Satellite Communication Systems
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Lecture - 06
Space Segment – 01

Welcome, we had already talked about the orbit in Satellite communication and now we will start the next topic the thing which is to be put into the orbit that is about which you called space craft or Satellite. So, that part will be discussing now. Now this will contain certain descriptive matters which are not much useful to us communication engineers. So, therefore, I will show you some pictures and the descriptive part and where the communication thing comes we will go into little more detail right.

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So, we start on the Satellite Communication Systems Space Segment part. What will be covered in general the sub topics will be the Satellite bus, the Payload, the Antenna and the environment in which this Satellite or Space craft will be functioning and; obviously, there will be certain reliability requirements.

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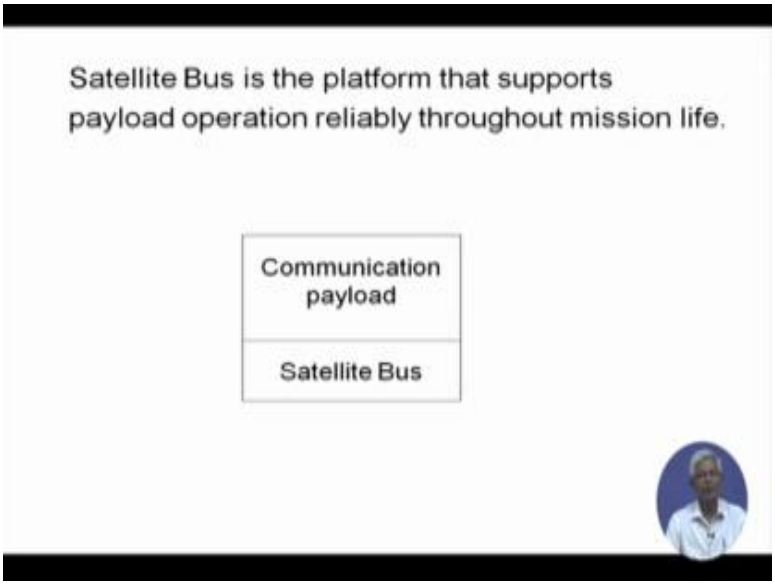

Now, in the Satellite bus it is the bus which carries the payload. So, basically our requirements are the communication payload. The payload can be remote sensing can be meteorology can be scientific in our case it is a Communication payload earlier we used to called we have called it a repeater a microwave repeater. So, let us see what is this bus which carried this payload.

Satellite bus is a platform that supports the payload operation reliably throughout the mission life that is very important. The payload has to operate reliably that is within the specification and throughout its life which is set at the beginning. So, this communication payload will be carried by A system which is called Satellite bus or it can be called a platform. What are the contents of the platform what could be the functions of the Satellite bus.

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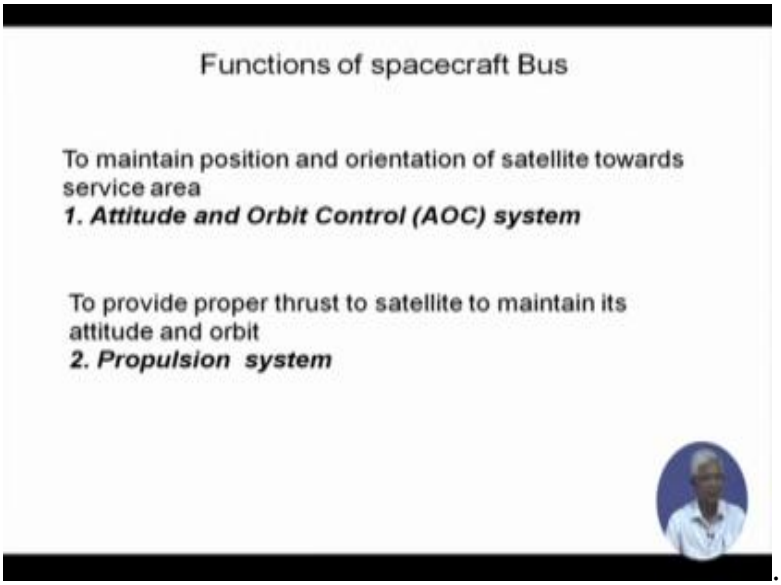

Let us look at it, now the first function could be; obviously, to maintain the position and orientation of the Satellite towards surface area in our case communication if it is from earth to earth our service area will be earth. So, the Satellite will be oriented towards earth it transmitter and receiver if the Satellite has to communicate from earth to let us say moon or another spacecraft. So, the orientation of the Satellite should be such the transmitters receiver in this particular repeater has to look towards earth as well as to the other Satellite or moon or whatever it is communicating.

