CBCS SCHEME

USN | | | | | | | | | |

18EC732

Seventh Semester B.E. Degree Examination, Dec.2023/Jan.2024

Satellite Communication

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. State and explain all the three Kepler's laws with necessary figures and expressions. **(07 Marks)**

b. The apogee and perigee distances of a satellite orbiting in an elliptical orbit are respectively 45000km and 7000km. Determine the following:
   i) Semi major axis of the elliptical orbit.
   ii) Orbit eccentricity.
   iii) Distance between the center of the Earth and the centre of the elliptical orbit. **(06 Marks)**

c. With neat diagram explain the different types of satellite orbits. **(07 Marks)**

OR

2 a. With neat diagram, explain the following orbital parameters:
   i) Apogee ii) Ascending node iii) Eccentricity iv) Argument of perigee. **(08 Marks)**

b. Explain spin stabilization and three axis stabilization techniques for satellite altitude control. **(06 Marks)**

c. Explain the various orbital effects on satellites performance. **(06 Marks)**

Module-2

3 a. Explain the solar energy driven power supply system of a satellite. **(06 Marks)**

b. Write a note on payload subsystem of satellite. **(06 Marks)**

c. With neat block diagram, explain earth station architectures. **(08 Marks)**

OR

4 a. Explain Tracking, Telemetry and Command (TT&C) subsystem. **(08 Marks)**

b. Briefly explain the following types of earth stations:
   i) Fixed Satellite Service (FSS) Earth station.
   ii) Broadcast Satellite Service (BSS) Earth station. **(06 Marks)**

c. With neat block diagram, explain satellite tracking system. **(06 Marks)**

Module-3

5 a. Explain MCPC/FDM/FM/FDMA system with typical block diagram. **(10 Marks)**

b. What are the advantages and disadvantages of TDMA over FDMA? **(10 Marks)**

OR

6 a. Explain TDMA typical frame structure. **(10 Marks)**

b. Briefly explain important parameters that influence the design of a satellite communication link. **(10 Marks)**

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-4

7 a. With neat diagram explain the two types of satellite transponders. (10 Marks)

b. Explain the advantages and disadvantages of satellite with respect to terrestrial networks. (10 Marks)

OR

8 a. Explain the satellite cable television. (10 Marks)

b. With neat block diagram, explain the basic elements of satellite communication system. (10 Marks)

Module-5

9 a. Explain the Optical Remote Sensing system and Thermal Infrared Remote Sensing system. (10 Marks)

b. Explain the operation of the control segment of GPS system. (10 Marks)

OR

10 a. With neat block diagram, explain a typical GIS system in remote sensing. (10 Marks)

b. List and explain all the applications of weather forecasting satellite. (10 Marks)

* * * * *

1.a) Kepler's Laws

These laws are equally valid for the motion of natural and artificial satellites around Earth or for any body revolving around another body. These laws will be discussed with reference to the motion of artificial satellites around Earth.

Kepler's First Law

The orbit of a satellite around Earth is elliptical with the centre of the Earth lying at one of the foci of the ellipse. Eccentricity *(e)* is the ratio of the distance between the centre of the ellipse and either of its foci (= *ae*) to the semi-major axis of the ellipse a. A circular orbit is a special case of an elliptical orbit where the foci merge together to give a single central point and the eccentricity becomes zero.

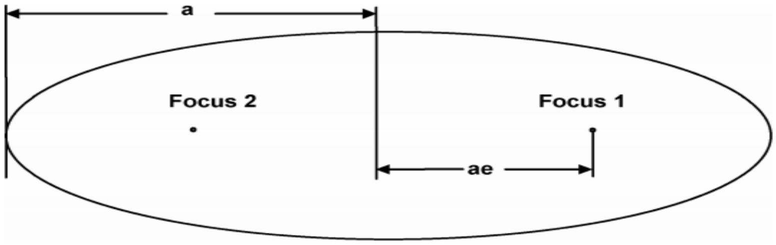


Fig: Kepler's first law

The law of conservation of energy is valid at all points on the orbit. In the context of satellites, it means that the sum of the kinetic and the potential energy of a satellite always remain constant. The value of this constant is equal to $-\frac{Gm_1m_2}{2a}$ where

m_1 = mass of Earth

m_2 = mass of the satellite

a = semi-major axis of the orbit

The kinetic and potential energies of a satellite at any point at a distance r from the centre of the Earth are given by

$$\text{Kinetic Energy} = \frac{1}{2}(mv^2)$$

$$\text{Potential Energy} = -\frac{Gm_1m_2}{r}$$

Therefore,

$$\frac{1}{2}(mv^2) - \frac{Gm_1m_2}{r} = -\frac{Gm_1m_2}{2a}$$

$$v^2 = Gm_1(\frac{2}{r} - \frac{1}{a})$$

$$v = \sqrt{\mu(\frac{2}{r} - \frac{1}{a})}$$

Kepler's Second Law

The line joining the satellite and the centre of the Earth sweeps out equal areas in the plane of the orbit in equal time intervals ie the rate (d*A*/d*t*) at which it sweeps area *A* is constant. The rate of change of the swept-out area is given by

$$\frac{dA}{dt} = \frac{angular\ momentum\ of\ the\ satellite}{2m}$$

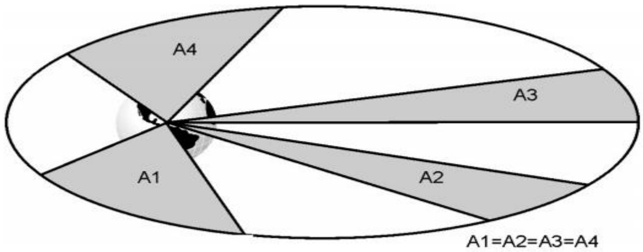


Fig: Kepler's second law

where m is the mass of the satellite. Hence, Kepler's second law is also equivalent to the law of conservation of momentum, which implies that the angular momentum of the orbiting satellite given by the product of the radius vector and the component of linear momentum perpendicular to the radius vector is constant at all points on the orbit.

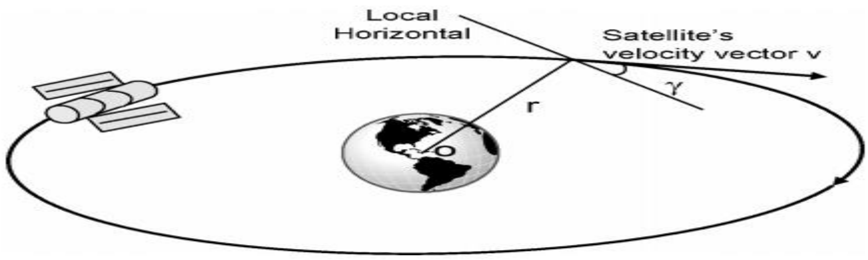


Fig: Satellite's position at any given time

For any satellite in an elliptical orbit, the dot product of its velocity vector and the radius vector at all points is constant.

$$v_p r_p = v_a r_a = vr\cos\gamma$$

Kepler's Third Law

The square of the time period of any satellite is proportional to the cube of the semi-major axis of its elliptical orbit. A circular orbit with radius *r* is assumed. A circular orbit is only a special case of an elliptical orbit with both the semi-major axis and semi-minor axis equal to the radius. Equating the gravitational force with the centrifugal force gives:

$$\frac{Gm_1m_2}{r^2} = \frac{1}{r}(m_2v^2)$$

Replacing v by $r\omega$ in the above equation gives,

$$\frac{Gm_1m_2}{r^2} = \frac{1}{r}\left(m_2r^2\omega^2\right) = m_2\omega^2 r$$

which gives $\omega^2 = Gm_1/r^3$. Substituting $\omega = 2\pi/T$ gives

$$T^2 = (\frac{4\pi^2}{Gm_1})r^3$$

This can also be written as

$$T = (\frac{2\pi}{\sqrt{\mu}})r^{3/2}$$

The above equation holds good for elliptical orbits provided r is replaced by the semi-major axis a. This gives the expression for the time period of an elliptical orbit as

$$T = (\frac{2\pi}{\sqrt{\mu}})a^{3/2}$$

1b) The apogee and perigee distances of a satellite orbiting in an elliptical orbit are respectively 45 000 km and 7000 km. Determine the following:

1. Semi-major axis of the elliptical orbit 2. Orbit eccentricity 3. Distance between the centre of the Earth and the centre of the elliptical orbit

Sol: 1) Semi-major axis of the elliptical orbit: a = (apogee + perigee)/2

=(45000+7000)/2=26 000km

2. Eccentricity e = (apogee – perigee)/2 =(45 000 – 7000)/(2 × 26 000)

= 0.73

3) Distance between the centre of the Earth and the centre of the ellipse = ae =26000 x 0.73= 18980 km

1c) Types of Satellite Orbits

The satellite orbits can be classified

on the basis of:

1.Orientation of the orbital plane

2.Eccentricity

3.Distance from Earth

Orientation of the Orbital Plane

The orbital plane of the satellite can have various orientations with respect to the equatorial plane of Earth. The angle between the two planes is called the angle of inclination of the satellite. On this basis, the orbits can be classified as

equatorial orbits, polar orbits and inclined orbits.

