Introduction to Remote Sensing
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Lecture 17

Hello everyone and welcome to the 17th lecture of this introduction to remote sensing course and especially we will be focusing on radar remote sensing and more on towards the SAR interferometry or in short we call in SAR technique. So far we have been discussing mainly the passive remote sensing technique where or more optical where the illumination sources generally shun but in radar remote sensing which is active remote sensing the sources will be itself on the sensor or satellite.

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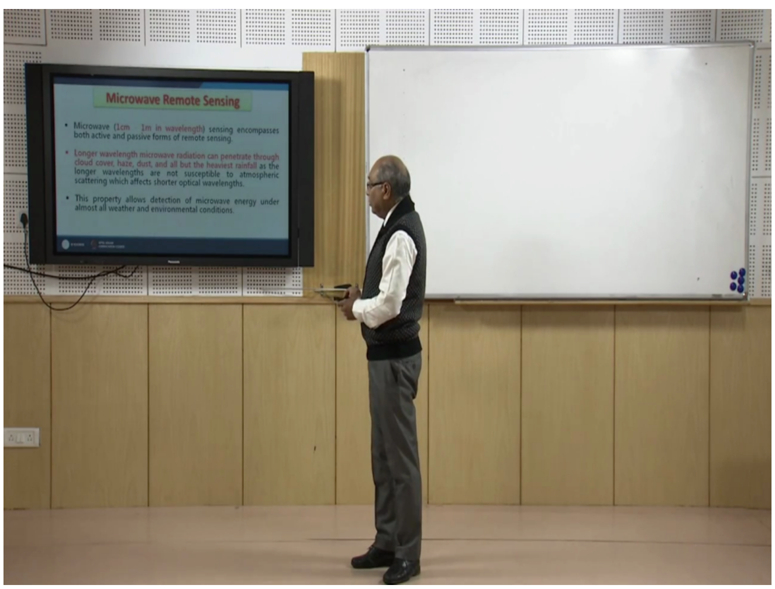

And as we know that microwave remote sensing it is having 1 centimetre to 1 metre in wavelength and it senses in compasses both active and passive form of remote sensing. So if we divide this microwave remote sensing microwave remote sensing can also be divided as also earlier mentioned in the beginning of this course as active microwave and passive microwave remote sensing.

Even for some time we had on passive microwave sensors on an passive micro region but because of very coarse resolution those were never become very popular. However active microwave is very very popular remote sensing and especially because of SAR interferometry it has become further popular. The main reason is the longer wavelength that and it allows the of microwave radiation which allows the penetration.

So it can penetrate through cloud cover it can penetrate haze, dust and except in where rare weather phenomena like a heaviest rainfall when we are having otherwise because being in a longer wavelength it can penetrate though all this metrological or atmospheric distortions which we consider in other optical remote sensing and this detection of microwave energy is almost in all weather and a day and night kind of technology.

This penetration of microwave remote sensing allowed us in India to discover the old sources of Saraswati river in Rajasthan because if you are having dry soil even microwave signals can penetrate up to few metres and if there were the moisture was found that has been detected. So old course of Saraswati River which still had some water supply through its old channels and today on the surface though you see just sand or sand dunes but on the top in the in beneath that sand are below few metres there old courses were present and those were detected using remote sensing, microwave remote sensing or radar remote sensing. So this is the advantage of having longer wavelength in penetration capabilities of this one.

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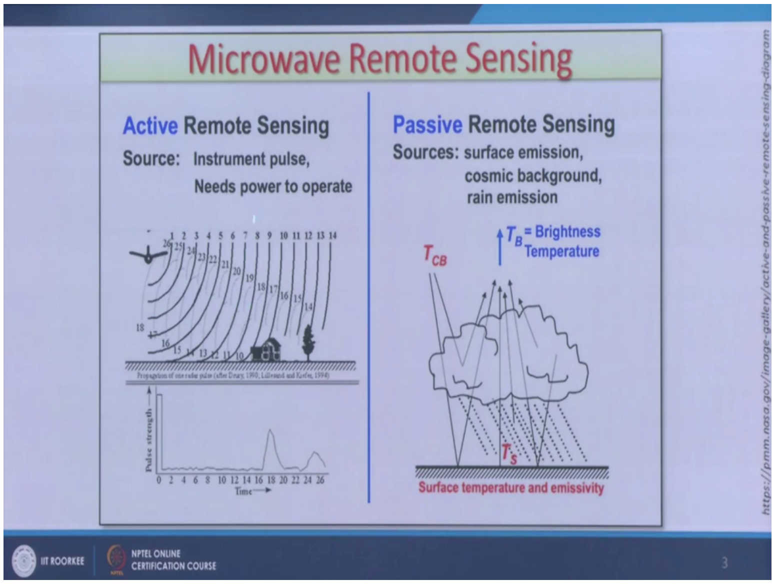

As a we have seen this one earlier also that in active remote sensing in micro like radar remote sensing we instruments and the pulse in like here in aircraft is shown but we can assume also in a satellite sense the and whatever the back is catered after interacting with different objects of the surface of the earth returned and these are recorded and based on this the distance are measured but still basically a ranging technique and then we then we ultimately create though complex numbers we create an image which is we call as radar image, so likewise with the time we that travel time it gives us the distance of different objects. Whereas in passive microwave the illumination source is generally sun or natural emissions and can give a problem. Here it is shown that if there are clouds then you are having problem in passive microwave.

