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Digital Image Processing of Remote Sensing Data

Lecture – 17
SAR Interferometry (InSAR) Technique

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Hello everyone and welcome to 17th lecture of digital image processing of remote sensing data and this topic which we are going to cover in this lecture is SAR interferometry or InSAR technique as most of the time we have spend in this so far in this course on optical remote sensing now we would like spend some time basic things we have already discussed on radar remote sensing or microwave remote sensing but SAR interferometry new technique so it is very important to discuss here and it has got good applications few applications I will be showing at the end of today's topic.

So this is SAR interferometry basically synthetic aperture radar interferometry and as you know that the there are two major types of remote sensing one is active remote sensing and passive remote sensing, so passive remote optical remote sensing thermal infrared another they fall in passive remote sensing technique where as microwave remote sensing is active remote sensing also radar remote sensing.

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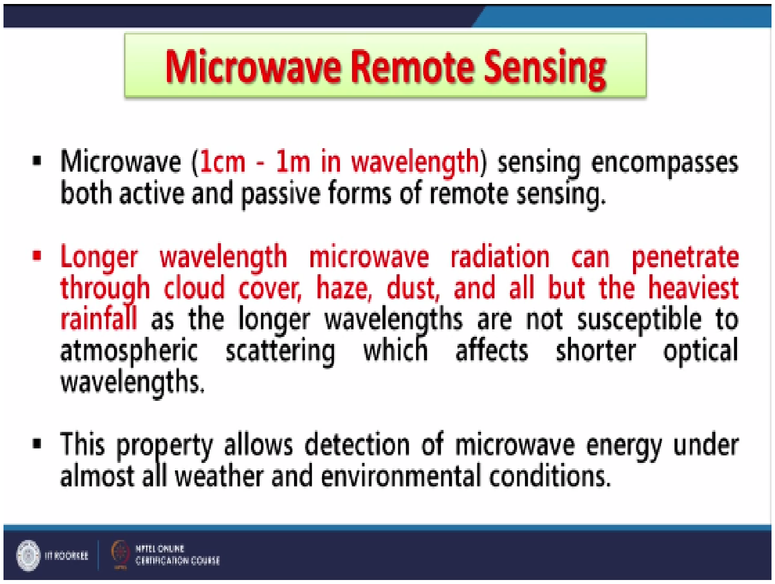

So microwave we say we are taking about one center to 1m in wave length, so very large wavelength compare to bussing bill or infrared or thermal infrared which in composes both active and passive forms of remote sensing, so not only microwave is active but there are positions of microwave where passive microwave is also possible because in some natural objects also emits might energy in microwave part of EM spectrum but that part we are not going to discuss so we will discuss mainly active microwave as though as you know that the longer wave length microwave radiation can penetrate through cloud cover.

Haze, dust mad all but the heaviest rainfall, because a if natural objects are particles which are smaller in size and are in present in a space but longer wave lengths microwave radiation it is for it for this kind of radiation it is easy to penetrate even microwave can penetrate through dry soil up to few meters and based on this old courses Saraswati river in parts of Haryana and some parts of Punjab been discovered in passed just please microwave remote sensing.

So longer wave length are not suitable to atmospheric scattering which affects shorter optical wavelength so in shorter in optical wave lengths in the visible infrared near infrared there are lot of problems and therefore we have got limited atmospheric windows but since longer wave length so question of atmospheric window does not come here and this propriety allows decoction of microwave energy under almost all weather and environmental conditions so this is another advantage with active microwave remote sensing that in all most in all weather condition whether is this rainy or cloudy and day or night data can acquired and as mentioning earlier that active microwave remotes sensing.

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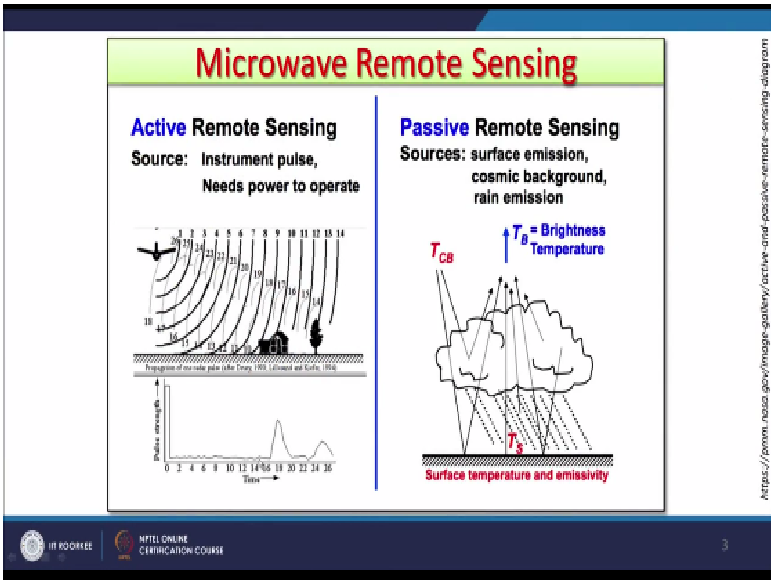

Where the signal is sent by the sensor itself and the back scattering comes it is collected by the receiver and then images are formed and where as we en can see also that the pulse is sent and then return whatever is the left or back scatter which is also received so likewise line by line pixel by pixel images formed but the image which we see in optical or near infrared thermal infrared the construction of those images is entirely different then in microwave.

In passive remote sensing or passive microwave what we see that whatever the emission which is coming from the surface is recorded by the sensor.