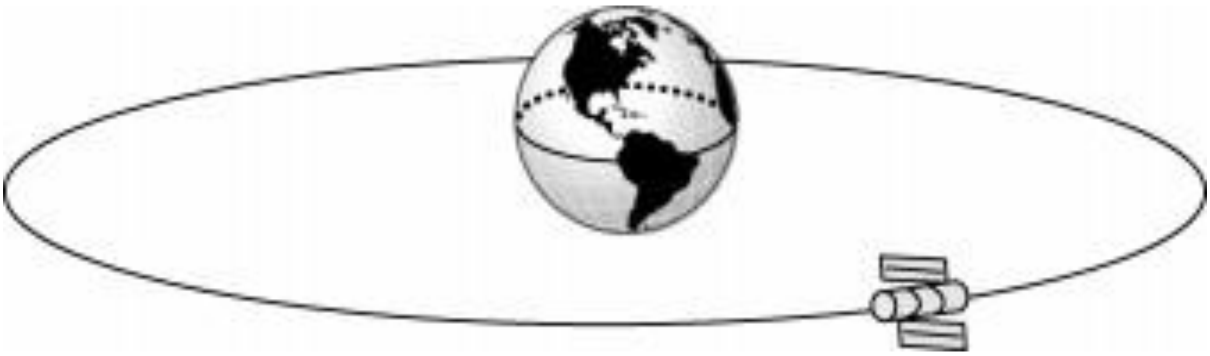


Fig: Equatorial orbit

Low Earth orbit (LEO)

- Satellites in the low Earth orbit (LEO) circle Earth at a height of around 160 to 500 km above the surface of the Earth.
- Shorter orbital periods and smaller signal propagation delays.
- The power required for signal transmission is also less.
- One important application of LEO satellites for communication is the project Iridium.

Medium Earth orbit (MEO)

- Satellites orbit at a distance of approximately 10 000 to 20 000 km above the surface of the Earth.

- Orbital period of 6 to 12 hours. These satellites stay in sight over a particular region of Earth for a longer time.

- Communication and navigation applications

Geosynchronous Earth orbit (GEO)

- Prograde orbit whose orbital period is equal to Earth's rotational period.
- Height of about 36 000 km, 35 786 km to be precise, above the surface of the Earth.
- The orbital period should be equal to 23 hours 56 minutes, which implies that the satellite must orbit at a height of 35 786 km above the surface of the Earth.
- The satellite motion must be from west to east.

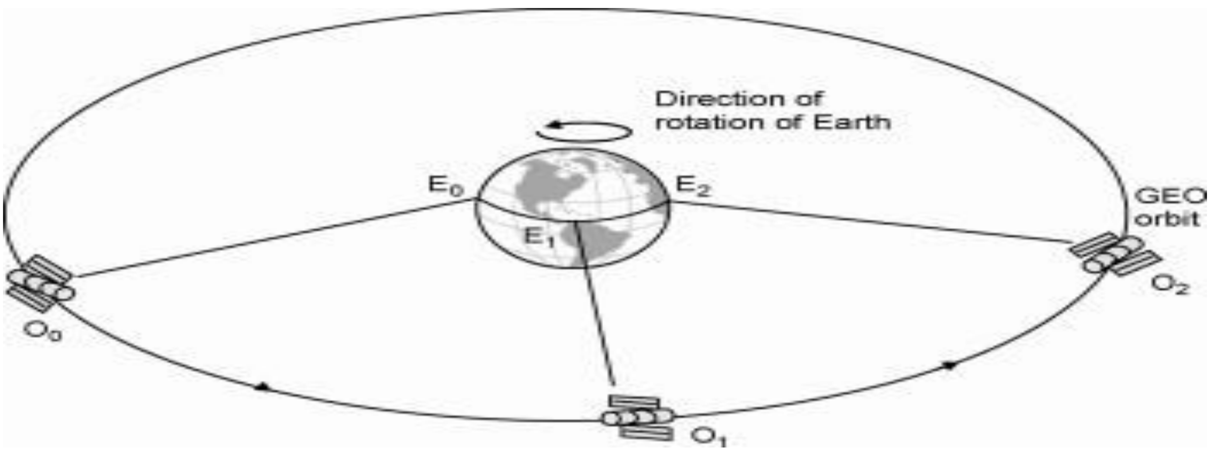


Fig: GEO satellites appear stationary with respect to a point on Earth

Sun-synchronous Orbit

A sun-synchronous orbit, also known as a heliosynchronous orbit, is one that lies in a plane that maintains a fixed angle with respect to the Earth–sun direction.

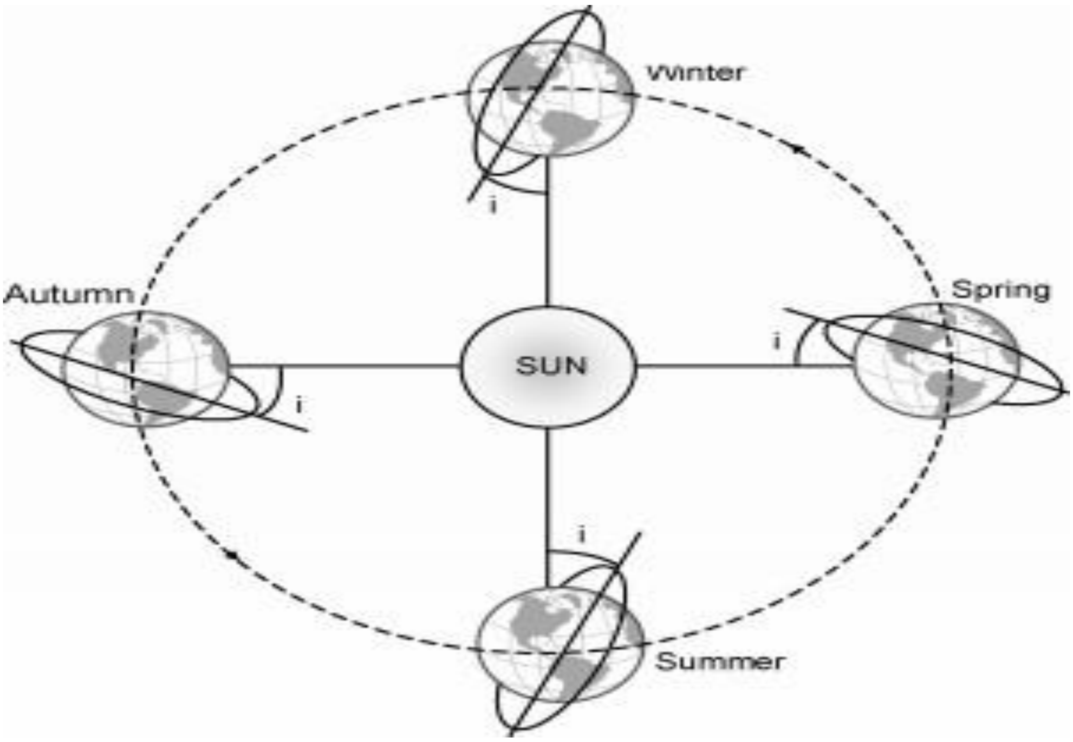


Fig: Sun-synchronous orbit

2.a)

Ascending and descending nodes

The satellite orbit cuts the equatorial plane at two points: **descending node (N1),** where the satellite passes from the northern hemisphere to the southern hemisphere, and the second, called the **ascending node (N2)**, where the satellite passes from the southern hemisphere to the northern hemisphere.

