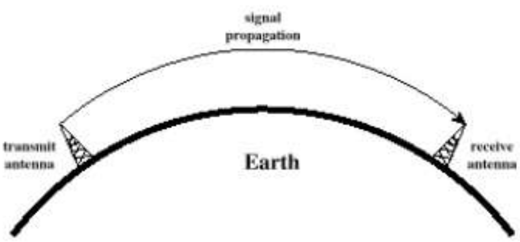
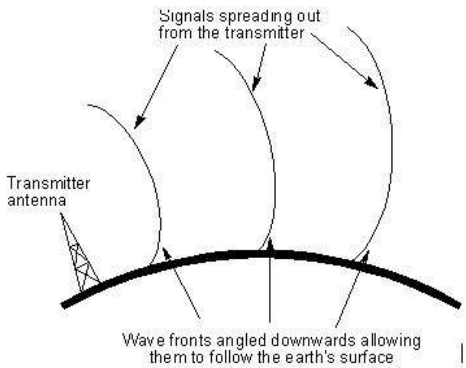
CHAPTER-4 PROPAGATION

Learning Objectives:
After completion of this chapter, the students will be able to explain various modes of propagation of waves i.e. Ground Wave, Sky Wave, Space Wave and Duct Propagation**.**

Introduction
A wave propagates due to refraction, diffraction or scattering. Reflection occurs when a propagating electromagnetic wave strikes an object which has very large dimensions when compared to the wavelength, e.g., buildings, walls. Diffraction occurs when the radio path between the transmitter and receiver is obstructed by a surface that has sharp edges. Scattering occurs when the medium through which the wave travels consists of objects with dimensions that are small compared to the wavelength. The received energy at a distant point may travel over any of the possible modes of propagations: Ground or surface wave propagation, Sky wave or Ionospheric wave propagation and Space wave propagation.

4.1 Ground Wave Propagation
Ground Wave propagation is a method of radio wave propagation that uses the area between the surface of the earth and the ionosphere for transmission. The surface wave can propagate over the earth's surface mainly in the low frequency and medium frequency ranges and used for short distance propagation. If the antennas are in the line of sight then there will be a direct wave as well as a reflected signal. The direct signal is one that travels directly between the two antennas and the reflected signal is received after reflection by the earth's surface and any hills or large buildings etc. The surface wave tends to follow the curvature of the Earth and enables coverage beyond the horizon. Instead of just travelling in a straight line the radio signals tend to follow the curvature of the Earth. This is because currents are induced in the surface of the earth and this action causes the wave-front of the radio communications signal to tilt downwards towards the Earth. With this tilted wave-front, it is able to curve around the Earth and be received well beyond the horizon.
The earth attenuation increases as frequency increases. So this mode of propagation is suitable for low and medium frequency i.e. up to 2 MHz only. It is called as medium wave propagation and is used in local broadcasting.





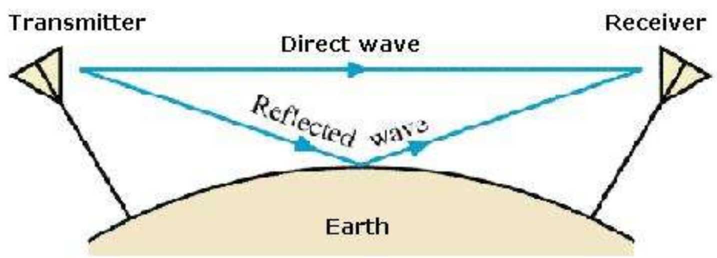
According to the Sommerfield Equation, Electric field strength E at a distance from transmitting antenna due to ground wave, is given by

$E = 120\,\pi\, h_t\, .h_r\, .I_s \,/\, \lambda.d$ (volt/meter)

where, $120\,\pi$ – Intrinsic impedance of free space
ht , hr – Effective heights of transmitting and receiving antennas
Is – Antenna currents
d – Distance between TX and RX antennas
λ – Wavelength

4.2 Space Wave Propagation

Space waves occur within the lower 20 km of the atmosphere and are comprised of a direct and reflected wave. These waves have the ability to propagate through atmosphere, from transmitter antenna to receiver antenna. These waves can travel directly or can travel after reflecting from earth’s surface to the troposphere. So, it is also called as Tropospheric Propagation and is used in VHF and UHF bands.



