SATELLITE COMMUNICATION

UNIT-1

PART-A

1. **Define ascending node and descending node**
2. **State Kepler's three laws**
3. **Define Geostationary orbit**
4. **Define apogee and perigee.**
5. **What is Satellite? and its types**
6. **List out the orbital parameters**
7. **What is station keeping?**
8. **What is meant by azimuth angle?**
9. **Define Look angle.**
10. **What is line of apsides?**
11. **What is Inclination?**
12. **Define mean anomaly and true anomaly.**
13. **Mention the apogee and perigee height.**
14. **What is sub-satellite point?**
15. **What is sun transit outage?**
16. **What is an orbital perturbation?**

PART-B

1.What are look angles? Explain how they are determined for geo stationary orbits? what are sun synchronous orbit ?

1. **State Kepler's three laws of planetary motion. Illustrate in each case their relevance to artificial satellites orbiting the earth.**
2. **(a) What are the orbital elements? Explain them.**
   (b) Discuss about the orbital perturbation.

i) Explain about Geo-stationary & near Geo-stationary orbits.

Determine the limits of visibility for an earth station situated at mean sea level, at latitude 48.42° north and longitude 89.26o west. Assume a minimum angle of elevation of 5°.

i) Explain the significance of station keeping.
ii) Discuss about launching satellite orbits.

3. **i. Explain how satellite position are estimated using Sub-satellite points. ii.What is meant by polar orbiting? Explain in detail.**

4. **(a) Explain about frequency allocations for satellite services.**
(b) Write a brief note on launch vehicles and propulsion.

5.Explain in detail the geocentric-equatorial coordinate system which isbased on the earth's equatorial plane.

PART-A

1. **Define ascending node and descending node**

   Ascending node:

   The point where the orbit crosses the equatorial plane going from south to north.

   Descending node:

   The point where the orbit crosses the equatorial plane going from north to south.

2. **State Kepler's three laws. [Apr/May 2015] [May/Jun 2012]**

Kepler's first law.

It states that the path followed by the satellite around the primary will be an ellipse.

An ellipse has two focal points F1 and F2. The center of mass of the two body system, termed the barycenter is always centered on one of the foci.

$$e = [\text{square root of } (a^2 - b^2)] / a$$

Kepler's second law.

It states that for equal time intervals, the satellite will sweep out equal areas in its orbital plane, focused at the barycenter.

State Kepler's third law

It states that the square of the periodic time of orbit is perpendicular
to the cube of the mean distance between the two bodies.

$$a^3 = 3 / n^2$$

Where, n = Mean motion of the satellite in rad/sec.

3 = Earth‟s geocentric gravitational constant. With the n in radians per sec. the orbital period in second is given by,

$$P = 2 / n$$

3. **Define geostationary orbit.**

The satellites present in the geostationary orbit are called geostationary satellite. The geostationary orbit is one in which the satellite appears stationary relative to the earth. It lies in equatorial plane and inclination is „0‟. The satellite must orbit the earth in the same direction as the earth spin. The orbit is circular.

4. **Define apogee and perigee. Apogee:**

The point farthest from the earth.

Perigee:

The point closest from the earth.

5. **What is Satellite? and its types**

An artificial body that is projected from earth to orbit either earth (or) another body of solar systems.

Types: Information satellites and Communication Satellites.

6. **List out the orbital parameters or Keplerian Element**

1. Eccentricity (e)

   They give the shape (of ellipse) to the satellites orbit.

2. Mean anomaly (M0)

   It denotes the position of a satellite in its orbit at a given reference time.

3. Argument of Perigee

   It gives the rotation of the orbit‟s perigee point relative to the orbits nodes in the earth‟s equatorial plane.

4. Inclination
5. Right ascension of ascending node

6. **Write short notes on station keeping.**

It is the process of maintenance of satellite‟s attitude against different

factors that can cause drift with time. Satellites need to have their orbits adjusted from time to time, because the satellite is initially placed in the correct orbit, natural forces induce a progressive drift.

7. What is meant by azimuth angle? It is defined as the angle produced by intersection of local horizontal plane and the plane passing through the earth station, the satellite and center of earth.

8. **Define Look angle.**

The azimuth and elevation angles of the ground station antenna are termed as look angles.

9. **What is line of apsides?**

The line joining the perigee and apogee through the center of the earth.

10. Define Inclination?

The angle between the orbital plane and the earth‟s equatorial plane. It is measured at the ascending node from the equator to the orbit going from east to north.

11. Define mean anomaly and true anomaly.

Mean anomaly.
It gives an average value of the angular position of the satellite with reference to the perigee.
True anomaly

It is the angle from perigee to the satellite position, measured at the earth‟s center.

12. Mention the apogee and perigee height.

$r_a = a(1+e)$

$r_p = a(1+e)$

$h_a = r_a – R$ ph

$_p = r_p – R_p$

13. Define polar-orbiting satellites.

Polar orbiting satellites orbit the earth in such a way as to cover the north and south polar regions.

14. What is sun transit outage?

The sun transit is nothing but the sun comes within the beam width of the earth station antenna. During this period the sun behaves like an extremely noisy source and it blanks out all the signal from the satellite. This effect is termed as sun transit outage.

15. What is an orbital perturbation?

An orbit described by Kepler is ideal as Earth is considered to be a perfect sphere and the force acting around the Earth is the centrifugal force. This force is supposed to balance the gravitational pull of the earth.

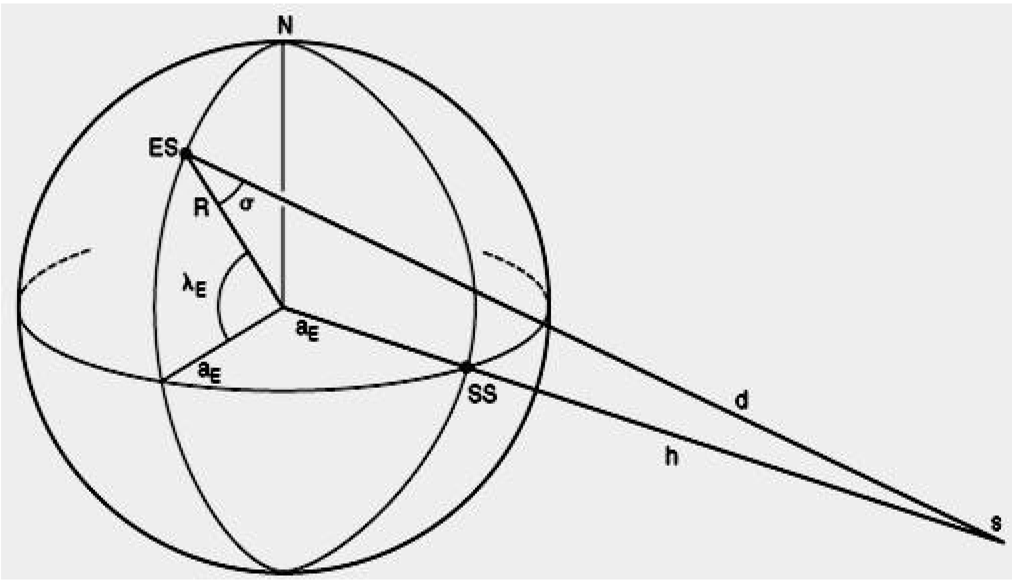
PART-B

1. What are look angles? Explain how they are determined for geo stationary orbits? what are sun synchronous orbit

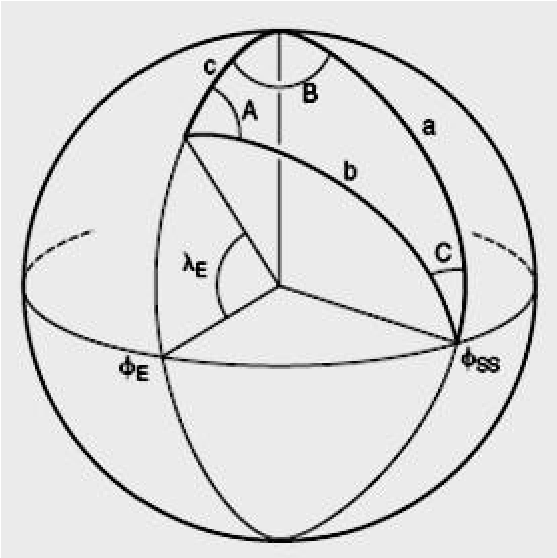
The look angles for the ground station antenna are Azimuth and Elevation angles. They are required at the antenna so that it points directly at the satellite. Look angles are calculated by considering the elliptical orbit. These angles change in order to track the satellite.

