

REMOTE SENSING SATELLITES AND ITS ORBITS

1. Introduction

When a satellite is launched into the space, it moves in a well-defined path around the Earth, which is called the orbit of the satellite. Gravitational pull of the Earth and the velocity of the satellite are the two basic factors that keep the satellites in any particular orbit. Spatial and temporal coverage of the satellite depends on the orbit. There are three basic types of orbits in use.

- ✓ Geo-synchronous orbits
- ✓ Polar or near polar orbits
- ✓ Sun-synchronous orbits

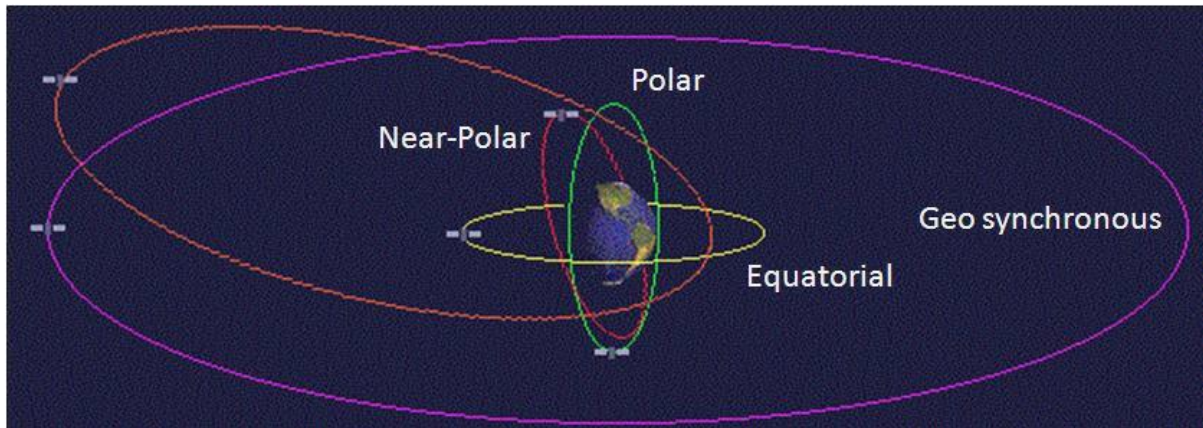


Fig.1 Different types of satellite orbits

Satellite orbits are matched to the capability and objective of the sensor(s) they carry. Orbit selection can vary in terms of altitude (their height above the Earth's surface) and their orientation and rotation relative to the Earth.

This lecture introduces some important terms related to the satellite orbits and the details of different types of satellite orbits.

2. Characteristics of satellite orbits

The path followed by a satellite in the space is called the orbit of the satellite. Orbits may be circular (or near circular) or elliptical in shape.

Orbital period: Time taken by a satellite to complete one revolution in its orbit around the earth is called orbital period.

It varies from around 100 minutes for a near-polar earth observing satellite to 24 hours for a geo-stationary satellite.

Altitude: Altitude of a satellite is its heights with respect to the surface immediately below it. Depending on the designed purpose of the satellite, the orbit may be located at low (160-2000 km), moderate, and high (~36000km) altitude.

Apogee and perigee: Apogee is the point in the orbit where the satellite is at maximum distance from the Earth. Perigee is the point in the orbit where the satellite is nearest to the Earth as shown in Fig.2.

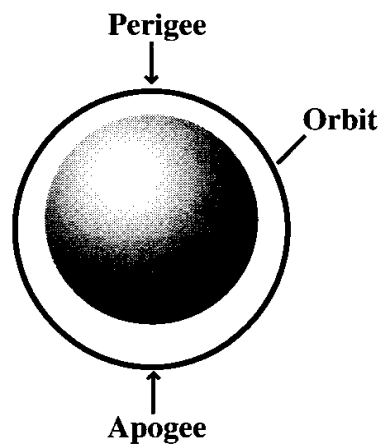


Fig.2 Schematic representation of the satellite orbit showing the Apogee and Perigee

Inclination: Inclination of the orbital plane is measured clockwise from the equator. Orbital inclination for a remote sensing satellite is typically 99 degrees. Inclination of any satellite on the equatorial plane is nearly 180 degrees.

