Remote Sensing: Principles and Applications
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Lecture – 20
RS Image Acquisition and RS Systems – Part 3

Hello everyone, welcome to the next lecture in the course remote sensing principles and applications. We are going to continue with the topic of remote sensing systems and image acquisition where we left from the previous lecture.

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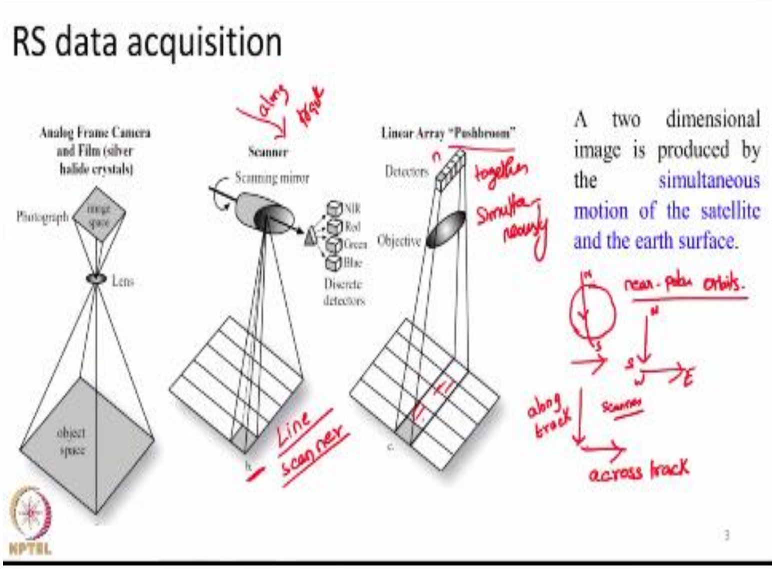

In the previous lecture, we saw different mechanisms or different ways in which data can be collected from satellites in near polar orbit. Some of the methods are line scanner, Whiskbroom scanner, Pushbroom scanner and 2 dimensional array type of detectors. We also saw a special case of how data will be collected in hyperspectral sensors and so on. Today, we are going to start with data collection from satellites in geostationary orbit.

So, in geostationary orbit, essentially the orbit of the satellite is much farther from the earth's surface like something around 36,000 kilometres away from the earth's surface. The satellite will be aligned along the equator. So, in the previous case near polar orbit, earth is here, satellite will be moving like this from north to south and geostationary orbit, that means, satellite is placed along the equator and the satellite will rotate the earth at the same speed of the earth, that is as the earth is moving, the satellite will also move at the same speed. So, essentially, satellites are launched into such geostationary orbits, when we want to observe the same part of the earth continuously, for communication purposes or meteorological purposes and all. We need to observe same part of the globe without any break.

So, for such applications, we normally put satellites in the geostationary orbit. So, the satellite will be seeing the same spot on the earth. As the earth is rotating, satellite will also be keep on rotating. So that, same place will be imaged continuously without any time gap. In the previous case, in the near polar orbit, satellite move like this, earth rotated like this and there was also some sort of scanning mechanism involved, which carted a 2 dimensional image like line by line the image was built either using a scanner or using a Pushbroom array, Pushbroom type of sensor. So, line by line, the image is built as satellite is moving, each line will be built. So, the entire image will be formed. In this case, when satellites are in geostationary orbit, there will not be any sort of relative motion because satellite will be keep on looking at the same spot of earth.

There will be no relative motion of satellite with respect to earth, they will look stationary, if your eyes have the capacity to look at a geostationary satellite, it will look stationary for our eyes, that is why the name geostationary. It will be stationed at one point. So, it will appear continuously that there is no relative motion between earth and the satellite.

In such cases, in order to build a 2 dimensional image, there should be a 2D scanning mechanism, that is the detector element should have a scanner which scans in both north-south direction and also east-west direction.