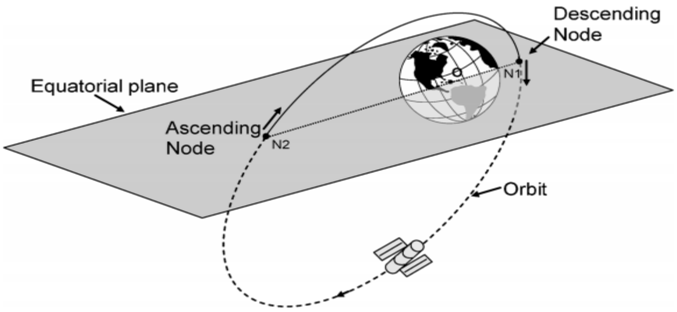
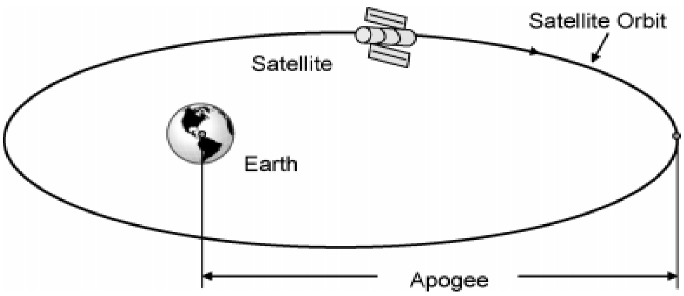


Fig: Ascending and descending nodes

Apogee

Apogee is the point on the satellite orbit that is at the farthest distance from the centre of the Earth. The apogee distance can also be computed from the known values of the perigee distance and velocity at the perigee Vp.

$$\text{Apogee distance}\ , A = a\,(1 + e)$$



Eccentricity

The orbit eccentricity e is the ratio of the distance between the centre of the ellipse and the centre of the Earth to the semi-major axis of the ellipse. It can be computed from any of the following expressions:

$$e = \frac{Apogee - Perigee}{Apogee + Perigee}$$

$$e = \frac{Apogee - Perigee}{2a}$$

$$e = \frac{\sqrt{a^2 - b^2}}{a}$$

Argument of Perigee

The argument of perigee is represented by symbol w, is the angle between the ascending node and perigee,measured in the direction of a spacecrafts motion along the orbital plane.It describes the orientation of an orbit with its orbital plane .and its value ranges from 0 degree to 360 degree.

2b.)

Types of Satellite Orbits

The satellite orbits can be classified

on the basis of:

1. Orientation of the orbital plane

2. Eccentricity

3. Distance from Earth

Commonly employed techniques for satellite attitude control include:

1.Spin stabilization

2.Three-axis or body stabilization

Spin Stabilization

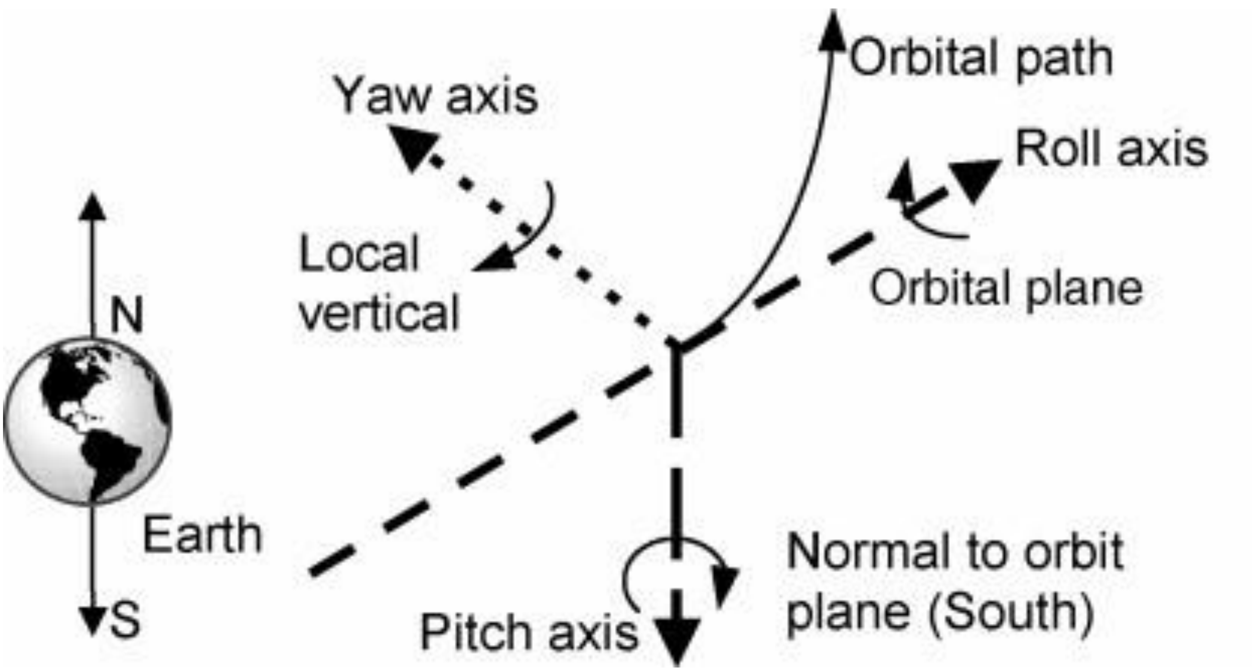
In a spin-stabilized satellite, the satellite body is spun at a rate between 30 and 100 rpm about an axis perpendicular to the orbital plane.Like a spinning top, the rotating body offers inertial stiffness, which prevents the satellite from drifting from its desired orientation.Spin-stabilized satellites are generally cylindrical in shape.There are two types of spinning configurations employed in spin-stabilized satellites. These include the simple spinner configuration and the dual spinner configuration.In the simple spinner configuration, the satellite payload and other subsystems are placed in the spinning section, while the antenna and the feed are placed in the de-spun platform.The de-spun platform is spun in a direction opposite to that

of the spinning satellite body.In the dual spinner configuration, the entire payload along

with the antenna and the feed is placed on the de-spun platform and the other subsystems are located on the spinning body. Modern spin-stabilized satellites almost invariably employ the dual spinner configuration.

Three-axis or Body Stabilization

In the case of three-axis stabilization, also known as body stabilization, the stabilization is achieved by controlling the movement of the satellite along the three axes, i.e. yaw, pitch and roll, with respect to a reference (Fig).



- The system uses reaction wheels or momentum wheels to correct orbit perturbations.The stability of the three-axis system is provided by the active control system, which applies small corrective forces on the wheels to correct the undesirable changes in the satellite orbit.The basic control technique used here is to speed up or slow down the momentum wheel depending upon the direction in which the satellite is perturbed.The satellite rotates in a direction opposite to that of speed change of the wheel.An increase in speed of the wheel in the clockwise direction will make the satellite to rotate in a counter clockwise direction.

- An alternative approach is to use reaction wheels.Three reaction wheels are used, one for each axis.They can be rotated in either direction depending upon the active correction force.The satellite body is generally box shaped for three-axis stabilized satellites.Antennae are mounted on the Earth-facing side and on the lateral sides adjacent to it.These satellites use flat solar panels mounted above and below the satellite body in such a way that they always point towards the sun, which is an obvious requirement.

Fig: Three-axis stabilized satellite (Intelsat-5) (Reproduced by permission of © Intelsat)

2c) Orbital Effects on Satellite's Performance

The motion of the satellite has significant effects on its performance. These include the Doppler shift, effect due to variation in the orbital distance, effect of solar eclipse and sun's transit outrage.

Doppler Shift

As the satellite is moving with respect to the Earth station terminal, the frequency of the satellite transmitter also varies with respect to the receiver on the Earth station terminal. If the frequency transmitted by the satellite is *fT*, then the received frequency *f*R.

$$\left(\frac{f_R - f_T}{f_T}\right) = \left(\frac{\Delta f}{f_T}\right) = \left(\frac{v_T}{v_P}\right)$$

Where,

vT is the component of the satellite transmitter velocity vector directed towards the Earth station receiver