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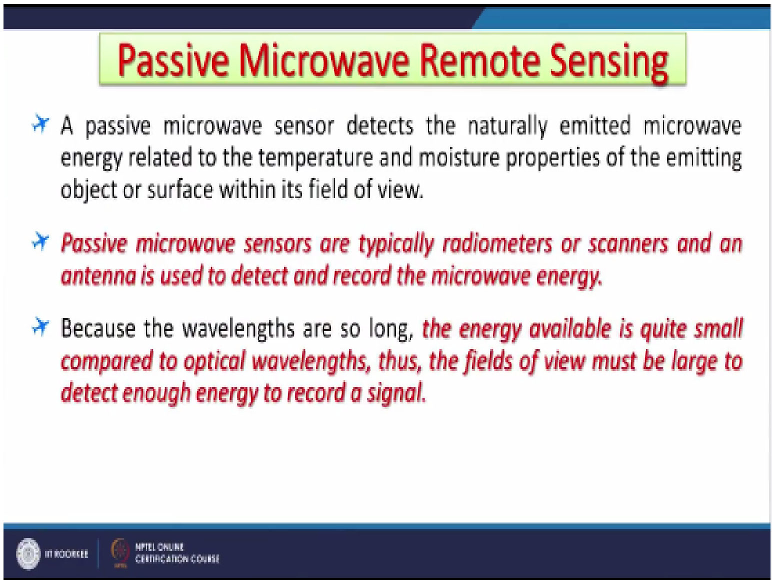

We will spend much time here now we come to the passive microwave sensor and it has naturally emitted microwave energy there used to be satellite or sensor same SMMI or SMMR which were capable of recording microwave radiation in passive mode and the advantage of such thing can that they can be used to estimate the snow deft and other thing which is otherwise impossible with any other remote sensing technique so passive microwave senor deducts naturally emitted microwave energy related to that temperature and moisture properties of emitting object or surface within it is field of view.

The high passive microwave sensors are typically radiometers or scanners and an antenna is used to detect and record microwave energy, and because of the wavelengths are so long very large wavelength the energy available is quite a small compared to optical wavelength and thus field of you must be large ducted energy to record a signal and this creates a problem of course so these seniors had very course resolution even 30km by 30km you had a pixel so 30 km resolution we are talking but the information which one could extract from these was very important like snow depth and snow cover information is possible with optical remote sensing but snow depth information is not possible any they expect with passive microwave sensors.

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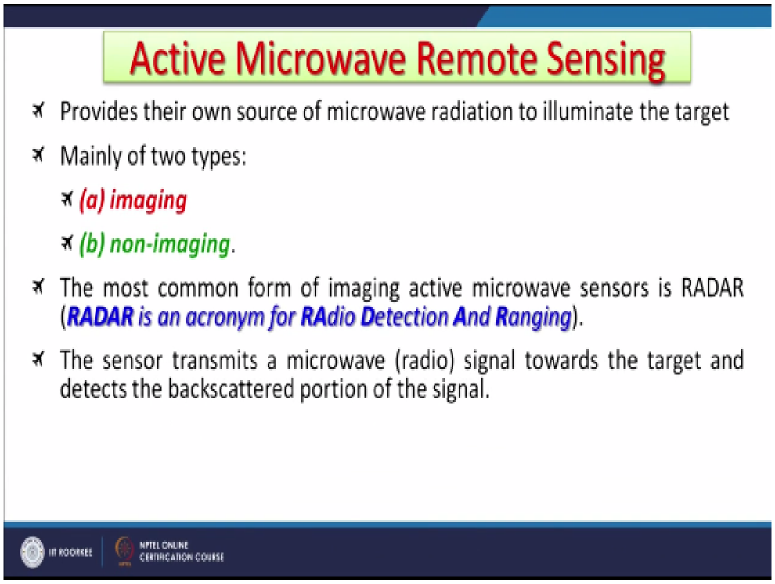

So provide this active microwave remote sensing provides their own source of microwave radiation to eliminate the target and this is what now a day's very popular mainly of two types again one is imaging and another one is non imaging and the most conman form of imaging active microwave sensors is RADAR which is RADAR is in abbreviation which extends Radio Detection and Ranging and as you can see a ranging it is majors the time taken by the signals to receive by the sensors and based on that it calculates many things.

So the sensors transmits a microwave or radio signal towards the target and detects the backscattered portion of the signal and the strength of the backscattered signal is measured to discriminate between different targets and the time delay between the transmitted and reflected signals determines the distance or range to the target.

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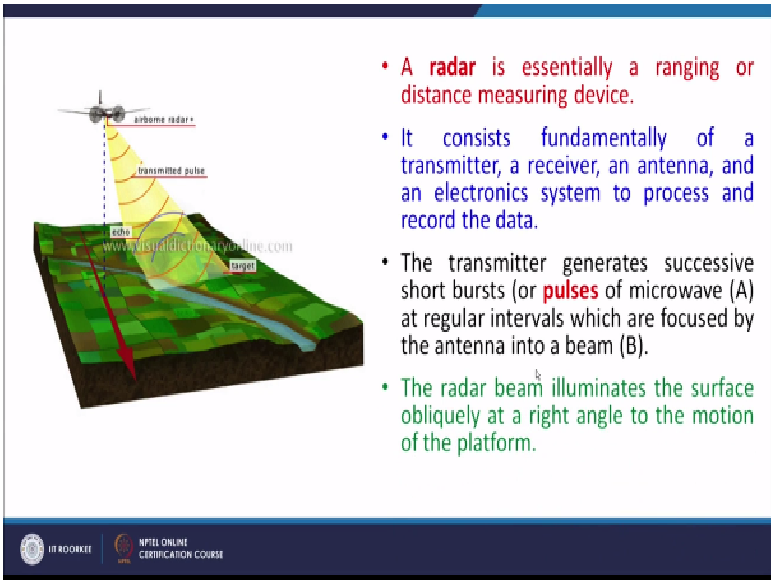

So this is how it creates the image here in this one we can see that the here though which is a hear bone sensor bud does not matter the same thing happens in case of satellite that they did and the signals are transmitted and then in the blue curves you have seeing the back is scattered which is going back and this is how different targets so different objects on surface of the behave differently in microwave region.