Now, this particular function to maintain its position and orientation of the Satellite towards the service area is called Attitude and Orbit Control system. In short it is called AOCS for system in this case I have written AOC. This in addition to this there will other things now to maintain its position and orientation we need to give thrust to keep the satellite and maintain its attitude and orbit because we have seen that Satellite orbit and Satellite in the orbit may be perturbed due to other forces acting on it. So, this subsistence is called Propulsion system. This Propulsion system provides the thrust to the Satellite to maintain its attitude and its orbit that is its particular position.

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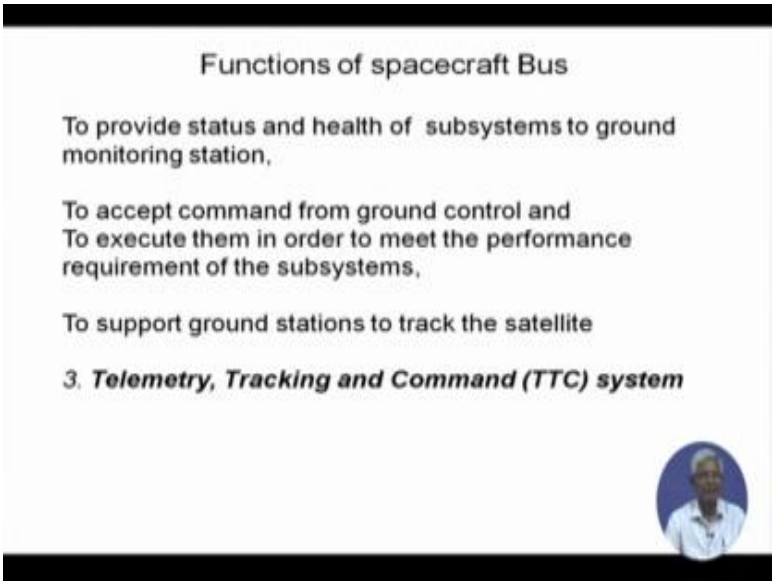

When the other functions, one of the very important functions is to provide the status and health of the subsystems to the ground monitoring station. Ground monitoring station should know how the Satellite subsystems are functioning how their health is.

And of course, if the health is not proper or during the operation it may have to be adjusted. So, the Satellite bus one of the function is to accept the command from the ground control and execute them in order to meet the perform requirements of the subsystems. So, it has to have a receiver which will receive the command from the ground control and execute them those commands, like you have to deploy the solar panel or you have to orient the antenna you have to adjust the orbit. So, all those commands have to execute. And then it has to, of course, it has to support the ground station to track where it is each has to provide a support that is very interesting. It can provide the support to the ground system to track where it is. So, that ground system knows which direction the command has to go how fast the commands has to be sent how much how many milliseconds or second earlier the command has to be sent etcetera.

So, this three functions is Telemetry, Tracking and Command in shorts it is called TTC system - Telemetry, Tracking and Command though each of this are separate functions,

but they are put as one single subsystems and you can observe that these definitely has some communication part of it. So, we will concentrate little more on this subsystem.

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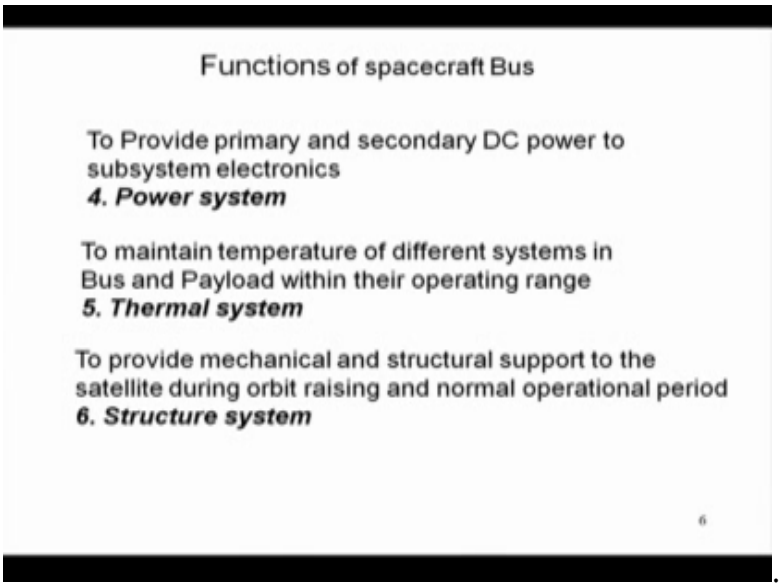

What is the other function, the other function is to provide; obviously, the primary and secondary dc power to the subsystems and electronics both in the Satellite bus as well as in the Payload. So, the power is one of the critical thing and of course, the power has to be mainly it is drawn from the sunlight solar energy. So, there has be primary a raw power and that has to be stored as we have seen some cases that eclipse or shadow may come solar energy may not come. So, it has to be stored in a battery and then its to be regulated. So, all these functions are done by a power system.

