Remote Sensing Essentials
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Lecture - 42
Active Microwave Remote Sensing-1

Hello everyone and welcome to a new discussion which we are going to have on active microwave remote sensing and this discussion I have divided in 2 parts. So, first we will go through the first part and then of course, the next part of the part 2 as you recall our discussion earlier and microwave remote sensing can be divided in 2 main categories basically, active microwave and passive microwave.

So, in active microwave what is done is the energy or pulses are sent by the sensor towards the surface and whatever the back scattering it collects and record it and whatever in this way we get the data or images and we analyze the data. Whereas in case of passive microwave, it records the natural emission, which is occurring in passing microwave, dead emission in microwave part of EM spectrum might be very little, but it is still there were sensors, there are sensors, which you can record or have been recording.

But when we talk about the special resolution of passive microwave remote sensing, then the passive resolution has been a big issue. So you do not get a resolution in meter scale or in meters, but you get in kilometres, maybe 20 kilometre 15 kilometre or 30 kilometre and nonetheless is still it can record with because the energy the amount in passing microwave region is so little, that in order to record you need the energy from a large area and therefore, we do not get high spatial resolution.

But in case of active microwave, high spaces relatively higher spaces of resolutions are possible and that is being done. So, in this discussion, we are going to mainly focus on active microwave remote sensing.

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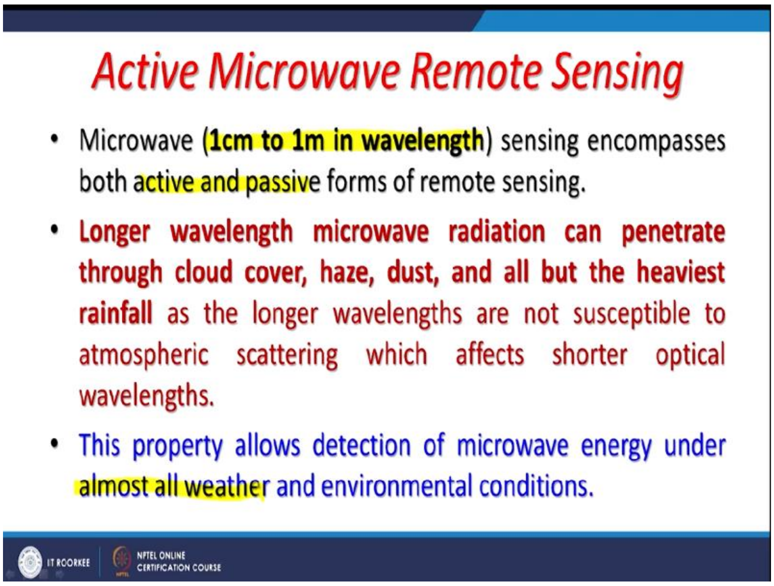

Now, as you recall the EM spectrum in the beginning of this course, we have discussed in length and then microwave part we put as starting from 1 centimetre to 1 meter in wavelength. So, that part of EM spectrum and which covers between 1 centimetre to 1 meter or 1000, you know this 1 centimetre to 1 meter in wavelength and which is considered as microwave and this you know encompasses both active and passive.

So, for microwave part of EM spectrum, whether it is active or passive, this wave or this wave band remain same that is 1 centimetre to 1 meter and in our remote sensing, but for remote sensing purposes, now longer wavelength microwave radiation, as you know can penetrate through cloud cover, haze dust and all but the heaviest rainfall as longer wavelengths are not suspect able to atmospheric scattering, which affects shorter optical wavelengths.

That there is a very simple thing which we have also discussed while discussing and different laws and remote sensing and also when we have been discussing about atmospheric effects and remote sensing data. So if wavelength is shorter then it will get affected by these atmospheric constituents like water content or haze dust or anything which is in between satellite and surface of that, but when we are having longer wavelength, like in case of microwave and then it can penetrate.

Because longer wavelength does not get affected by these small constituents, small size constituent of atmosphere, and like water, water droplets, tiny water droplets and or haze dust or any other thing. However, if we are having clouds, which are really rain bearing clouds or high water content clouds, sometimes they may get affected. Let me give you an example from our day to day life. And nowadays most of us have started using disc antenna to receive TV signals.

And you might have noticed that whenever there is a heavy rainfall, or high dense clouds, black clouds are present in that atmosphere. And we do not get signals from the satellites through our antenna to our TV, because the transmission is in microwave region from these satellites, these you know geostationary satellites, and therefore, in normal conditions, even when you are having cloud cover, but not a very heavy cloud, heavy clouds or rain bearing clouds or having dust or atmospheric distortion is still we get signals.

But whenever we are having such situation, and dark cloud water, water bearing clouds, dense clouds, then we do not get signals from the satellites through our disc antenna. So only in that condition it gets affected otherwise, not also these longer being longer wavelength, microwave radiation being longer in wavelength can also penetrate through dry sand and to up to few meters, may be 515 depending on at what depth it encounters the Moisture.

And if it is completely dry off say 10 or 15 meters it can penetrate as soon as you know it encounters the moisture or water in subsurface condition, then there is a absorption and then we do not you know, we do not get like in case of heavy rainfall, we do not get the signal So, same way we do not get the backscatter from such areas and exploiting this kind of property of a long wave wavelength microwave radiation and people have discovered like in India old courses of Saraswathy River using microwaves remote sensing data.

So, it plays very, important role as a very good way of assessing several things through this active microwave remote sensing also passive microwave having it is only applications, which we will be discussing sometime later. So, today we would like to focus mainly on the active microwave remote sensing. Now, this penetration property allows as already mentioned under almost all weather.

And all most all weather not in all weather conditions exception I just giving that heavy heaviest rainfall, or very dark cloud or water bearing cloud make a problem. And otherwise in all, almost all weather in environmental conditions microwave will work that is why whenever there are problems associated with flooding or some natural disasters we are same time you are having cloud cover people will go and look for microwave remote sensing data and this is a common thing.