And there will be recorded differently so this is how the images are formed so RADAR is essentially a ranging or distance measuring device i9s consists fundamentally of a transmitter a receiver and antennas and an electronic system to process and record the data here I am just mentioned that radar is an ending or in ranging or distance measuring device and here we can take the advantage in later one where we measure the changes in the distance and through the inter technique so that is exploited later.

The transmitter generates successive short bursts or pulses of microwave like a here and at regular intervals which are focused by the antennas into a beam and the radar beam illuminates the surface oblique at a right angle to the motion of the platform.

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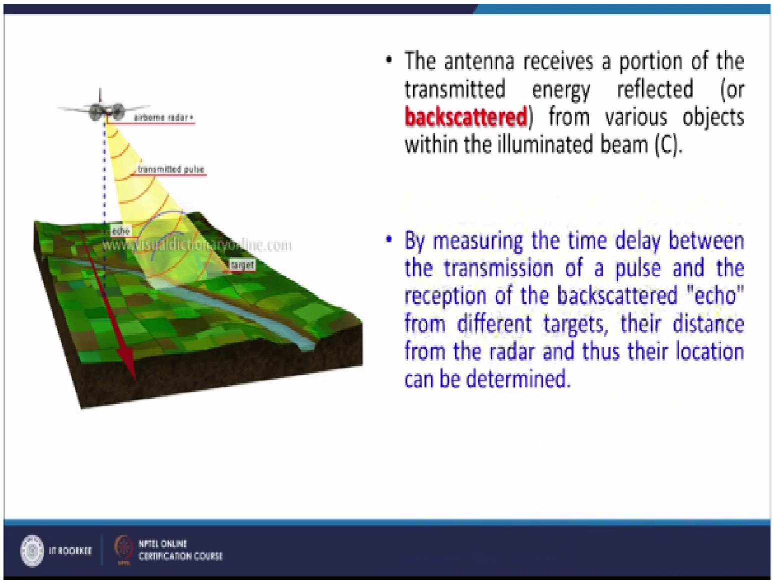

and the antennas receives a portion of a transmitting energy reflected or backscattered from various objects within the illuminated beam by measuring the time delay between the transmission of a pulse and the reception of the backscattered or echo from the different targets their distance from the radar and thus location can be determined.

And this is something like a back when it is sends the signals and ultra sonic signals and then backscattered so by which it can estimate the distance of even if of flying object so this is almost the same concept here is our satellites are also moving in the orbits or a graphs so it is the same concept said that it is an microwave region.

As the sensor platform moves forward recording and the processing of the backscattered signals builds up a two dimensional image of the surface.

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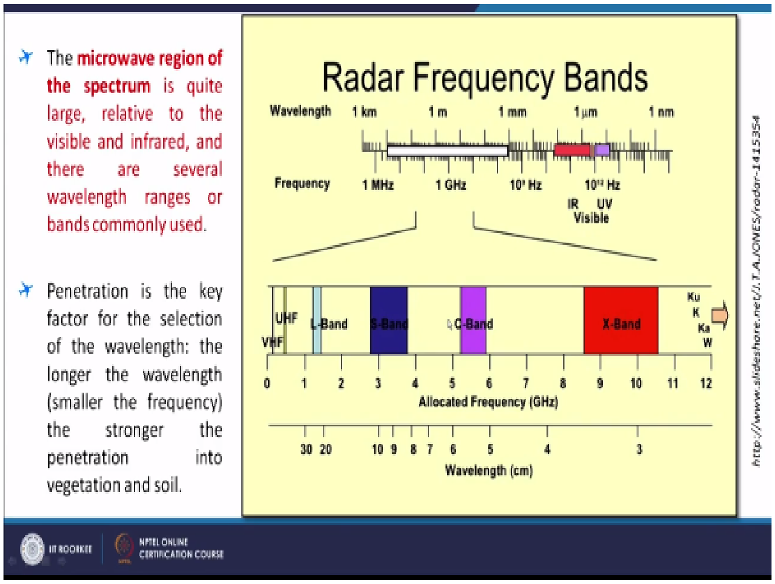

This is the different bends of frequency bends which are bold in microwave and as you can see that there is an X band there is a C band S band L band and some other bands are here so the most popular one are X band and C band which belongs to part of microwave region so microwave region of a spectrum is quite large not like visible in infrared there you are having the very small part of the spectrum level.

But it is very large part related to as I mention and the penetration is the key factor for the selection of the wavelength so there are especially designed machines are there in a microwave so some people go for X band some people go for C band and C band is also very popular in few examples we will seeing about this one as well.

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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

So like a the first microwave length is fully operation satellite by ERS one and later which is ERS 2 and that was in the C band RISAT in the Indian one is also a C band satellite and the C band is also on the sentinel which is European satellite and providing data free of cost to a users so thus the biggest advantage with sentinel and the data is available for the C band that X band is also in TERRA SAR a COSMO-skymed there are K band which are Military domain not in civilian domain.

But this about five points X cm wavelength which is hither in radar sat and we said is are again very popular there are some other sensors on different bands of a microwave region but the most current and popular now is one sentinel which is used directly for that we will see little later.

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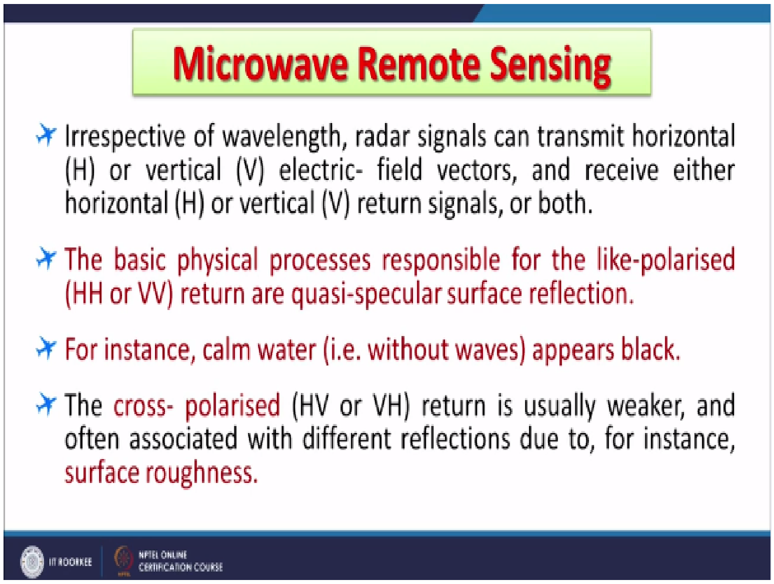