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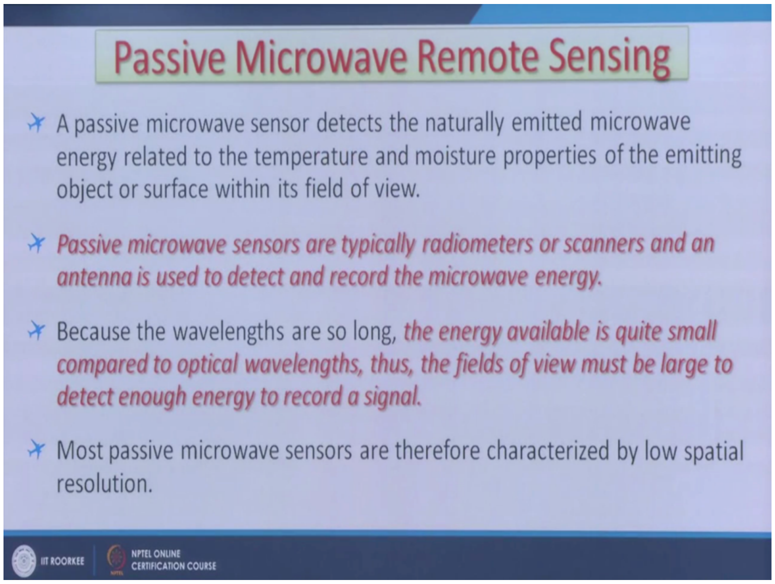

But in a normal remote sensing even so now in just slightly about the passive microwave rather than active microwave that passive microwave as I have said the sensor detects the naturally emitted microwave energy related to temperature and moisture properties of the emitting objects of surface within the field of view. Passive microwave sensors are typically radiometer scanners and antenna is used to detect and record microwave energy but this energy is so small this energy is so small that high resolution passive microwave images cannot be generated so easily and therefore in order to get sufficient energy which can reach up to the satellite large area was involved and that means compromising on special resolution and that is why I said like SSMI, SSMR sensors were there on board of different missions which were in the passive microwave region but they had relatively very poor special resolution as I mentioned about 30 kilometre.

So because of the less energy available to the sensor passive microwave never became that popular, so the energy available is very small as I have already mentioned compared to optical wavelengths like in case of simple passive remote sensing thus field of view must be large to detect the enough energy to record as a signal and the most passive microwave sensors are therefore characterised by low special resolution and that became a problem with them.

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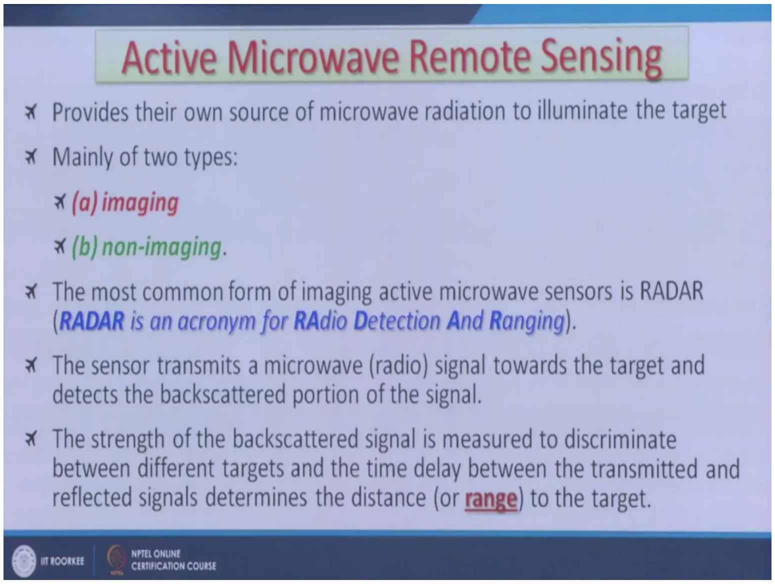

The popular one is the active microwave where it provides their own source of microwave radiation to illuminate the target and this source is coming basically from the sensor itself, so there are 2 types of sensors systems are exist one is imaging another one none imaging, the most common form of imaging active microwave sensor is radar which is what is being used, radar is a abbreviation which stands for Radio Detection And Ranging, so basically radar remote sensing or microwave remote sensing in short we say is a ranging technique and based on that everything then later on are tried.

So the sensor transmits a microwave signal radio signal towards the target if it is on the on board of a satellite towards the earth which is having different objects present and detects the back scattered portion of the signal and this strength of that back scattered signal is measured to discriminate between different targets and time between transmitted and reflected signals determines the distance or the range to the target. So the strength the changes in its strength and time it has taken these 2 parameters will help us to make a make an image through a complex number.

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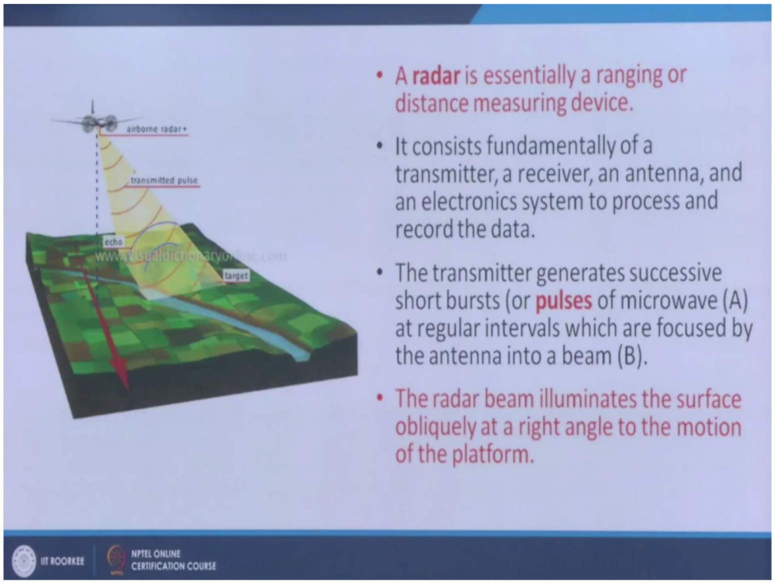

So here this is shown through an aircraft that airborne radar system also exists that a pulse is sent towards the earth and then back scattered which is shown in this view graph as a or in short we say eco also and that is recorded. So this is transmitted, this is back scattered and likewise the aircraft or satellite keeps forward moving having movement. So radar is essentially ranging or distance measuring device, it consists fundamentally of a transmitter.

