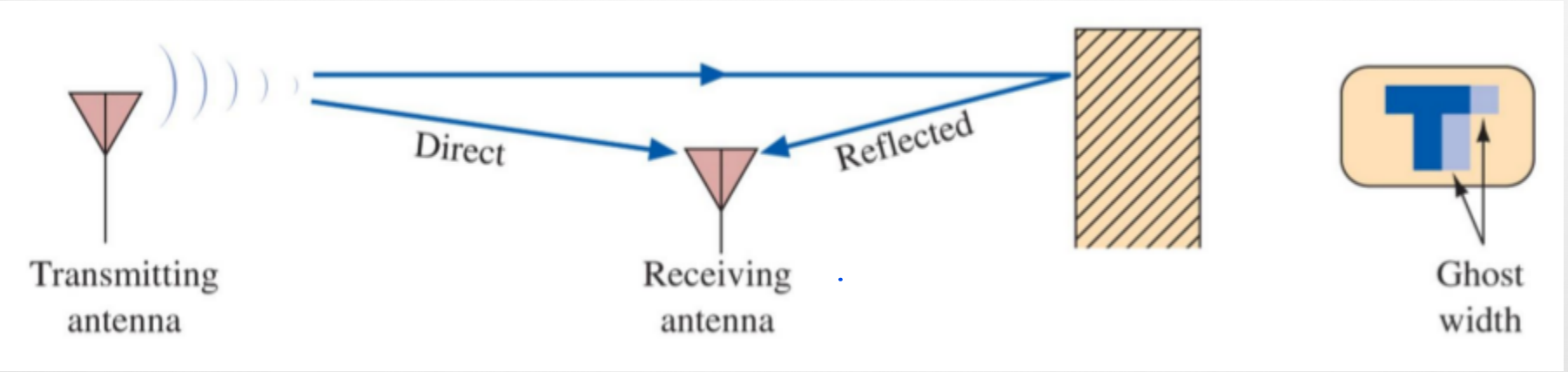
h_t = transmitting antenna height (ft)

h_r = receiving antenna height (ft)



Ghosting Condition

- Ghosting is a condition that occurs when the same signal arrives at a TV receiver at two different times; the reflected signal travels farther and is weaker than the direct signal, resulting in double image



Sky Wave Propagation

- The propagation of Space and Ground waves are limited by the curvature of earth.

- So for long distance communication of thousands of km or more are performed by Sky waves or ionospheric waves.

- Also Known as Skip/ Ionospheric/Hop/ wave.

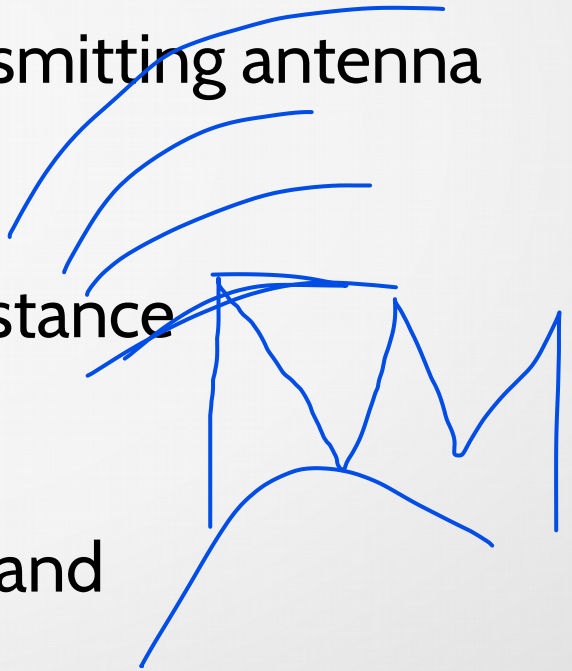
- HF radio communication (2 and 30MHz) is a result of sky wave propagation.

Examples: Amateur radio.

Sky Wave Propagation

- The ionosphere is a layer of atmosphere from 25 to 250 miles above earth's surface which contains charged particles.