So irrespective of wavelength radar signals can transmit horizontal or vertical electric fields vectors and receive either horizontal or vertical this is another advantage that you can have both together and basic physical processes responsible for like polarized return are quasi-specular surface reflection and for instance calm water that is without waves appears black and the cross polarized that is HV or VH and that is horizontal vertical or vertical horizontal return is used weaker and often associated with different reflections due to instance4 surface roughness.

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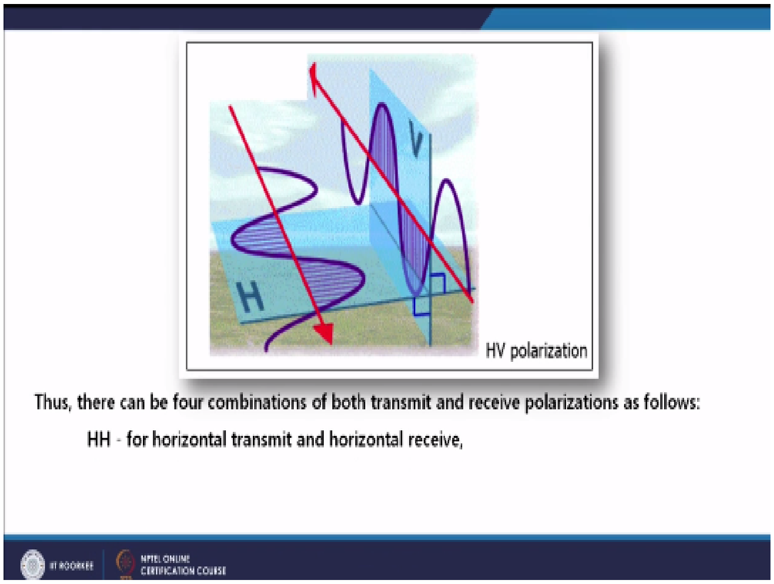

So for what kind of applications one is intending accordingly the polarized is chosen this is the example this is like a horizontal polarized this is the vertical polarized which we see or if we combined it that the signals are from the satellite or coming in horizontal polarized while in return beam is an the vertical polarized so overall which say HV polarization so thus there can be four combinations of both transmitter and recipolarised as follows that you are having horizontal, horizontal vertical, vertical horizontal vertical and vertical horizontal vertical, vertical horizontal, now radar image in s digital radar image each pixel gives a number.

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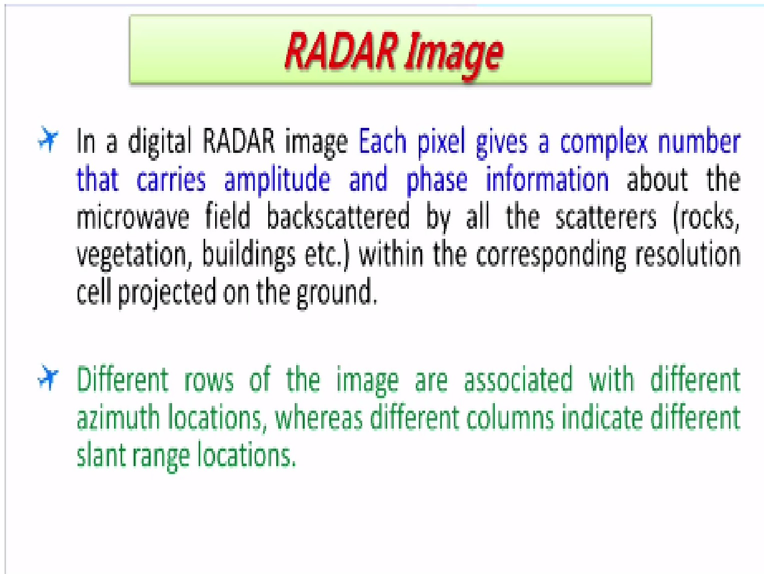

As I already mentioned it is not like optical remote sensing where the whole thing is very systematic and it is easy to understand but here they each pixel is made from a complex, a number that number carries two main important thing, one is the amplitude of wavelength and also the phase information and this phase delay, whenever the phase delay or when the satellites have sent the signals later on the objects is shifted or changed, there will be a delay or regional information or something.

That is exploited in far reiteration, this complex number carries two main important things, one is the amplitude one phase information about the microwave field scatter by all the scatters like rock, vegetation building etc and within the corresponding resolution is projected on the ground, so a depending like you can have a 30m resolution or maybe larger resolution is possible, but relatively very high resolution as compared to your visible is not possible yet.

So 30 m is the most common currently the special resolution is with the microwave remote sensing, so different rows of the image are associated with different azimuth locations, whereas different columns indicate different slant range locations, we will see what is slant range here. So suppose this is the flight path.