It has to have its own illumination source, a receiver and antenna and electronic system to process and record the data and this transmitter generates successive short pulse or pulses of microwave as soon at a regular intervals which are focused by antenna and into the beam and this radar beam illuminates the surface. Illuminate means the pulse is there and then oblique and this is not Nadir viewing, so far the passive remote sensing is always Nadir viewing.

In most of the cases except in generating stereo pairs but this is, it is oblique because if satellite moving like forward then it sense a pulse and when the back scatter comes back by that time the satellite is there and to collect that back scatter otherwise a if it is Nadir then it will move off and it will not be able to collect it unless we are having a very huge antenna which is not possible in a space bond platforms.

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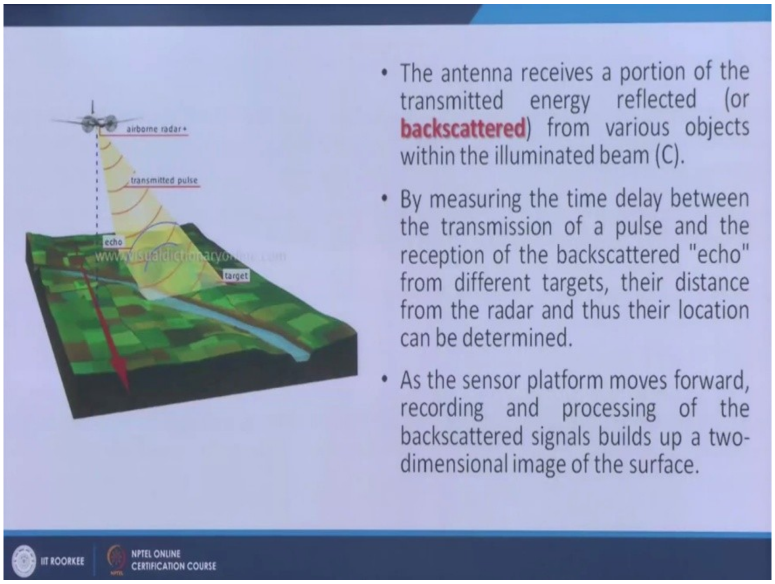

So the antenna receives a portion of transmitted energy reflected or back scattered from various objects within the illuminated beam and they say then by measuring the timely between the transmission of the pulse and the reception of the back scattered are also called eco from different target their distance is from the radar and thus their location can be determined. And as sensor platform moves forward recoding and processing of back scattered signals build up a 2 dimensional image of a complex numbers of that part of the area or that part of.

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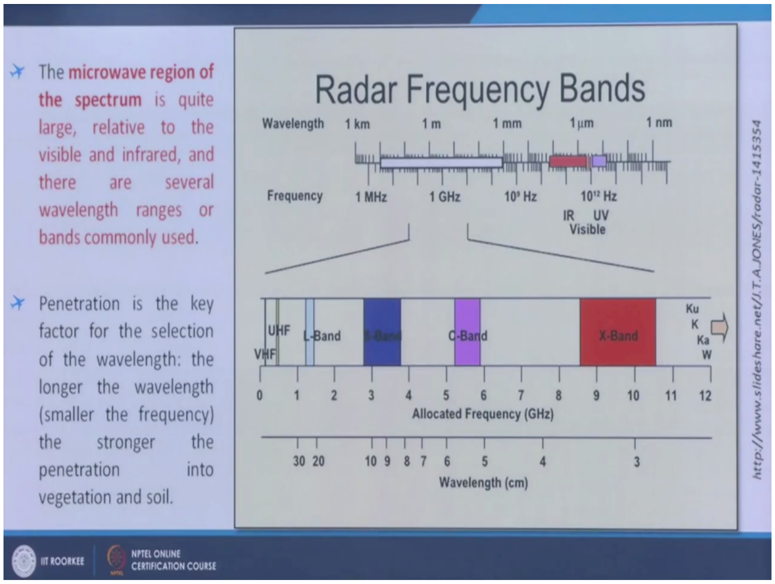

As a there are different radar frequency bands which are which have been used like L band which is located here, then you are having S band, then C band and X band, so C band and X band have become very popular but there are different satellites are having different bands which we will see, which are still operational then you are having KUKK and W bands are there, the most popular one are the C and X bands.

So microwave region of spectrum is quite large as you can see from 1 centimetre to you know 1 metre and in that way in quite large to visible and infrared there are several wavelengths range or bands commonly used in this and this the the basic advantage, the major advantage is the penetration, so penetration is the key factor for selecting the wavelength which band, C band or X band, depending on our requirements accordingly the sensors are designed the longer the wavelength.

If we go in this example right way the smaller the frequency is going to be the stronger the penetration into vegetation and soil especially dry vegetation. Soil and sand and I gave the example of discovering the lost course of Saraswati River over dry sand. If it is having water then dry electric constant are different than energy is observed and then detection, the penetration does not become possible.