For geostationary orbit, these angels values does not change as the satellites are stationary with respect to earth. Thus large earth stations are used for commercial communications, these antennas beamwidth is very narrow and the tracking mechanism is required to compensate for the movement of the satellite about the nominal geostationary position.

For home antennas, antenna beamwidth is quite broad and hence no tracking is essential. This leads to a fixed position for these antennas.



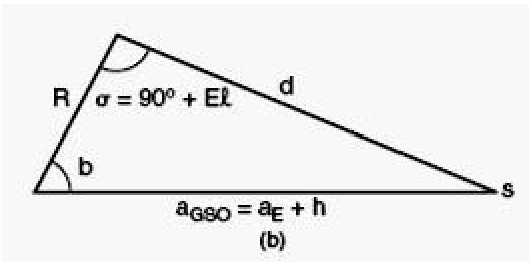
The geometry used in determining the look angles for Geostationary Satellites.



The spherical geometry

The following information is needed to determine the look angles of geostationary orbit.

1. Earth Station Latitude: λE
2. Earth Station Longitude: ΦE
3. Sub-Satellite Point‟s Longitude: ΦSS
4. ES: Position of Earth Station
5. SS: Sub-Satellite Point
6. S: Satellite
7. d: Range from ES to S
8. ζ: angle to be determined



A plane triangle obtained from figure

Considering its a spherical triangle. All sides are the arcs of a great circle. Three sides of this triangle are defined by the angles subtended by the centre of the earth.

1. Side a: angle between North Pole and radius of the sub-satellite point.

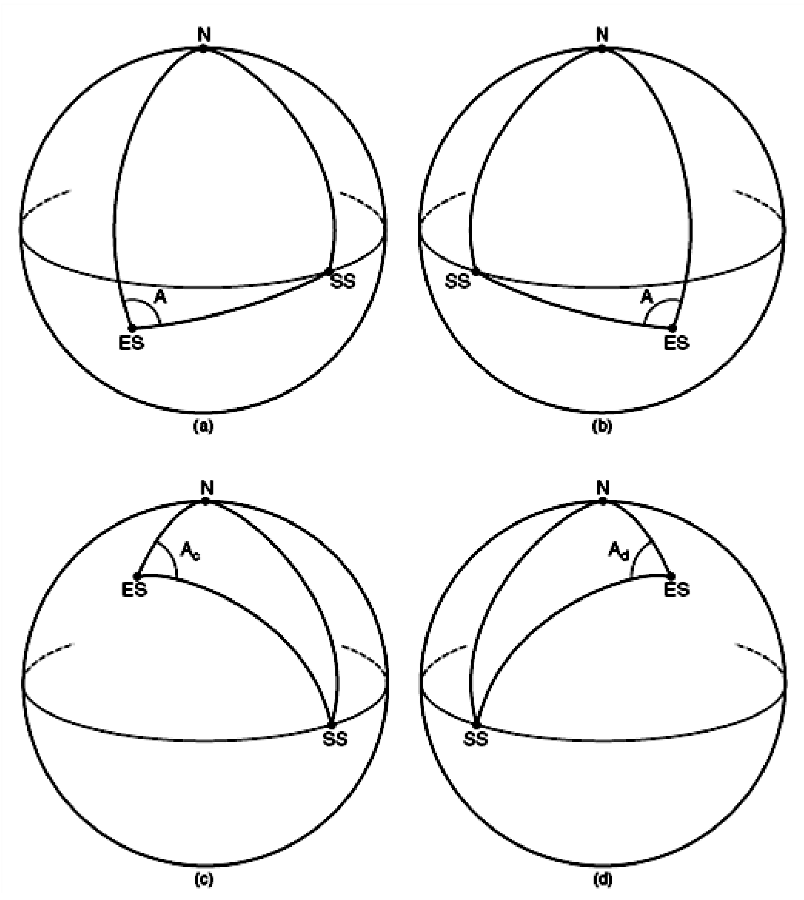
2. Side b: angle between radius of Earth and radius of the sub-satellite point.

Side c: angle between radius of Earth and the North Pole.

a = 900 and such a spherical triangle is called quadrantal triangle. c = 900 – λ

Angle B is the angle between the plane containing c and the plane containing a.

Thus, B = ΦE-ΦSS Angle A is the angle between the plane containing b and the plane containing c. Angle C is the angle between the plane containing a and the plane containing b. Thus, a = 900 c = 900 - λE B = ΦE-ΦSS Thus, b = arcos (cos B cos λE) A = arcsin (sin |B| / sin b)



Azimuth angle related to angle A with respect to table

Fig. 3.3	λ_E	B	A_z, degrees
a	<0	<0	A
b	<0	>0	$360° - A$
c	>0	<0	$180° - A$
d	>0	>0	$180° + A$

$$B := \phi_E - \phi_{SS} \qquad B = -10 \cdot deg$$

$$b := acos(\cos(B) \cdot \cos(\lambda_E)) \qquad b = 36.2 \cdot deg$$

$$A := asin\left(\frac{\sin(|B|)}{\sin(b)}\right) \qquad A = 17.1 \cdot deg$$

By inspection, **λE**> 0 and B < 0. Therefore

$$A_z := 180 \cdot deg - A \qquad A_z = 162.9 \cdot deg$$

Applying the cosine rule for plane triangle to the triangle of figure 3.3 allows the range d to be found to a close approximation:

$$d = \sqrt{R^2 + a_{GSO}{}^2 - 2Ra_{GSO}\cos b}$$

Applying the sine rule for plane triangles to the triangle of figure 3.3 allows the angle of elevation to be found:

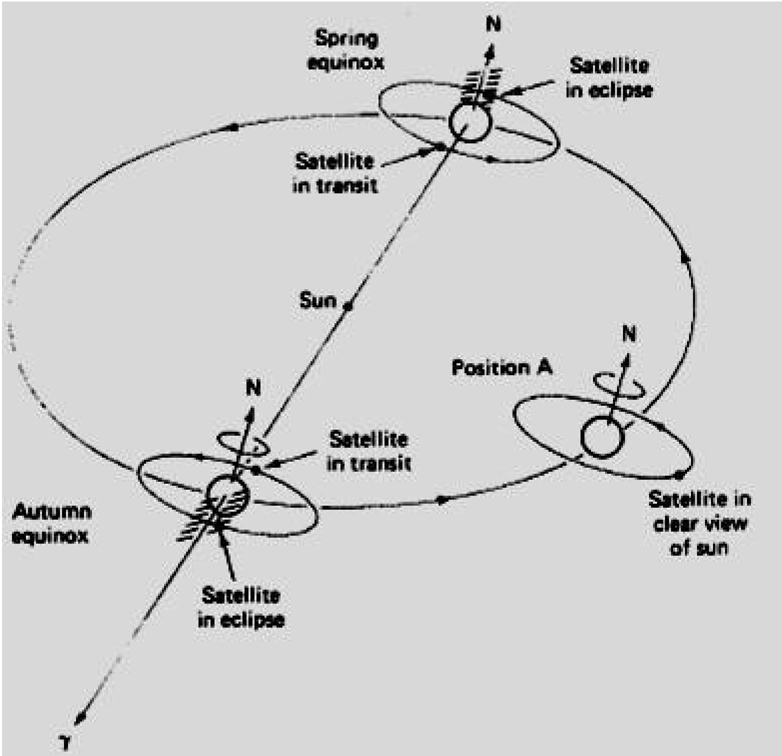
$$El = \arccos\left(\frac{a_{GSO}}{d}\sin b\right)$$

Sun Transit outage:

Sun transit outage is an interruption in or distortion of geostationary satellite signals caused by interference from solar radiation. Sun appears to be an extremely noisy source which completely blanks out the signal from satellite. This effect lasts for 6 days around the equinoxes. They occur for a maximum period of 10 minutes.

Generally, sun outages occur in February, March, September and October, that is, around the time of the equinoxes. At these times, the apparent path of the sun across the sky takes it directly behind the line of sight between an earth station and a satellite. As the sun radiates strongly at the microwave frequencies used to communicate with satellites (C-band, Ka band and Ku band) the sun swamps the signal from the satellite.

The effects of a sun outage can include partial degradation, that is, an increase in the error rate, or total destruction of the signal.