So, in flood is studies and microwave plays very important role because and during the rainy season when flood occurs, you might be having cloud and all other remote sensing will fail except active microwave remote sensing. So, it plays very important role for various studies whereas passive microwave remote sensing.

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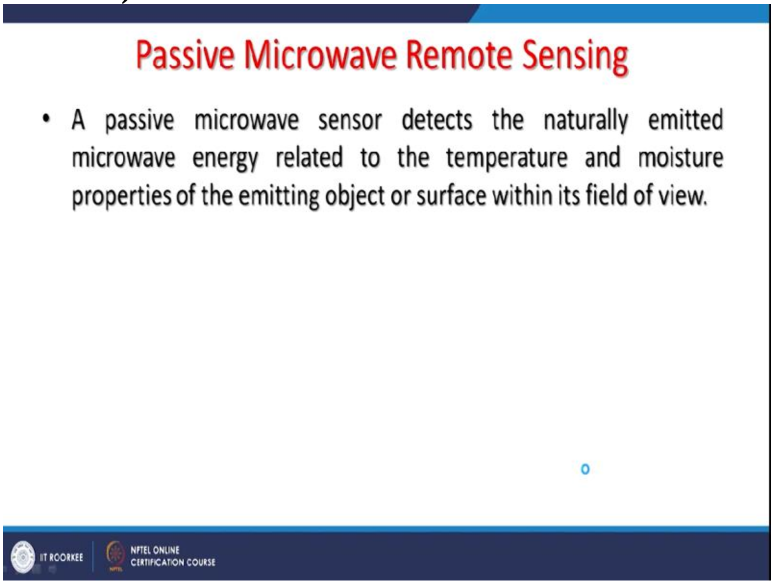

And basically detects that naturally emitted microwave energy and though this energy is very tiny, very small, and which is related to temperature and moisture properties of the emitting object. Soil or rocks are surface within his field of view. So, because the energy is tiny, then you require a large area to cover to register it is you know effects in the sensors those are which are very far or maybe 850 kilometre away from earth.

So, that is why in passive microwave remote sensing the data is available at relatively very good resolution. Nonetheless, basic microwaves sensors are typically radio meters or scanners and an antenna used to detect and record the microwave energy. Now, the passive remote sensing, not passive microbial remote sensing I am saying simple, passive remote sensing, visible infrared and near infrared and their energy is available either through the sun and that is the reflected energy or emitted energy in case or you know.

Thermal channels and the system or sensors are completely different here the sensors are again completely different even in case of active microwave or passive microwave. So, one has to keep in mind that the sensors or radio meters are completely different than in normal remote sensing which we call as passive remote sensing.

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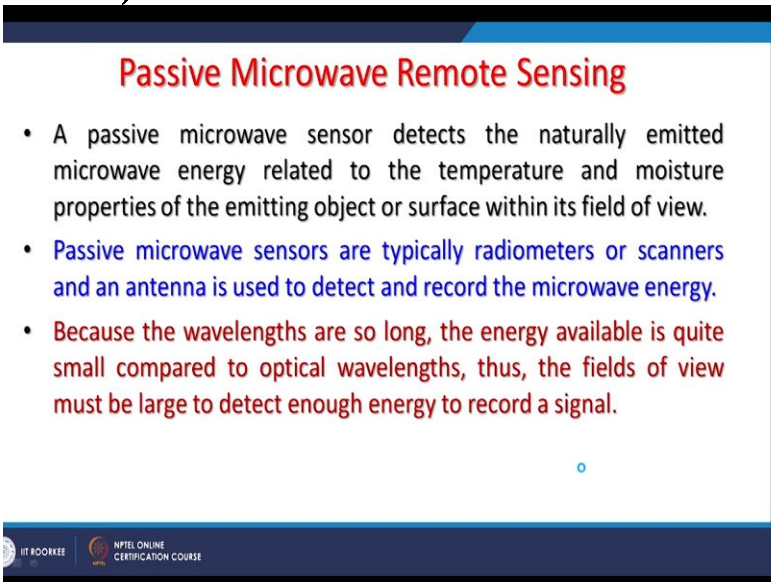

And because of wavelength are long in case of microwave, the energy level is quite small compared to optical wavelengths, and therefore, and the field of view must be large. The area of coverage per say per pixel has to be very large, that means coarser resolution to detect energy to record as a signal, this is at this point I have been emphasizing again and again in active microwaves remote sensing we have reached to up to 30 meter spatial resolution.

But in passive microwave, we have reached up to 15 kilometre only. So, relatively is a very coarser resolution data, but it has got its own application. So, because the wavelength is large and or long the energy level is very small compared to optical wavelengths like visible red or infrared or blue bands. And therefore, we require a large area to be covered, which will register as a signal or that energy which is available will be registered by the radio meter as a signal and therefore, we end up with a coarser spatial resolution data.

So, most and so far whatever it has been developed in case of passive microwave sensors are therefore characterized by low spatial resolution because of less energy available.

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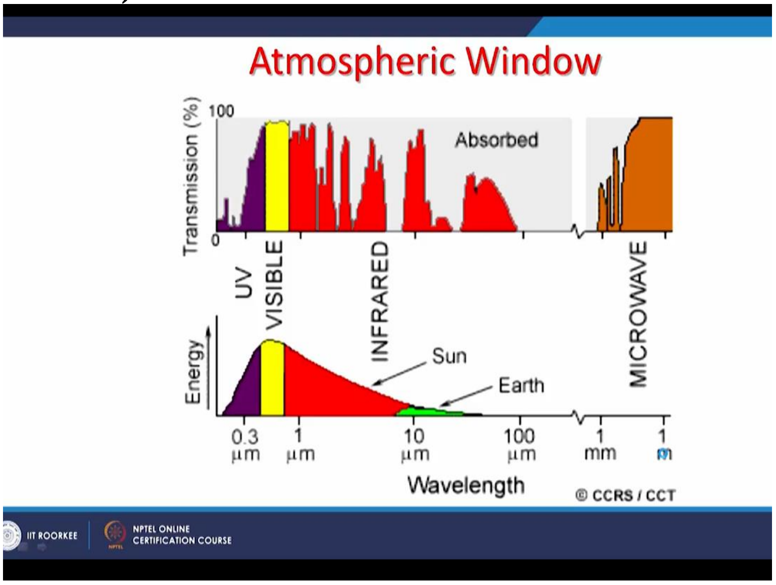