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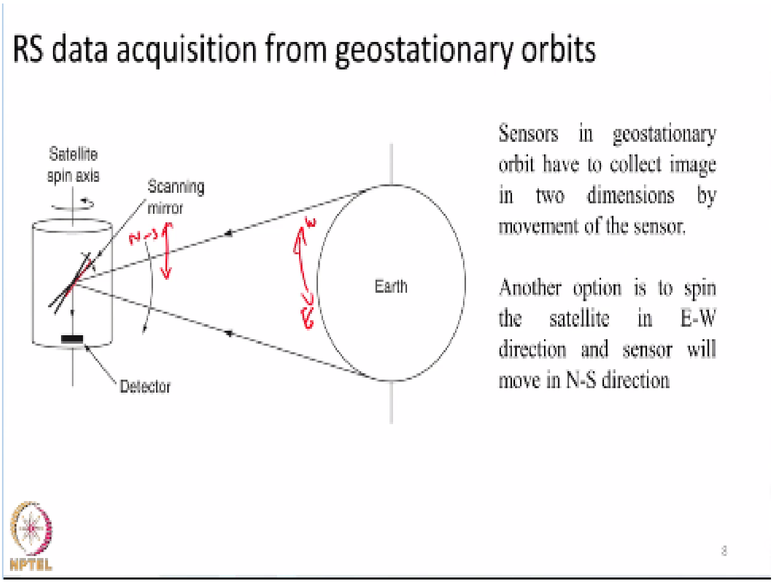

So, the scanner will essentially do a 2 dimensional image collection that is depicted in this particular figure. You can see here a scanning element which scans in both north-south like this from top to bottom and also east-west. This east-west scanning can be done in 2 ways. The scanner itself can move 2 ways that is say for example, there is like a scanner attached. Let us assume, it is scanning first in this direction in north-south. So, it looks in the top, scans one line. Then comes down scans one line like this or it can move like this and then slowly can move like this. The scanner itself can move in 2 dimensions up-down, left-right, and so on. Or in some satellites, the east-west movement is provided by spinning the satellite along its axis. Say if the satellite is moving like this**,** there will be a satellite axis, around this axis, the satellite will be made to spin that is to cover the east-west direction. The satellite will be actually spinning. So, what will happen? The scanner will be there. So, when the satellite does one spin, the scanner will scan one line. Satellite will rotate.

Now, the scanner may start from the northernmost point. It may look like this. Satellite will spin one line is collected, then the satellite will rotate, come back again. By the time, the scanner would have moved one line down or one row down, then it will collect. Satellite will spin, second line is collected. Now, the scanner will be again brought down like this. So, line by line, image will be collected by spinning the satellite. The scanner will move along the latitudes from north to south, the scanner will move slowly by spinning the satellite, east-west scan will be established or it will be carried out. This is one way. There was a satellite called MSG SEVIRI which will spin and collect the data like this way.

On the other hand, some satellites will not spin because spinning again involves a lot of energy, the satellite has to come exactly to the same orientation, a lot of things are there. So, as I said whenever there is a mechanical movement, it is always problematic. So, some sensors or some satellites will have a 2D scanning mechanism. The scanner itself may scan both east-west and north-south like this. It will scan, maybe one line then the scanner will come to the next line scan east-west, third line scan east-west and so on. Like this, image can be collected in 2 dimensions for satellites in geostationary orbits.

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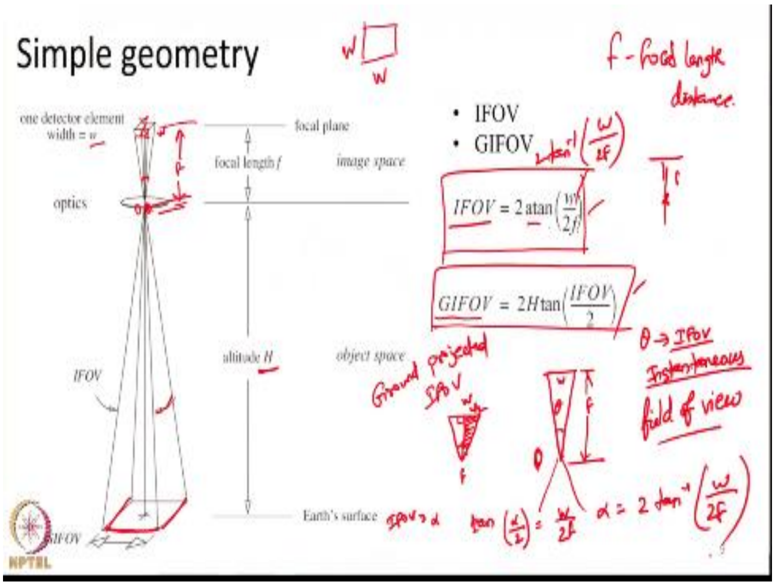