Earth Eclipse of a Satellite and Sun transit Outage

2. State Kepler's three laws of planetary motion. Illustrate in each case their relevance to artificial satellites orbiting the earth. Kepler's laws

Johann Kepler developed empirically three laws of planetary motion, based on conclusions drawn from the extensive observations of Mars by Tycho Brahe (taken around the year 1600). While they were originally defined in terms of the motion of the planets about the Sun, they apply equally to the motion of natural or artificial satellites about the Earth. Kepler sfirst law states that the satellite follows an elliptical path in its orbit around the Earth. The satellite does not necessarily have uniform velocity around its orbit. Keplers second law states that the line joining the satellite with the centre of the Earth sweeps out equal areas in equal times. Keplers third law states that the cube of the mean distance of the satellite from the Earth is proportional to the square of its period.

Kepler's First Law

I. The path followed be a satellite (in our case artificial satellite) around the primary (a planet and in our case Earth) will be an ellipse.

The orbit of every planer is an ellipse with sun at one of the two foci. "

II. An ellipse has two focal points. Let us consider F1 and F2. The centre of mass of the two body system, known as the barycentre as always cantered at one foci. Due to the great difference between the masses of the planet (Earth) and the satellite, centre of mass always coincides with the centre of Earth and hence is always at one foci.

Foci: The center of interest and in our case centre of the ellipse.)

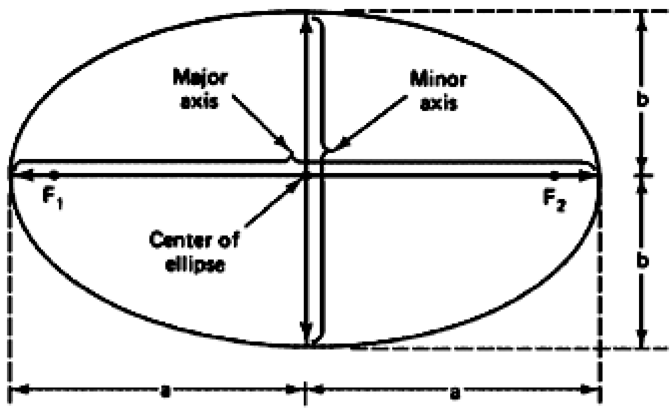
I. Parameters associated with the 1st law of Kepler:

o ***Eccentricity (e):*** it defines how stretched out an ellipse is from a perfect circle.

o ***Semi-Major axis (a):*** It is the longest diameter, a line that runs through the centre and both foci, its ends being at the widest points of the shapes. This line joins the points of apogee.

o ***Semi-Minor axis (b):*** the line joining the points of perigee is called the Semi-Minor axis.

The value of e could be determined by: e = (√a2 – b2) / a

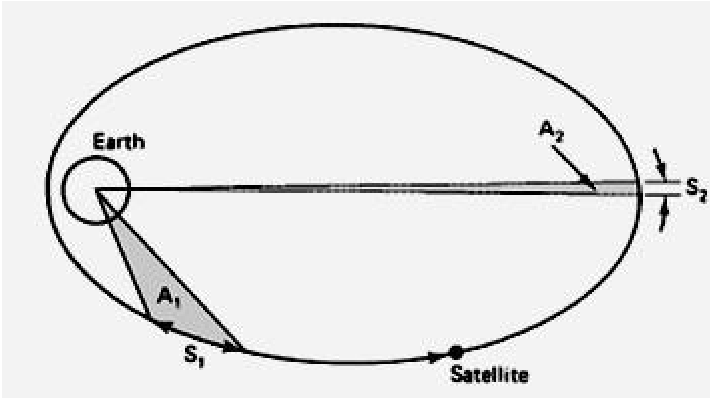


Foci F1 and F2, Semi-major axis a and semi-minor axis b of an ellipse.

Kepler's Second Law

□ "For equal time intervals, a satellite will sweep out equal areas in its orbital plane focussed at the barycentre".

□ With respect to the laws governing the planetary motion around the sun, tis law could be stated as "A line joining a planet and the sun sweeps our equal area during equal intervals of time and considering the law stated above, if satellite travels distances S1 and S2 meters in 1 second, then areas A1 and A2 will be equal.



The areas A1 and A2 swept out in unit intervals of time.

□ The same area will be covered everyday regardless of where in its orbit a satellite is. As the First Keplerian law states that the satellite follows an elliptical orbit around the primary, then the satellite is at different distances from the planet at different parts of the orbit. Hence the satellite has to move faster when it is closer to the Earth so that it sweeps an equal area on the Earth.

□ This could be achieved if the speed of the satellite is adjusted when it is closer to the surface of the Earth in order to make it sweep out equal areas (footprints) of the surface of the Earth.

Kepler's Third Law

□ The square of the periodic time of orbit is proportional to the cube of the mean distance between the two bodies.

□ The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.

□ This law shows the relationship between the distances of satellite from earth and their orbital period.

□ Example: suppose satellite Satellite-I is four times as far from Earth as Satellite-II. Then **I** must traverse four times the distance of **II** in each orbit. Now considering the speed of **I** and **II**, suppose **I** travels at half the speed of **II**, then in order to maintain equilibrium with the reduced gravitational force (as **I** is four times away from Earth than what **II** is), then in all it will require 4 x 2 = 8 times as long for **I** to travel an orbit in agreement with the law which comes down to (82 = 43).

□ Symbolically: P2 α a3 (P2 is directly proportional to a3) Where **P** is the orbital period; **a** is the semi-major axis a3 = μ/n2 Where **n** is the mean motion of satellite in radians per second and **μ** is the Earths geocentric gravitational constant. μ = 3.986005 x 1014 m3/sec2 Due to Earths oblateness, a new parameter called drag is taken into account. P = 2Π / n Here, P is in seconds and n is in radians/ second This law also confirms the fact that there is a fixed relation between period and size.

3. (a) What are the orbital elements? Explain them.

Apogee: A point for a satellite farthest from the Earth. It is denoted as ha.

Perigee: A point for a satellite closest from the Earth. It is denoted as hp.

Line of Apsides: Line joining perigee and apogee through centre of the Earth. It is the major axis of the orbit. One-half of this lines length is the semi-major axis equivalents to satellites mean distance from the Earth.

Ascending Node: The point where the orbit crosses the equatorial plane going from north to south.

Descending Node: The point where the orbit crosses the equatorial plane going from south to north.

Inclination: the angle between the orbital plane and the Earths equatorial plane. Its measured at the ascending node from the equator to the orbit, going from East to North. Also, this angle is commonly denoted as i.

Line of Nodes: the line joining the ascending and descending nodes through the centre of Earth.

Prograde Orbit: an orbit in which satellite moves in the same direction as the Earth‟s rotation. Its inclination is always between 00 to 900. Many satellites follow this path as Earths velocity makes it easier to lunch these satellites.

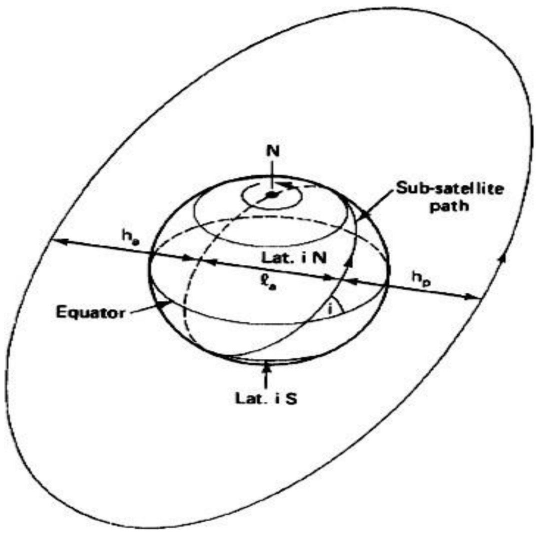
Retrograde Orbit: an orbit in which satellite moves in the same direction counter to the Earth‟s rotation.

Argument of Perigee: An angle from the point of perigee measure in the orbital plane at the Earth"s centre, in the direction of the satellite motion.

Right ascension of ascending node: The definition of an orbit in space, the position of ascending node is specified. But as the Earth spins, the longitude of ascending node changes and cannot be used for reference. Thus for practical determination of an orbit, the longitude and time of crossing the ascending node is used. For absolute measurement, a fixed reference point in space is required. It could also be defined as "right ascension of the ascending node; right ascension is the angular position measured eastward along the celestial equator from the vernal equinox vector to the hour circle of the object".