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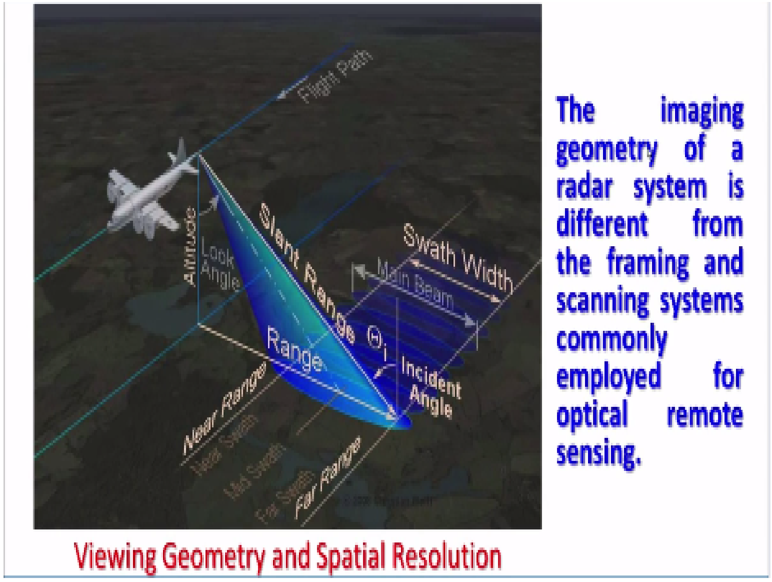

So this is the slant range, this is the range on the horizontal plane and this is the ultimatum, with this triangle this is the slant range and this is the incidental angel main been the coverage area, or swath width is that much, so we also say far range and near range, so the imaging geometry of a radar system is different from the framing and scanning systems commonly employed for optical remote sensing.

So here the image acquisition is very different and instead of having a simple pixel value you are having simple pixel value either having in reflection or emission but here it is complex number which is having amplitude and phase information both together. So the image here is completely different the data acquisition system is completely different and therefore the applications are also different.

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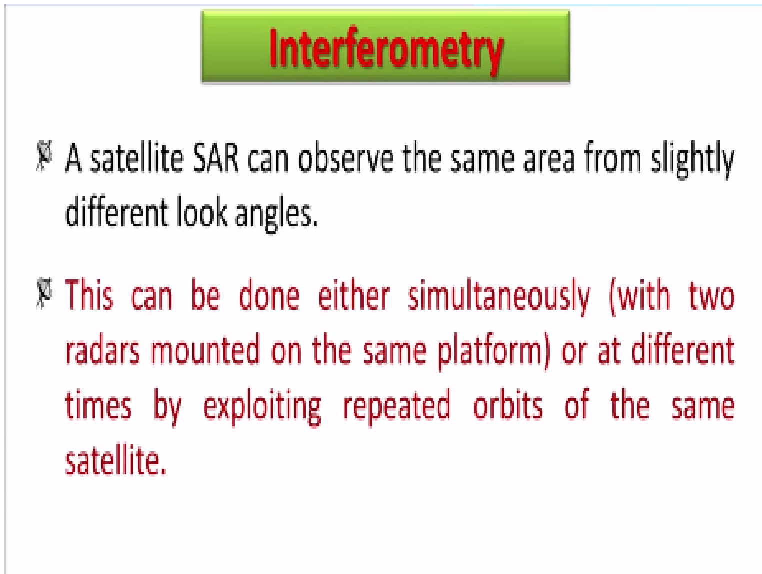

Now we come to the SAR geometry or interferometry which is satellite which is having the upper radar observed the same area from slightly different look angles and this can be the advantage yes, to create intro far gram, so this can be done either simultaneously, that is you are having, you are looking the same ground area with two different angels, at the same time when the satellite is flying and it has happen in case of SRTM.

Which was a special mission which stead about 18 days and has cover the 80% of the globe, except the polar region and have acquired the data of the entire globe and this was maintained on the same platforms, so they were transforming and collecting the data at the same time, but it is possible to collect later on, today there is overpass by the satellite and probably maybe after 35 days there might be a over pass by which you can get the data.

So the advantage becomes in-between these 35 day, some natural disaster events have occurred then you know that there will be some information and basically radar is arranging technique and therefore, there will be in changes in the distance between the satellite and land, so suppose there is an earthquake, now the land as subsided because of earthquake event, so the range will increase and that can be exploited to create a beautiful intro for grams which we will see the examples.

So it is possible to collect the data where two different radar mountained at the same time or may be different times with two different angles, so there is purpose here why we should have data with two different angles and the interferometrics are.

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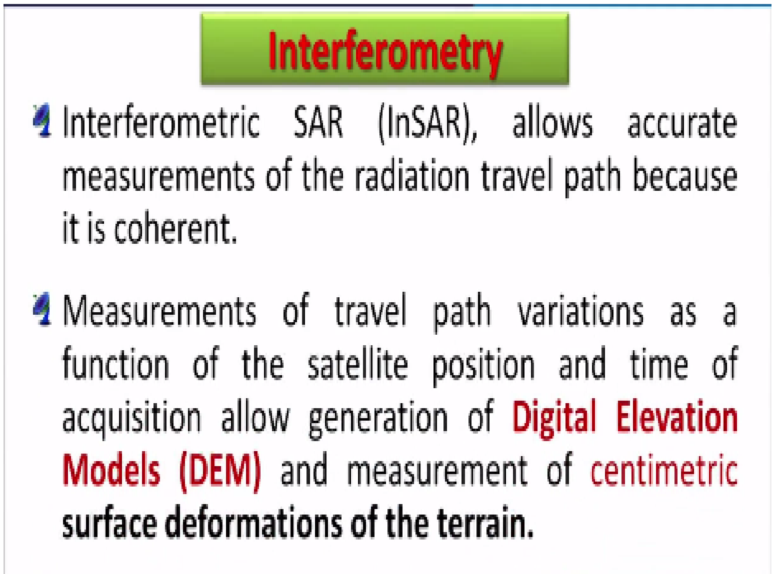

Also called as a InSar allows accurate measurements of the radiation travel path because it is coherent. The coherent is another condition required that means there should not be any seasonal change in so on and so forth. If the coherent image are there the pre post event then nice interforograms can be created, the measurement of travel path variations as s function of the satellite position and time of acquisition allow generation of digital elevation model DEM and measurements of centimetric surface deformations of the terrain.

This is the advantage, this is what done in the case of SRTM. So SRTM digital elevation were generated using simultaneously for two different look angels acquisition and create intro grams and through threw interforograms, digital elevation models were generated for 80 % of the globe. And the second one is the measurements of centimetric surface deformations of the terrain if there is some change on the ground that can also be estimated or measured and this is how the two time two different angels , the data is collected these two examples through this schematic is there.