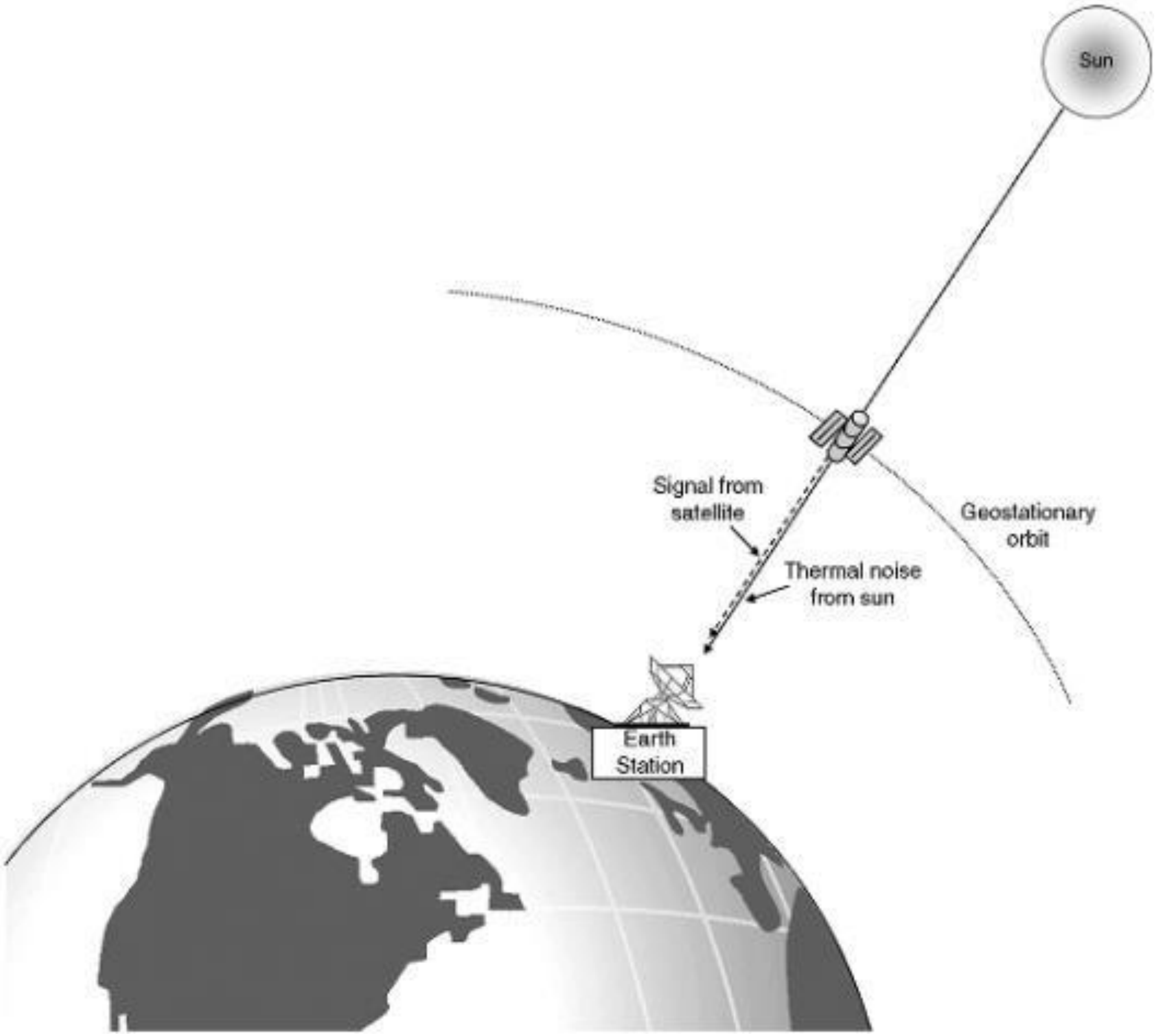
vP is the phase velocity of light in free space (3 × 108 m/s)

Solar Eclipse

- There are times when the satellites do not receive solar radiation due to obstruction from a celestial body.
- During these periods the satellites operate using onboard batteries.
- Ground control stations perform battery conditioning routines prior to the occurrence of an eclipse

  to ensure best performance during the eclipse.
- he rapidity with which the satellite enters and exits the shadow of the celestial body creates sudden temperature stress situations

Sun transit outrange



- The Earth station antenna will receive signals from the satellite as well as the microwave radiation emitted by the sun.

- This might cause temporary outrage if the magnitude of the solar radiation

  exceeds the fade margin of the receiver.

- The traffic of the satellite may be shifted to other satellites during such periods.

Eclipses

- An eclipse is said to occur when the sunlight fails to reach the satellite's solar panel due to an obstruction from a celestial body.

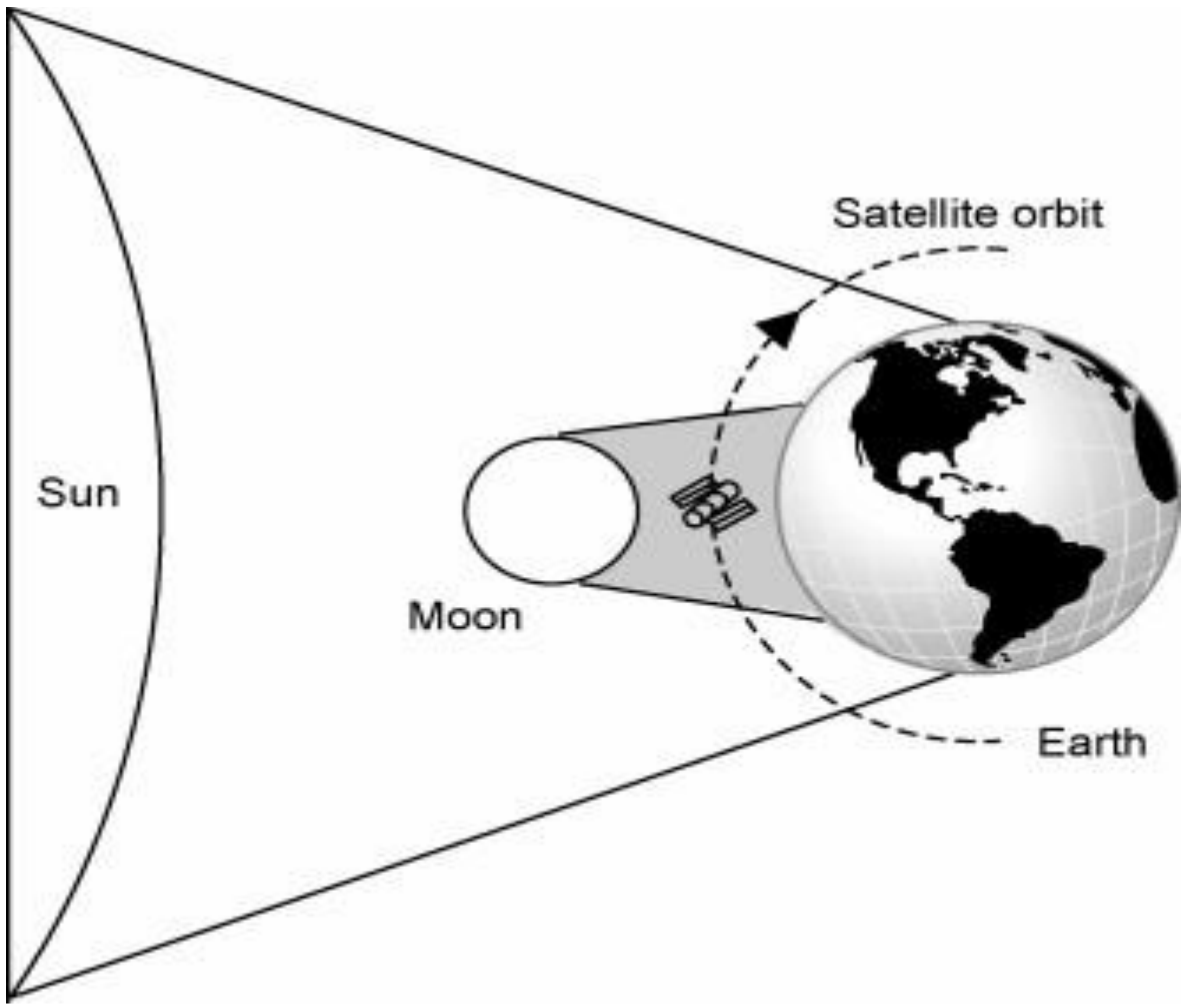
- The eclipse is total; i.e. the satellite fails to receive any light whatsoever if it passes through the **umbra**, which is the dark central region of the shadow, and receives very little light if it passes through the **penumbra**, which is the less dark region surrounding the umbra.

- The duration of an eclipse increases from zero to about 72 minutes starting 21 days before the equinox and then decreases from 72 minutes to zero during 21 days following the equinox.

- The duration of an eclipse on a given day around the equinox can be seen from the graph.

- Another type of eclipse known as the lunar eclipse occurs when the moon's shadow passes across the satellite. This is much less common and

  occurs once in 29 years.