Now, we have seen how data is being collected, the simple mechanism of data collection. Next, we are going to enter into the important concept of spatial resolution. In the beginning of this particular topic, I told you, each sensor has 4 specific characteristics spatial, spectral, radiometric and temporal resolutions. These 4 will define the data collected by the system and also for which applications that data can be used. Everything will be defined by these 4 characteristics.

So, now, we are going to start with looking at the concept of spatial resolution. Before, we move on to explaining what spatial resolution is, we will first see a simple geometry of how earth is being perceived by one detector element within the sensor. So, let us assume, one detector element within the sensor. The width of detector is w. Let us assume the width is in the form of a square with the width w1 both the sides.

This will be like the optics element and the distance from the focal plane where the detector will be located and the first point where the light from earth enters is focal length. So, f is focal length. Now, even our cameras have a focal length or focal distance we can say, relating the distance between the centre of object point where the light first enters the system to the point where the detector elements are kept. So, this is focal length f.

So, based on the focal length, each detector element will have a small angle subtended that is now, I am drawing it in 2 dimension, let us say, this is width w of the sensor. This is the optical point O and this is focal length f. So, whatever light ray coming in from the ground, within this particular angle will be focused on to this particular detector. This is not a 3D angle. This is not a solid angle I am talking about. I am just talking about plane angle in 2 dimensions because we are assuming it as a square element. So, essentially, it will have one one plane angle in this direction. The angle will be same. So, we are talking in terms of a plane angle. So, this is one side of detector element. This is the point O. This is focal length f.

This angle maybe, we can label it as θ which is known as the IFOV, instantaneous field of view. So, what this IFOV defines? The IFOV is actually determined by 2 parameters. One, the detector width, how wide or how small the detector element is, the physical size of the detector, maybe in the order of few micrometres. And what is the focal length of the system? These 2 will determine this angle IFOV. So, what essentially it does?

Now, the satellite is being put to space let us imagine. Now, the detector is in space observing earth. So, whatever the angle was there inside the system, this angle IFOV, the same angle will be there on the earth’s surface. Each detector element will have the same angle on the earth’s surface and whatever energy coming in from that particular 2D angle will be reaching the detector element. If it is a square, it is like one angle this side, one angle this side. If you imagine like plane angle in all directions, you will complete like a square. Please imagine it in your mind. So, the IFOV will determine the angle from which the energy incoming will be collected by the sensor.

And this IFOV is determined by the physical size of the detector, like one side size, if it is a square, it is like one side size and the focal length of the system. So,

$$IFOV = 2\,atan\frac{w}{2f}$$

where w is the physical width of the detector element; f is the focal length. So, here atan means tan inverse. So, this is the IFOV. So, IFOV means the angle subtended by the detector in its focal plane or in its optics assembly, we can say like optic point.

From there, what is the angle subtended by the detector that is this particular angle? From this point O, what is the angle subtended by one side detector? So, if you put the same angle in all directions, you will essentially get a square element. So, then the satellite is launched to space. Each satellite will have a characteristic orbital height, some satellites are put in height of 700 kilometres, some satellites are put in the height of 400 odd kilometres and so on. So, that determines the orbit height.