But then you see Satellite is facing sun some other side it is facing the cold side. So, there is a great temperature difference and inside also Satellite there are certain circuits which are carrying heavy current which might dissipate some current. So, it will be heated up. Now, inside the Satellite at that environment it is vacuum, therefore, there will be certain thermal adjustment that has to be done. So, to maintain the temperature of the different systems in the bus and the payload within its operating range all the circuits' electronic or mechanical systems will have certain temperature range of operation.

So, within that range if it is be adjusted the subsystem which function for that is thermal system and then of course, the primary thing has to hold the Satellite all this electronics, all this mechanical thing, the chemical thing everything has to be held. So, to provide mechanical and structural support to the Satellite during the orbit raising when it is being launched we have seen how orbit raising is done by giving different velocity at different locations and during the normal operation where the orbit if it is perturbed within the station keeping box it is to be adjusted back to the normal location. So, during its normal operational life the structure has to support. So, it is this structure system.

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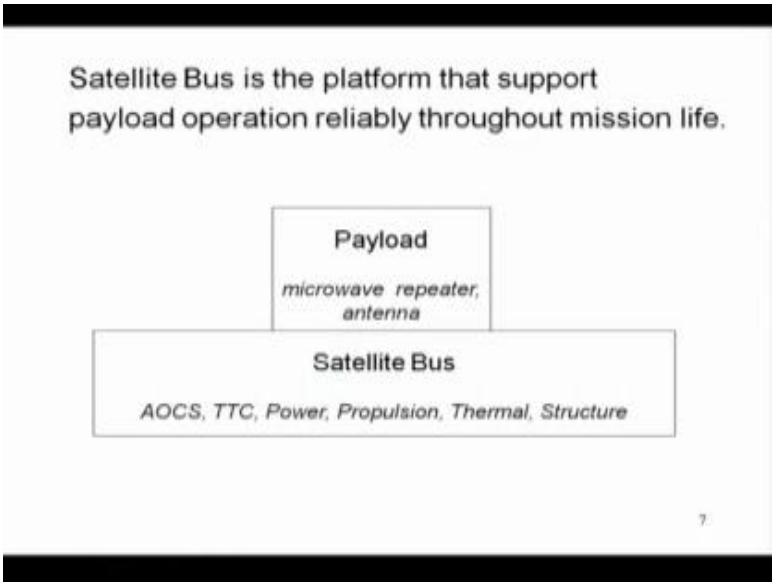

So, now with this we can repeat the same thing the Satellite bus is the platform that supports payload operation reliably throughout mission life and now the Satellite bus contains AOCS attitude and orbit control system TTC Telemetry Tracking Tele command system, Power, Propulsion, Thermal, Structure each of them are important, but will go briefly for some of them and a little more detail in some of them based on our basic requirement of a communication. And this whole Satellite bus is holding the payload and payload is what? It is the microwave repeater and antenna. So, that also will be discussing in this and also the whole Satellite bus and payload together they will be operating in a particular environment will be discussing after that environment also. So, today we are discussing on the Satellite bus. So, let us start with AOCS.

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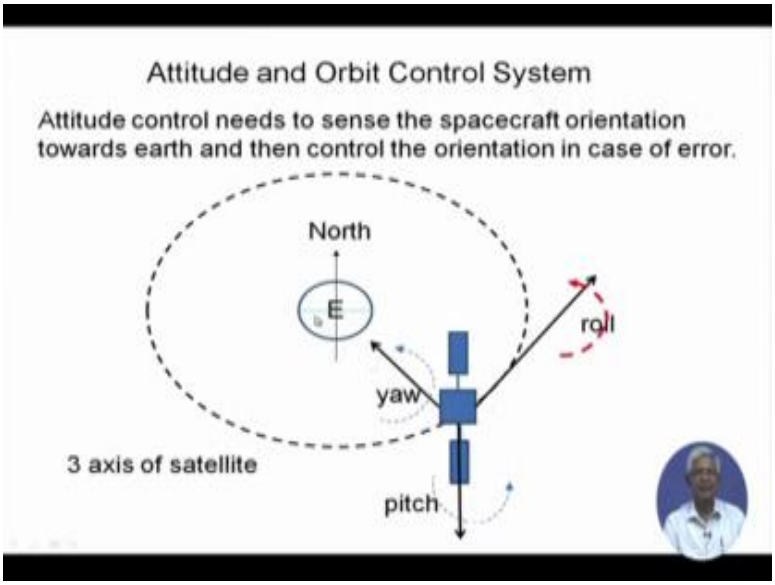