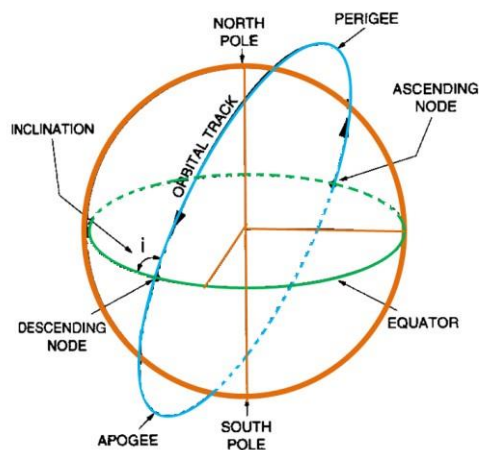


Fig.3 Schematic representation showing the orbital track and inclination

Nadir, ground track and zenith: Nadir is the point of interception on the surface of the Earth of the radial line between the center of the Earth and the satellite. This is the point of shortest distance from the satellite to the earth's surface. Any point just opposite to the nadir, above the satellite is called zenith. The circle on the earth's surface described by the nadir point as the satellite revolves is called the ground track. In other words, it is the projection of the satellites orbit on the ground surface.

Swath

Swath of a satellite is the width of the area on the surface of the Earth, which is imaged by the sensor during a single pass.

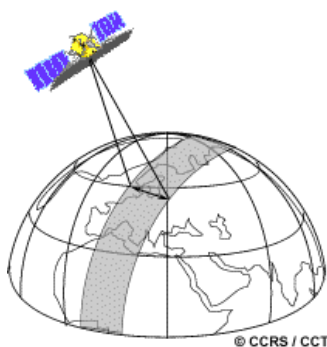


Fig. 4 Schematic representation of the satellite swath

For example, swath width of the IRS-1C LISS-3 sensor is 141 km in the visible bands and 148 km in the shortwave infrared band.

Sidelap and Overlap

Overlap is the common area on consecutive images along the flight direction. For example, IRS-1C LISS-3 sensors create 7 km overlap between two successive images.

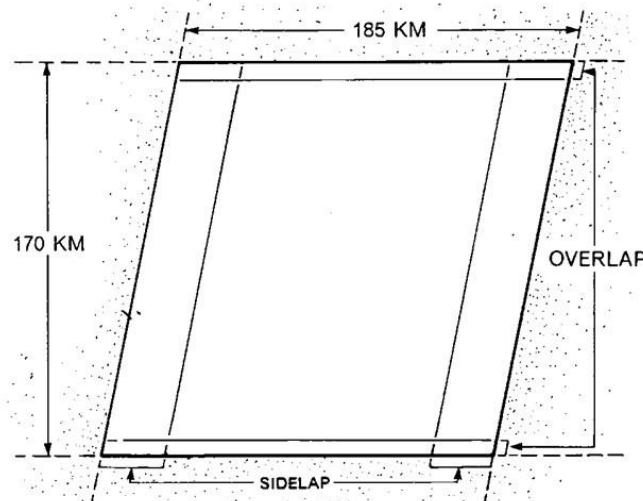


Fig.5. Sidelap and overlap in a typical satellite image

Sidelap is the overlapping areas of the images taken in two adjacent flight lines. For example, sidelap of the IRS 1C LISS-3 sensor at the equator is 23.5 km in the visible bands and 30km in the shortwave infrared band.

As the distance between the successive orbital passes decreases towards the higher latitudes, the sidelap increases. This helps to achieve more frequent coverage of the areas in the higher latitudes. IRS-1C WiFS sensors provide nearly 80-85% overlap and sidelap.