So, now, based on this IFOV angle and based on the orbital height, each satellite will have a ground area to be seen by each detector element. That is let us say, the IFOV is looking like this and the sensor is in top. As you increase the height of the satellite from the ground, the same angle will subtend a larger area. What essentially it means? First, I told you, IFOV means whatever the energy that is coming in within that particular angle will be observed by that one detector element. Now, depending on the orbital height, if you take into account both this IFOV and the height of orbit, we will be able to determine the ground area covered by each detector element. So, that is given here in this particular formula.

And you can see it in from this particular diagram. So, this angle is IFOV. So, the IFOV and this orbital altitude H will determine what is the ground area covered by each detector element. So, if there is a detector element w here, there will be a corresponding value on this particular side based on the orbital height. So, this ground coverage provided by each detector element is known as GIFOV, ground projector IFOV. So, ground projected instantaneous field of view.

So, for that particular corresponding IFOV, if you multiply with the orbital height, you will be able to determine the ground area or distance in the ground covered by that small detector elements with a width of w. So, if the width is w in one direction, a corresponding distance will be covered in the ground based on the orbital height. Similarly, there will be like another within the same width w in this direction. Now, it is a square element that is another width w.

So, the same distance will be covered in the another direction also. So, if you take this as x that is in y direction. So, it will form like a square for the 4 sides. So, 2 terms, we introduced now, one is IFOV. The plane angle subtended by the detector element on the ground, which is determined by the physical size of the detector and the focal length of the system.

Based on this angle and based on the orbital height h, we can determine what is the ground distance covered by this particular detector element for each side and that ground distance covered; we call it as ground projected IFOV or GIFOV. So, the formula of GIFOV is

$$GIFOV = 2H \tan \frac{IFOV}{2}$$

It is a simple geometry, you can work upon.

Let us say, this is the detector element w; this is a perpendicular bisector; this is the focal point f. let us assume IFOV is equal to α. So, this is w/2, this is f. So, tan of α/2, I am taking one particular triangle. So, where half of α I have taken. So, tan of α by 2 is equal to opposite side w/2 divided by adjacent side w/(2f), I am interested in getting α; IFOV is α. I have labelled it as α.

So, α is equal to 2 $\tan^{-1}$(w/2f), extremely simple geometry. Same similar kind of geometry, you can build for determining GIFOV 2 H tan (IFOV/2), you will get the same thing, but, just one assumption we are making here for the sake of simplicity, we are assuming, the detector as a square element and also earth as a flat horizontal surface that is earth is not a sphere anymore. Earth is not undulating anymore. It is a pure flat horizontal surface and we are considering the detector element as a square in order to get these 2 equations. They are like simplified representations of, what is happening in the satellite. So, just imagine remember always one point, whatever energy coming in within the GIFOV, will be collected by one detector element and will be averaged out and stored as one single value.

Say, for example, if a detector has a GIFOV of 1000 metres, so, essentially 1000 metres by 1000 metres that complete square will be observed as one single point in the remote sensing system and whatever energy that comes out will be collected as one single point and averaged out and stored as one energy term inside the detector element. So, energy is averaged out within GIFOV.

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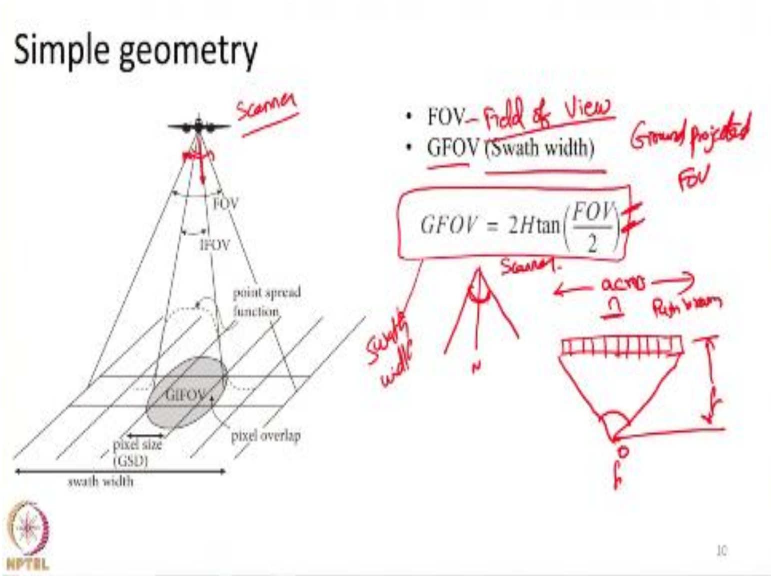