AOCS is Attitude and Orbit Control System lets have a very small sketch of this as if the earth is there at the center and a Satellite appears stationary orbits is orbiting around it and orbit is on the in the equatorial plane though if the drawing you have to imagine that it is in the equatorial plane and north is showing up and this two wind bar that is the top and bottom is solar panel and in between the box this let us assume that this is the Satellite. And, which is normally oriented such that the solar panel is looking north and southward top and bottom and in between is that structure which is this Satellite payload and the bus. All we can call as a Satellite.

Now we have to maintain the attitude of the Satellite towards the service area and this service area in this case let us assume that this is earth. So, from earth will receive the transmission and to the earth we will transmit back so; that means, the orientation of the Satellite phase which pass the repeater communication has to be towards the earth. If that repeater which contains the antenna it looks some other direction it will not be able to communicate with earth. So, therefore, this has to be maintained in its position.

So, let us try to define certain axis of this particular body which is Satellite let us make it three axis. So, Attitude control needs to sense the spacecraft orientation towards earth and then control the orientation in case of error. This 3 axis of the Satellite are one is roll,

you see the Satellite is orbiting in a this dotted line which is orbit and tangential to the orbit you can put axis on which Satellite may roll now this role thing is coming almost from the ship or aircraft type of axis orientation you can see if it rolls than it will the solar panel will move like a fan like this in this direction.

So, role axis is Satellite is orbiting and tangential to the orbit the direction the Satellite is moving that direction is a roll axis. Now if the roll axis is slightly changed axis is not exactly tangential to that the phase which is looking towards the earth also will change. So, therefore, this roll axis has to maintain properly. So, let us see another axis which is pitch which is in this case the 2 solar panel and the straight line you have put which is perpendicular to the roll axis or perpendicular to the orbital plane of the Satellite is the pitch axis. So, around the pitch axis if the Satellite rotates then the body of the Satellite the phase which is facing towards the earth also will move east or west. So, that will away. So, pitch axis is important, roll axis is important.

Try to see the role axis movements will make something like north south movement and pitch axis this orientation east west movement and there is one more axis which is pointing to the earth that is called yaw axis. So, in that yaw axis as if the Satellite can if is around the yaw axis Satellite will rotate like this fan in other direction. So, yaw axis Satellite center point is pointing to the center of the earth if you remember that in case of communication we have said in case of orbit we have said there is a sub Satellite point which is connecting which is falling on the surface of the earth from the center of the Satellite and center of the earth if you draw a line. So, that line is the yaw axis line. So, now, we have defined the 3 axis of the Satellite roll pitch and yaw and we have to maintain then exactly proper position. So, that this axis in proper position which are perpendicular to each other. So, that the phase of the Satellite which has the repeater antenna is facing towards the service area of the earth. So, how do you do it?

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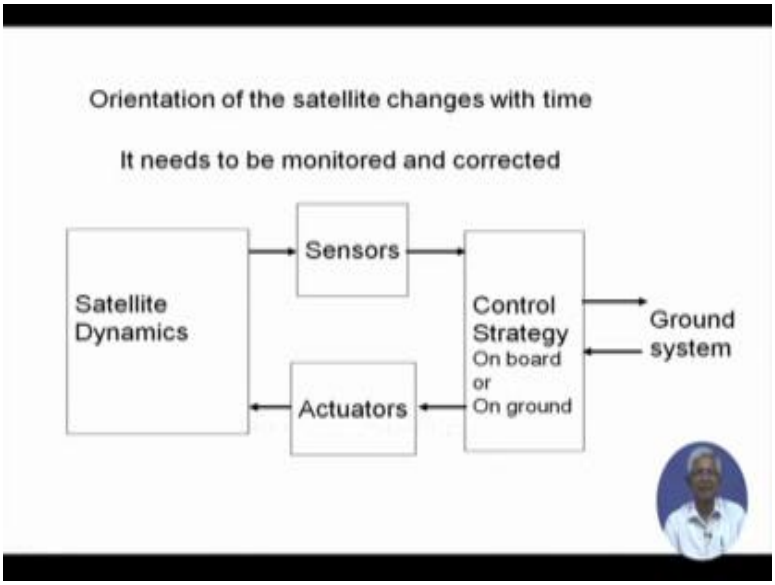

Orientation of a Satellite may change with time because of other forces acting on it. So, it has to be monitored and it has to be corrected. Now that mean Satellite has a Dynamics it is changing because certain forces are acting on it and we have to adjust that. So, first we have to sense which direction it has moved the orbit with respect to the ideal three axis position where is there is there any change. So, will put certain Sensors and the Sensors will give the output to a on board system or may send it down to the ground system to know with respect to the ideal reference whether is there any disturbance or error has come or not. And if there is error ground system or on board system will give the command in the opposite direction to adjust the error and make the error 0 as near to 0 as possible those are done by actuators. This is the term that is actuators. We will see what are those things it takes.