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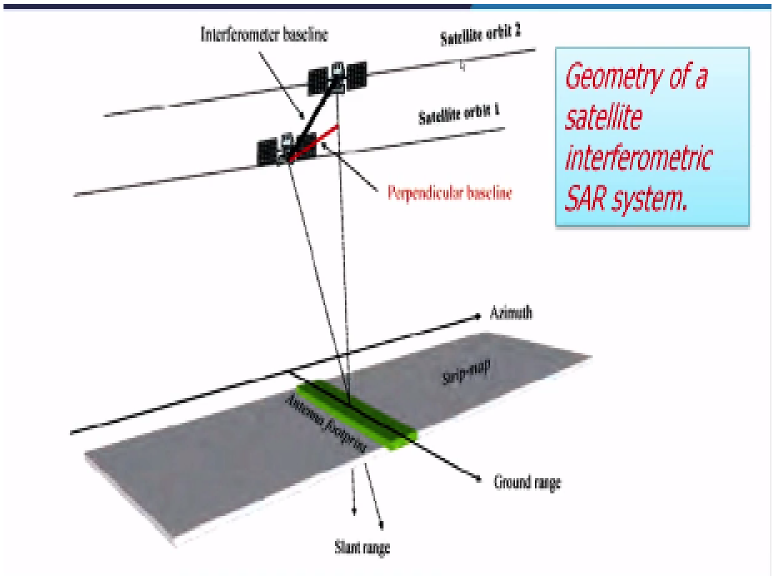

That this is the orbit one a1 after 35 days again the same area is covered by but by two different angels and this is the perpendicular based line, this is another very important factor that closer the orbits 1 and orbit 2 are, the smaller the perpendicular base line better the interferometry would been able to create because we could code and in these two images and likewise this is the data and is required.

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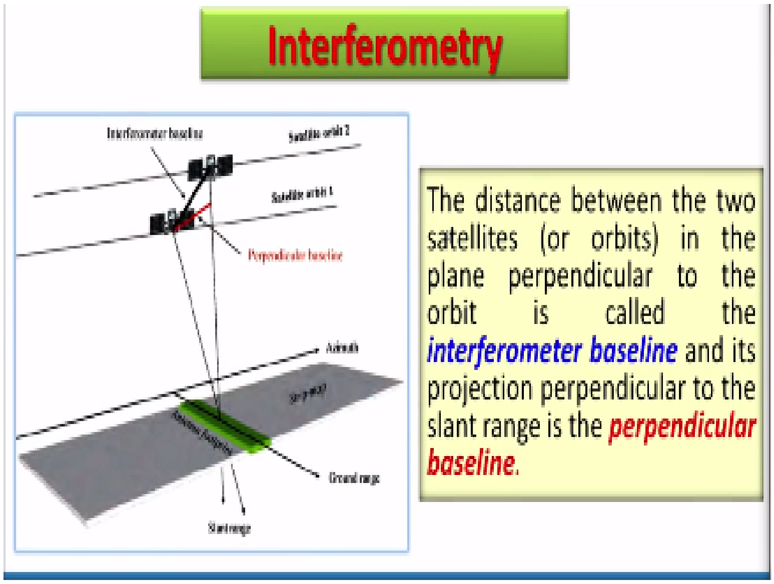

And the distance between the two satellite sheer or in plane perpendicular to the orbit is called interferometer baseline or and its projection perpendicular to this is the interference meter base line and this is the perpendicular and it is the perpendicular base line this is more important for interferometer now the asp programmed is generated by cross multiply.

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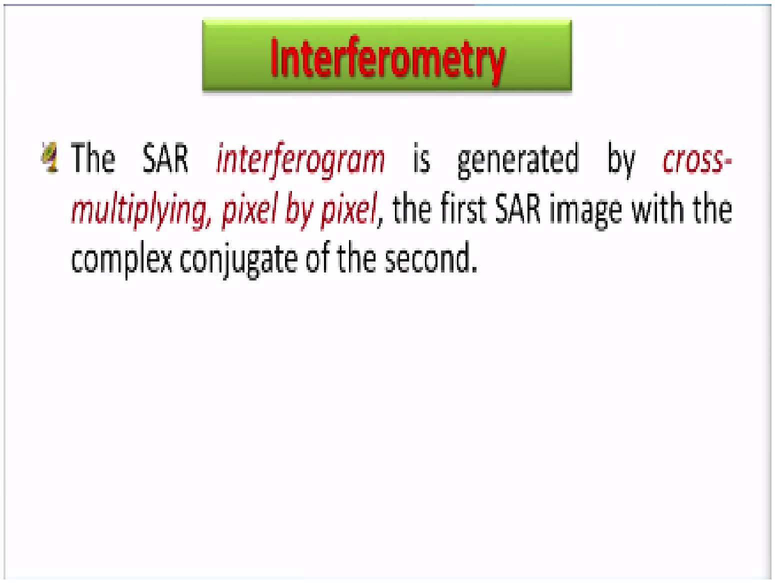

In the white pixel and remember pixel in case of microwave remotes sensing is a complex number and the first S A R image the complex conjugate of the second thus the interference programmers and the amplitude to the first image multiplied by the part of the second one where as the its feast interferometer face is the face difference between the images and this face difference is will give you the beautiful legends like this one example of earth quick.