Space wave, comprising direct + reflected waves

At higher frequencies the sky wave propagation and ground wave propagation can’t work. These waves are limited to the curvature of the earth and have line of sight propagation. The LOS distance is that distance at which both the sender and receiver antenna are in sight of each other. By extending the heights of both the sender and the receiver antennas, the transmission range can be increased. Its applications are in radar and television communication.

Direct Wave transmission includes line of sight transmission. Due to atmospheric refraction the range extends slightly beyond the horizon.

Ground Reflected Wave occurs when the radio waves strike the earth and bounce off. The strength of the reflection depends on local conditions. The received radio signal can cancel out if the direct and reflected waves arrive with the same relative strength and 180^o out of phase with each other. A direct space wave can travel 4/3 greater distance than line-of-sight due to diffraction. This distance is known as the radio horizon and can be written as:

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

Where, d = radio horizon (mi), h_t = transmitting antenna height (ft), h_r = receiving antenna height (ft)

4.3 Sky Wave propagation

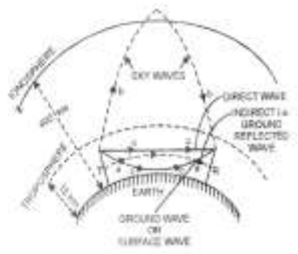
In this mode of propagation, when the EM waves are radiated towards the sky, they are either refracted or reflected back to the earth by the ionosphere. The height of the ionosphere ranges from 50 to 400 km. Radio waves are refracted by the ionized gas created by solar radiation. The amount of ionization depends on the time of day, season and the position. This ionosphere propagation takes place mainly in the HF band. The ionosphere is composed of several layers. Each layer has different propagation characteristics:

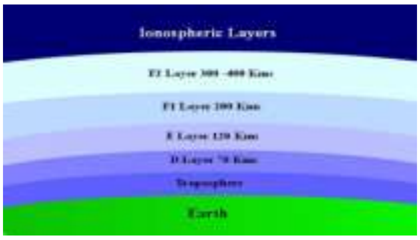
D layer – This layer occurs only during the day at altitudes of 60 to 90 km. High absorption takes place at frequencies up to 7 MHz.

E layer – This layer occurs at altitudes of 100 to 125 km. In the summer, dense ionization clouds can form for short periods. These clouds called *sporadic E* can refract radio signals in the VHF spectrum. This phenomenon allows amateur radio operators to communicate over enormous distances.

F layer - This single night-time layer splits into two layers (F1 and F2) during the day. The F1 layer forms at about 200 km and F2 at about 400 km. The F2 layer propagates most HF short-wave transmissions.

Because radio signals can take many paths to the receiver, multipath fading can occur. If the signals arrive in phase, the result is a stronger signal. If they arrive out of phase with each other, they tend to cancel.



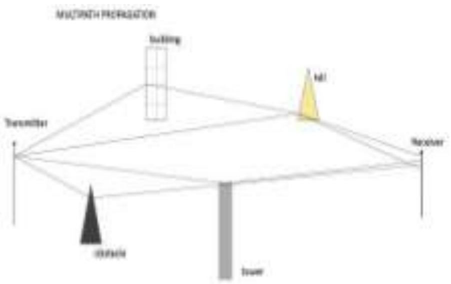


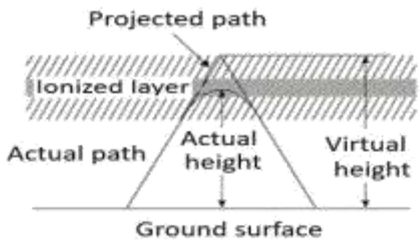
Ionosphere: The ionosphere is the ionized part of Earth's upper atmosphere, from about 60 km to 1000 km altitude, a region that includes the thermosphere and parts of the mesosphere and exosphere. The ionosphere is ionized by solar radiation.

