Remote Sensing: Principles and Applications

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Lecture-51
Platforms for Remote Sensing Observations-Part-2

Hello everyone, welcome to the next lecture in the course remote sensing principles and applications. In the last lecture we started discussing about the various platforms that we use in remote sensing. We discussed about ground based platforms and aerial platforms. Today we are going to start the main discussion topic of these lecture series, space based satellite platform which is one of the most widely used data collection platform for remote sensing activities. Any user across the globe has the capacity to download the data acquired from a satellite and use it for their applications. Whereas mostly aircraft observed data or ground observed data are still treated confidentially or not available in public domain.

Relatively satellite observed data are available in a more easy manner**.** We can just download almost any data we want acquired from a satellite over any region of our interest across the globe. So, that is why satellite remote sensing is one of the most widely used technology, when you compare with other platforms. The remote sensing principles are more or less the same, but we have to understand the platform to some more extent. Like how the data is being collected from satellites, how the characteristics of the satellite orbits will affect the way we collect the data, all these things we should get an idea in order for to appreciate this in a better way.

Each satellite that is observing the earth from space will revolve around the earth in a particular orbit. So, a satellite orbit is the path in which the satellite will be constantly moving. So basically each satellite will be in its own orbit, a predefined path in which the satellite has to move perfectly. If the satellite comes out of its path, normally the engineer sitting from ground will try to bring it back to its designated orbit to achieve the required project goals**.** An orbit is a predefined path in which the satellite moves around the earth.

For any particular mission satellites has to be in that particular orbit in order to achieve the mission goals. If the satellite comes out of it, definitely has to be brought back to its orbit. So, it is kind of a predefined path in which a satellite revolves around it. And for earth observing satellites, all the satellites will revolve around the earth with earth center as the center for their circular orbits also. So, for remote sensing applications generally we will assume the orbits as circular orbits. Because most of them are near circular if not perfectly circular. There are special cases in which orbits are elliptical like the way earth revolves around the sun.

A satellite has to be launched from ground carried by a rocket. Some sort of manoeuvre will be carried out by the ground based controls in order to put the satellite in its designated orbit. Once the satellite reaches its orbit, it will self sustain for a certain period, without requiring any sort of ground based control. How the satellite sustains itself in an orbit with very minimal support from the ground? There are majorly 2 forces which will be acting on the satellite. First thing is earth's gravity. If a satellite is moving around the earth, earth's gravity will try to pull it downwards. Second force is, due to the circular motion of the satellite there will be a centrifugal force which will try to take the satellite in the opposite direction. So, the effect of centrifugal forces take the satellite away from the circular motion. So, these 2 forces will balance out each other in order to maintain the satellite in its orbit; the earth's gravitational force will be balanced out by the centrifugal force due to the revolution of the satellite around the earth surface.

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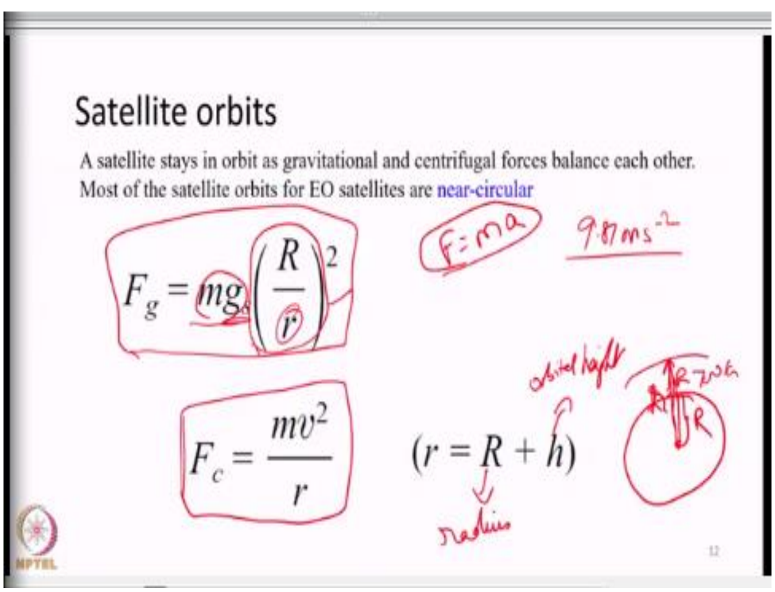