Mean anamoly: It gives the average value to the angular position of the satellite with reference to the perigee.

True anamoly: It is the angle from point of perigee to the satellites position, measure at the Earths centre.



***Apogee height ha, Perigee height* hp*, Inclination* i*, line of apsides* la**

Following are the 6 elements of the Keplerian Element set commonly known as orbital elements.

1. Semi-Major axis (a)

2. Eccentricity (e)

They give the shape (of ellipse) to the satellites orbit.

3. Mean anomaly (M0)

It denotes the position of a satellite in its orbit at a given reference time.

4. Argument of Perigee

It gives the rotation of the orbits perigee point relative to the orbits nodes in the earths equatorial plane.

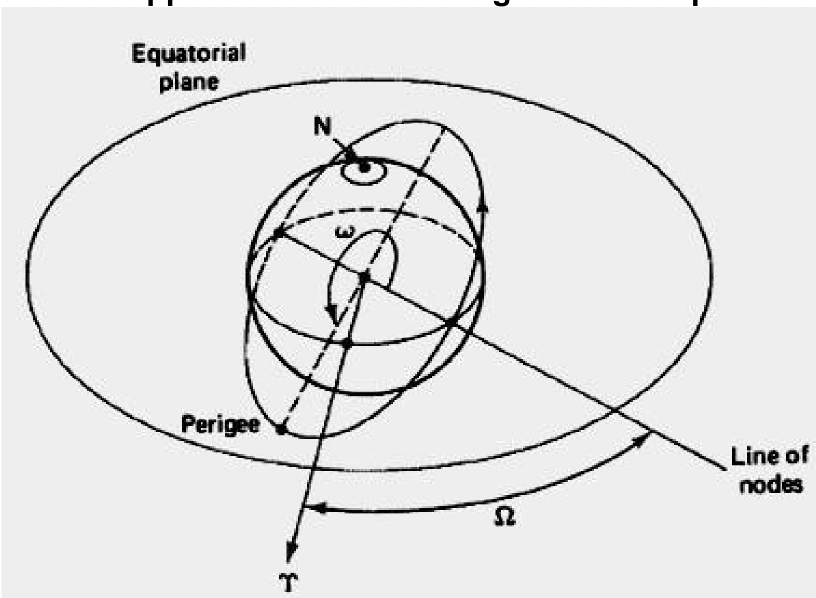
5. Inclination

6. Right ascension of ascending node

They relate the orbital planes position to the Earth. As the equatorial bulge causes a slow variation in argument of perigee and right ascension of ascending node, and because other perturbing forces may alter the orbital elements slightly, the values are specified for the reference time or epoch.

(b) Discuss about the orbital perturbation.

Theoretically, an orbit described by Kepler is ideal as Earth is considered to be a perfect sphere and the force acting around the Earth is the centrifugal force. This force is supposed to balance the gravitational pull of the earth.



Argument of Perigee and Right ascension of ascending node

In reality, other forces also play an important role and affect the motion of the satellite. These forces are the gravitational forces of Sun and Moon along with the atmospheric drag.

Effect of Sun and Moon is more pronounced on geostationary earth satellites where as the atmospheric drag effect is more pronounced for low earth orbit satellites.

Effects of non-Spherical Earth

- As the shape of Earth is not a perfect sphere, it causes some variations in the path followed by the satellites around the primary. As the Earth is bulging from the equatorial belt, and keeping in mind that an orbit is not a physical entity, and it is the forces resulting from an oblate Earth which act on the satellite produce a change in the orbital parameters.

- This causes the satellite to drift as a result of regression of the nodes and the latitude of the point of perigee (point closest to the Earth). This leads to rotation of the line of apsides. As the orbit itself is moving with respect to the Earth, the resultant changes are seen in the values of argument of perigee and right ascension of ascending node.

- Due to the non-spherical shape of Earth, one more effect called as the "Satellite Graveyard" is seen. The non-spherical shape leads to the small value of eccentricity (10-5) at the equatorial plane. This causes a gravity gradient on GEO satellite and makes them drift to one of the two stable points which coincide with minor axis of the equatorial ellipse.

- Working satellites are made to drift back to their position but out-of-service satellites are eventually drifted to these points, and making that point a Satellite Graveyard.

Atmospheric Drag

For Low Earth orbiting satellites, the effect of atmospheric drag is more pronounces. The impact of this drag is maximumat the point of perigee. Drag (pull towards the Earth) has an effect on velocity of Satellite (velocity reduces).

This causes the satellite to not reach the apogee height successive revolutions. This leads to a change in value of semi-major axis and eccentricity. Satellites in service are maneuvered by the earth station back to their original orbital position.

4. i) Explain about Geo-stationary & near Geo-stationary orbits.

Geo stationary:

A **geostationary** orbit is one in which a satellite orbits the earth at exactly the same speed as the earth turns and at the same latitude, specifically zero, the latitude of the equator. A satellite orbiting in a geostationary orbit appears to be hovering in the same spot in the sky, and is directly over the same patch of ground at all times.

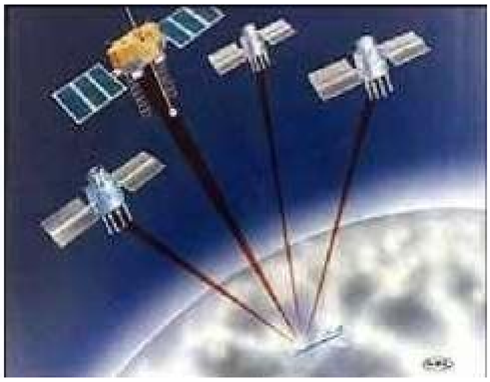
A geosynchronous orbit is one in which the is synchronized with the earth's rotation, but the orbit is tilted with to the plane of the equator. A satellite in a geosynchronous orbit up and down in latitude, although it will stay over the same longitude. Although the terms geostationary' and are sometimes used interchangeably, they are not the geostationary orbit is a subset of all possible geosynchronous. The person most widely developing the concept of geostationary orbits is noted science. Geostationary objects in orbit must be at a certain distance above the earth; any closer and the orbit would decay, and farther out they would escape the earth's gravity altogether. This distance is 35,786 kilometers (22,236 miles) from the surface.

The first geosynchrous satellite was orbited in 1963, and the first geostationary one the following year. Since the only geostationary orbit is in a plane with the equator at 35,786 kilometers, there is only one circle around the world where these conditions obtain. This means that geostationary 'real estate' is finite. While satellites are in no danger of bumping in to one another yet, they must be spaced around the circle so that their frequencies do not interfere with the functioning of their nearest neighbors Geostationary Satellites: There are 2 kinds of manmade satellites in the heavens above: One kind of satellite ORBITS the earth once or twice a day, and the other kind is called a communications satellite and it is PARKED in a STATIONARY position 22,300 miles (35,900 km) above the equator of the earth. A type of the orbiting satellite includes the space the international space station which keep a low earth orbit (LEO) to deadly Van Allen radiation belts.

The most prominent satellites in medium(MEO) are the satellites which comprise the GLOBAL or GPS as it is called.

The Global Positioning System The global positioning developed by the U.S. military and then opened to civilian use. It today to track planes, ships, trains, cars or literally anything that Anyone can buy a receiver and track their exact location by using a .

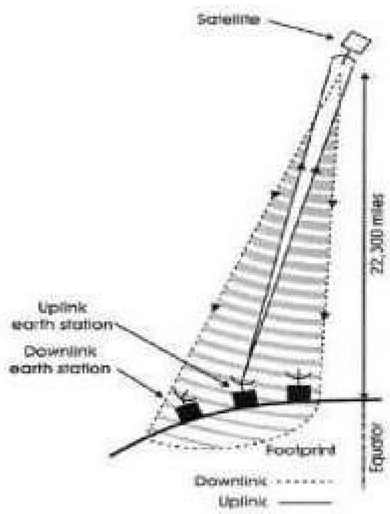
GPS satellites orbit at a height of about 12,000 miles (19,300 km) and orbit the earth once every 12 hours. These satellites are traveling around the earth at speeds of about 7,000 mph (11,200 kph). GPS satellites are powered by solar energy. They have backup batteries onboard to keep them running in the event of a solar eclipse, when there's no solar power.