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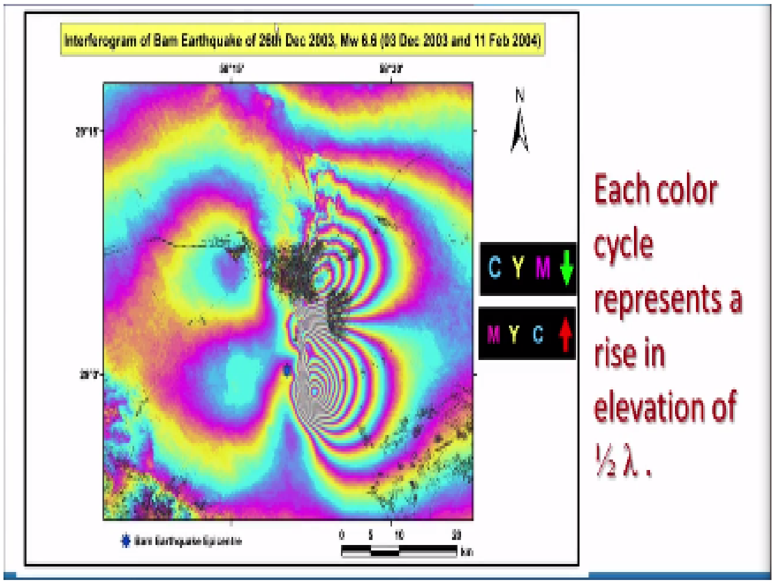

Which occurred on the December and in the 2003 of the heavily magnitude of 6.6 and these two images were involved to create this interferogram and the one was taken on the 3december 2003 just before the earth quick because the satellite was regular orbit no body do the earth quick is know going to come but it has quanta data and the normal condition and again after the 35 days again on the 11 February and the satellite orbit quit the same area and the base line different of this example was only 0.6n meter And the ideal and therefore the currency except for the area as which has some buildings and you will damage and which you are seeing in the back portions .

So this is basically nothing but the balm town ship was there and these wrenches which you are seen in the can give you the ides how much ground formation has changed not only that it can tell you that the weather ground as related to the satellite this has gone in the line of the site weather it has gone of the and come closer to the satellite.

So the both things can also be estimated and this example if we have to see this count these drenches and see this wrenches from the centre to going away their more concentration is their connotation as that is their centre and then we count the these wrenches and see the their change in color so if we start from this sand and that is in the casing the subsidence here where as the magenta start from the centre ageist so the magenta yellow and then might be up liftmen there are these two looks were similar if we see carefully .

They are having completely different and the colour pattern counting from and once we count the number of wrenches then and multiply by the half of the wave length then I multiply by in this case f the total wave length of the is 5.6 and the wave length becomes2.8 millimeter and the 2.8 centimeter and this way you multiply way the suppose there are ten wrenches you multiply by 2.8 centimeter you know that about 26 deformation as taken in place.

So likewise one can completely meter how much deformation as taken place and what kind of deformation weather there is subsidence are applied in the line of the site satellite this is important to remember this is know that the vertical one but this is olive detection so in the line of that side that can converted to the vertical one and this is that the vertical one which is we will see little later name contribution to the interferematic place is the possible ground information.

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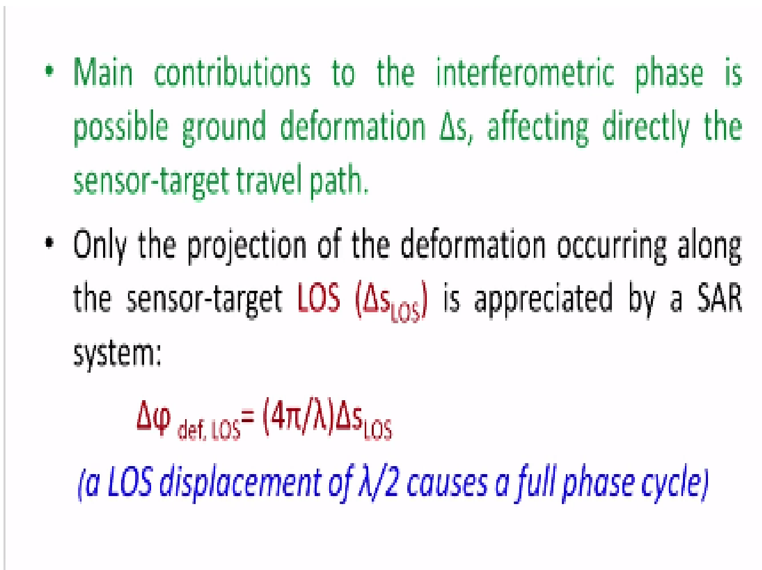

And the ΔS is affecting directly the sensor target and the travel path the only the projection is the deformation occurring along the sensor target that is the line of the side the ΔS (LOS) is appreciated by a SAR system .so this can be calculated using this equation and this the line of the side of the placement of wave length /2 half of the wave length causes a full phase cycle.

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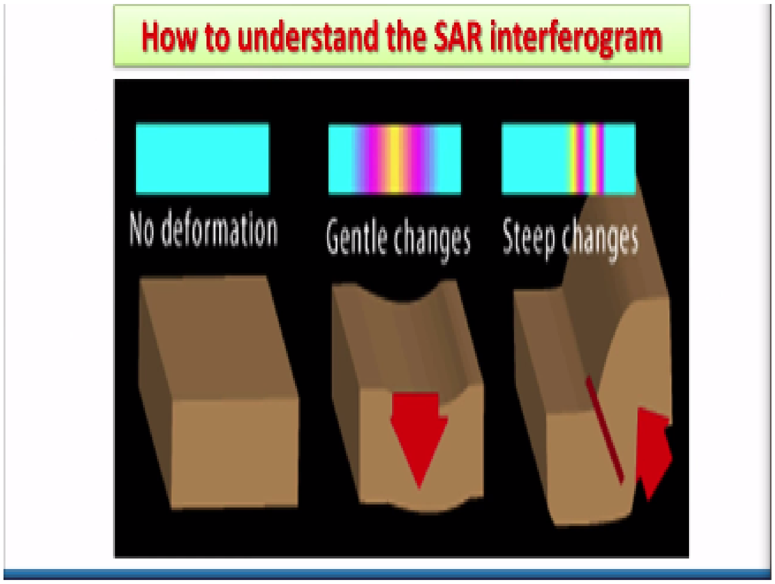

And this is what happens in the case of if dictate of the example of the grounded formation. If there is no deformation will not see any fringes between a two accusation looking on two different states. May be the difference generally in case of remote sensing of microwave satellite it is the orbit design like they are is a time difference. So these difference of 35 it is. Is there is a difference formation like gentle changes.