So, simply put the force due to gravity can be written as F = ma**.** So, m is the mass, a is acceleration, since we are talking about gravity, we use the acceleration due to gravity g_s. So, the value of g_s we know 9.81 m/s^2 on the surface of the earth. We have to balance this force due to gravity for this particular orbital height. So, that is why we are using inverse square law

$$F_g = mg_s\left(\frac{R}{r}\right)^2$$

where R is the radius of earth, the small r is a summation of radius of earth plus the orbital height. So, this particular equation basically gives you the force due to gravity and this force is balanced by the centrifugal force

$$F_c = \frac{mv^2}{r}$$

$$r = R + H$$

where m is the mass of the body, v is the velocity with which the satellite is moving and r again the radius at which the object is moving from the center of earth. So, this centrifugal force and force due to gravity, both of them will balance out each other so equate both of them. From this equation we can cancel out the terms and get the velocity of the satellite that is moving around.

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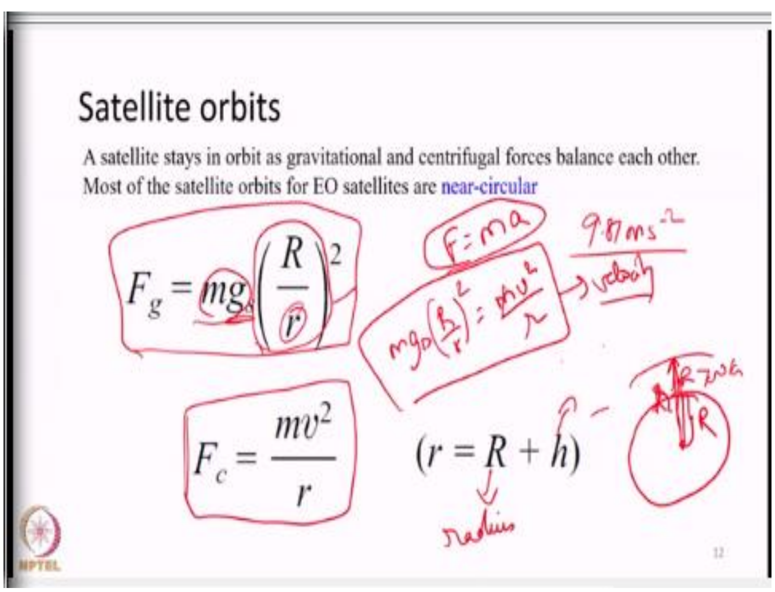

The velocity is equal to square root of acceleration due to gravity multiplied by radius of earth square divided by radius of the orbit from the earth center**.**

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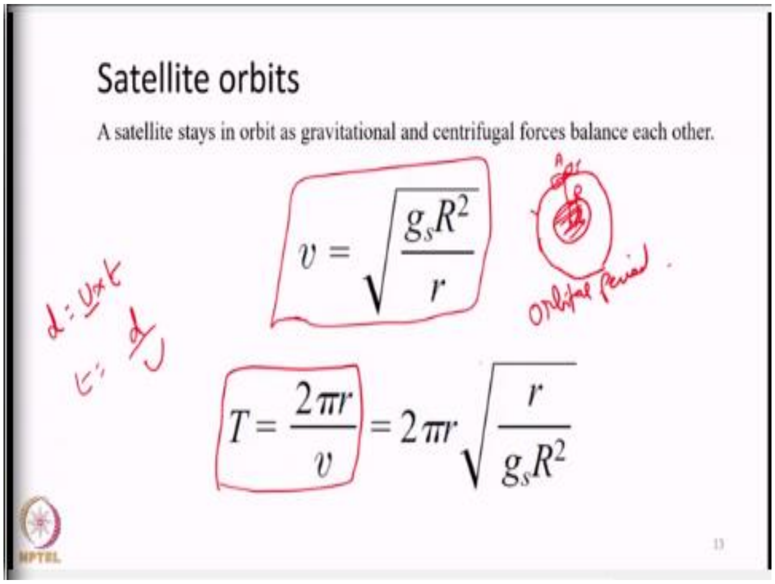

So, this is a very simple formula to calculate the velocity at which a satellite is moving around the earth. If we know the velocity, we can calculate the time taken by a satellite to complete one full orbit around the earth. As we know, the earth takes one full year to complete one full circle around the sun**.** Similarly each satellite will take certain amount of time to complete one full circle around the earth; we call it as the orbital period of the satellite and that can be calculated as follows.