Virtual Height: The height to which a short pulse of energy sent vertically upward and travelling with speed of light would reach taking same time as the original wave would have reflected from the ionosphere.

Critical Frequency: The highest frequency that will be reflected and returned down to the earth by a layer at vertical incidence.

Multi-path: The wave, which is reflected from the ionosphere, can be called as a hop or skip. There can be a number of hops for the signal as it may move back and forth from the ionosphere and earth surface many times. Such a movement of signal can be termed as multipath propagation.





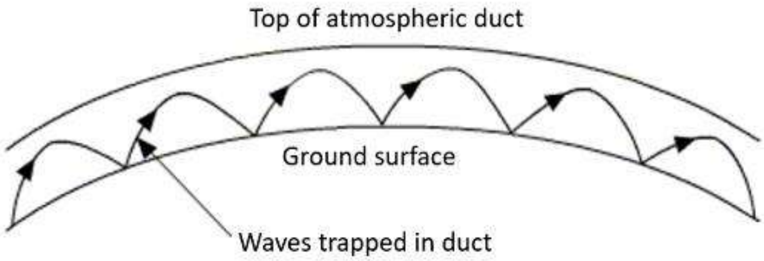
Fading: Fading refers to the variation of the signal strength with respect to time/distance. It is widely prevalent in wireless transmissions. The most common causes of fading in the wireless environment are multipath propagation and mobility.

Skip Distance: The measurable distance on the surface of the Earth from transmitter to receiver, where the signal reflected from the ionosphere can reach the receiver with minimum hops or skips, is known as skip distance.

Maximum Usable Frequency (MUF): It is the highest frequency that can be used to receive sky wave signals at the receiving point.

4.4 Duct Propagation

At a height of around 50 meters from the troposphere, the temperature increases with the height. In this region of troposphere, the higher frequencies or microwave frequencies tend to refract back into the Earth's atmosphere, instead of shooting into ionosphere, to reflect. These waves propagate around the curvature of the earth even up to a distance of 1000km. This refraction goes on continuing in this region of troposphere. This can be termed as Super refraction or Duct propagation.



The main requirement for the duct formation is the temperature inversion. The increase of temperature with height, rather than the decrease in the temperature is known as the temperature inversion.

Multiple Choice Questions

1. What type of propagation uses radio signals refracted back to earth by ionosphere?
a) sky- wave
b) earth-moon-earth
c) ground-wave
d) tropospheric

2. What type of propagation involves radio signals that travels along the surface of the earth?
a) sky-wave propagation
b) knife-edge difraction
c) E-layer propagation
d) ground –wave propagation

3. What is the area of weak signals between the range of ground-waves and the first hope called?
a) The skip zone
b) The hysteresis zone
c) The monitor zone
d) The transequatorial zone

4. What type of radio wave propagation makes it possible for amateur stations to communicate long distance?
a) direct –inductive propagation
b) knife –edge diffraction
c) ground –wave propagation
d) sky-wave propagation

5. Ground waves propagate in the frequency range of .
a) 3 khz to 30 khz
b) 30khz-3mhz
c) 3mhz-30mhz
d) 30mhz-300mhz

6. The skip distance for radio wave increases with
   a) increace in frequency
   b) reduce in frequency
   c) temp of atmosphere
   d) none of the above

Short Answer Questions

1. Define maximum usable frequency
2. Write the application of ground-waves
3. On what factors does skip distance depends?
4. Write the disadvantage of ground –wave propagation
5. What is ionosphere?
6. Explain in the detail the term critical frequency.
7. Discuss in brief the propagation characteristics of short waves.

Long Answer Questions

1. Explain the concept of ground wave propagation.
2. Explain the concept of sky wave propagation.
3. Explain in detail the space wave propagation.

CHAPTER 5: SATELLITE COMMUNICATION

Learning Objectives:
After completion of this chapter, the students will be able to explain satellite communication link and terms related it.