So, this is the a close loop system you can see the Satellite positions are sensed and then we take controls command adjustment is done and those command gives command to the actuators which adjust the Satellite orientation this is very briefly the function of the AOCS.

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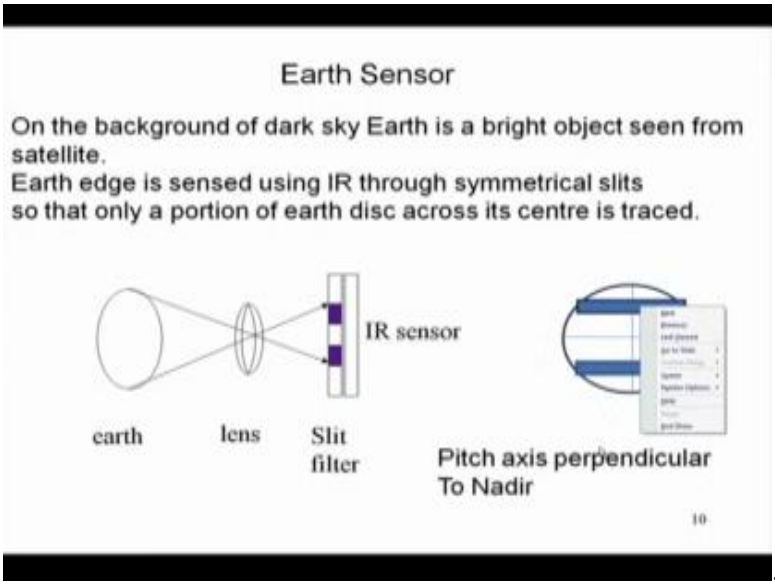

Now how do we sense this, on the background of the dark sky Satellite is seeing dark sky and there is earth and earth is a bright object; obviously, dark sky earth is a bright object whether you sense in terms of visible light or even in infra red. So, the boundary of the earth can be used as a reference. So, earth edge is sensed using I Infrared through symmetrical slits. So, that only a portion of the earth is across the center is traced. Let us see, this the sketch, this is the edge of the earth, at the Satellite there is a sensor, there is a lens behalf before the sensor and this is shown that in a right angle slash a is there in that it is shown that there is a projection on there, there at 2 slits and there is the IR sensor detector. In the other angle it can be seen this IR sensor will be seeing the boundary of the earth on that there are two slits at cut and in that it can see up to edge of the earth to other edge of the earth.

Now, if it is oriented properly then a electronic circuit can sense that these 2 slice can be converted into a scan reading and it can show the duration of the scan reading is same. If there are symmetrically placed. In this case pitch axis is perpendicular to the Nadir point. You remember the definition Nadir, Nadir is from Satellite towards the earth if you directly see. So, if these 2 slits through which the earth edge is being seen is same in dimension or by electronic (Refer Time: 18:41) it can be converted into two duration of constant voltage.

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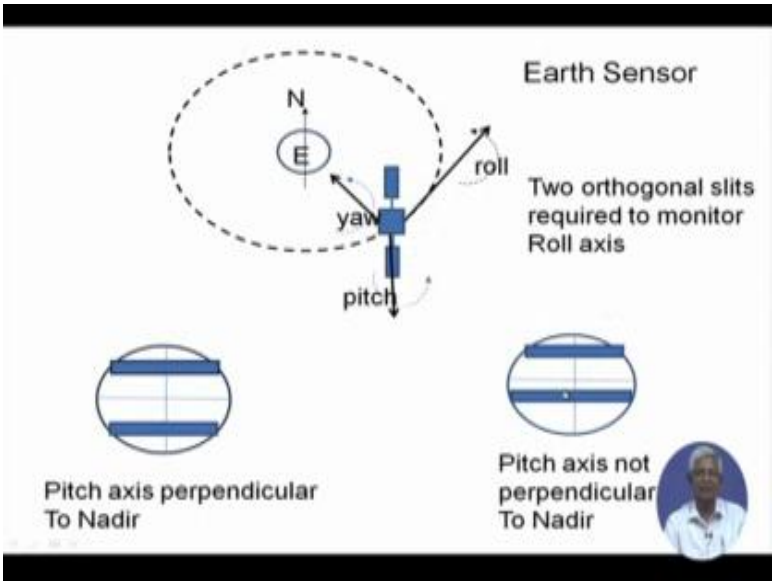