Now, if we quickly we will go through these atmospheric windows though we have discussed in length about this the micro part if you recall here it is this part of EMS spectrum, 1 centimetre and 2 or 1 centimetre to 1 meter and this is the absorb part which you are seeing here, but, you know large part is not get is not affected by atmosphere and therefore, transmission go this is what is the transmission is so, transmission high transmission is possible and therefore, only in case of heavy rains, it gets affected otherwise it is not affected.

And if you see the energy which is available, invisible part the maximum Energy is available, this is visible part of the EM spectrum. And whereas when we move towards the longer wavelengths, especially in this part of EM spectrum, then hardly energy is available. And therefore, it is challenging in cases of passive microwave. Now, we come back to active microwave because there are a lot of satellite load of sensors are there in active microwave and lot of applications new applications are being developed.

Especially measuring the deformations induced by an earthquake landslides over exploitation of groundwater and many other things. So, in Geodesy basically active microwave remote sensing is playing a major role and it is becoming very, very powerful tool for such kind of studies. So, we will be more focusing on active microwave remote sensing and which provides and their own source of micro radiation. It will give the target and that is that is why it is called active microwave.

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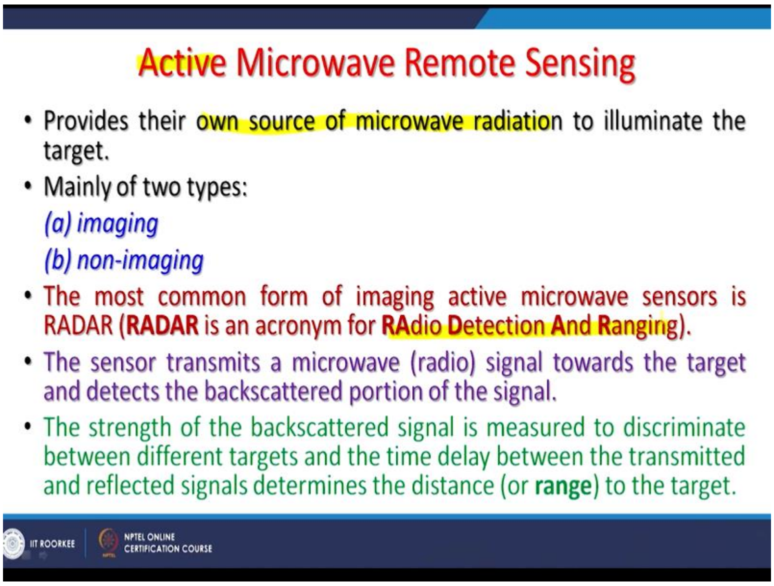

Because the sensor itself will send the pulse towards the earth. So, that is what source of own source of microwave radiation in microwave part of course, to illuminate that target and then whatever is backscattered it is record so, it is a 2 types mainly and one is imaging type and another one is non imaging. And, you know the most common form of imaging active microwave sensor is radar that is radio detection and ranging.

This is Radar is the most common microwave active microwave remote sensing, which is being which has been incorporated in many satellites and sensors. So, basically sensor transmits a microwave signal or radio signal towards the target and detect the backscattered portion of that signal 100 percent energy will not come back there will be some changes some attenuations some deformations, but nonetheless that is recorded. So, the strength of backscatter signal is measured.

Because you are having the strength of you are already having recordings of original strength of the signal which has been sent towards the target and then you get back the backscattered signal and if there are changes that can be you know assess. So, this is strength of best scattered signal is measured to differentiate or discriminate between a different target because different objects on the surface of the earth will behave differently with microwave and you know the signals and the time and delay time which will create some time delay time.

And between the transmitted and reflected signals or backscattered signal and which determines the distance and that is why it is called range. So, the radio detection and ranging. So, the signals are and microwave signals that is the radio signals are sent towards the earth and then whatever comes back the delay time is used to detect or measure or estimate the distance which has which is been sensor and the object and that is why it is called radio detection and ranging. Ranging means finding the distance and by using the time delay factor.

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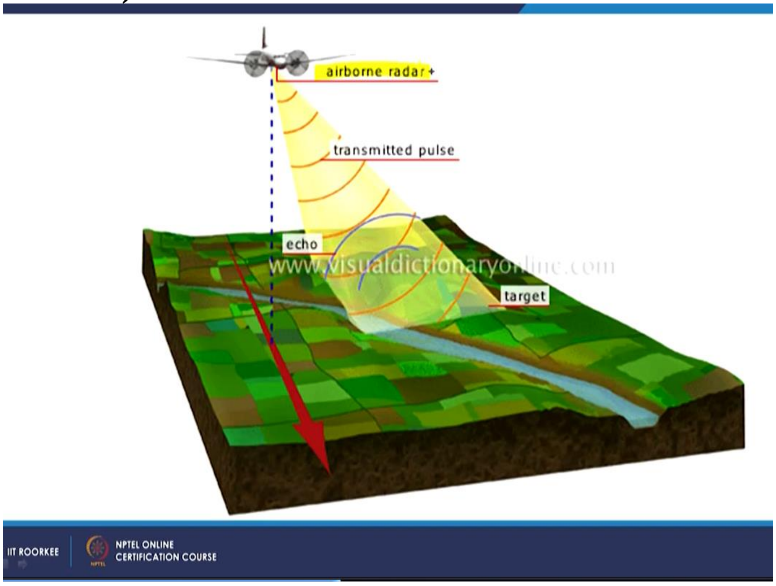

So, this is how is in case of airborne radar or the same also in case of satellite based or space pondered on that the signal is first sent towards the target. Here the surfaces of the earth many objects are present saying this one agricultural field, water body and others. So, it equal interval, a regular interval, these pulses are sent towards the earth and then in the blue colours which you are seeing in this photograph or in this image figure is the getting reflected.