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

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So different satellite like airborne AESR or this Alos Palsar which is still operational, Alos Palsar too is working it is n L band, so it is on relatively in a lesser wavelength and then like a sea band as I mentioned is very popular and the first two radar remote sensing satellite was radar sat then ERS, Envisat these were the European satellite which has the ASAR sensor then Risat is our own Indian remote sensing satellite, radar remote sensing satellite and Sentinal, these are still working in sea band, these are still working.

Alos 2 is also working and then X band in the TERRA which is also being used and then some, some bands are purely reserved for army or military purposes like KKU bands and other things, so mainly L band because of Alos Palsar or C band or X bands, these are the very common bands of radar remote sensing which are being used here.

Now these values are important because when we go for SAT interferometry we see that what is the the the wavelength in a particular band because this wavelength we divide by 2 in order to measure the deformation which has taken place, so one has to remember that what wavelength is Indian bands are having against a satellite. So like sentinel if I am using sentinel data in interferogram if I have to estimate the ground deformation then I will divide this value. Basically it is not exactly 5 in case of this Envisat or in Sentinel it was 5.6 centimetre, so where it is located that value, exact value has to be used and then divided by 2 and count a 1 width of a fringe.

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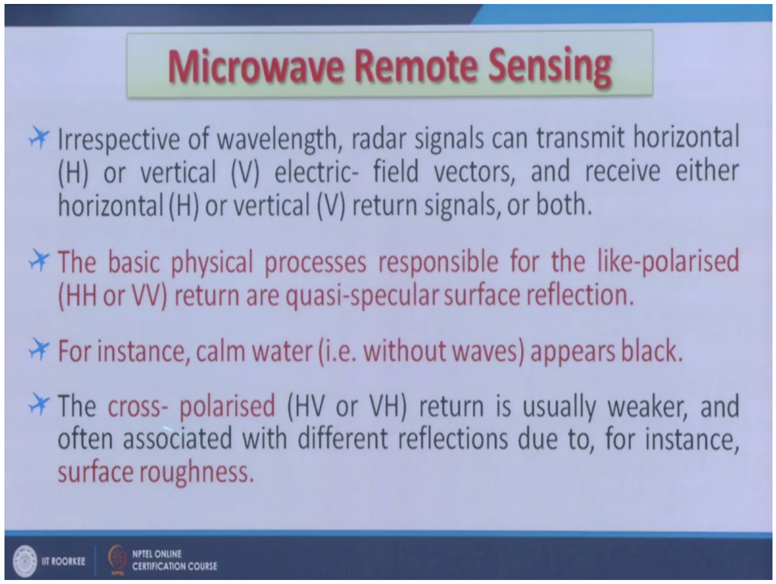

So microwave remote sensing in this respective of wavelength radar signals can transmit horizontal or vertical electric field vectors and they receive either horizontal or vertical return view, so there can be different combinations in it. There are certain advantages uh and the basic physical processes responsible for like polarise HH or VV return are quasi-specular surface reflection and for example like calm water that is without any wave or disturbances will appear black in such situations and we can also as a cross polarise also possible return is usually but this kind of back scatter is very poor, so in certain applications one can think in that but generally cross polarisations are not used.

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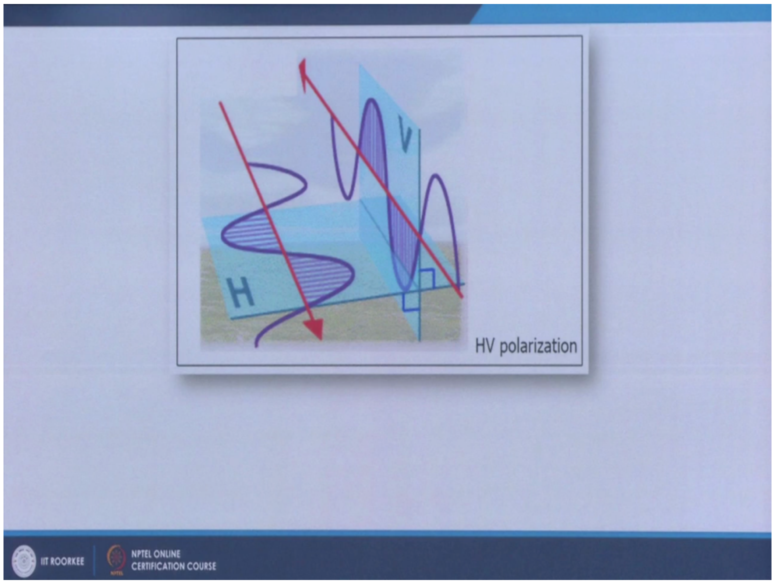

4 combinations, one is horizontal HH, another one is VV or we can have in combination that we can have HV or VH for vertical that like is when we say HS means the transmission and receiving both are in the same and like in horizontal transmit, horizontal receive vertical transmit, vertical receive horizontal transmit vertical receive or in reverse is also possible. So depending on the requirements and design of sensors these are decided and once they are decided for a particular sensor it is fixed throughout the life of that sensor.