5.1 Basic Idea

A satellite is a body that moves around another body in an orbit. A communication satellite is a microwave repeater that helps in telecommunications, radio, television and internet applications. A repeater increases the strength of the signal and retransmits it. It works as a transponder, which changes the frequency band of the transmitted signal also. The frequency with which the signal is sent into the space is called Uplink frequency, while the frequency with which it is sent by the transponder is Downlink frequency.

Advantages of satellite communications are

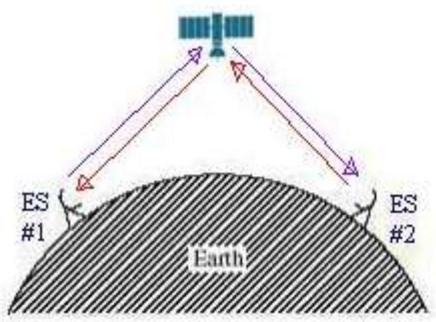
- Flexibility
- Ease in installing new circuits
- Large Distances covered and cost doesn't matter
- Broadcasting possibilities
- Large coverage
- User can control the network

Drawbacks of Satellite communication are

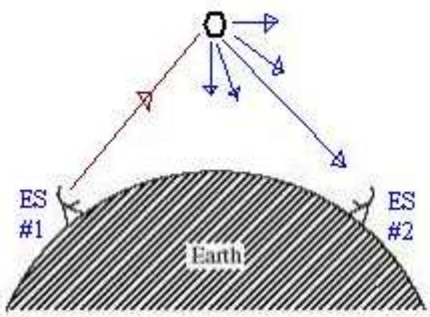
- The initial costs such as segment and launch costs are too high.
- Congestion of frequencies
- Interference and propagation

5.1.1 Active Satellite: The active satellite has its own transmitting and receiving antennas. It amplifies the signal received from earth station or ground station and retransmits the amplified signal back to earth. It also performs frequency translation of the received signal before retransmission. Active satellite can generate power for its own operation. It is also known as active repeater.

5.1.2 Passive Satellite: It is basically a reflector which receives the signal from the transmitting earth station and scatters the signal in all the directions. It reflects the electromagnetic radiations without any modification or amplification. Passive satellite cannot generate power of its own and simply reflects the incident power.



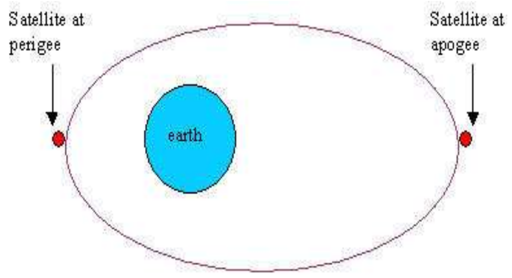
ACTIVE SATELLITE



PASSIVE SATELLITE

5.1.3 Orbit: A curved path (usually elliptical) followed by the satellite while revolving around the earth is known as orbit. For example, in geostationary satellite, the position of the satellite is constant with respect to earth because its time period of revolution is equal to time period of rotation of earth on its own axis.

5.1.4 Apogee: The point in the orbit of the satellite which is at the farthest distance from the centre of the earth is called as Apogee. It is denoted by r_a.
5.1.5 Perigee: It is the nearest point from the earth existing on the satellite orbit and is denoted by r_p.