Lunar elipse

Module 3

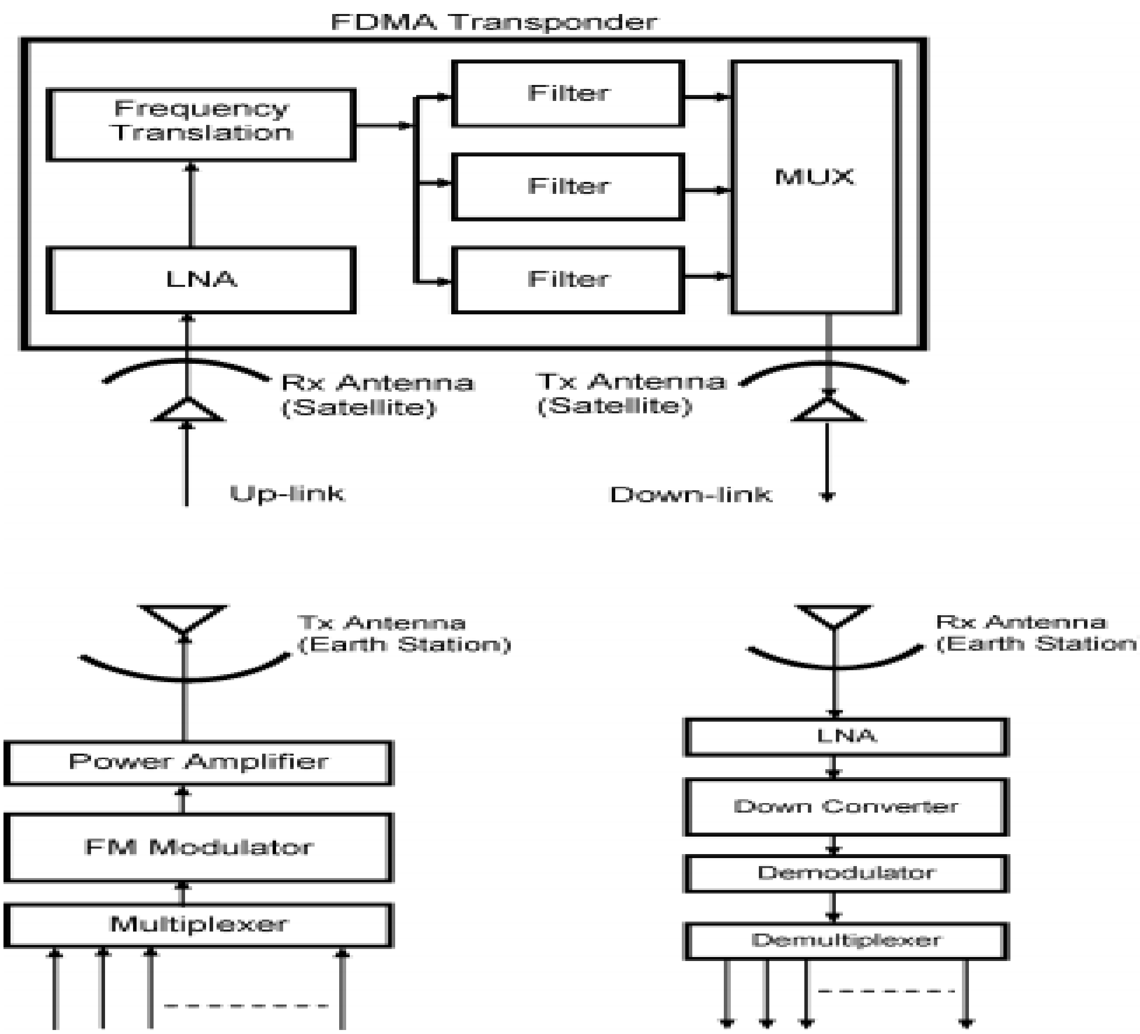
Ans 5a)

Multiple access means access to a given facility or a resource by multiple users. In the context of satellite communication, the facility is the transponder and the multiple users are various terrestrial terminals under the footprint of the satellite. The transponder provides the communication channel(s) that receives the signals beamed at it via the uplink and then retransmits the same back to Earth for intended users via the downlink.

Multiple Channels Per Carrier (MCPC) Systems:

Multiple signal channels are first grouped together to form a single base band signal assembly. These grouped base band signals modulate preassigned carriers which are then transmitted to the FDMA transponder.

***MCPC/FDM/FM/FDMA System*:**

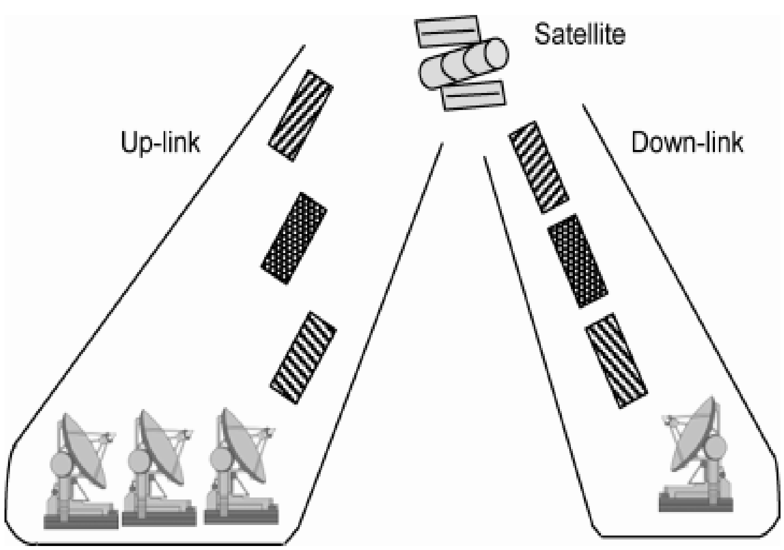


Multiple baseband signals are grouped together by using frequency division multiplexing to form FDM baseband signals. The FDM base band assemblies frequency modulate pre-assigned carriers and are then transmitted to the satellite. The FDMA transponder receives multiple carriers, carries out frequency translation and then separates out individual carriers with the help of appropriate filters. Multiple carriers are then multiplexed and transmitted back to Earth over the downlink. The receiving station extracts the channels assigned to that station.

Ans 5b)

Key	TDM	FDM
Definition	TDM stands for Time Division Multiplexing.	FDM stands for Frequency Division Multiplexing.
Signal	TDM works well with both analog as well as digital signals.	FDM works only with analog signal.
Conflict	TDM has low conflict.	FDM has high conflict.
Wiring	Wiring or Chip of TDM is simpler.	Wiring or Chip of FDM is complex.
Efficiency	TDM is efficient	FDM is quiet inefficient.
Sharing	Time is shared in TDM.	Frequency is shared in FDM.
Required Input	Synchronization pulse is mandatory in TDM.	Synchronization pulse is not mandatory.

Ans 6a)



- Time division multiple access (TDMA) is a technique in which different Earth stations use a single carrier on a time division basis.

- The traffic bursts from different Earth stations are synchronized so that all bursts arriving at the transponder are closely spaced but do not overlap.

- The transponder works on a single burst at a time and retransmits back to Earth a sequence of bursts.

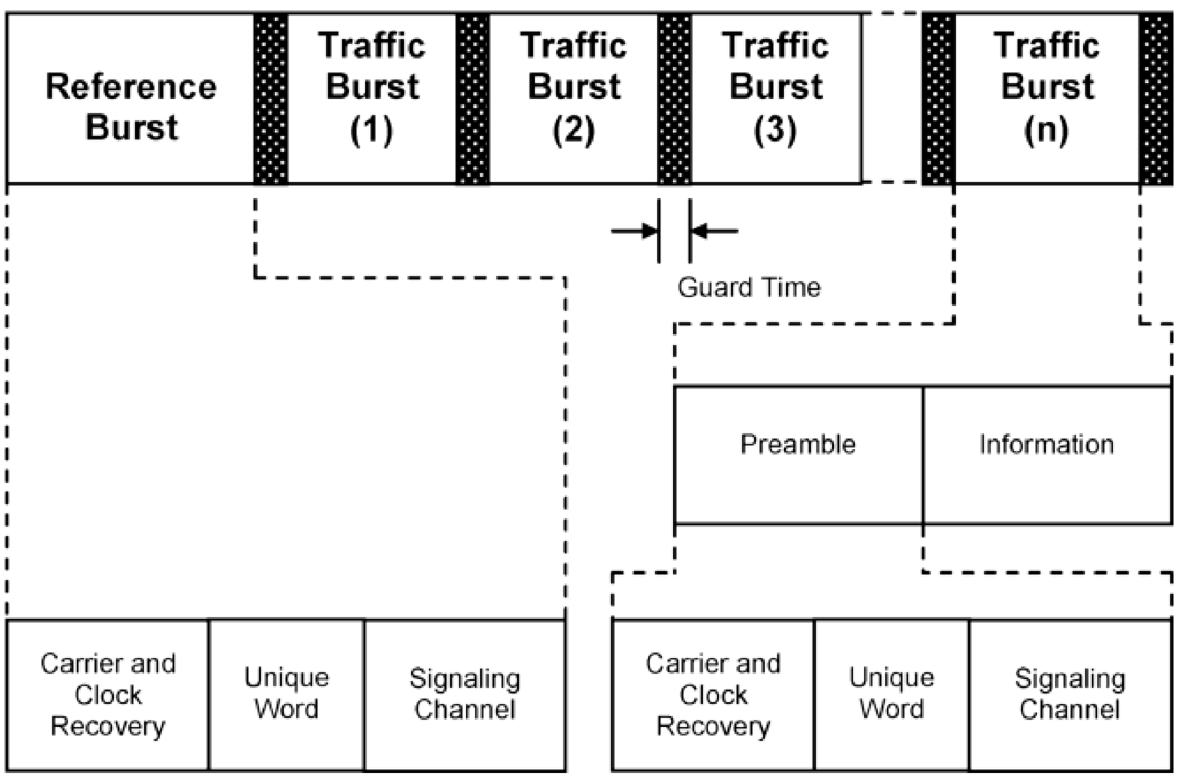
- All Earth stations can receive the entire sequence and extract the signal of their interest.