And we call them as also echo. So, this gets back and now, when if these pulses are hitting water body, the return or backscattered will have a different reaching time or delay time whereas, if it is hitting a built up a building or maybe a land or rock or soy or agricultural land vegetation will build back a scattered differently, so by using this delay in time of reaching these signals and we can identify different objects on the surface of the earth and when we when we study for ground formations.

Then in that case single data collection is not sufficient, then data from between 2 different dates are used to detect the changes which has occurred might be due to earthquake might be due to landslide might be due to the over exploitation of water or any other human and due to human interventions. So, these changes might be there, this is the basically and neither height (()) (18:46) or just above the ground.

So, this is the ground track of that aircraft or a satellite and it is looking obliquely, this one has to remember it you know the sensor and if it is looks downward, then it will not be able to collect the data or back scattering signals. So, it first it sends the signal as you might have been realizing in an oblique direction is slanting direction and then when it when the energy is getting backscattered these equal signals are going towards the satellite or a aircraft by the time the aircraft will reach so, and by the time it will collect also.

So, there are you know in either a large antenna or synthetic antenna and the used means that the antenna is synthesized and therefore, it is possible to collect the data backscattered data. So, it is looking towards in a slanting range not vertically downward. So radar microwave active microwave remote sensing is not their view, whereas your simple normal passive remote sensing is generally not their view only in case of a studio pairs.

It looks in side directions or maybe forward backward direction, but in microwave active microwave remote sensing, it looks in a slant direction or oblique direction we also sometimes call it.

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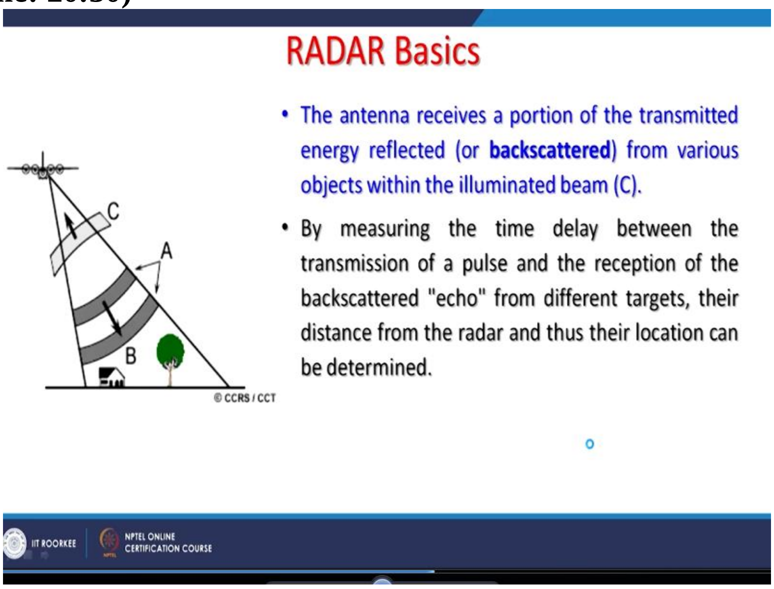

So, here the radar if we see the basics here radar and that is essentially ranging or a distance measuring device and that is why it is part of also geodesy that when signal comes here and then these are the pulses which are coming marked here as A then getting through then they will hit it and then backscattered his mark here is C and then it is collected. So, radar is essentially ranging or distance measuring device, it consists fundamentally of a transmitter which transmit the pulses at regular intervals of same strength.

Because it has to that is the condition otherwise, whatever the backscattered will come, if the original signals are bearing in his strength, then it will not be useful the data. So, regularly transmits the data of same strength, there has to be antenna to collect the backscattered signals and an electronic system to process and record the data because recording is also equally important and this transmitter basically which sends them microwaves or radio signals towards the earth and basically generates successive.

As I have said regular sort bursts pulses of microwave which is in this a schematic it is shown as A at regular intervals. So, you will have successive such signals and which are focused by antenna on to a beam which is soon here as B. So, by this arrangement we get then Backscattered signal so radar beam illuminates the surface. And obliquely this I have been emphasizing again and again it is obliquely at a right angle to the motion of the platform.

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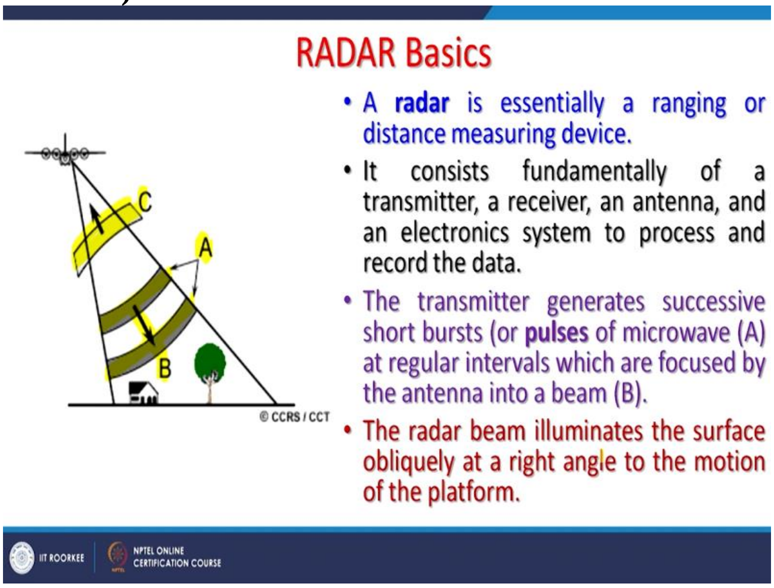

So, if a platform is moving like this, then at right angle of that the direction it is sending the signal and collecting the data. Now, the antenna receives a portion of transmitted energy reflected and or backscattered energy from various objects within the illuminated beam. And then by measuring the time delay because after all radar is a you know this ranging technique, so, there will be some time delay and depending on the properties of the objects on the surface.