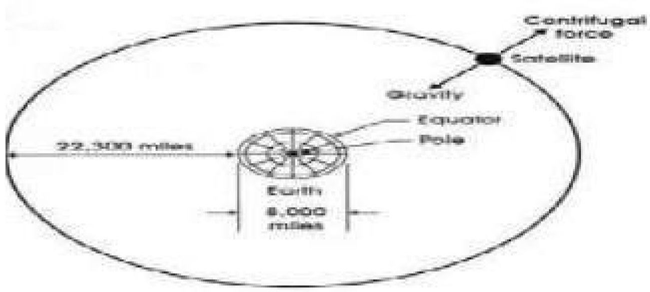


About 24 GPS satellites orbit the earth every 12 hours

Small rocket boosters on each satellite keep them flying in the correct path. The satellites have a lifetime of about 10 years until all their fuel runs out. At exactly 22,300 miles above the equator, the force of gravity is cancelled by the centrifugal force of the rotating universe. the ideal spot to park a stationary satellite.

At exactly 22,000 miles (35,900 km) above the equator, the earth's force of gravity is canceled by the centrifugal force of the rotating universe.





At exactly 22,000 miles (35,900 km) above the equator, the earth's force of gravity is canceled by the centrifugal force of the rotating universe. .

Non Geo-Stationary Orbit:

For the geo- stationary case, the most important of these are the gravitational fields of the moon and the sun, and the non spherical shape of the earth. Other significant forces are solar radiation pressure and reaction of the satellite itself to motor movement within the satellite. As a result, station-keeping maneuvers must be carried out to maintain the satellite within set limits of its nominal geostationary position.

An exact geostationary orbit therefore is not attainable in practice, and the orbital parameters vary with time. The two-line orbital elements are published at regular interval.

The period for a geostationary satellite is 23 h, 56 min, 4 s, or 86,164 s. The reciprocal of this is 1.00273896 rev/day, which is about the value tabulated for most of the satellites.

Thus these satellites are geo- synchronous, in that they rotate in synchronism with the rotation of the earth. However, they are not geostationary. The term geosynchronous satellite is used in many cases instead of geostationary to describe these near-geostationary satellites. It should be noted, however, that in general a geosynchronous satellite does not have to be near-geostationary, and there a number of geosynchronous satellites that are in highly orbits with comparatively large inclinations (e.g., the Tundra The small inclination makes it difficult to the position of the ascending node, and the small eccentricity difficult to locate the position of the perigee. However, because of the small the angles w and Ω can be assumed to be in the same plane. of the sub satellite point is the east from the Greenwich meridian.

The Greenwich time (GST) gives the eastward position of the Greenwich to the line of Aries, and hence the subsatellite point is at the mean longitude of the satellite is given by can be used to calculate the true anomaly, and because of the small eccentricity, this can be approximated as v= M + 2esinM.

NEAR GEOSTATIONARY ORBITS

There are a number of perbuting forces that cause an orbit to depart from ideal Keplerian orbit. The most effecting ones are gravitational fields of sun and moon, non-spherical shape of the Earth, reaction of the satellite itself to motor movements within the satellites.

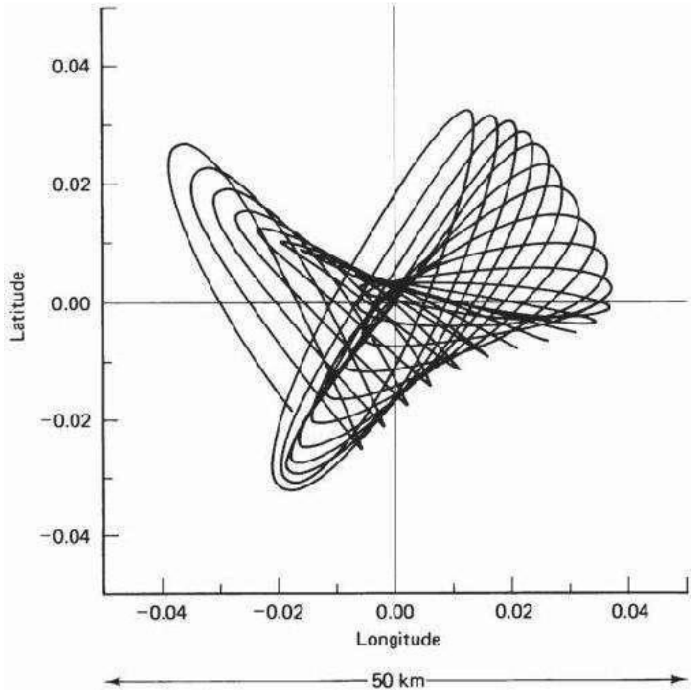
Thus the earth station keeps maneuvering the satellite to maintain its position. Within a set of nominal geostationary coordinates. Thus the exact GEO is not attainable in practice and the orbital parameters vary with time. Hence these satellites are called “Geosynchronous” satellites or “Near-Geostationary satellites”.

ii) Determine the limits of visibility for an earth station situated at mean sea level, at latitude 48.42° north and longitude

The east and west limits of geostationary are visible from any given Earth station. These limits are set by the geographic coordinates of the Earth station and antenna elevation. The lowest elevation is zero (in theory) but in practice, to avoid reception of excess noise from Earth. Some finite minimum value of elevation is issued. The earth station can see a satellite over a geostationary arc bounded by **+- (81.30)** about the earth stations longitude.

5. i) Explain the significance of station keeping.

In addition to having its attitude controlled, it is important that a geostationary satellite be kept in its correct orbital slot. The equatorial ellipticity of the earth causes geostationary satellites to drift slowly along the orbit, to one of two stable points, at 75°E and 105°W.To counter this drift, an oppositely directed velocity component is imparted to the satellite by means of jets, which are pulsed once every 2 or 3 weeks. These maneuvers are termed *east-west station-keeping maneuvers*.Satellites in the 6/4-GHz band must be kept within 0.1° of the designated longitude, and in the 14/12-GHz band, within 0.05°.



Typical satellite motion.

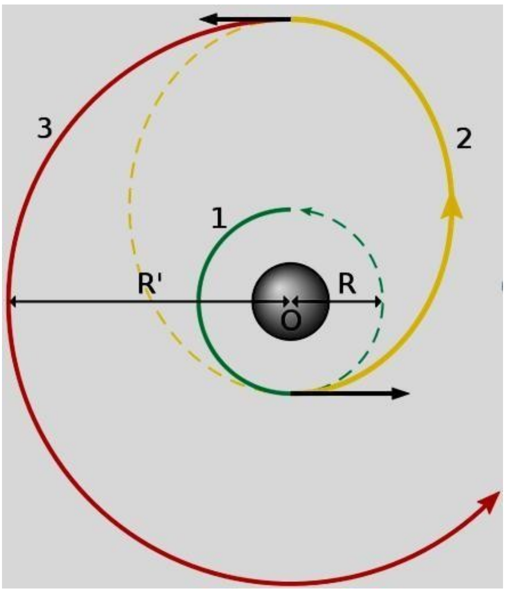
ii) Discuss about launching satellite orbits.

Low Earth Orbiting satellites are directly injected into their orbits. This cannot be done in case of GEOs as they have to be positioned 36,000kms above the Earth‟s surface. Launch vehicles are hence used to set these satellites in their orbits. These vehicles are reusable. They are also known as „Space Transportation System (STS).

When the orbital altitude is greater than 1,200 km it becomes expensive to directly inject the satellite in its orbit. For this purpose, a satellite must be placed in to a transfer orbit between the initial lower orbit and destination orbit. The transfer orbit is commonly known as *Hohmann-Transfer Orbit.

(*About Hohmann Transfer Orbit: This manoeuvre is named for the German civil engineer who first proposed it, Walter Hohmann, who was born in 1880. He didn't work in rocketry professionally (and wasn't associated with military rocketry), but was a key member of Germany's pioneering Society for Space Travel that included people such as Willy Ley, Hermann, and Werner von Braun. He published his concept of how to transfer between orbits in his 1925 book, The Attainability of Celestial Bodies.)