- The disadvantages of TDMA include a requirement for complex and expensive Earth station equipment and stringent timing and synchronization requirements.

- TDMA is suitable for digital transmission only.

TDMA Frame Structure

In a TDMA network, each of the multiple Earth stations accessing a given satellite transponder transmits one or more data bursts. The satellite thus receives at its input a set of bursts from a large number of Earth stations. This set of bursts from various Earth stations is called the TDMA frame.



The frame structure that starts with a reference burst transmitted from a reference station in the network. The reference burst is followed by traffic bursts from various Earth stations with a guard time between various traffic bursts from different stations. The traffic bursts are synchronized to the reference burst to fix their timing reference.

Reference Burst

• The reference burst is usually a combination of two reference bursts (RB-1 and RB-2).

• The primary reference burst, which can be either RB-1 or RB-2, is transmitted by one of the stations, called the primary reference station, in the network.

• The secondary reference burst, which is RB-1 if the primary reference burst is RB-2 and RB-2 if the primary reference burst is RB- 1, is transmitted by another station, called the secondary reference station, in the network.

• The reference burst does not carry any traffic information and is used to provide timing references to various stations accessing the TDMA transponder.

Traffic Burst

• Different stations accessing the satellite transponder may transmit one or more traffic bursts per TDMA frame and position them anywhere in the frame according to a burst time plan that coordinates traffic between various stations.

• The timing reference for the location of the traffic burst is taken from the time of occurrence of the primary reference burst.

• With this reference, a station can locate and then extract the traffic burst or portions of traffic bursts intended for it.

• The reference burst also provides timing references to the stations for transmitting their traffic bursts so as to ensure that they arrive at the satellite transponder within their designated positions in the TDMA frame.

Guard Time

• Different bursts are separated from each other by a short guard time, which ensures that the bursts from different stations accessing the satellite transponder do not overlap.

• This guard time should be long enough to allow for differences in transmit timing inaccuracies and also for differences in range rate variations of the satellite.

MODULE 4

Ans 7a)

Types of Transponders:

Transponders may be broadly classified into two types depending upon the manner in which they process the signal:

1. Transparent or bent pipe transponders
2. Regenerative transponders

Transparent or Bent Pipe Transponders:

• Transparent transponders process the uplink satellite signal in such a way that only their amplitude and the frequency are altered; the modulation and the spectral shape of the signal are not affected.

• They are also referred to as 'bent pipe' transponders as they simply transmit the information back to Earth.

• Transparent transponders comprise an input filter, low noise amplifier (LNA), down converter, input multiplexer, channel amplifiers, high power amplifiers and output de-multiplexer.

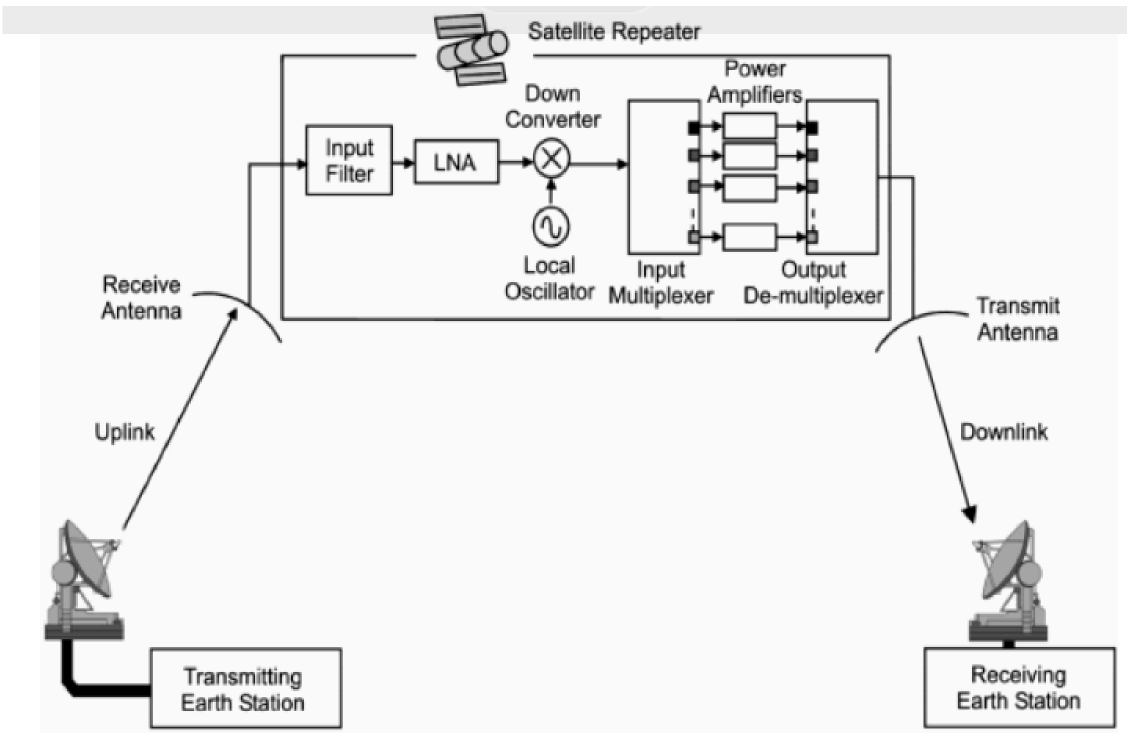


Fig: Transparent transponders

• The uplink section of the transponder, comprising the input filter, LNA and the down converter is common to all the channels and is shared by all the transponders.

• The down converter is basically a mixer which provides a fixed frequency translation corresponding to the exact frequency difference between the center of the uplink and the downlink frequency bands.

• For example, the down converter for a C band transponder provides a frequency translation of 2.225 GHz as the difference between the center of the uplink frequency band (5.925–6.425 GHz) and the downlink frequency band (3.7–4.2 GHz) in this case is 2.225 GHz.

Regenerative Transponders:

• Regenerative transponders are those in which some onboard processing is done and the received signal is altered before retransmission.

• This onboard processing helps to improve the throughput and error performance by restoring the signal quality prior to retransmission to the Earth.

• These repeaters are also called digital processing repeaters as they use various digital techniques like narrowband channel selection and routing, demodulation, error correction, reformatting of data, etc., for processing the received signal.

• Transparent transponders, although they are simplest to design and can handle all three multiple-access methods.

• Regenerative transponders offer the flexibility of link design for optimizing satellite performance as they actively alter the signal before retransmission to the Earth.

Ans 7b)

Advantages of Satellites Over Terrestrial Networks

• Broadcast property – wide coverage area.

• Wide bandwidth – high transmission speeds and large transmission capacity.

• Geographical flexibility – independence of location.

• Easy installation of ground stations.

• Uniform service characteristics.

• Immunity to natural disaster.

• Independence from terrestrial infrastructure.

• Cost aspects – low cost per added site and distance insensitive costs.

Disadvantages of Satellites with Respect to Terrestrial Networks

• Transmission delay-Large transmission delays also have an adverse impact on the quality of voice communication and data transmission at high data rates.

• Echo effects-This is due to larger transmission delays involved in the case of satellites. The development of new echo suppressors, satisfactory link quality has been provided in the case of single-hop GEO satellite networks.

• Launch cost of a satellite -Although the cost of a satellite ground station is less than that of terrestrial networks and the cost of satellite services are independent of the distances involved, the cost of launching a satellite is huge.

Ans 8a)

Satellite television is the most widely used and talked about application area of communication satellites. Satellite television basically refers to the use of satellites for relaying TV programmes from a central broadcasting centre to a large geographical area. Satellites, by their very nature of covering a large geographical area, are perfectly suited for TV broadcasting applications. Satellites like GE and Galaxy in the US, Astra and Hot Bird in Europe, INSAT in India and JCSAT (Japanese communications satellite) and Super bird in Japan are used for TV broadcasting applications. The five Hot Bird satellites provide 900 TV channels and 560 radio stations to 24 million users in Europe. Other means of television broadcasting include terrestrial TV broadcasting and cable TV services.