5.2 Geostationary Satellite and Its Need

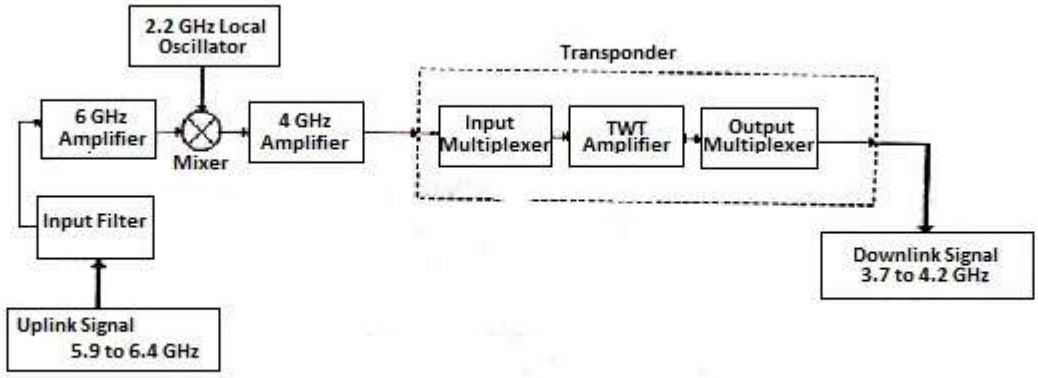
A geostationary satellite is an earth-orbiting satellite, placed at an altitude of approximately 36000 kilometers directly over the equator. It revolves in the same direction the earth rotates (west to east) and takes 24 hours (the same time period as the earth requires to rotate once on its axis). A geostationary satellite appears nearly stationary in the sky when seen by an observer on earth. A single geostationary satellite can cover about 40% of the earth's surface. Hence three such satellites, each separated by 120 degrees of longitude, can provide coverage of the entire planet. It has the main advantage of permanently remaining in the same area of sky, so ground based antennas do not need to track them. The geostationary satellites are needed for weather forecasting, global communication, satellite TV and radio etc.

5.3 Satellite Communication link

Communications Satellites consist of the following subsystems:

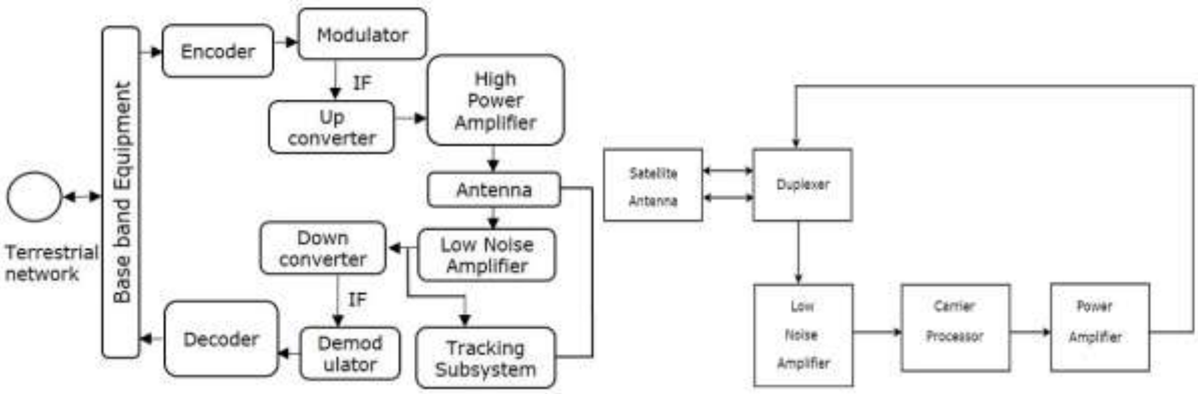
- Communication Payload, normally composed of transponders, antennas, and switching systems
- Engines used to bring the satellite to its desired orbit
- A station keeping, tracking and stabilization subsystem used to keep the satellite in the right orbit, with its antennas pointed in the right direction, and its power system pointed towards the sun
- Power subsystem, used to power the Satellite systems, normally composed of solar cells, and batteries that maintain power during solar eclipse
- Command and Control subsystem, which maintains communications with ground control stations. The ground control Earth stations track the satellite performance and monitor its functionality during various phases of its life-cycle.

The available bandwidth depends upon the number of transponders provided by the satellite. Each service requires a different amount of bandwidth for transmission.



Satellite Communication System Block Diagram

Uplink, downlink filters, amplifiers, local oscillator and transponder are the basic blocks of the satellite communication system. The uplink and downlink frequency ranges are respectively 5.9 – 6.4 GHz and 3.7 – 4.2 GHz. The mixer and local oscillator convert the uplink frequency to lower frequency. The satellite receives the signals transmitted from the ground stations, amplifies it and retransmits it at downlink frequencies to avoid interference.
A satellite can have many transponders. The transponder consists of input and output multiplexer and one TWT amplifier.
The block diagram of an earth station and transponder consists of various elements as shown below.