Then it is perpendicular, but then if the role axis is moved a little downward or upward then one part of the slit will see a smaller portion of an earth edge the other part will see a larger portion of the earth edge. So, if there is a mismatch between these 2 slits or where it is converted into voltage are a way form you can see that 2 rectangular waves can be different they are not matching then; obviously, there is a error; that means, the roll axis has changed. So, sorry Pitch axis is not perpendicular to Nadir.

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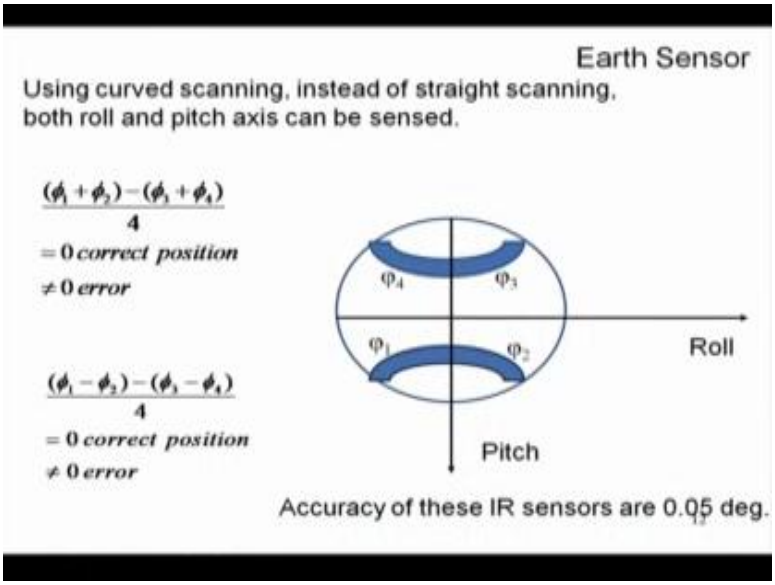

So, 2 orthogonal slits required to monitor the roll axis and pitch axis together, one is horizontal pair and one is a vertical pair, but then there are instead of 2 pairs you can put curved slits. So, it can be drawn like this two curves slits and this angles phi 1 is the from the from the center point that the equatorial point that is the center point to the slit, that phi 1 similarly center point to the other end of the slit is phi 2 and in the northern part similarly phi 3 and phi 4. So, these angles when they are all symmetrical then we can frame a expression that is phi 1 plus phi 2 minus phi 3 and phi 4 that is together. That is these 2 angles and these 2 angles divide by 4 is equal to 0 when they are same it is correct position. When they are not same in the one of the slits has gone upwards. So, that side angle is more and the other side angle will be less. So, therefore, it will be not equal to 0. So, that is the error.

Similarly, we can with the same slits phi 1 minus phi 2 if you put and minus phi 3 minus phi 4 if you put the other side movement also can be detected. There also if it is equal to zero then its correct position if it is non zero there is error. So, in this way by cutting two curved slits you can you can checked the roll and pitch together both axis can be checked ok. Now this type of infrared sensors are about accuracies of the order of 0.05 degree are. So, that is quite good generally it is used, but there are other ways of doing it.

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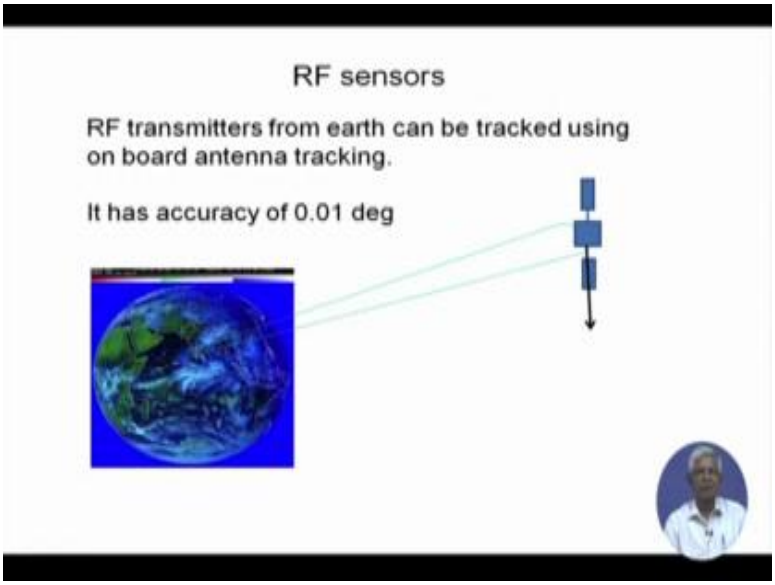