So, by measuring the time delay between transmissions of pulse or that signal and the reception of the backscattered echo from different targets, they are distance from the radar and their location can be determined. And this ultimately these signals are processed in a way that ultimately we can create power images like your normal not really normal but quite close to the normal image we will be seeing also examples also very soon.

So, as sensor platform moves forward a whether a airborne or satellite based or a space borne then recording and processing of backscattered signals builds up in 2 dimensional image of the surface. So, those signals are recorded in a manner and processed in the way that ultimately we get a 2 dimensional raster data or an image of the that part of the earth which has been covered by that sensor.

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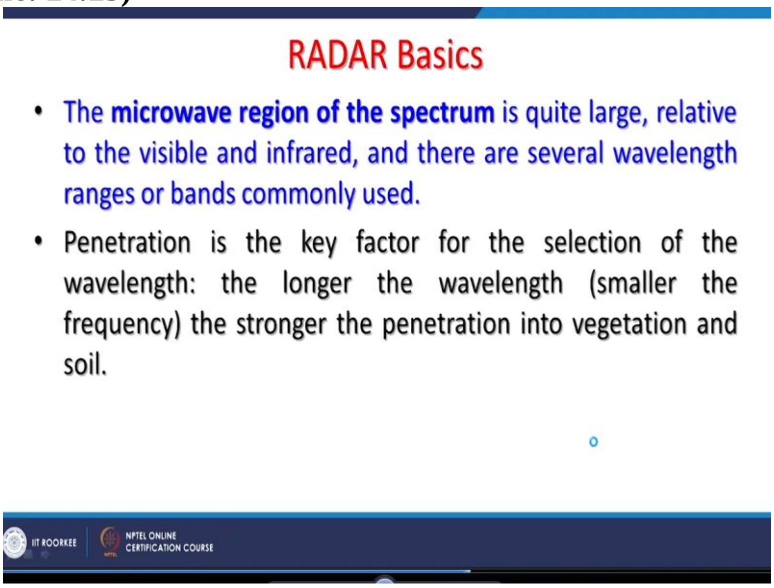

As you know that microwave region of the spectrum is quite large and 1 centimeter to 1 meter and relatively and compared to visible and infrared which are having in micro meters only the bandwidth and there are several wavelengths or bands commonly used in microwaves. So, there are various bands are used which will we are going to see soon. Now, the penetration because of these radar waves, or radio waves, penetration is the key factor for the selection of wavelength with wavelength baseband.

And the divisions of bands are also little different in microwave and part of the EM spectrum, the longer the wavelength and smaller the frequency the shorter the penetration into vegetation and soil.

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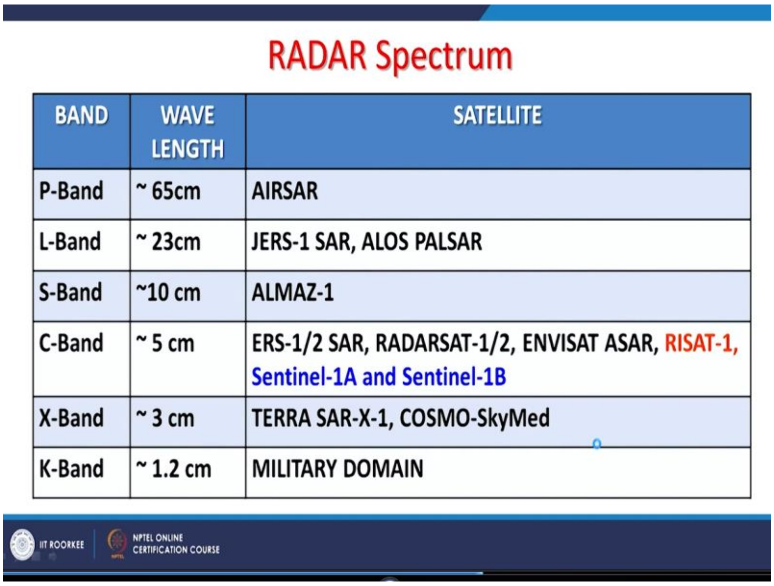

RADAR Spectrum

BAND	WAVE LENGTH	SATELLITE
P-Band	~ 65cm	AIRSAR
L-Band	~ 23cm	JERS-1 SAR, ALOS PALSAR
S-Band	~10 cm	ALMAZ-1
C-Band	~ 5 cm	ERS-1/2 SAR, RADARSAT-1/2, ENVISAT ASAR, RISAT-1, Sentinel-1A and Sentinel-1B
X-Band	~ 3 cm	TERRA SAR-X-1, COSMO-SkyMed
K-Band	~ 1.2 cm	MILITARY DOMAIN

So, that one has to keep in mind depending on the what for what purpose and this kind of data or this kind of remote sensing is being implied. And let us see with the different bands and how they are associated with different sensors on board of different satellite. So in this table, and we will go one by one, that say P-Band that is a part of EM spectrum or microwave part of EMS spectrum, between 1 centimetre to 1 meter, and here it is roughly located near 65 centimetre there is a satellite which is called AIRSAR.

L Band is another element is very common band having a location around 23 centimetre in that spectrum of microwave and a very popular sensor and that is PULSAR OR ALOS PUKSAR is there of Japan. JERS-SAR are also is there having L band then S band is there about 10 centimetre and ALMAZ -1 is there and when we see the another very common band is the C band somewhere around 5 centimetres maybe some time you get 5.8 centimetres and you end up 5.6 centimetres and dividend but on average we consider is around 5 centimetres and ERS 1 and 2.