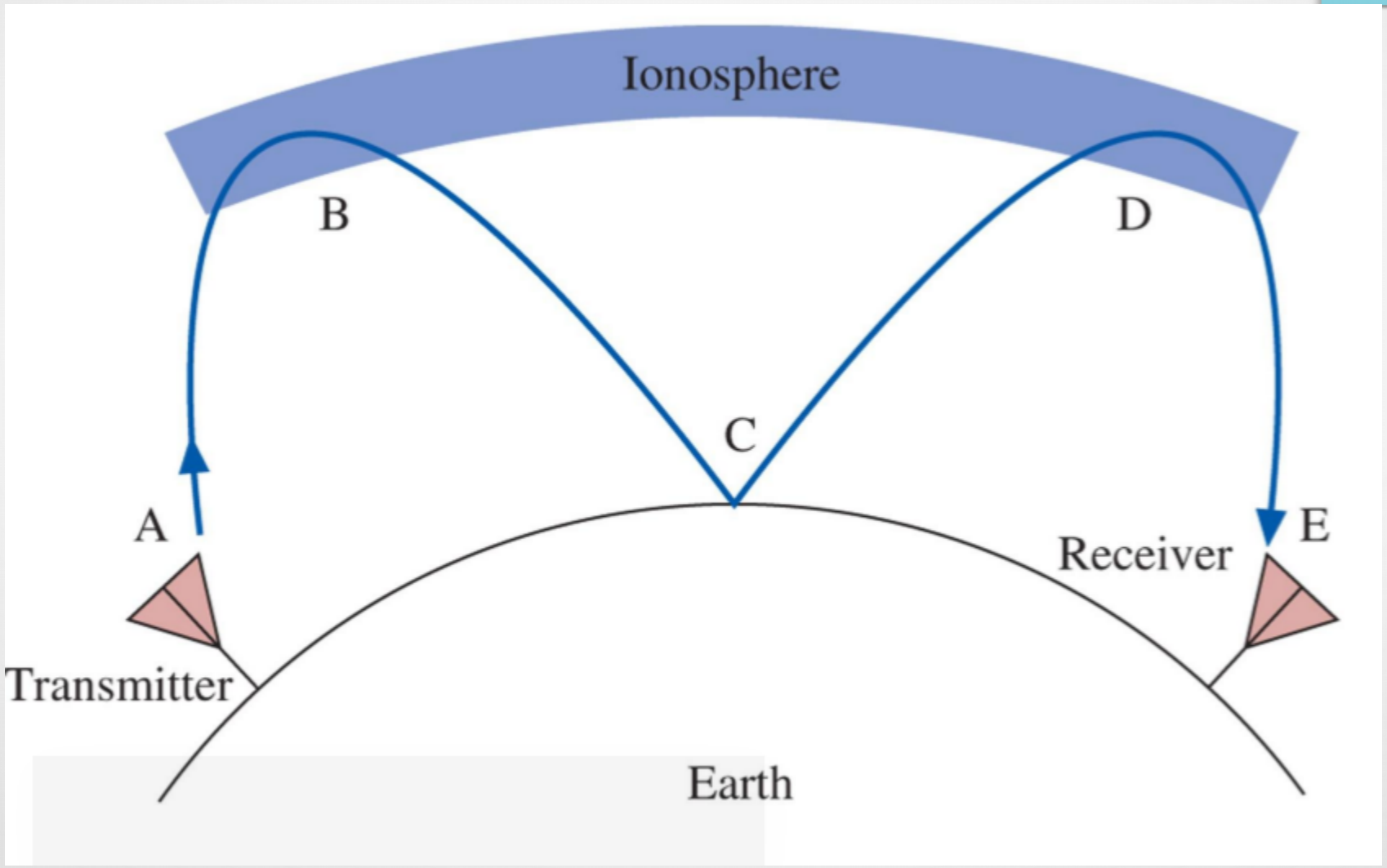
- A Sky Wave is a radio wave that is radiated from a transmitting antenna in a direction toward the ionosphere.