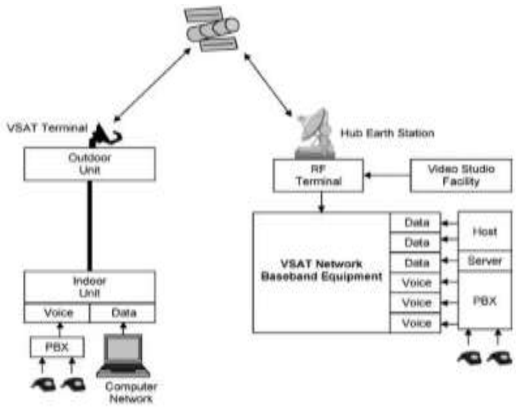
Earth station: The input baseband signal from the terrestrial network enters the earth station at the transmitter. The signal is encoded, modulated and up-converted. Then it is amplified and passed through antenna terminal. The signal received from the satellite is amplified in a low noise amplifier, and down-converted. It is then demodulated and decoded to get the original baseband signal.
Transponder: Duplexer is a two-way microwave gate. Duplexer receives uplink signal from the satellite antenna and transmits downlink signal to the satellite antenna. The Low Noise amplifier increases the strength of the weak received signal. Carrier Processor carries out the frequency down conversion of received signal (uplink). The power of frequency down converted signal (down link) is amplified to the required level using a suitable power amplifier.

5.3 VSAT and its features:
A very small aperture terminal is a satellite ground station with a dish antenna with a diameter of size smaller than 3.8 meters. The VSAT antennas range from 75 cm to 1.2 m. Data speed range from 4 kbit/s up to 16 Mbit/s. VSATs access satellites

in geosynchronous orbit to relay data from small remote Earth stations to other terminals or master Earth station.

VSAT Network:

- The ground segment of a VSAT network consists of a high performance hub Earth station and a large number of low performance terminals referred to as VSATs.
- The space segment consists GEO satellites acting as communication links between the hub station and the VSATs.
- A typical VSAT network is shown below.



- VSATs use a high performance central station so that the various remote stations can be simpler and smaller in design.
- The hub station is usually a large, high performance Earth Station comprising an outdoor antenna for transmission, RF terminals for providing a wideband uplink of one digital carrier per network, base band equipment comprising modems, and various kinds of interfacing equipment to support a wide variety of terrestrial links.
- The terrestrial links connect the hub station to the head office.
- VSATs are smaller and simpler in design as compared to the hub centre and comprise an outdoor antenna, an RF terminal comprising an LNB for reception and baseband equipment.
- VSAT networks use either C band or Ku band.
- VSATs generally carry digital signals. BPSK or QPSK modulation schemes with forward error correction are often used.
- Applications of VSAT include File transfers, Computer communications, Database enquiries, Video conferencing, Reservation systems, Credit checks and credit card verification, Billing systems, Stock control and management, Electronic mail and Point of sale transactions.

Multiple Choice Questions:

1. A passive satellite
a) Amplifies the signal
b) Reflects the signal
c) Absorbs the signal
d) None of the above

2. The source of energy for a satellite is
a) Battery
b) Fuel cell

c) Magneto hydrodynamic generator
d) Solar cell

3. Which of the following bands cannot be used for satellite communication?
a) MF
b) Ku
c) X
d) C

4. The reason for carrying multiple transponders in a satellite is
a) More number of operating channel
b) Better reception
c) More gain
d) Redundancy

5. A transponder is a satellite equipment which
a) receives a signal from Earth station and amplifies
b) changes the frequency of the received signal
c) retransmits the received signal
d) does all of the above-mentioned functions

6. A geosynchronous satellite
a) has the same period as that of the Earth
b) has a circular orbit
c) rotates in the equatorial plane
d) has all of the above

Short Answer Questions
1. What is geostationary satellite?
2. Differentiate between active and passive satellites.
3. Define and explain orbit, apogee and perigee.
4. Write applications of VSAT.

Long Answer Questions
1. Explain the block diagram of communication link.
2. Explain the VSAT operation and features.