Say this is earth this is the orbit in which the satellite is moving, say the satellite is here. Let us say the satellite starts from point A, it will revolve around the earth something like this, it will again come back to the same point A. So, the time elapsed between the satellite to complete one full circle is called as the orbital period. And within that orbital period the satellite completes this one full circle, the circumference it completes, the circumference is given by 2πr. That is the radius of this circle which is a combination of radius of earth plus orbital height h and it moves with a velocity of v. We know that distance = velocity × time. So, the time taken to complete is distance/velocity, and the distance is the circumference of the orbit which is 2πr and then velocity can be calculated from the formula. So, using this we can calculate the time taken for the satellite to complete one full revolution around the earth surface.

So, if you look at the below slide, we can understand that there is a relationship between the altitude of the platform, the velocity of the platform and the orbital period of the satellite. If the altitude increases then the velocity will decrease, say altitude is given in x axis, velocity is given in this particular axis**.** So, the velocity decreases as the altitude increases, similarly the time period taken to complete one full circle around the earth surface increases as the orbital height increases**.**

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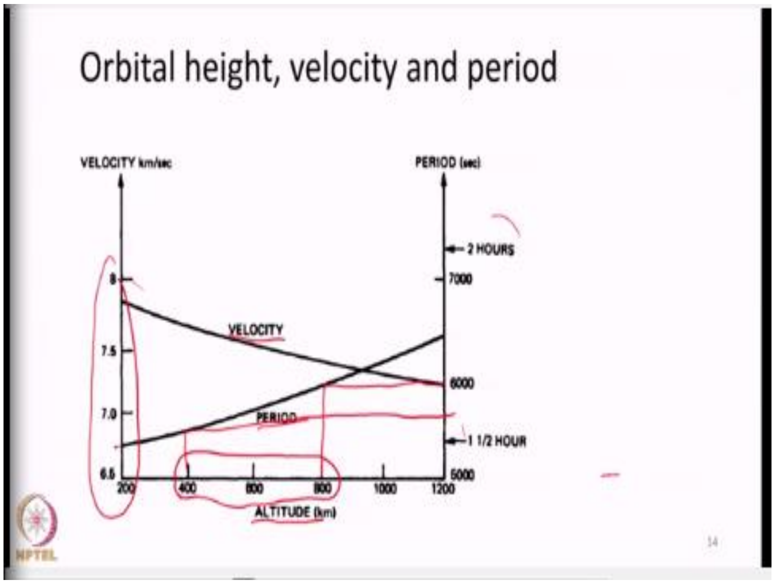

So, most of the satellites in the near polar orbit will be around this range 400 to 800 kilometer range, typically. So, they may take anywhere between 1 and half hours to 2 hours to complete one full revolution around the earth surface. So, based on the orbital height, the velocity of the platform will be fixed. Once it is put into orbit, the satellite has to move in that particular velocity. It will automatically start moving then only it will be balanced out. If it moves any faster or any slower the orbit is going to change actually**.**

Say for example if the satellite is going to slow down due to some effect, then the earth's gravity will try to start pulling it down easily. So, this is called orbital perturbations. So, unless the velocity is maintained, the orbit cannot be maintained, the velocity will be there, it is defined by this law, gravitational force has to be balanced out by centrifugal force. Only if this happens satellite will be in its orbit. So, the mission planners when they plan for a mission they will try to analyze what orbital height we should plan in order to achieve the mission goals.

People will plan all these things based on the metioned factors and decide the orbital height. Based on the orbital height the orbital period and also the coverage around the earth surface will vary. So, in order for us to further discuss orbits, we need to know 2 important variables or parameters related to orbit. Actually in order to locate a satellite in space we need 6 different elements to know, we call it as a Keplerian elements.