The (()) (26:54) aperture radar sensor we are having C band antenna radar set also of Canada, 1 and 2 both there in C-Band and we said ASAR which was very popular, no more now functional or neither the ASAR or radar set including and we said these are not functional, they all had this C band and RISAT which is our own Indian remote sensing satellite and that was also functioning in C band then Sentinel-1A and 1B be very, very much functional and they 2 uses C band.

Now X band also has been used again we are going for less wavelength or shorter wavelength that is the 3 centimetre and TERRA SAR X-1 and COSMO Skymed, they uses this band and then finally the K band which is about 1.2 centimetre and which is in the MILITARY DOMAIN. Now so, we as a just mentioned earlier, that the penetration is the key factor for selection of wavelength, longer the wavelength, the stronger the penetration into vegetation and soil. So, depending on that, you know applications, these have been designed.

The most common one nowadays which we are finding also ISRO has found is the C band which is around 5 centimetre. So, it is a basically you can see as a compromise between shorter microwave wavelength and longer wavelength and in between you are having 5 centimetre wavelength that is basically the C band. Now, whichever the wave length is being used, and radar signals can transmit.

And to you know that horizontal and vertical electric field vectors and can also receive in the same way that means in horizontal either horizontal or vertical return signals. So, that is another advantage with microwave that we can have signals either in horizontal and vertical electric field vectors.

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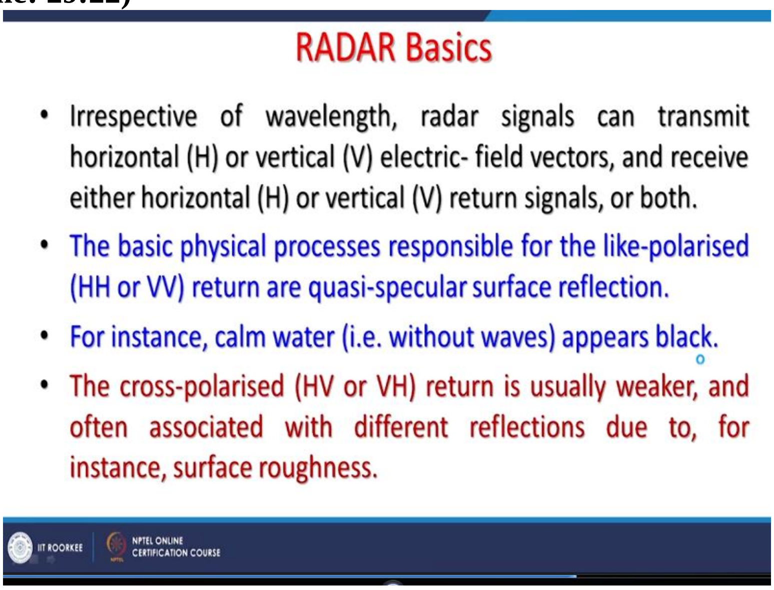

So, the basic basically the physical processes is responsible for this polarization or like polarized HH or VV we return our quasi - specular surface reflection because that reflection or Back scattering coming from different objects of the surface are responsible for this kind of polarization. So, for instance calm water, a water is (()) (29:53) distilled water without any waves or any other thing and can appear black that means it is completely absorbing the microwave energy.

Whereas cross polarized HV or VH return is usually weaker and often associated with different reflections and due to for instance surface roughness. So, you know sensors are recording data they are recording in different polarizations and depending on our locations we can use different polarizations.

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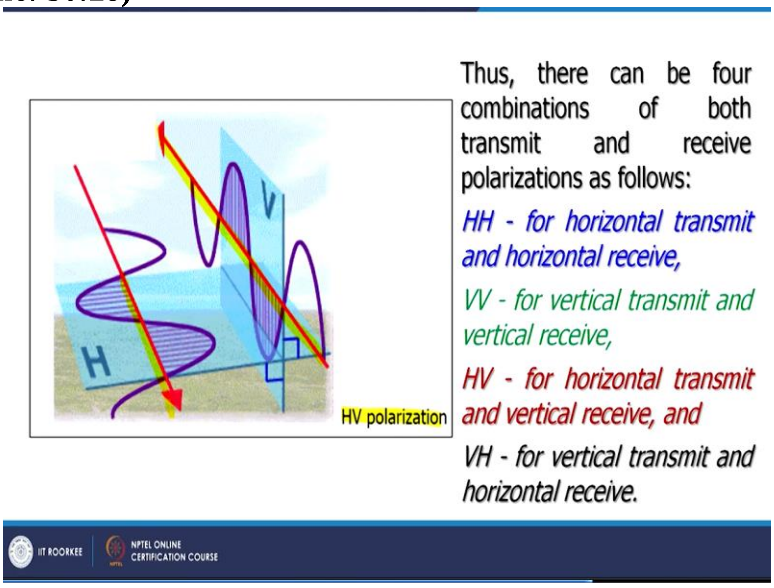

So, here what basically HH and V means different polarizations. This is a combination of H and V population is that in horizontal the polarization or wave say moving like this in vertical, it is booming in vertical plane and this is the direction of propagation This is also the direction of propagation so that there can be 4 combinations between HH VV HV and VH that there can be 4 combinations of both transmit and receive polarizations.