One of the way is the instead of looking at the earth edge and using a IR Sensor you can put a microwave receiver and there is a RF transmitter on the ground and that transmitter is radiating a beam of energy towards the Satellite direction a very sharp point would be and on the Satellite we can make some sort of a arrangement which will track this particular beam. So, that the antenna on the Satellite if it is not looking at this particular source it will not get the energy if it is directly looking at the source it will get the energy this is another way of tracking is called RF Sensing.

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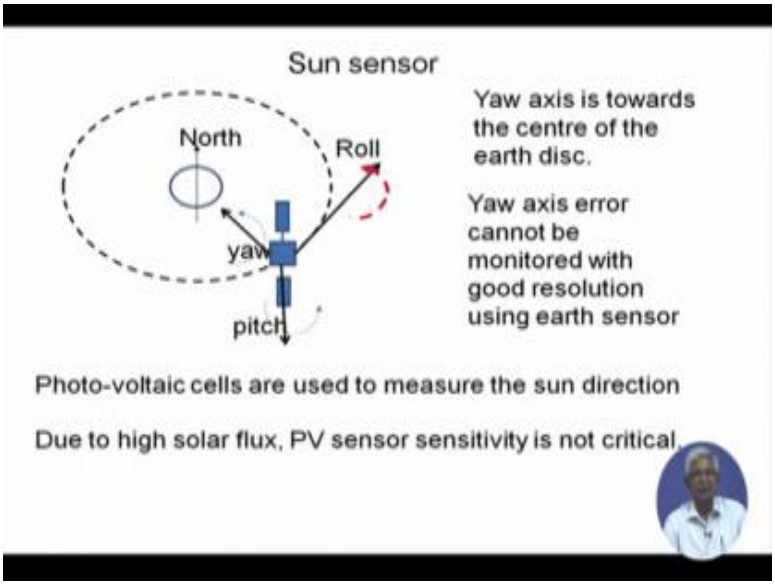

And it also has a good accuracy is of the order of 0.01 degree some Satellites are using this. But in all this process roll and pure pitch in axis roll and pitch axis we have seen what about the yaw axis error the since the yaw axis is moved towards the center of the earth it is difficult to monitor the center this yaw axis pointing to the center of the earth because earth is having some surface area means some area which is away from the center from the edge of the earth monitoring you cannot do it.

So, we need another reference. So, we can have sun as a reference which is some other direction. So, you monitor sun and angle from the sun to Satellite to the earth if we know this angle we can we can adjust our yaw axis according to that. So, we can put sun sensors. So, yaw axis error cannot be monitored with good resolution using earth sensor. So, therefore, sun sensor are used and sun sensor has a advantage that for sun as transmitting huge energy for photo voltaic cells which are used to measure the sun direction need not be sensitivity need not be very critical because in the outer space you are getting large sun high flux.

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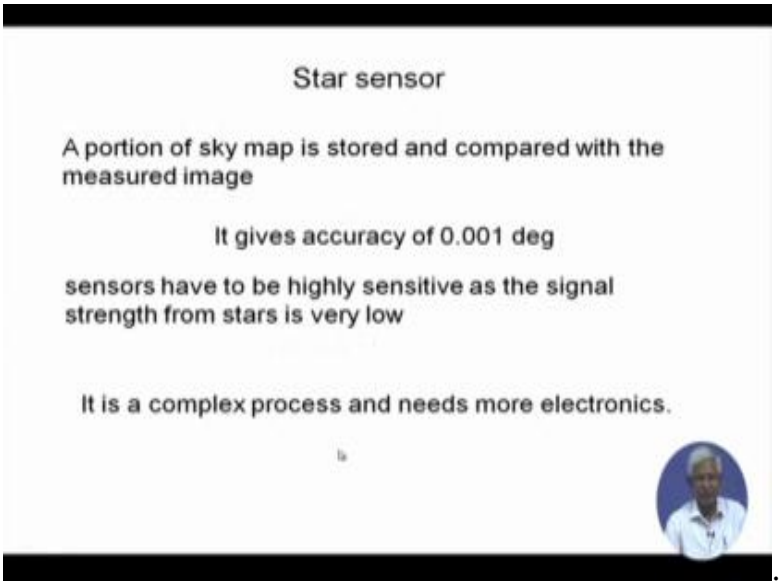

So, this is, there are other way also people do it that is called star sensors. So, in the sun sensor if there be accuracy of 0.01 degree; in star sensors a portion of the sky is mapped and it is stored in the memory of the Satellite and it is compared with the measured image that is in that direction you put a camera and try to image that the portion of that that part of the sky that is with stars and with the stored image you compare this and you try to find out what is the type of air that is coming it can give a better accuracy, but it is very complex also. It can be better accuracy of 0.001 degree, but it has to be very highly sensitive because you are monitoring the stars and the signal strength of the stars is very low. So, therefore, star sensors are used for very critical type of applications or services. So, needs more electronic obviously.