Next important thing, we are going to see is, what is known as a field of view. Here, we first talked about one single detector element, what is the angle covered by one single detector element, what is the ground covered by that single detector element IFOV and GIFOV. But, I also told you that we will be collecting information for a broad range, for a broad distance on the ground.

So, there will be a scanner which will scan a certain angle. So, rather than each detector just collecting data from it, now, it covers a wide track of ground in the across direction or if you talk about Pushbroom sensors, there are like say, 1000 detectors in each row, they will be collecting energy from 1000 pixels or 1000 GIFOV's on the ground simultaneously together. So, for each sensor, what is the total ground area covered in one go in the across track direction. That is what we are going to see now.

Let us say, this is a scanner system. So, the scanner is present inside and this is the nadir point. So, from here to here, it is scanning in the 2 dimensional plane. So, scanner starts from here, moves like this towards nadir and moves away, stops here and keep on oscillating. So, this particular angle what is subtended by the full scan along one line, we call it as FOV, field of view. So, the field of view will determine what is the angle covered by the scanner or if you have a Pushbroom sensor, let us say, some n number of detectors in the across track direction. This is object point O. This is the focal length f. Earlier when we talked about one single detector element, we calculated IFOV that is from this point O. What is the angle subtended by one detector element?

Now, if you are having a Pushbroom type of sensor, let us say, you have n detectors in the across track direction, what is the total angle subtended by this entire detector elements. Say, you have 100 detector elements in the across track, what is the total angle subtended by all these 100 detectors together on that single point of your optics is known as a FOV, field of view. That will determine the total angle subtended by the entire sensor element on the ground at a time.

If it is a scanner, the angle is determined by what angle the scanner rotates. Say for example, in MODIS, it has a scanning angle of 55 degrees. So, it is scan like this, 27.5 degrees, 27.5 degrees. It will cover 55 degrees by its oscillation. It is kind of like a scanner.

On the other hand, if you take a Pushbroom type of sensors where we have n number of detectors in the across track, the total angle subtended by this n detectors from that particular point O, that angle, we call it as FOV and if you take this FOV and associate it with the orbital height H that will give us the total ground area covered by the sensor in one go in the across track direction.

That is say, a scanner scanning like this based on the angle it scans and based on orbital height, there will be a definite width of ground covered by one scan line. So, one full scan line here for the 55 degrees, it may cover certain distance on ground. For MODIS, it is 2300 kilometres. One scan will cover 2300 kilometres totally. Similarly, Landsat will cover 185 kilometres. This distance covered by one scan on the ground is known as swath width or another term is GFOV, ground projected FOV. So, here I have given it is ground projected FOV or we also call it as swath width that will determine the total ground area covered by the satellite in one line across track direction. So, this will essentially determine if a satellite collects one line of image, what is the exact ground distance of that particular one line that is swath width.

So, the swath width will be an important parameter in order for us to understand the data collection from satellite. So, as a summary, today what we have seen in this particular lectures, we have seen how data will be collected by satellites in geostationary orbit and also, we have got reduced to 4 important terms IFOV, GIFOV, which relates to single detector element on the space.

And we also came to know about FOV and GFOV, field of view and ground projected field of view also, known as the swath with. So, just as a summary, the swath with is given by this particular formula. GFOV is equal to 2 H tan (FOV/2), very similar to IFOV. The geometry is one and the same. We can also relate with the IFOV geometry. It is very easy to derive this. So, this particular equation will tell you, how to calculate the swath width of the sensor.

With this, we end this particular lecture. In the next lecture, we will try to explain what is meant by spatial resolution.

Thank you very much.