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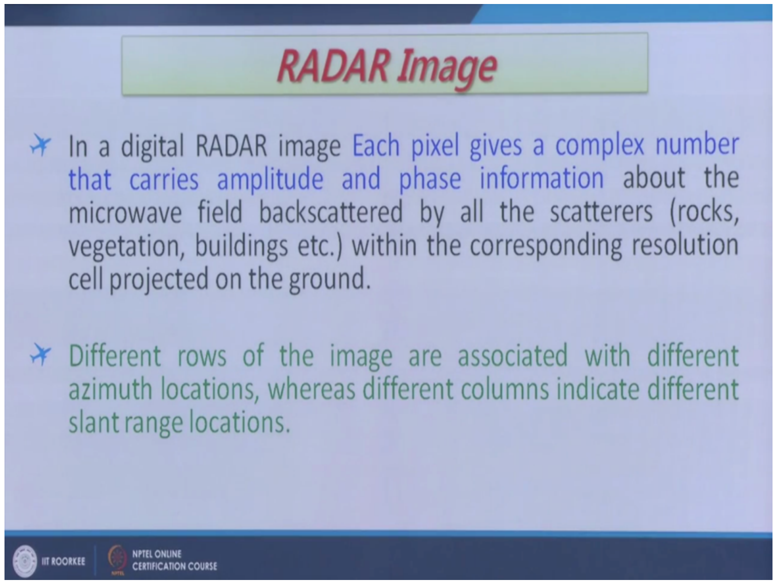

So radar as a but how that image is created, that as I have mentioned that each pixel give a complex number, it is not a simple image like we have seen in passive remote sensing that you are having a pixel and it is having a digital number which might be reflection value or might be emitted value. It is not like that here, radar image each pixel is a complex number and which (comple) that complex number contains 2 major information, one is amplitude another one is phase information and about the microwave field scattered by the scatters like caterers like rocks, vegetation, building, etc.

So different objects will scatter differently, so doing the corresponding resolutions and projected on the ground, so this this is very important to note that in normal passive remote sensing the pixel value is indicate a just having one value but here is a complex number having a amplitude information as well as phase information. So different rows of image are associated with different azimuth locations because for every role the azimuth location is hanging because satellite is also moving and whereas different columns indicate different slant range location, we will see through a diagram.

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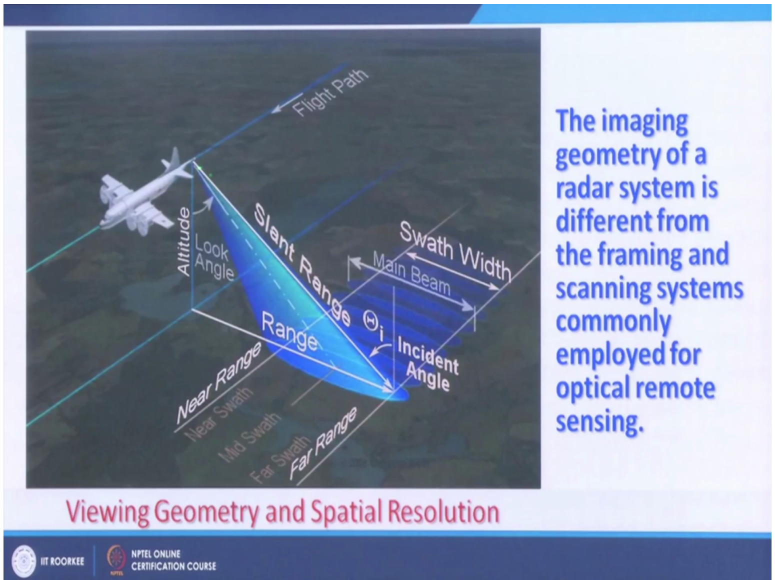

That this is what the slant range is called if flight path is like this, this is the slant range oblique view is there, this is the height that is altitude and this is the range projected on a horizontal plain. So this is the band or the main width or the swath we call, so only this much strip of the part of the earth will be covered and there the furthest part is called far swath, the nearest is called the near range or near swath or middle swath and then this is the incident angle because it is a complex number, so all these things are very very important here.

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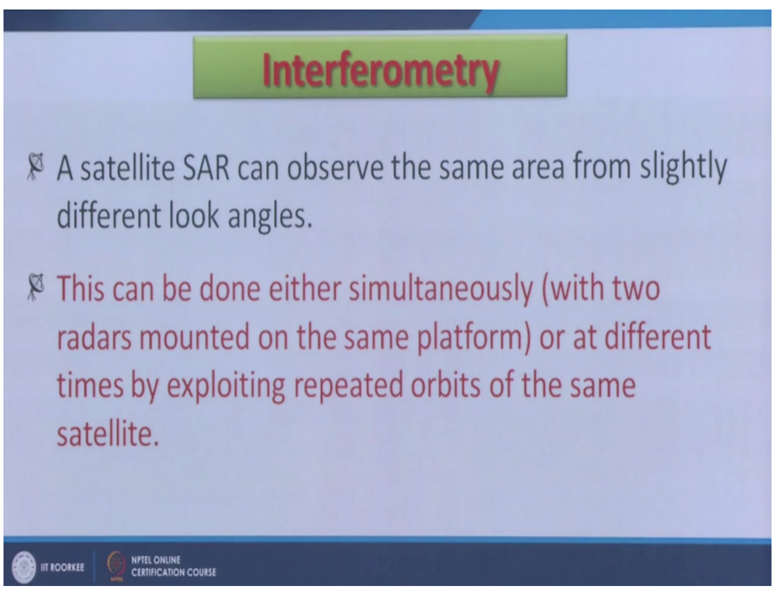

Now interferometry, interferometry requires that the same area should have been looked at least twice maybe from different angle or maybe from the same angle but there might be in between changes on the ground, so if this happens then we can measure or estimate the ground deformation which has taken or changes on the ground has taken place within those 2 dates when the 2 data sats have been acquired.

So in this one, that is the synthetic aperture radar the satellites SAR can observe the same area from slightly different look angles, it is very difficult in a space bond remote sensing that you can visit or revisit the same area with same look angle. There might be some changes, does not matter these things can be processed and still deformation estimation or change estimations can be done very accurately.

So this can either be done simultaneously, this is also possible, this was done in case of this SRTM, Settle Radar Topographic Mission instead of revisiting the same site a mass long pool was put on the, on the spacecraft itself and it was taking the, it was looking the same area or making a radar image from 2 different angles and that data was used to create a digital elevation model.