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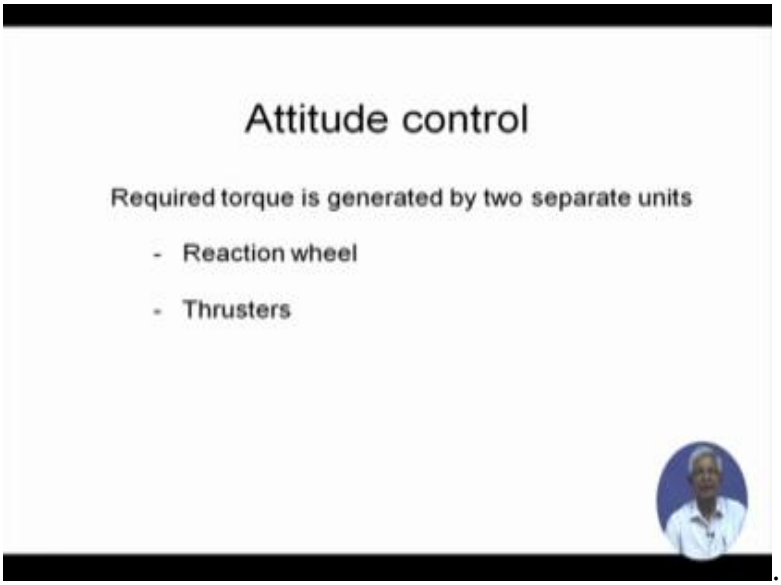

Now, with this you have to do certain control you have sensed it. Now if the sensed information has gone to ground or on board is compared and then a decision has to be taken that you have to control it now how we control it. So, attitude is controlled. There are two types of unit for control one is called Reaction wheel another is called Thrusters.

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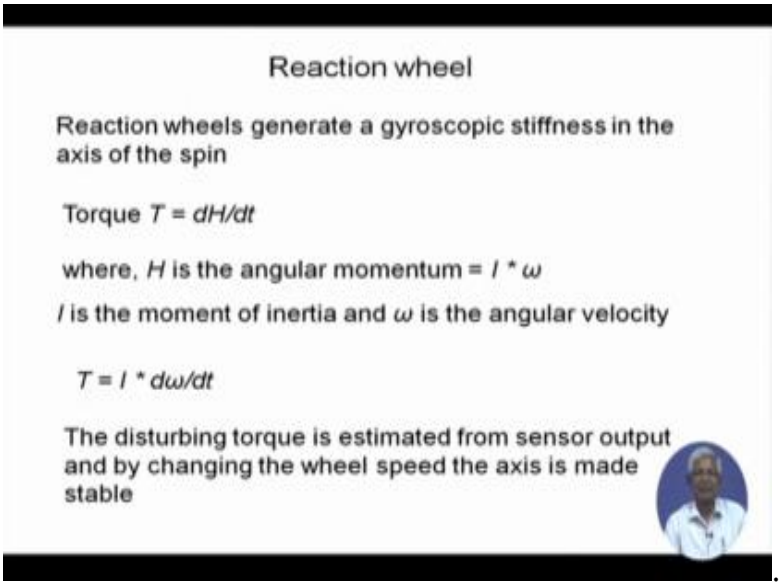

So, we will have brief touch upon this reaction wheel and the Thrusters. Reaction wheel generates a gyroscopic stiffness in the axis spin. You just move a top is spin a top it gives a gyroscopic stiffness or you your bicycle or your bike as you go in a higher speed if keeps a gyroscopic stiffness.

So, those types of principles are used in the rehearsal there is a momentum wheel which is spun very heavily and then it gives a gyroscopic stiffness. So, the Torque generated is can be equated as angular momentum per unit time and tap can be if it is a Torque is momentum inertia into that angular momentum per unit time small different in the angular dw (Refer Time: 26:35). So, this is disturbing torque is estimated from the sensor output and then the wheel speeds are adjusted to show that axis is made stable you make a stiffer, stiffer axis on that. So, this reaction went.

So, let us stop here and then will discuss continue our discussion in the next class.

Thank you.