3. Geosynchronous orbit

Geostationary or geosynchronous orbit is the one in which the time required for the satellite to cover one revolution is the same as that for the Earth to rotate once about its polar axis. In order to achieve this orbit period, geo-synchronous orbits are generally at very high altitude; nearly 36,000 km. Geo-synchronous orbits are located in the equatorial plane, i.e with an inclination of 180 degrees. Thus from a point on the equator, the satellite appears to be stationary. The satellites revolve in the same direction as that of the Earth (west to East).

Fig.6 shows the pictorial representation of the geo-stationary orbit.

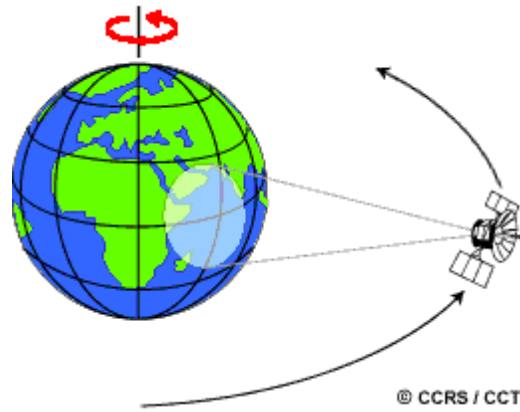


Fig.6. Pictorial representation of a geostationary orbit

Geostationary or geosynchronous orbits are used for communication and meteorological satellites. Example: INSAT, MeteoSAT, GOES, GMS etc.

Satellites in the geo-synchronous orbit are located above any particular longitude to get a constant view of any desired region. For example, the GOES East and GOES West satellites are placed in orbits over North America (normally at 75° W and 135° W, respectively), INSAT 3-A is located at 93.5° E longitude, the Japanese Geostationary Meteorological Satellite (GMS) is located over New Guinea, and Meteosat over Europe.

Because of the very high altitude, the foot prints of geostationary satellites are generally very high. They can yield area coverage of 45-50% of the globe.

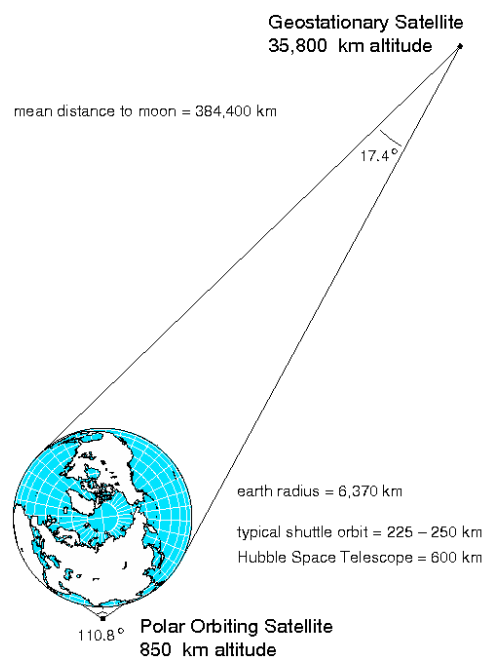


Fig.7. Foot prints of a typical geosynchronous satellite and a polar orbiting satellite

4. Polar (or Near Polar) orbits

These orbits have near 90 degree inclination.