So that is also possible but that was an mission only it lasted for about 20 days, it covered almost entire globe and purpose was solved but having such a long mass is not possible all the time on the spacecraft, so different (ti) or different times, rather than simultaneously at one time with 2 different angles or at different times by exploiting repetitive orbits of the same that is for the change detection.

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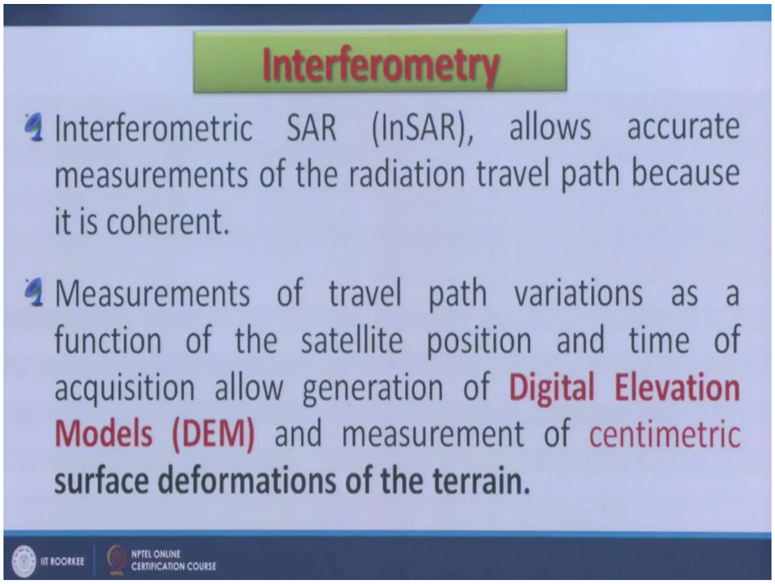

So interferometry SAR or in short as I have mentioned we also is known now as a in SAR allows accurate measurement of radiation travel path because of its coherence. Coherence is very much required for this, this kind of change detection using radar remote sensing especially in SAR. The measurements of travel path variations as a function of satellite position and time of acquisition allow generation of digital elevation model like in Settle Radar Topographic mission but otherwise also digital elevation model at very high resolution can also be generated and measurement of centimetric surface deformations of the earth. This is very very important of a millimetre accuracy deformations of the earth can be measured we will see some examples as well.

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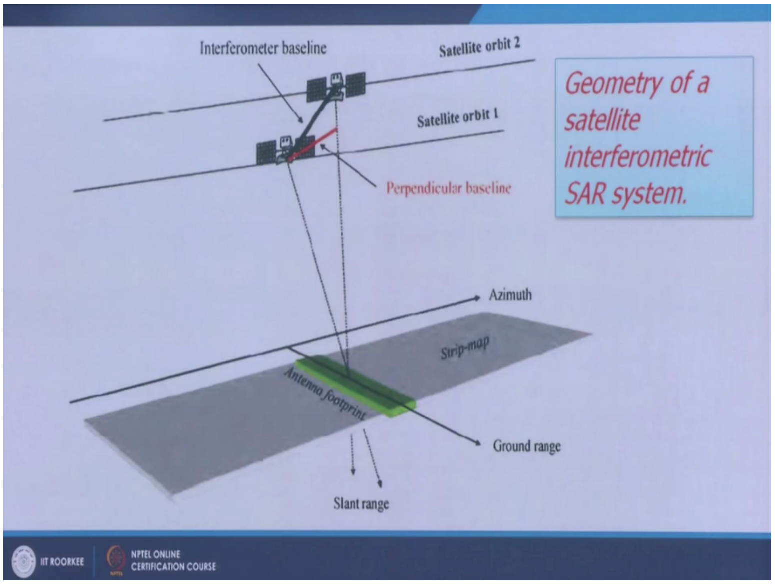

How it is done basically suppose there is orbit one the satellite next time it is orbiting may not be from exactly from same location, in both these overpass it has covered an area, this much area and this is the strip. Now using this data and if they this is the perpendicular base line and this is very important, if this perpendicular base line is very less that means the both during the both visits the satellite was almost in the same location then we can achieve better coherence and whatever the deformations which has taken place on ground maybe induced by an earthquake or maybe flooding, landslide subsidence any other such regions can be measured or very accurately. So this is that is why this perpendicular base line is very very important and this is how in 2 visits of the same satellite can allow us to create interferograms.

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The distance between two satellites as mentioned here or orbits in the plain perpendicular the orbit is called the interferometric base line and its cross backs in perpendicular to this is interferometric base line in black and red one is the perpendicular base line. Perpendicular base line becomes very important for any deformation studies.

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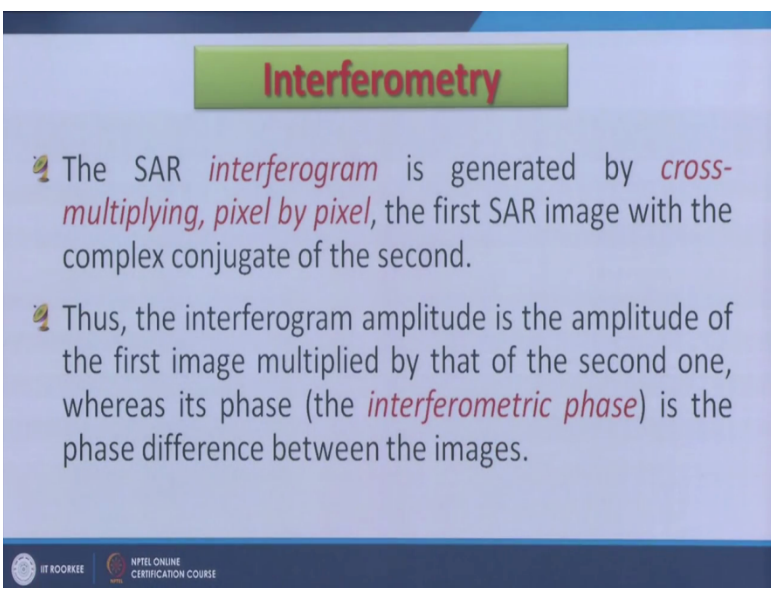