As HH for horizontal transmission and horizontal receive and vertical transmission vertical receiver, for a HV for a horizontal transmit and vertical receive and reverse also VH that is vertical transmit and horizontal receive. So, 4 combinations are possible with these radar data

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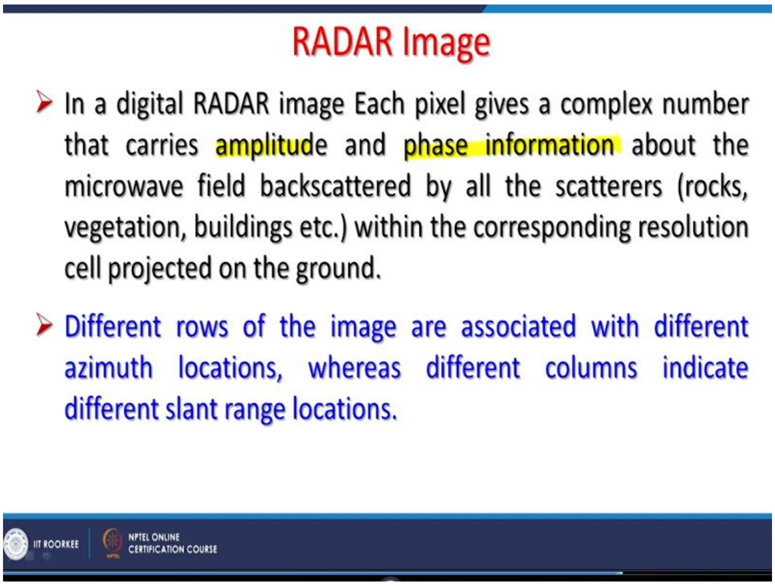

And of course, everything is now digital. So, digital RADAR image that each pixel gives a complex number because it is not simple and normal remote sensing. So, the against the pixel it is a complex number and what this number carries basically it carries the amplitude and the phase information about the microwave field which has been backscattered by the you know scatterers might be rocks or rock surfaces, vegetation, building water body anything which is present on the surface of the earth will have this kind of backscattered different backscattered.

So, they will have 2 things in this complex number that is amplitude of that wave and of course, the phase information and the different rows of the image and are associated with different azimuth locations, because a different when you go through the microwave images. And they are representing different locations in terms of you know, these signals and direction azimuth here is for direction so, different rows of image are associated with different locations where as different columns indicate slant range location so, that has to be kept in mind.

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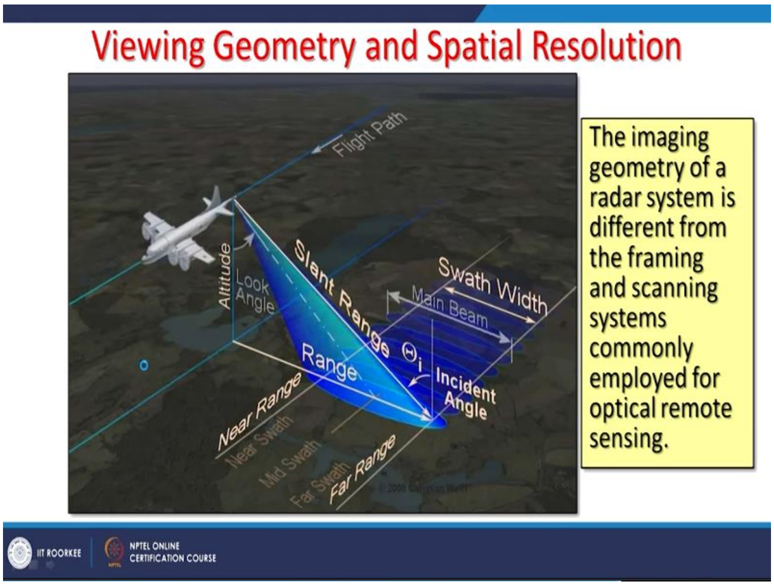

While seeing or analyzing active microwave data, here is the geometry and the spatial resolution and this is the slant range which I was mentioning, this is the flight path here and of course, the ground track is this one which is just vertically downward, this is the height altitude of the aircraft or spacecraft. Then the look angle that is there and this is what is the slant range if we go slant range is oblique obviously.

When you go on the horizontal plane, then it calls the range and the area which is near is called near range, the area which is far from the slant range or the far range. Then we measure with the vertical, the slant range then this becomes our incident angle and of course as swath we say in normal remote sensing. So, here also you will have swath width and that is basically between near range and far range.

So that is main beam and swath is there. So, main beam is little larger than what we get the swath as you can see the blue lines, these blue bands are waving like this. So, this imaging like in these we said in other satellites we are having the imaging geometry arrangement. So, in imaging geometry arrangement in radar system is different from framing and scanning systems because of this commonly employed for optical remote sensing.

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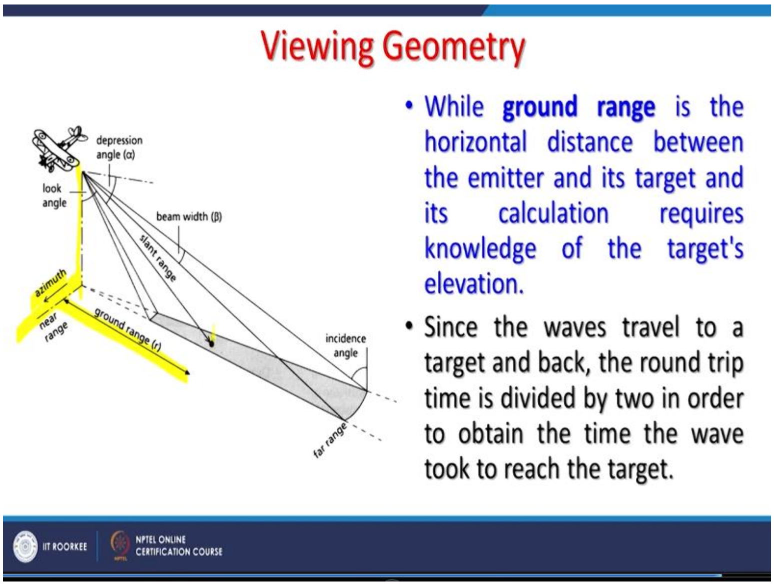

And this viewing geometry in this one and we will pick a signal and then see what happens after this when it returns back to the satellite. So, starting say here, and when signal are starting this is the first signal might have reached there now you are having a 9th, 8th, 7th like this and the first one is here which is coming like this and then time passes and the signals will end then you are having backscatter 9 10 11 12 13. So, these are the basically the return signal from the house and the vegetation will have different return signals.