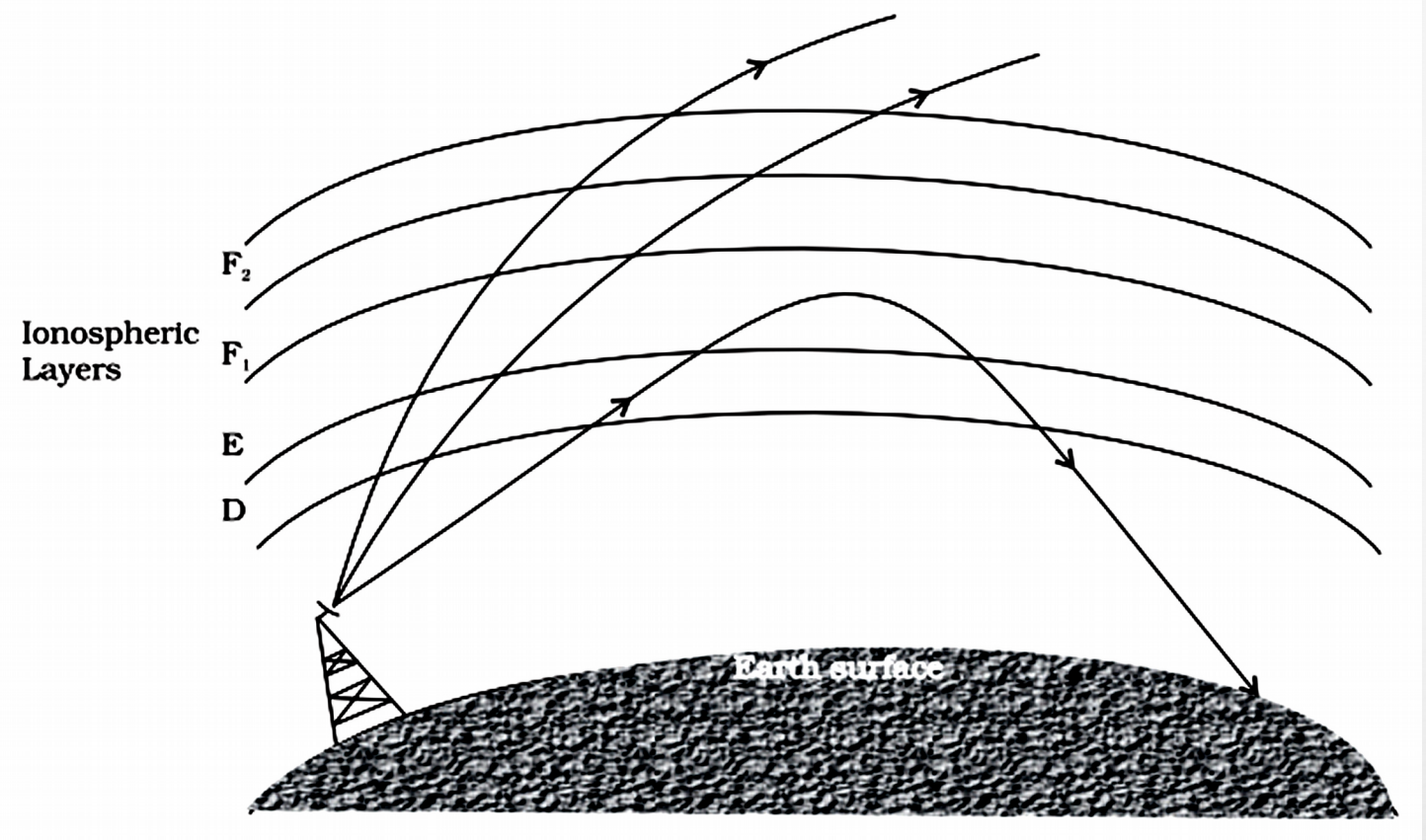
- One of the most frequently used methods for long-distance transmission.

- Waves bounce between the ionosphere via refraction and the ground via reflection.
- The alternate bouncing is known as skipping.