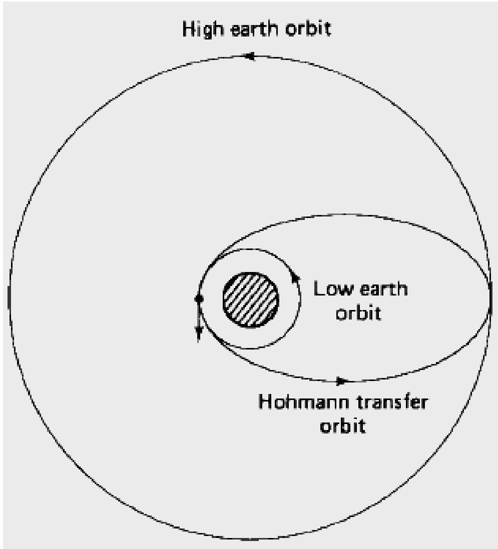
The transfer orbit is selected to minimize the energy required for the transfer. This orbit forms a tangent to the low attitude orbit at the point of its perigee and tangent to high altitude orbit at the point of its apogee.



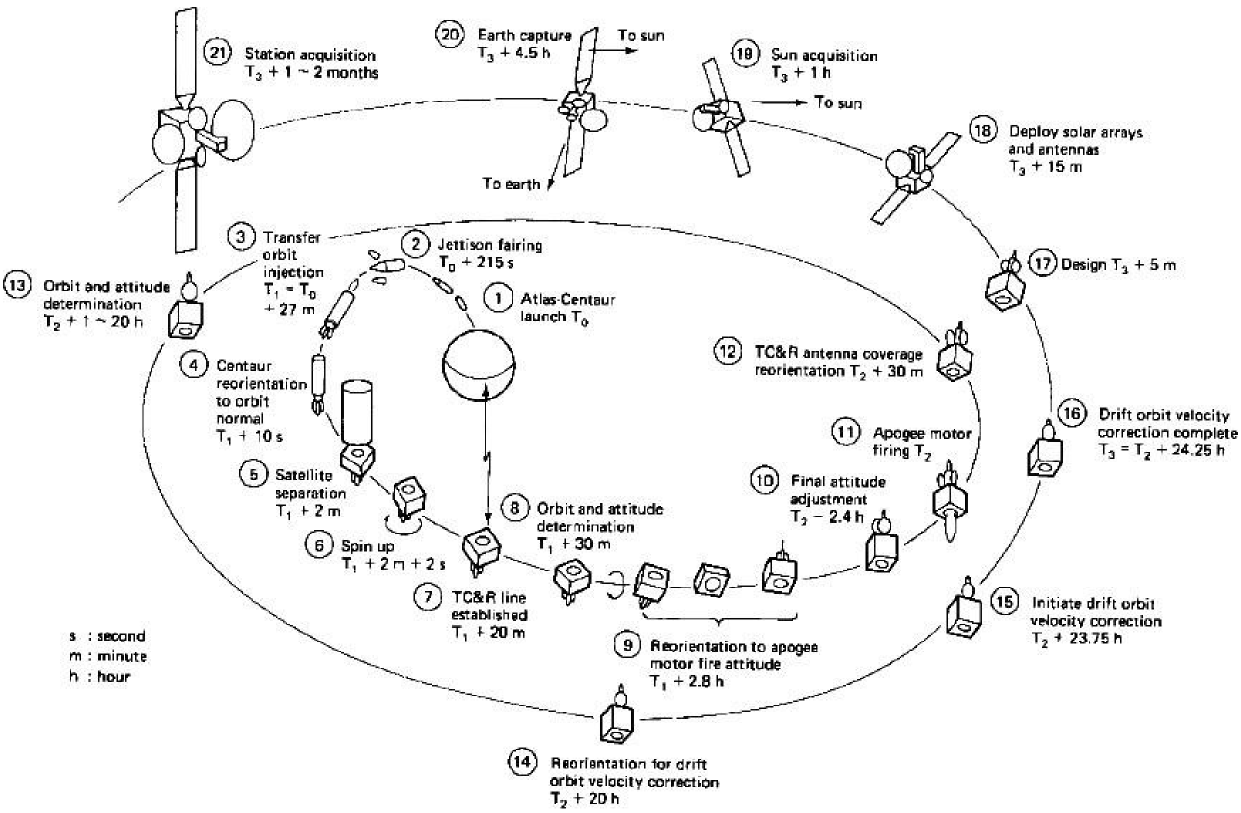
Orbit Transfer positions

The rocket injects the satellite with the required thrust** into the transfer orbit. With the STS, the satellite carries a perigee kick motor*** which imparts the required thrust to inject the satellite in its transfer orbit. Similarly, an apogee kick motor (AKM) is used to inject the satellite in its destination orbit.

Generally it takes 1-2 months for the satellite to become fully functional. The Earth Station performs the Telemetry Tracking and Command**** function to control the satellite transits and functionalities.



Hohmann Transfer Orbit



Launching stages of a GEO (example INTELSAT)

It is better to launch rockets closer to the equator because the Earth rotates at a greater speed here than that at either pole. This extra speed at the equator means a rocket needs less thrust (and therefore less fuel) to launch into orbit. In addition, launching at the equator provides an additional 1,036 mph (1,667 km/h) of speed once the vehicle reaches orbit. This speed bonus means the vehicle needs less fuel, and that freed space can be used to carry more pay load.

6. Explain how satellite positions are estimated using Sub-satellite points.

Point at which a line between the satellite and the center of the Earth intersects the Earth"s surface

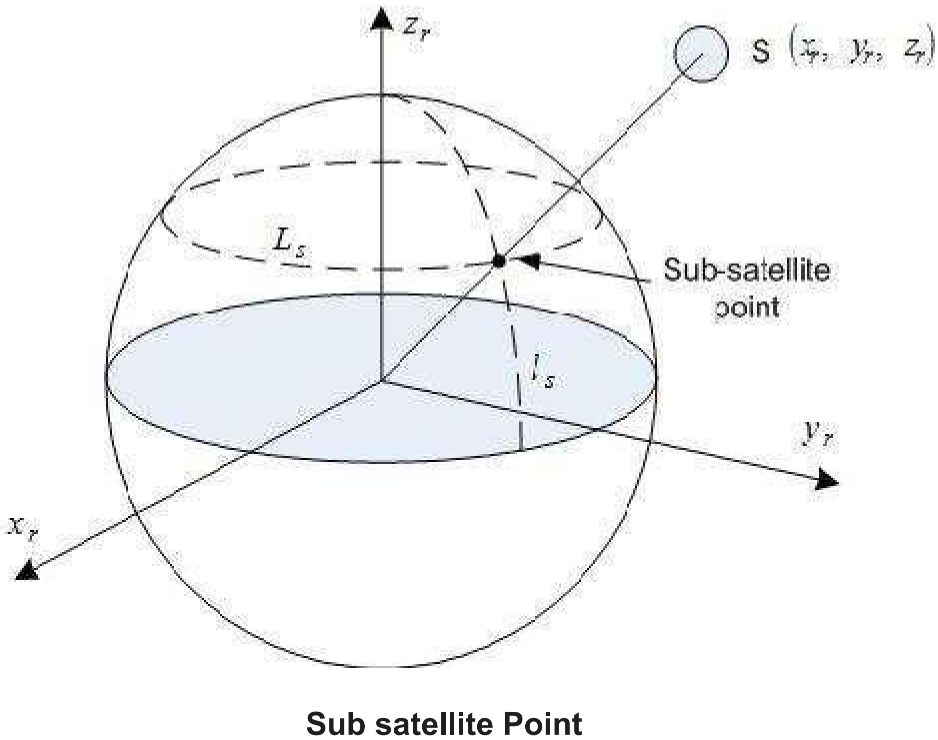
□ Location of the point expressed in terms of latitude and longitude

□ If one is in the US it is common to use

o Latitude – degrees north from equator

o Longitude – degrees west of the Greenwich meridian

Location of the sub satellite point may be calculated from coordinates of the rotating system as:



Sub satellite Point

$$L_s = \frac{\pi}{2} - \cos^{-1}\left(\frac{z_r}{\sqrt{x_r^2 + y_r^2 + z_r^2}} \right)$$

ii. What is meant by polar orbiting? Explain in detail.

Polar Orbiting Satellites

These satellites follow the Polar Orbits. An infinite number of polar orbits cover north and south Polar Regions. Weather (ultraviolet sensor also measure ozone level) satellites between 800 and 900 km National Oceanic and Atmospheric Administration (NOAA) operate a weather satellite system

Satellite period is 102 minutes and earth rotated 25 degree.

Estimate the sub-satellite point at the following times after the equator 90 degree E North-South crossing:

a) 10 minutes, 87.5 degree E and 36 degree S;

b) 102 minutes, 65 degree E and equator;

c) 120 minutes, 60 degree E and 72 degree S.