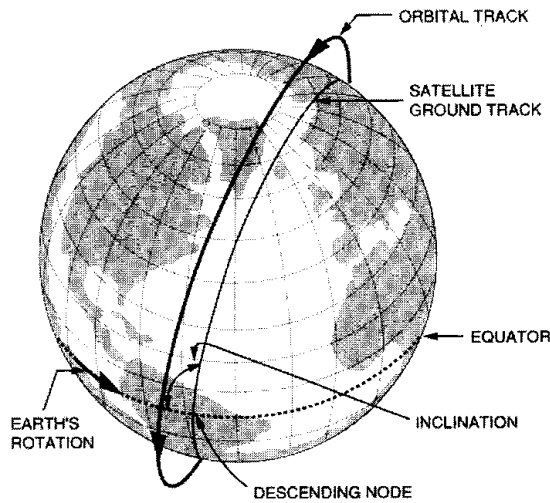


Fig.8. A typical near polar orbit around the Earth

Polar orbits are usually medium or low orbits (approximately 700-800km) compared to the geo-synchronous orbits. Consequently the orbit period is less, which typically varies from 90-103 minutes. Therefore satellites in the polar orbits make more than one revolution around the earth in a single day. Fig.9 shows the multiple orbits of a satellite in a typical near-polar orbit.

The National Oceanic and Atmospheric Administration (NOAA) series of satellites like

NOAA 17, NOAA 18 are all examples of polar orbiting satellites

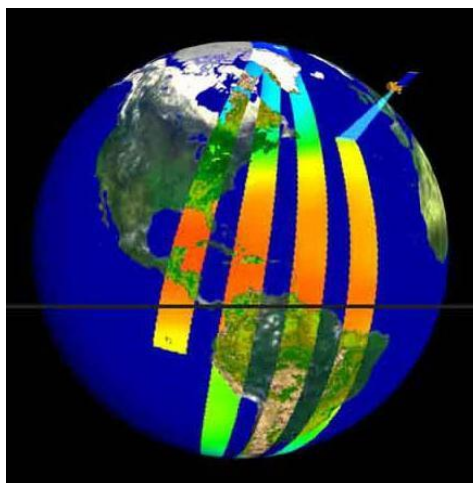


Fig.9 Typical ground track of a near polar satellite (Source: <http://www.ppi.noaa.gov>)

Taking advantage of the rotation of the earth on its own axis, each time newer segments of the Earth will be under view of the satellite. The satellite's orbit and the rotation of the Earth work together to allow complete coverage of the Earth's surface, after it has completed one complete cycle of orbits.

An orbital cycle is completed when the satellite retraces its path, i.e., when the nadir point of the satellite passes over the same point on the Earth's surface for a second time. Orbital cycle is also known as repeat cycle of the satellite. The orbital cycle need not be the same as the revisit period.

Revisit period is the time elapsed between two successive views of the same area by a satellite. Using steerable sensors, a satellite-borne instrument can view off-nadir areas before and after the orbit passes over a target. In view of this off-nadir viewing capability of the satellites, revisit time can be less than the orbital cycle.

The revisit time is important especially when frequent imaging is required.

In near-polar orbits, areas at high latitudes will be imaged more frequently than the equatorial zone due to the increasing overlap in adjacent swaths as the orbit paths come closer together near the poles.

5. Sun-synchronous orbits

It is a special case of polar orbit. Like a polar orbit, the satellite travels from the north to the south poles as the Earth turns below it. In a sun-synchronous orbit, the satellite passes over the same part of the Earth at roughly the same local time each day. These orbits are between 700 to 800 km altitudes. These are used for satellites that need a constant amount of sunlight.

A typical sun synchronous satellite completes 14 orbits a day, and each successive orbit is shifted over the Earth's surface by around 2875 km at the equator. Also the satellite's path is shifted in longitude by 1.17deg (approximately 130.54 km) everyday towards west, at the equator "from platforms and sensors", as shown in Fig.10.