And this SAR interferograms is generated by cross multiplying pixel by pixel the first SAR image with the complex conjugate of the 2nd and the again here the phase difference because a this complex number or if this, if I say very in a normal term the pixel of a radar image there is getting 2 values, 1 is amplitude another one is your phase, so I can I can use either one, so if I use the phase of image 1 and image 2 then the phase difference can give me the deformation information, so this is how it is achieved. Thus the interferogram amplitude is the amplitude of the first image multiply by that of the second one whereas it phase the interferometric phase is the phase difference between the images.

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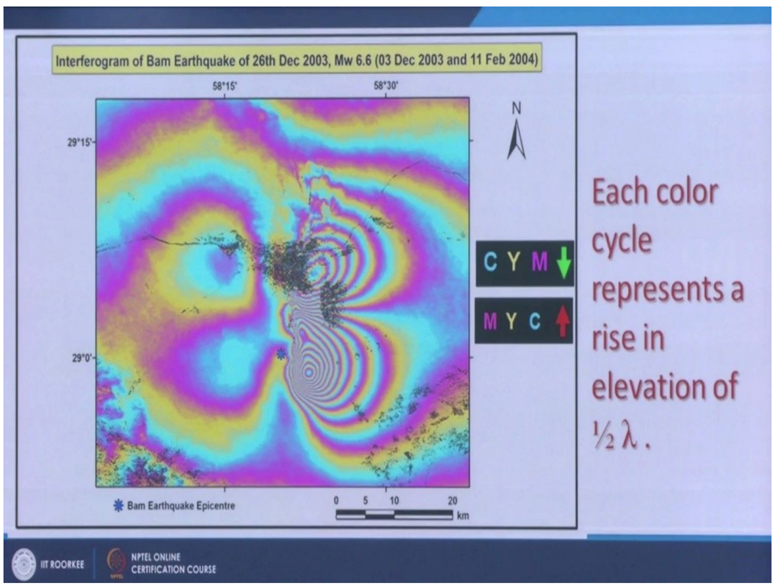

The example here in which this is Envisat data and of your sea band and the wavelength was 5.6 metre and here sorry 5.6 centimetre and here 2 images having baseline difference of only point 6 metre, very ideal were acquired and of 3rd December 2003 and 11th February 2004 and in between an earthquake on 26th December 2003 of magnitude 6.6 which is known as Bam earthquake of Iran occurred.

Now using this 2 SAR images interferograms were generated and all these fringes are telling that how much deformation and where deformation is taking place. Now this color pattern, these have to be interpreted but there are automatic wave also, so like if I get from, if I from the centre I have to see the colors, if I see that cyan magenta, cyan yellow magenta this kind of scheme I have found then I say that this is probably the subsidence which has occurred here, so like in this example if I start from centre to away where I am having less concentration of in fringes then cyan yellow magenta so that means this area must have gone subsided.

Whereas (megen) like if I start here magenta yellow cyan, magenta yellow cyan that means this area must have visit and half the wavelength, so 5.6 centimetre was the wavelength of Envisat SAR sensor, so half the wavelength is counted, so if I count number of these fringes multiply by 2.6 or 2.8 half the wavelength that is 5.6 divided by 2, 2.8 then I get exact deformation and this can also be done using some software's so deformation maps was also generated in that case.

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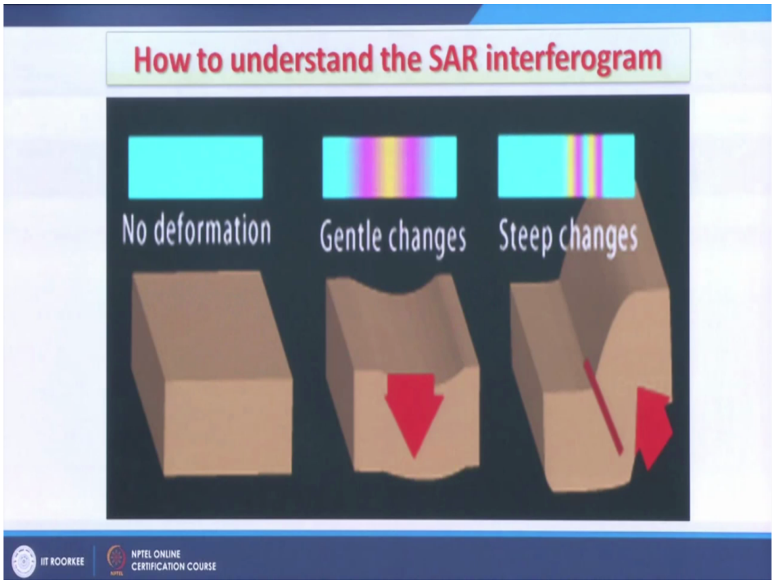

Now wherever, wherever the (fing) if no changes has occurred then it will show no fringes will be observed but if the ground has got deformations then fringes will have a far distances and wherever the more concentration or steep changes have occurred on the ground then we will see very close fringes like in 3 examples, no changes, no deformation, some deformation and very sharp deformation and they are also demonstrated through these models.