The system uses both geostationary operational environment satellite (GOES) and polar operational environment satellite (POES)

Sun synchronous: they across the equator at the same local time each day

The morning orbit, at an altitude of 830 km, crosses the equator from south to north at 7:30 AM, and the afternoon orbit, at an altitude of 870 km, at 1:40 PM

7. (a) Explain about frequency allocations for satellite services.

Allocation of frequencies to satellite services s a complicated process which requires international coordination and planning. This is done as per the International Telecommunication Union (ITU). To implement this frequency planning, the world is divided into three regions:

- Region1: Europe, Africa and Mongolia
- Region 2: North and South America and Greenland
- Region 3: Asia (excluding region 1 areas), Australia and south-west

Pacific.Within these regions, he frequency bands are allocated to various satellite services. Some of them are listed below.

□ **Fixed satellite service**: Provides Links for existing Telephone Networks Used for transmitting television signals to cable companies

□ **Broadcasting satellite service**: Provides Direct Broadcast to homes. E.g. Live Cricket matches etc

□ **Mobile satellite service**s: This includes services for:

Land Mobile Maritime Mobile Aeronautical mobile

□ **Navigational satellite services** : Include Global Positioning systems

Meteorological satellite services: They are often used to perform Search and Rescue service

Below are the frequencies allocated to these satellites:

Frequency Band (GHZ) Designations:

□ VHF: 01-0.3

□ UHF: 0.3-1.0

□ L-band: 1.0-2.0

□ S-band: 2.0-4.0

□ C-band: 4.0-8.0

□ X-band: 8.0-12.0

□ Ku-band: 12.0-18.0 *(Ku is Under K Band)*

□ Ka-band: 18.0-27.0 *(Ka is Above K Band)*

□ V-band: 40.0-75.0

□ W-band: 75-110

□ Mm-band: 110-300

□ **μ**m-band: 300-3000

Based on the satellite service, following are the frequencies allocated to the satellites:

Frequency Band (GHZ) Designations:

□ VHF: 01-0.3 Mobile & Navigational Satellite Services

□ L-band: 1.0-2.0 Mobile & Navigational Satellite Services

□ C-band: 4.0-8.0 Fixed Satellite Service

□Ku-band: 12.0-18.0 Direct Broadcast Satellite Services

(b) Write a brief note on launch vehicles and propulsion. (

The rocket injects the satellite with the required thrust into the transfer orbit. With the STS, the satellite carries a perigee kick motor***which imparts the required thrust to inject the satellite in its transfer orbit.**

Similarly, an apogee kick motor (AKM) is used to inject the satellite in its destination orbit. Generally it takes 1-2 months for the satellite to become fully functional. The Earth Station performs the Telemetry Tracking and Command****function to control the satellite transits and functionalities.(**Thrust: It is a reaction force described quantitatively by Newton's second and third laws. When a system expels or accelerates mass in one direction the accelerated mass will cause a force of equal magnitude but opposite direction on that system.)

Kick Motor refers to a rocket motor that is regularly employed on artificial satellites destined for a geostationary orbit. As the vast majority of geostationary satellite launches are carried out from spaceports at a significant distance away from Earth's equator. The carrier rocket would only be able to launch the satellite into an elliptical orbit of maximum apogee 35,784-kilometres and with a non-zero inclination approximately equal to the latitude of the launch site.

TT&C: it" s a sub-system where the functions performed by the satellite control network to maintain health and status, measure specific mission parameters and processing over time a sequence of these measurement to refine parameter knowledge, and transmit mission commands to the satellite. Detailed study of TT&C in the upcoming units.

Transfer Orbit:

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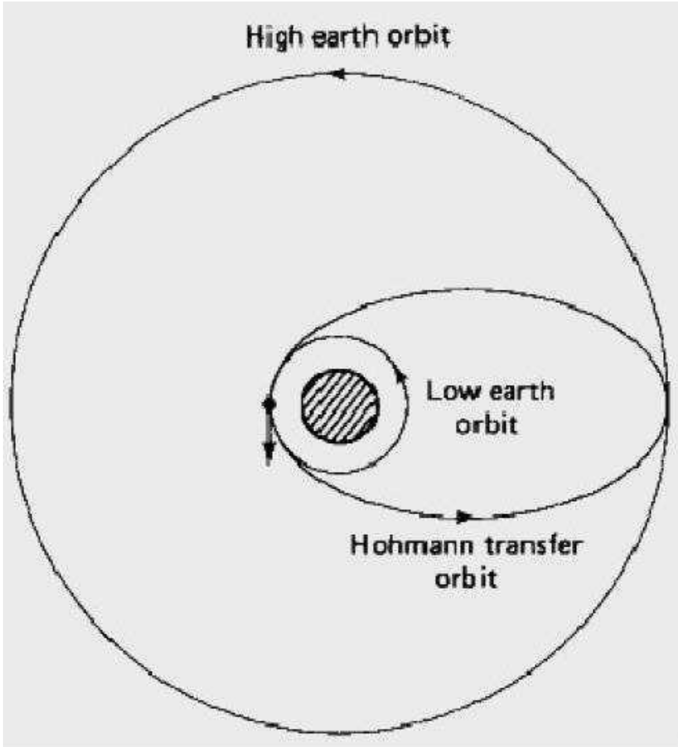
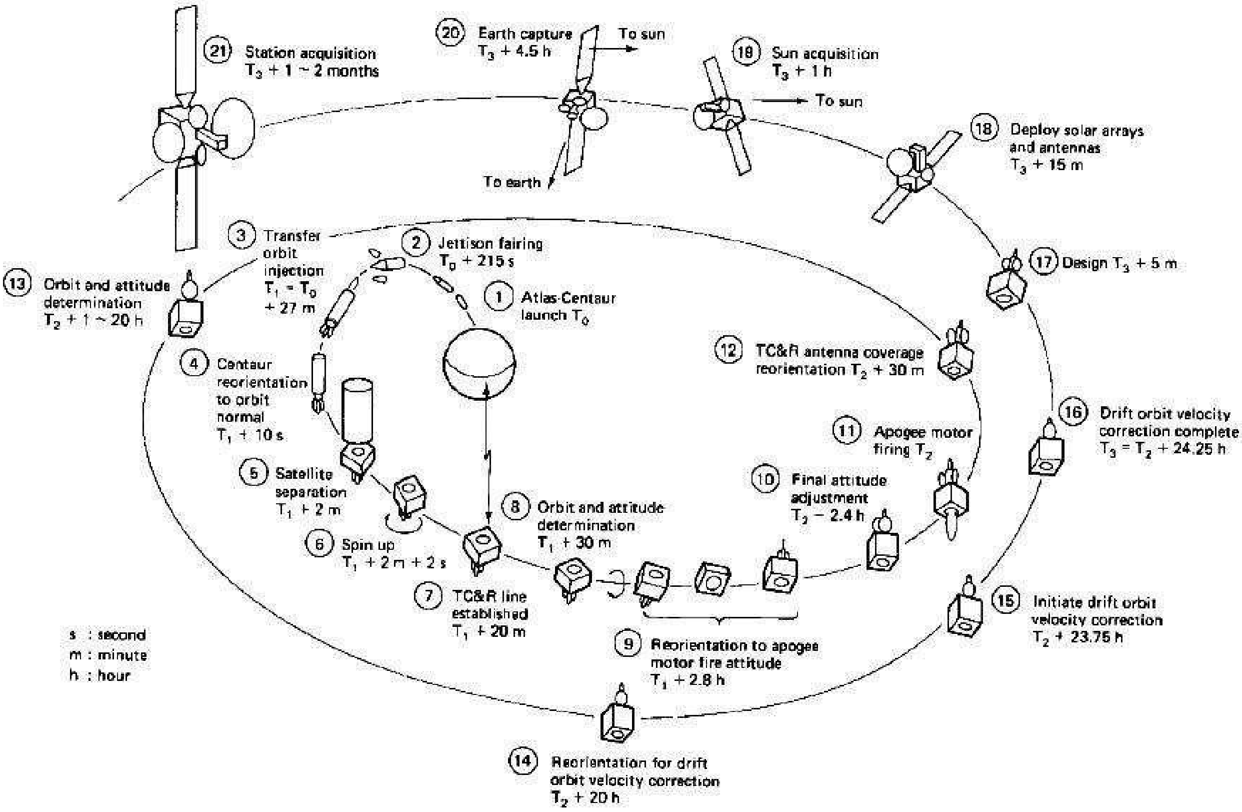
In addition, launching at the equator provides an additional 1,036 mph (1,667 km/h) of speed once the vehicle reaches orbit. This speed bonus means the vehicle needs less fuel, and that freed space can be used to carry more pay load.