So, vegetation return signals are different and see the time difference when we come in between 6 and 7, it is 11 here it is evident from the vegetation whereas in case of house it is 12. So, this will allow us to identify different objects in microwave remote sensing to return signals from tree is these ones whereas return signals from house are different. And the radar pulse from the aircraft which is coming downward from there.

So, likewise and this is how pulse by pulse the data is sent and then backscattered is recorded and microwave images are generated, which is a value is a complex number, the unit value same thing here which is we have just discussed and so, the distance is determined from the running time of high frequency transmitted signal and the propagation from the sensor and the actual range of target from radar is known as the slant range which we are seeing actual range of target from the radar and that is the slant range.

In this case the target is here and the slandering in the line of sight and distance between the radar and the object illuminated line of sight means that direct signals here we are getting while ground range which we have also identified earlier, this is the ground range that means the vertically downwards you know the track of the sensor, ground track of the sensor or also here the direction will also matter.

So, azimuth is there, so, ground range from that line to the slant range that is ground range is the horizontal distance and between the meter and his target and his calculation requires basically knowledge of targets elevation. So, what is the height of the target that will allow us to find out the ground range and this is the you know the wave travels to a target and back. The round trip time is divided by 2 in order to obtain the time that we took and to reach to the target and

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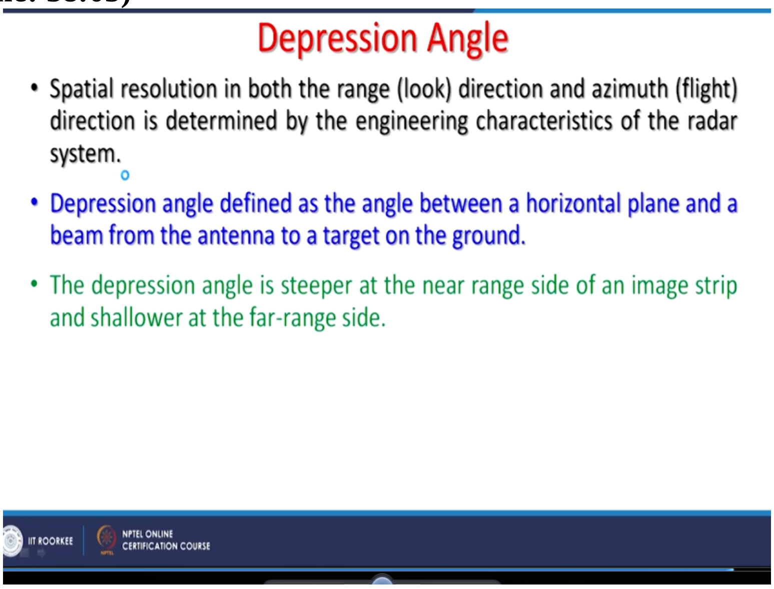

There is also we have seen the depression angle, the depression angle is this penetrate measured with the oriental at the height of the at that elevation at which the satellite or aircraft is flying. So, this depression angle is basically and will allow us to find out the spatial resolution. So, spatial resolution in both the range that is a look and direction azimuth energy that is the flight direction is determined by the engineering characteristics of the radar system.

And the depression angle is defined angle between horizontal plane and beam from the antenna to the target on the ground. And this depression angle is steeper at the near range, obviously, and it is going to be you know shallow at the far range side and this average depression angle is generally measured for a beam of the middle line of the image strip. So, that is why the target is was also fixed in the middle and incident angle is defined as the angle between radar beam and a line perpendicular to the surface. So, these are 2 different angles which are used.

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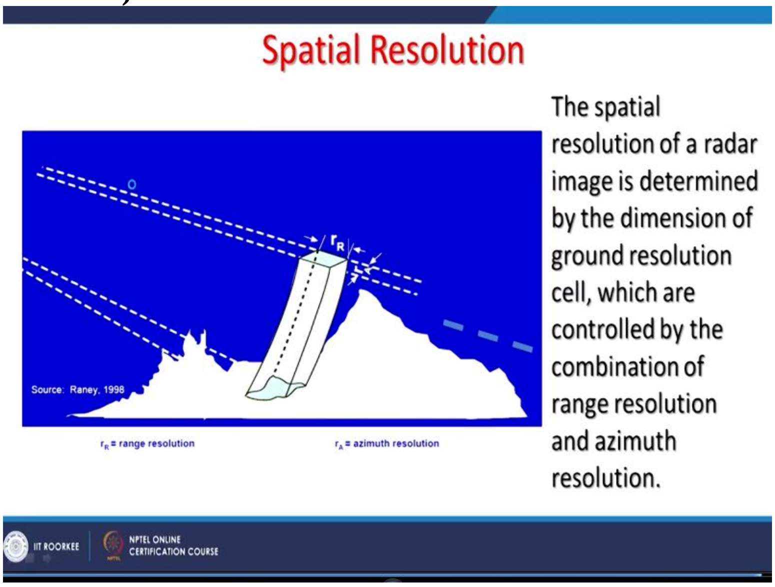

Now, how is spatial resolution is decided and spatial resolution in radar images is determined by that dimension of ground resolution or ground area which is covered by which is controlled by the combination of range resolution and azimuth resolution. So here and what we are seeing that in this case, this is the range resolution and here we are having azimuth resolution also.

So, this is range resolution this is azimuth resolution here. So, this further we will be discussing on this microwave active microwave remote sensing in part 2 for time being I am going to stop here. And in the next discussion, we will continue, especially in the processing part and application part of active, microwave remote sensing. So, this brings to end of this particular discussion, part 1 on active microwave remote sensing. Thank you very much.