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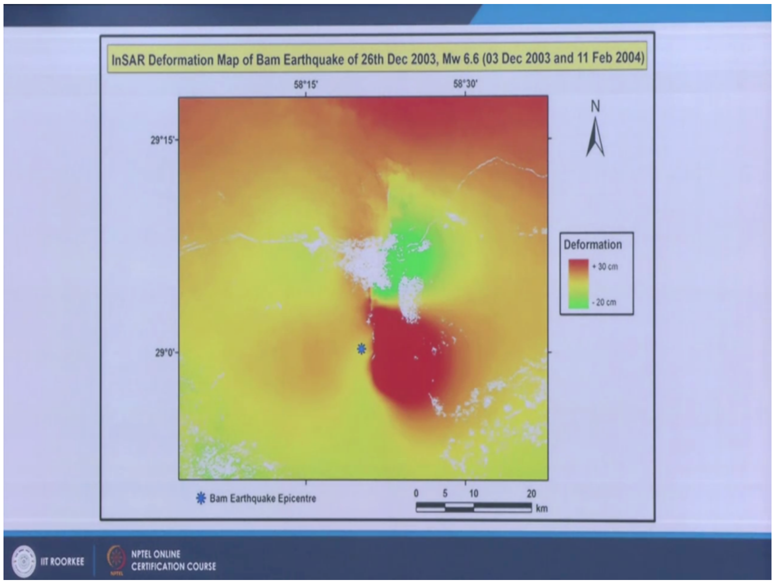

So this this interferogram was later as I mentioned was converted through the (int) you know computer based interpretation in a form of deformation map and as you can see that this area subsided by 20 centimetre and this area got uplifted because of that earthquake by 30 centimetre. So this is, these are the plus values in terms of before earthquake and after earthquake, so after earthquake this area got uplifted by 30 centimetre and this green area got subsided by 20 centimetre.

So this is very unique powerful technique that is the in SAR technique to exploit or to measure a such deformations which otherwise are impossible to measure and as you know I have been saying in this course of remote sensing that remote sensing not only provides the synoptic view, not only provides the digital data but is a completely unbiased recording and these satellites are orbiting continuously acquiring the data if an such even occurs I get just we have to get the pre earthquake data as close as possible and post-earthquake data.

And once these data is there coherence is available then things can be why the less coherence was available in these white patches because, because of the these areas have the buildings or built up areas and that got completely wiped out because of that earthquake. So that is why there were less coherence otherwise no problem, the still this can be measured and all of a sudden these fringes stopped here, all of a sudden these fringes because there is a fault line was going something like this only, roughly north south in this and the epicentre was on the other side.

So the major deformations have taken place like this, some area has got subsided and there some area has got uplifted and this is remember this is in against the range or slant range so that means what we can conclude here that this area the distance because after all radar remote sensing is a ranging so from the between these 2 scenes and the baseline difference in this particular case was only point 6 metre so that means thus the this area has gone away, the green area has gone away by 20 centimetre from the satellite and this area has come close to 30 centimetre of the satellite.

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Similarly people have used the these things SAR interferometric technique for land subsidence due to ground water and this is the example of Kolkata city where in between 92 to 98 in roughly 6 yeas time about 5 to or about 6 millimetre per year subsidence have been observed in this part of the country. So subsidence or ground deformations might be earthquake, landslide, ground water, mining all these now is possible to measure.

Another very important thing is earlier like Envisat data Radarsat data even Alos Palsar, these data becomes were very expensive but the Sentinel 1 data is free and it is providing interferometric data. Risat they say radar remote sensing but it does not have the capability of providing interferogram, interferometric data for interferogram but the Sentinel data is free, provides the data one can wherever one find problem being related to ground deformation induced by some factor then one can imply and estimate this thing,

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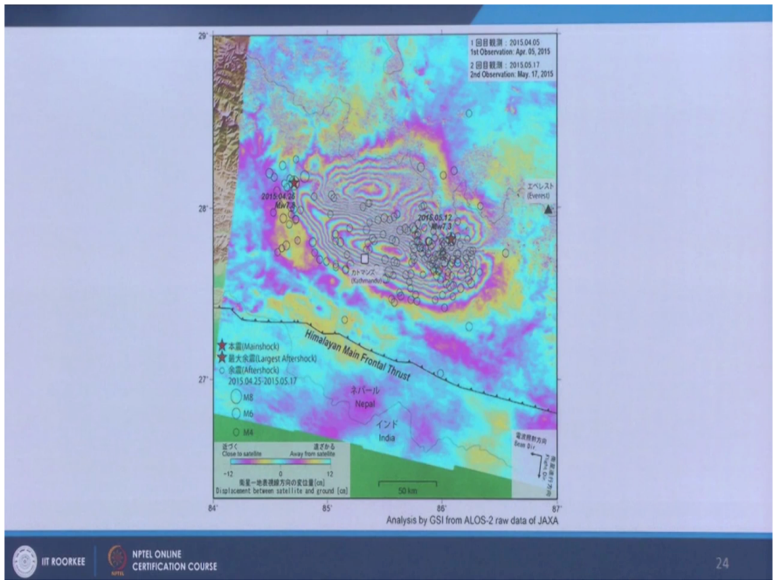

And the last one here is example of recently occurred major earthquake in Nepal, there were 2 successive earthquake and using Alos Palsar data this, this is how the fringes were generated and the subsidence, the upliftment of about 1 metre in Kathmandu valley was induced by that that particular earthquake of 25th April 2015 of magnitude 7.8, so this has become very very popular technique of remote sensing where very accurately deformations can be measured. So this brings to the end of this presentation, thank you very much.