But in order to keep the discussion simple, we will just try to learn about only 2 important parameters about orbits which we should understand.

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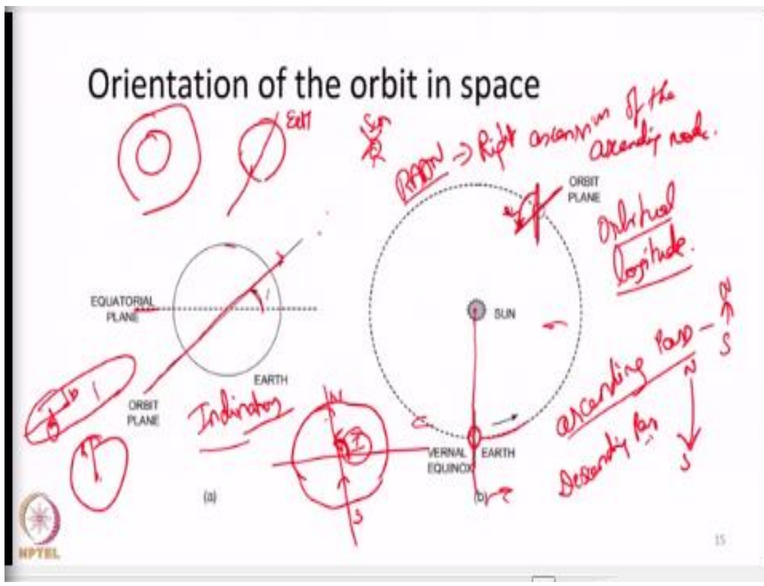

The first thing is orbital inclination, and second thing is RAAN, right ascension of the ascending node**.** So, we will learn these 2 parameters before we move ahead. Inclination means the angle made by the orbital plane with respect to earth's equatorial plane. So, each satellite will have its own orbit defined, say when you look from any one particular angle, it will be appearing like a line. In fact it is like a 2 dimensional plane, if the earth is like this, the orbit will be kind of like this, it is the orbital plane. So, the angle made by the orbital plane and the equator we call as orbital inclination. So, this orbital plane or the inclination can vary between 0 to 180 degrees. So, 0 means orbit is placed along the earth's equator, satellite is moving in the same direction as that of earth surface. Then 180 degrees, is still in equator but the satellite is moving in direction opposite to that of earth.

Some satellites maybe having inclination around 90^o to 100^o. That means satellite will move from pole to pole or near pole to near pole, near north pole to near south pole, the orbital plane will be oriented like this. So, this angle is called as the orbital inclination**.** So, typically for a satellite which is in near polar orbit, the general convention to measure inclination is as follows. Say this is earth, this is the earth's equator; let us say there is some orbit like this. So, when the satellite is moving towards north, we will measure the inclination angle i, in anti-clockwise rotation. That is we will see in that particular direction in which the satellite appears as if it is moving from south to north.

Then at that particular direction, we will measure the angle between earth's equator and the orbital plane in anti-clockwise direction**.** So, this is the convention for measuring inclination angle for satellites that are moving from pole to pole. Similarly if the satellite has i is 0^o or 180^o based on the direction in which it moves. Normally say if earth and satellite is moving in the same direction, we call it as 0^o inclination. If the satellite is at the equator but it moves in opposite direction, we call it having an inclination of 180^o, these are basically the conventions. So, normally a satellite with inclination angle 0 to 90^o will be understood to move in the direction same that of earth.

So, for certain satellites inclination will be more than 90^o under certain circumstances we have to understand that the satellite moves in a direction opposite that of earth's motion. Say earth is moving like this, satellite will be moving in some other plane, either along the equator or along the pole to pole. But still the net resultant direction will be say earth moves from west to east the satellite will be moving from east to west, so this is regards to orbital inclination.