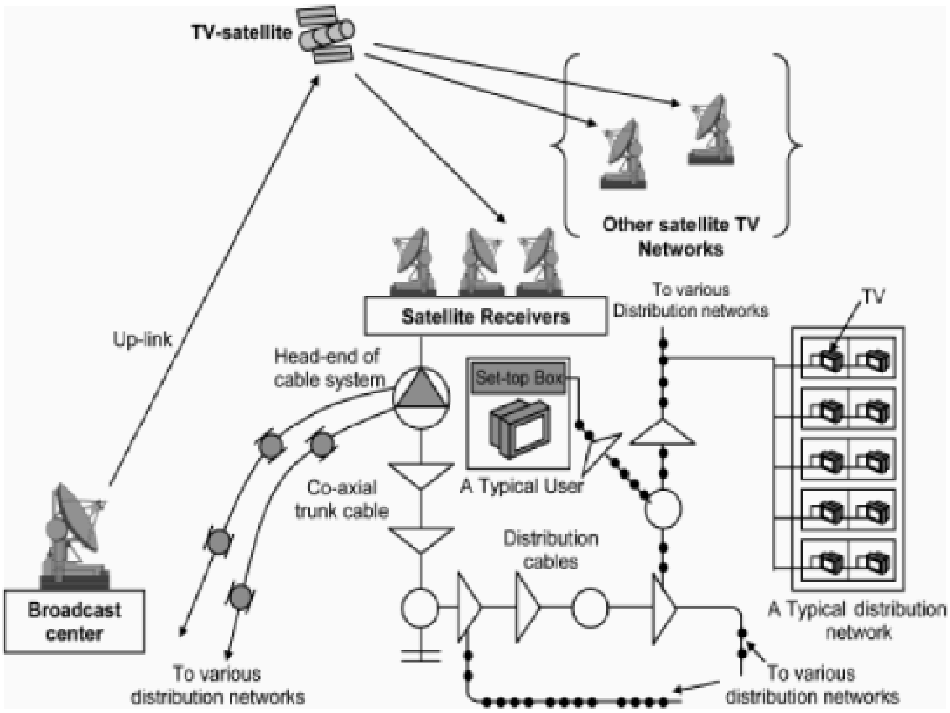
Satellite–Cable Television

• Cable TV refers to the use of coaxial and fibre optic cables to connect each house through a point-to-multipoint distribution network to the head end distribution station.

• Cable TV, originally referred to as CATV (community antenna television) stood for a single head end serving a particular community, like various houses in a large building.

• The head ends receive programming channels from either a local broadcasting link or through satellites.

• The use of satellites to carry the programming channels to the cable systems head ends is referred to as satellite–cable television



• The head end in this case consists of various receive-only Earth stations with the capability of receiving telecast from two to six satellites.

• These Earth stations either have multiple receiving antennas or, a single dish antenna with multiple feeds, with each feed so aligned as to receive telecast from a different satellite.

• The transmission from the satellite is either in the analogue format (mainly in the C band) or in the digital format (mainly in the Ku band).

• In analogue format of transmission, each receiver is tuned to a different transponder channel and the signals from various receivers are multiplexed for transmission to the users.

• The channels received in the digital format can be transmitted either digitally or in the analogue form.

• This processed digital or analogue information is then transmitted over a typical cable distribution network to a large number of houses known as subscribers, who pay a monthly fee for the service.

• The receiving end then consists of a set top box to descramble and retrieve the original signal. The cable TV operators also transmit the videotaped recorded programmes from other sources in addition to showing programmes received from the satellites.

Ans 8b)

Satellite Communication System:

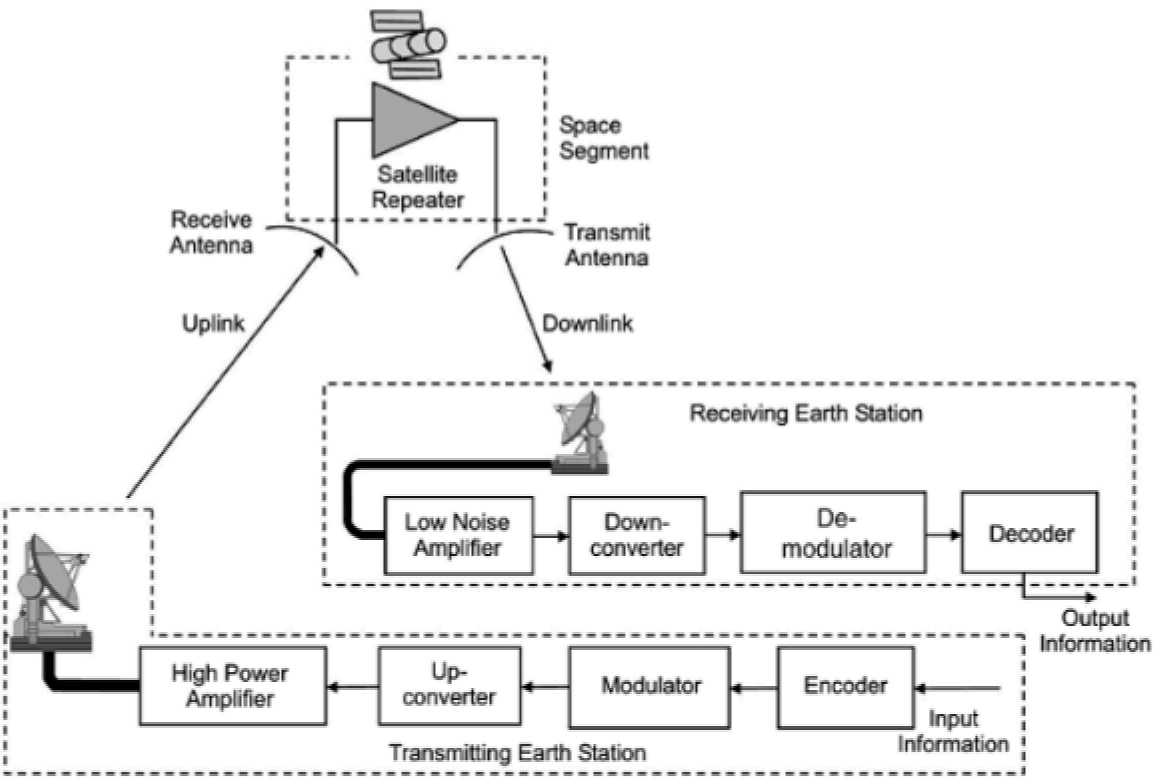


Fig: Basic elements of a satellite communication system

- The information to be transmitted (including voice channels for a telephone service, a composite video signal or digital data, etc.) is modulated using analogue or digital means, up-converted to the desired microwave frequency band of transmission (VHF, UHF, L, S, C, X, Ku or Ka), amplified to the required power level and then beamed up to the satellite from the transmitting Earth station (uplink). The received signals are amplified by the satellite, down converted to a different frequency and then retransmitted towards Earth (downlink).

• The device on board the satellite that performs the amplification and frequency conversion is referred to as a transponder and is the main payload of any communication Satellite. Satellites carry a number of these transponders, varying from 10 to as many as 100 on a high capacity satellite. The downlink signal, received either by an Earth station, a DTH receiver or a mobile receiver, is weak and is first amplified to bring it to a level where it can be processed.

• The downlink signal, received either by an Earth station, a DTH receiver or a mobile receiver, is weak and is first amplified to bring it to a level where it can be processed.

• A transponder is the key element in the satellite communication network and is essentially a repeater which receives a signal transmitted from the Earth station on the uplink, amplifies the signal and retransmits it on the downlink at a different frequency from that of the received signal.

• The first generation satellites used single channel repeaters providing a single channel of transmission within the satellite.

• The available satellite bandwidth, typically 500 MHz for the C and Ku bands and 2000 MHz for the Ka band, is divided into various frequency channels, typically 30 to 80 MHz wide, each of which is handled by a separate repeater.

• Typical transponder bandwidths are 27 MHz, 36 MHz, 54 MHz and 72 MHz, of which 36 MHz is the most common as it is the bandwidth required to transmit one analogue video channel.

MODULE 5

Ans 9)

Depending on the spectral regions used for data acquisition, they can be classified as:

1. Optical remote sensing systems (including visible, near IR and shortwave IR systems)
2. Thermal infrared remote sensing systems
3. Microwave remote sensing systems

Optical Remote Sensing Systems

• Optical remote sensing systems mostly make use of visible (0.3–0.7µm), near IR (0.72–1.30 µm) and shortwave IR (1.3– 3.0 µm) wavelength bands to form images of the Earth’s surface.

• The images are formed by detecting the solar radiation reflected by objects on the ground (Figure) and resemble the photographs taken by a camera.

• Some laser-based optical remote sensing systems are also being employed in which the laser beam is emitted from the active sources mounted on the remote sensing platform.

• The target properties are analysed by studying the reflectance and scattering characteristics of the objects to the laser radiation.