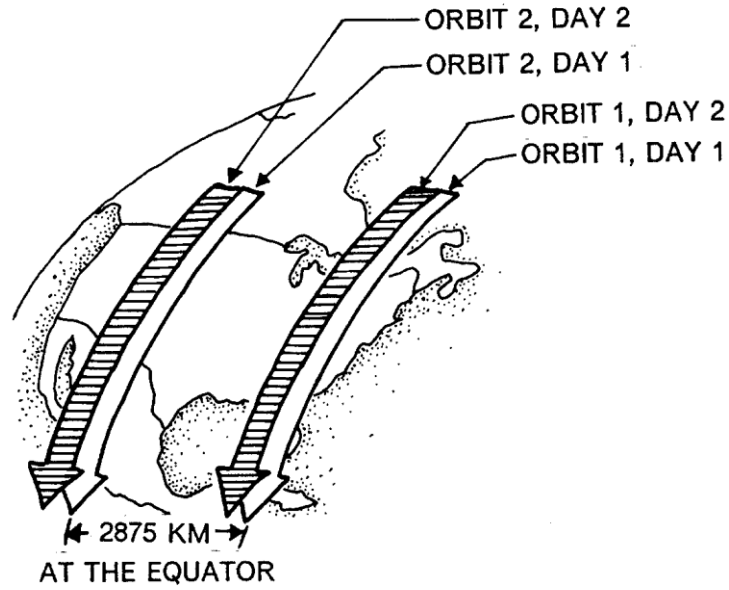


Fig.10. Orbits of a typical sun-synchronous satellite

Landsat satellites and IRS satellites are typical examples of sun-synchronous, near-polar satellites. Fig.11 shows the orbits of the Landsat satellites (1, 2 and 3) in each successive pass and on successive days. Repeat cycle of the satellite was 18 days and each day 14 orbits were completed.

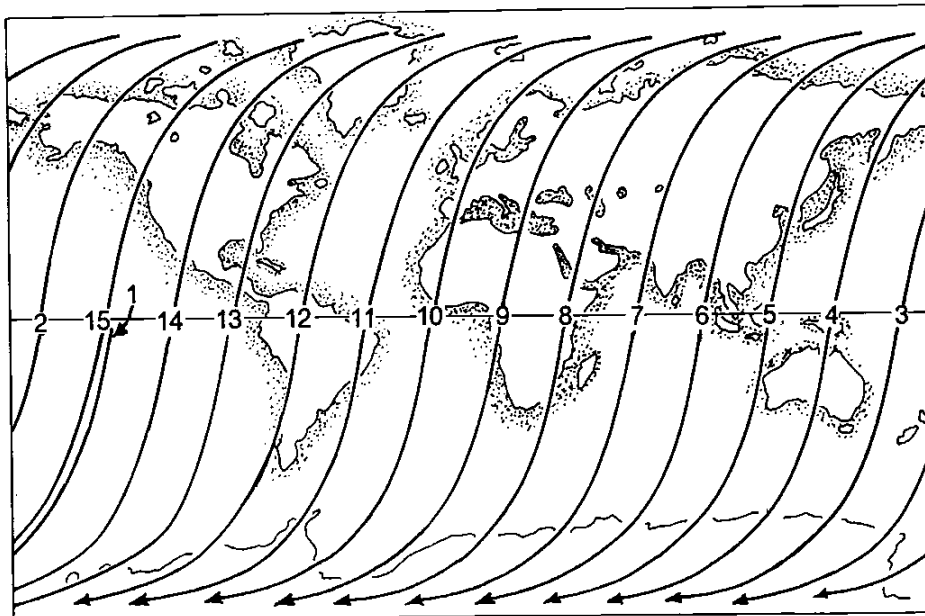


Fig.11. Orbits of sun-synchronous, near polar Landsat 1,2, 3 satellites

6. Remote sensing application

Remote sensing applications generally use near polar, sun-synchronous, near circular orbits. The near polar orientation helps to attain near global coverage, whereas the near circular orbit helps to attain uniform swath for the images. Sun synchronous orbits are preferred for maintaining constant angle between the aspect of incident sun and viewing by the satellite.

Remote sensing satellite orbits maintain nearly 90 degree inclination from the equatorial plane for the difference in the gravitational pull. Also, medium orbit periods are adopted for the remote sensing satellites so as to assure the global coverage in each single day.