Sky Wave Propagation



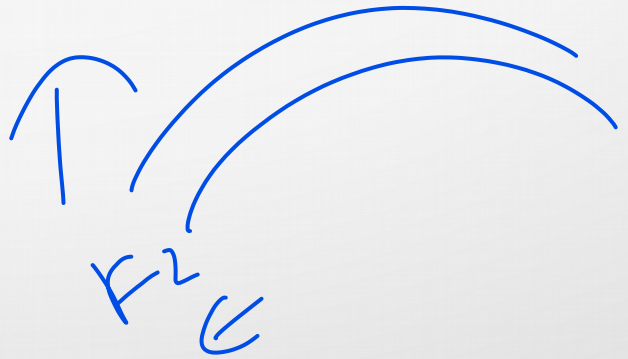
Sky Wave Propagation



Sky Wave Propagation

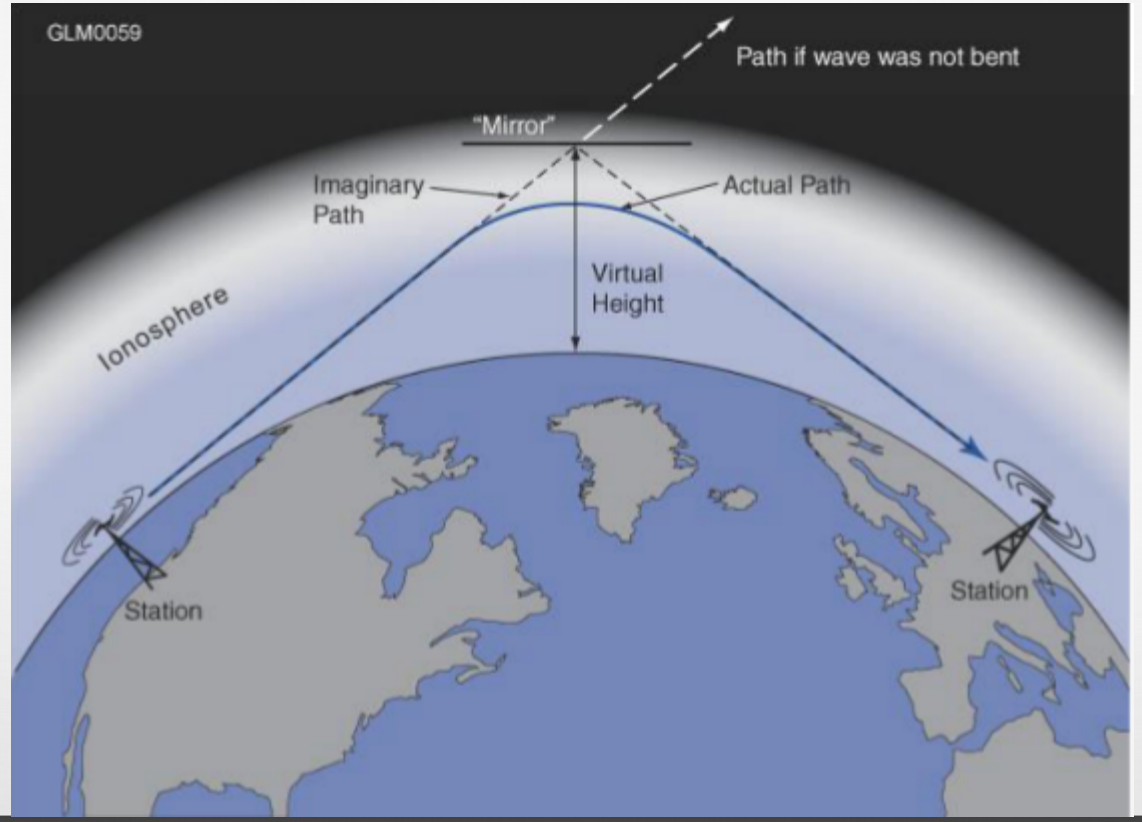
- Signal reflected from ionized layer of atmosphere back down to earth
- Signal can travel a number of hops, back and forth between ionosphere and earth's surface
- Reflection effect caused by refraction.
- The higher the region in the ionosphere where the hop occurs, the greater the distance the wave can travel.

- F2 skip can travel up to 2500 miles
- E skip can travel up to 1200 miles



Sky Wave Propagation

The virtual height is the height from which the radio wave appears to be reflecting



Sky Wave Propagation

Fluctuations in the ionosphere can cause radio signals to take different paths (multipath) as they travel between the Earth and the ionosphere. These multipath signals can arrive at the receiver with different delays, resulting in signal distortion, fading, or interference.

- Sky-wave propagation can include **multiple hops** between the Earth and the ionosphere.
- Sky-wave signals due to fluctuations in the ionosphere which can create **multiple paths for the signal (multipath)**. The combination of multipath signals can cause some **distortion or fading**.
- If the ionosphere is very dense, then the critical angle is high and short skip is possible.
- Short skip distances are much shorter than the usual skip Distances.

Short skip on the 10 M band is a good indicator that sky wave propagation is possible on 6 M.

Ionospheric Propagation

- For many years, numerous organisations have been employing the **High Frequency (HF) spectrum to communicate over long distances**.
- It was recognised in the late 30's that these communication systems were subject to marked variations in performance.
- It was hypothesised that most of these variations were directly related to changes in the ionosphere.
- Considerable effort was made to investigate ionospheric parameters and determine their effect on radio waves and the associated reliability of HF circuits.
- World-wide noise measurement records were started and steps were taken to record observed variations in signal amplitudes over various HF paths.

Ionospheric Propagation

- It was found that ionised regions ranging from approximately 70 to 1000 km above the earth's surface provide the medium of transmission for electromagnetic energy in the HF spectrum (2 to 30 MHz) and that most variations in HF system performance are directly related to changes in these ionised regions.

- The ionisation is produced in a complex manner by the photoionization of the earth's high altitude atmosphere by solar radiation.

Reference

- Sanjeeva Gupta, “Microwave Engineering”