Hohmann Transfer Orbit



Launching stages of a GEO (example INTELSAT)

Rocket launch:

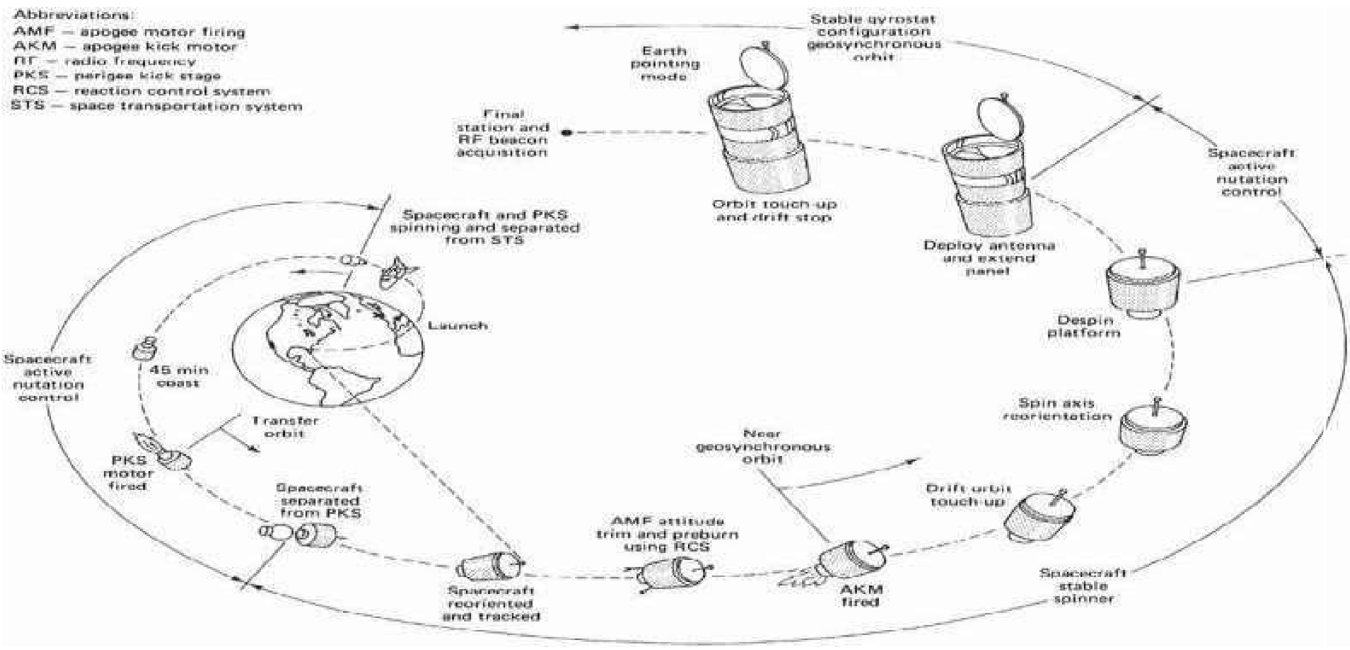
A **rocket launch** is the takeoff phase of the flight of a rocket. Launches for orbital spaceflights, or launches into interplanetary space, are usually from a fixed location on the ground, but may also be from a floating platform (such as the Sea Launch vessel) or, potentially, from a superheavy An-225-class airplane

Launches of suborbital flights (including missile launches), can also be from:

- a missile silo
- a mobile launcher vehicle
- a submarine
- air launch:
- from a plane (e.g. Scaled Composites Space Ship One, Pegasus Rocket, X-15)
- from a balloon (Rockoon, da Vinci Project (under development))
- a surface ship (Aegis Ballistic Missile Defense System)
- an inclined rail (e.g. rocket sled launch)

"Rocket launch technologies" generally refers to the entire set of systems needed to successfully launch a vehicle, not just the vehicle itself, but also the firing control systems, ground control station, launch pad, and tracking stations needed for a successful launch and/or recovery.

Orbital launch vehicles commonly take off vertically, and then begin to progressively lean over, usually following a gravity turn trajectory. Once above the majority of the atmosphere, the vehicle then angles the rocket jet, pointing it largely horizontally but somewhat downwards, which permits the vehicle to gain and then maintain altitude while increasing horizontal speed. As the speed grows, the vehicle will become more and more horizontal until at orbital speed, the engine will cut off.



STS-7/Anik C2 mission scenario.

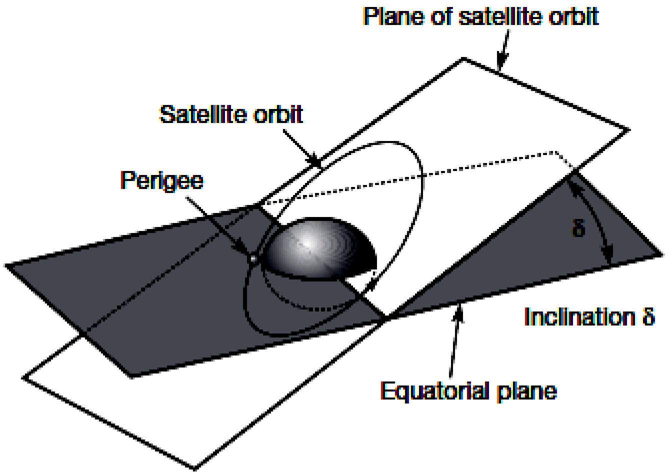
8. Explain in detail the geocentric-equatorial coordinate system which is based on the earth's equatorial plane.

Satellites orbit around the earth. Depending on the application, these orbits can be circular or elliptical. Satellites in circular orbits always keep the same distance to the earth‟s surface following a simple law:

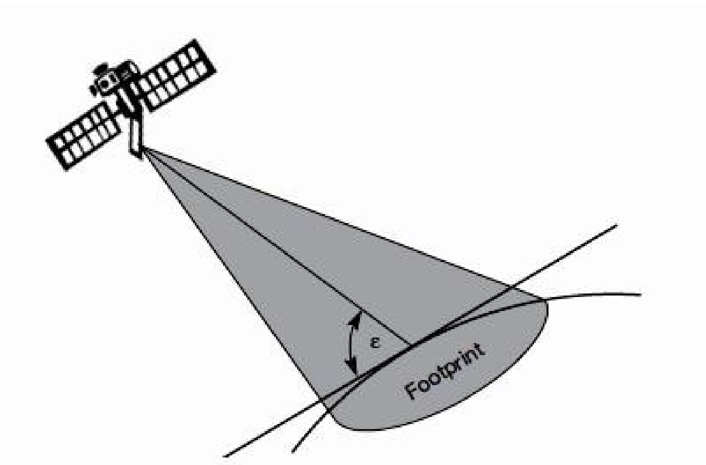
The attractive force *Fg* of the earth due to gravity equals *m·g* (*R/r*) 2 The centrifugal force *Fc* trying to pull the satellite away equals *m·r·*ω2 *The variables have the following meaning: m* is the mass of the satellite; *R* is the radius of earth with *R* = 6,370 km; ri s the distance of the satellite to the centre of the earth; *g* is the acceleration of gravity with *g* = 9.81 m/s2; ω is the angular velocity with ω = 2·π·*f*, *f* is the frequency of the rotation. To keep the satellite in a stable circular orbit, the following equation must hold: *Fg* = *Fc*, i.e., both forces must be equal. Looking at this equation the first thing to notice is that the mass *m* of a satellite is irrelevant (it appears on both sides of the equation). Solving the equation for the distance *r* of the satellite to the centre of the earth results in the following equation:

From the above equation it can be concluded that the distance of a satellite to the earth‟s surface depends on its rotation frequency. Important parameters in satellite communication are the *inclination* and *elevation* angles. The inclination angle δ is defined between the equatorial plane and the plane described by the satellite orbit.

An inclination angle of 0 degrees means that the satellite is exactly above the equator. If the satellite does not have a circular orbit, the closest point to the earth is called the perigee.



Angle of Inclination



Angle of Elevation

The elevation angle ε is defined between the centre of the satellite beam and the plane tangential to the earth‟s surface. A so called footprint can be defined as the area on earth where the signals of the satellite can be received.