Then comes right ascension of the ascending node or simply put we will call it as orbital longitude. So, what exactly this orbital longitude is? Let us say we have sun, earth revolves around the sun again in an elliptical orbit but here we have put it in kind of a circular orbit for simplicity sake. So, in this orbit there will be say earth is tilted in its axis for 23 and half degrees in its axis. So, due to this earth's tilt and this is sun, this is earth and due to earth's revolution around the sun over a period of year, the sun will appear as if it is moving from 23 and half degrees north to 23 and half degrees south, and then come back. So, if we say earth is tilted like this, sun is here due to earth's rotation and changing its elliptical orbit and all sun will appear to move from 23 and half degree north to 23 and half degrees south, we know this.

During March the sun will be around near the equator, it will slowly move towards 23 and half degree north latitude, we call it as summer for the northern hemisphere. Then again it is slowly moved towards the equator, go towards southern hemisphere 23 and half degrees south, then again it will come to equator, it will complete one full cycle, equator to 23 and half degree north again come to equator go to 23 and half degrees south, again come to equator, one full circle it will complete in 1 year.

So, you can see the sun moves from equator to north 23 and half degree in tropic of cancer and tropic of Capricorn, repeatedly within a year. So, you can think of the sun moves in one particular direction**,** so there is particular day in which sun will be exactly over at the equator in its way to the northern hemisphere. Say now the sun is at southern hemisphere 23 and half degree south here, then while moving towards northern hemisphere it will cross the equator once. We call it as vernal equinox, where the daylight period will be most likely equal to the length of night. So, during summer we have longer days, during winter we have longer nights. On equinox or around equinox the length of day will be exactly equal. On the day of vernal equinox you draw a line connecting sun and the earth and fix this line. Wherever the earth moves, we are like able to somehow fix this line. So, the angle between this particular line and our orbital plane is called as orbital longitude**.** So, this is again a very simplified definition. Like vernal equinox we defined, earth is moving from southern hemisphere to northern hemisphere, on that particular day it will cross the equator. So, it is coming from bottom of earth to top. If you orient north upwards, you can think it off it is coming from here to here there it is crossing the equator, that day is vernal equinox.

Similarly if satellite are moving from pole to pole, it will move from southern hemisphere to northern hemisphere, northern hemisphere to southern hemisphere. Then also even satellites around the earth will cross the equator from south to north once, from north to south once in every orbit. In every single rotation around the earth it will cross the equator moving from south to north and then similarly moving from north to south**.**

So, when a satellite moves from southern hemisphere to northern hemisphere, we call this motion as ascending pass**.** So, we should know and understand some of these terminologies. When the satellite moves from south to north we call it as ascending pass, when a satellite moves from north to south, we call it as descending pass**.** So, there will be a point in the orbit when the satellite will be exactly over the equator moving from south to north.

Say this is earth, satellite is moving like this from south to north. When it is moving, at a given point of time, it will cross the equator. Let us say we are able to hold the satellite at that particular point, and measure the angle between orbital plane and this line joining the sun and the earth on the day of vernal equinox, we call it as orbital longitude or technically we call it as right ascension of the ascending node RAAN**.** The angle made by this ascending node point like the orbital plane where the ascending node is and the line joining sun and the earth, is called as right ascension of the ascending node. So, these 2 things orbital inclination and the right ascension of the ascending node are the 2 important things we should know.

Actually there are plenty of other elements we should know in order to define a satellite in its orbit. Like if it is a circular orbit, we need to know this H basically the orbital height above the earth surface or if it is a elliptical orbit instead of this orbital height H we should know what is known as the semi major axis and semi minor axis. If you have an elliptical orbit we will always have something kind of a semi major axis A, semi minor axis B. We do not have one single radius, we have this A, B, we have learned it in school geometry**.** If it is an elliptical orbit we should know this, if it is a circular orbit we should know the orbital height H or the distance of the orbit from the center of the earth. So, these things we should know, similarly we should know the angle between perigee positions and all. So, just for simplicity only 2 parameters we are defining, one is inclination another one is orbital longitude or RAAN right ascension of the ascending node.

So, in this lecture as a summary we started discussing about the satellite based orbits, we just got introduced to how satellites orbit is maintained, the relationship between the orbital height, velocity and the time period of the orbit to complete one full revolution assuming circular orbits. And also we got introduced to 2 important concepts the orbital inclination of the orbital plane and the orbital longitude or right ascension of the ascending node. With this we end this lecture.

Thank you very much.