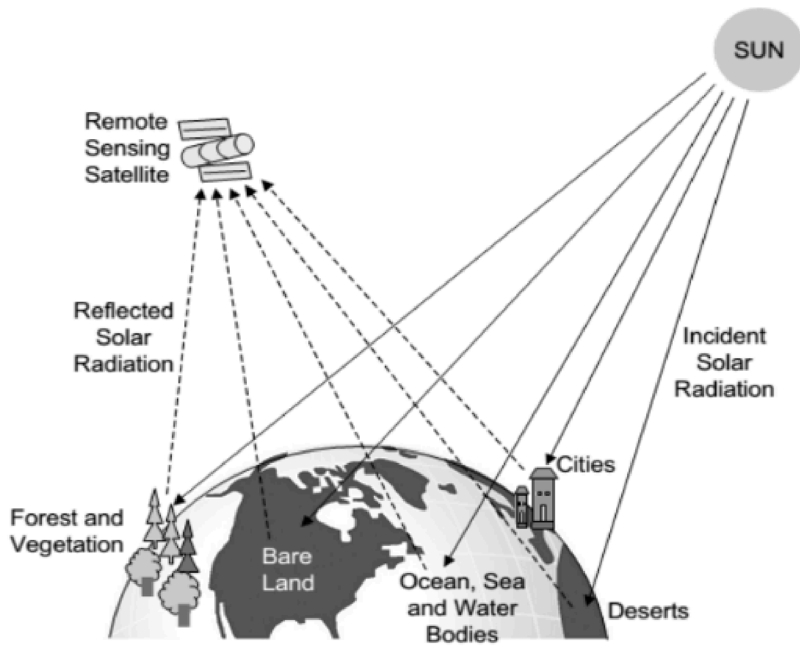


Fig: Optical remote sensing

Optical remote sensing systems employing solar energy come under the category of passive remote sensing systems and the laser-based remote sensing systems belong to the category of active remote sensing systems. Solar energy based optical remote sensing systems work on the principle that different materials reflect and absorb differently at different wavelengths in the optical band. Hence the objects on the ground can be differentiated by their spectral reflectance signatures in the remotely sensed images.

As an example, vegetation has a very strong reflectance in the green and the near IR band and it has strong absorption in the red and the blue spectral bands.

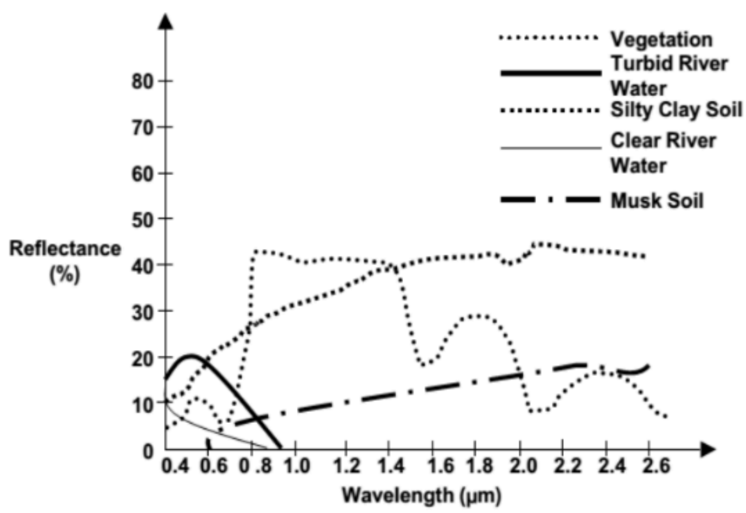


Fig: Spectral reflectance signatures of different objects

Thermal Infrared Remote Sensing Systems:

• Thermal infrared remote sensing systems employ the mid wave IR (3–5 μm) and the long wave IR (8–14 µ m) wavelength bands.

• The imagery here is derived from the thermal radiation emitted by the Earth's surface and objects.

• As different portions of the Earth's surface are at different temperatures, thermal images therefore provide information on the temperature of the ground and water surfaces and the objects on them.

• As the thermal infrared remote sensing systems detect the thermal radiation emitted from the Earth's surface, they come under the category of passive remote sensing systems.

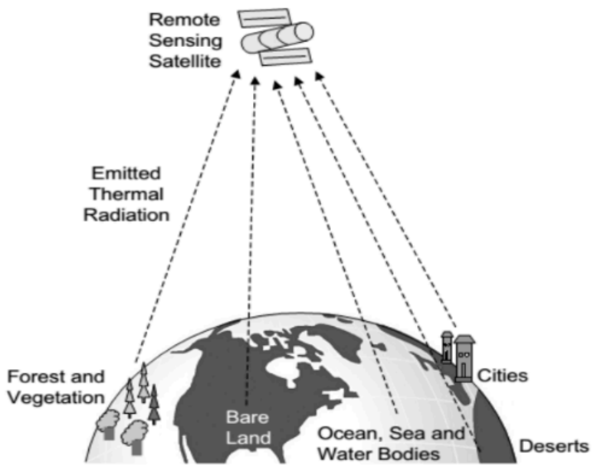


Fig: Thermal remote sensing

The 10 µm band is commonly employed for thermal remote sensing applications as most of the objects on the surface of the Earth have temperatures around 300 K and the spectral radiance for a temperature of 300 K peaks at a wavelength of 10 µm.

• Colder surfaces appear darker in the raw IR thermal images, but the general remote sensing concept for IR images is to invert the relationship between brightness and the temperature so that the colder objects appear brighter as compared to the hotter ones.

• Thermal systems work both during the day and night as they do not use solar radiation, but they suffer from the disadvantage that they are weather-dependent systems.

Ans 10)

Weather Forecasting Satellite Applications:

• Satellites play a major role in weather forecasting.

• Satellites have helped in predicting the paths of tropical cyclones far more reliably than any other weather forecasting tool.

• They also help in predicting the frost, rainfall, drought and fog and so on that is of immense help to farmers.

• Various combinations of satellite images are used to identify clouds and determine their approximate height and thickness.

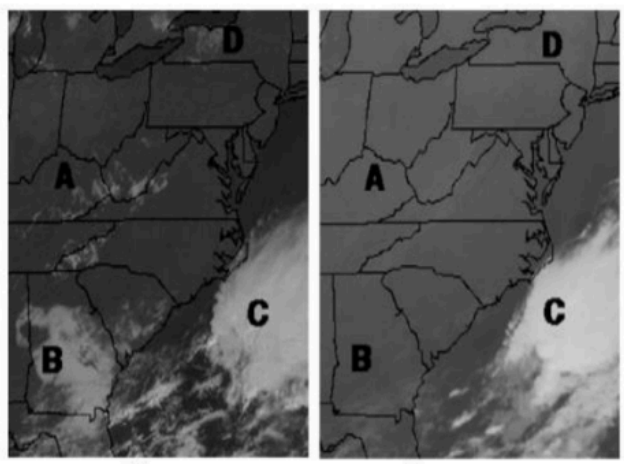
Measurement of Cloud Parameters:

• Satellite imagery enables meteorologists to observe clouds at all levels of the atmosphere, both over land and the oceans. Generally, both visible and IR images are used together for the identification of clouds. Visible images give information on thickness, texture, shape and pattern of the clouds. Information on cloud height is extracted using IR images.

• False colour IR images are used for a detailed analysis of clouds. Information from visible and IR images can be combined to identify the types of clouds and the weather patterns associated with them.

• Figures (a) and (b) show a visible image and IR image respectively, taken from the GOES satellite. The map of the area is overlaid on the image to help in locating the places.

• The clouds marked as A and D in the images appear to be fairly bright in the visible image and are barely seen in the IR image. This indicates that these clouds are low lying warm clouds of medium thickness. The clouds marked as B are very bright in the visible image but they are not seen in the IR image.



(a) (b)

Fig: (a) Visible image taken by GOES satellite used for determining cloud parameters and (b) IR image taken by GOES satellite used for determining cloud parameters

Rainfall

• Imagery from space is also used to estimate rainfall during thunderstorms and hurricanes. This information forms the basis of flood warnings issued by meteorologists.

• Satellite images of the clouds are processed and analyzed to predict the location and amount of rainfall. It is possible to determine the cloud thickness and height using visible and IR images respectively.

• Both these images are combined to predict the amount of rainfall, as it depends both on the thickness and height of clouds.

• Thick and high clouds result in more rain. Moreover, clouds in their early stage of development produce more rain. Therefore, regular observations from GEO satellites,

which can track their development, are used for rainfall prediction.

Wind Speed and Direction:

Determination of wind speed and direction is essential to provide an accurate picture of the current state of the atmosphere. Wind information can be determined by tracking cloud displacements in successive IR and visible images taken from geostationary weather forecasting satellites.

• However, these measurements can only be taken when the cloud cover is present. To overcome this, successive water vapour channel images are used to track the movement of wind fields.

- **Ground-level Temperature Measurements**
- **Air Pollution and Haze**
- **Fog**
- **Oceanography**
- **Severe Storm Support**
- **Fisheries**
- **Snow and Ice Studies**