Then these fringes will not be closely space they will be wider space like so we can say the change is argental changes. Nut very fingers are very close then we says steep changes which we are seeing here.

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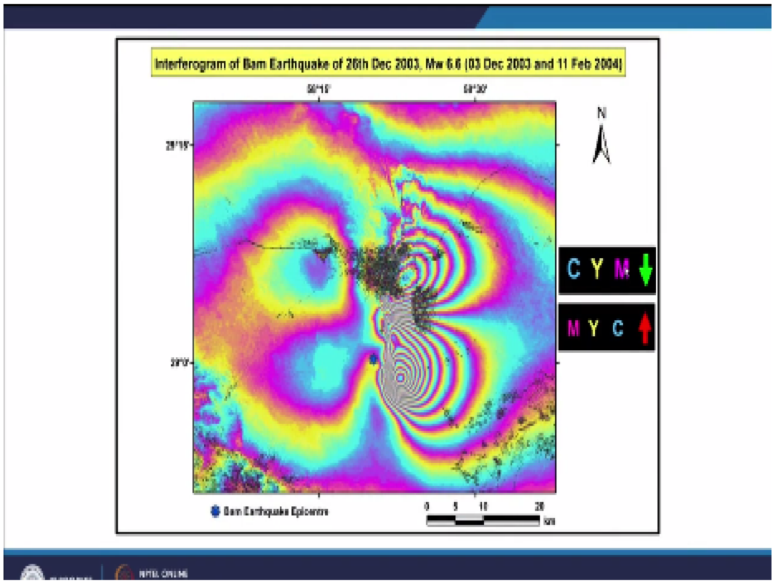

So if we go back again to the same image. Here the change is are very steep and compare to this are very gently here.

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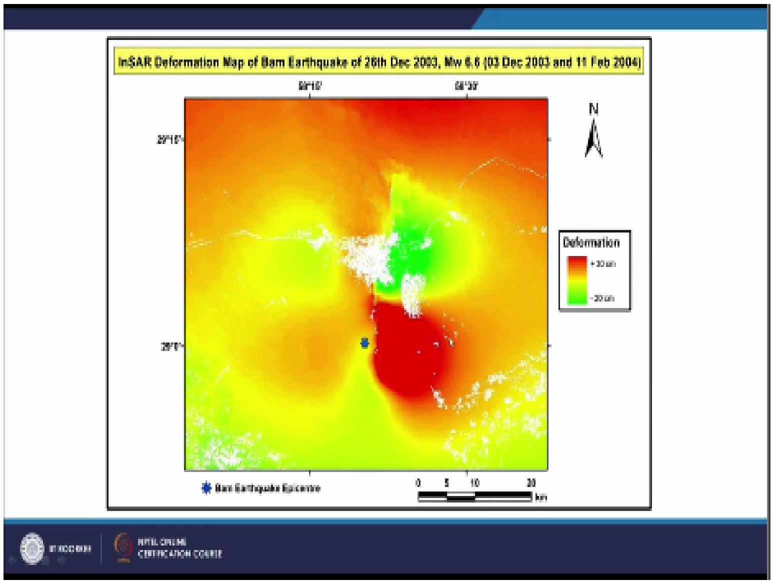

So this the deformation map and now it is the line of side, now this is in vertical component which we are talking. So there is up liftmen as I was mentioning here and this was the position of the epicenter so there is a up liftmen in this particular case was 30 cm in the – of the due to the earthquake and there where the subside in this part of 20 cm. so then you can say the half meter, the total half meter deformation on the area uptake place to that earthquake event.

So mentioning these deformation so accursedly really very nice technique which is now we you know do – this now being used in almost each and every earthquake which are occurring in different parts of the world. Because now data is a available then to it is freely available. Few more example is that means only note only earthquake in the deformations. One can employee but it deformation which are little slow or and which is like this the example. Because the over withdrawal of ground water and over Kolkata city.

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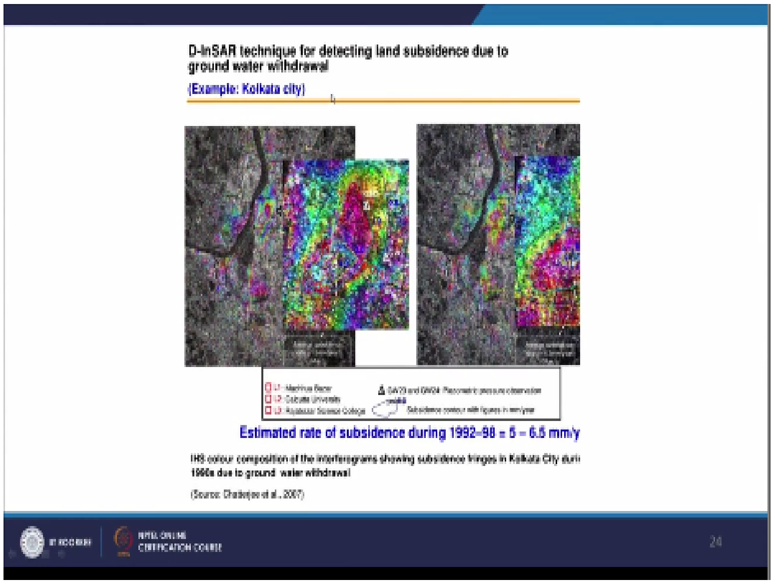

The subsistence is taking place that subsidence the example here the Kolkata city. And subsidence can also be measured. That how much subsidence is taken place. So if you are having a time difference of five year time difference satellite image is of microwave region. You can create an interfere program in see that what is happen in last five years for during the period. So in this one can estimate that how much ground deformations, Because of over withdrawal of ground water has taken place.

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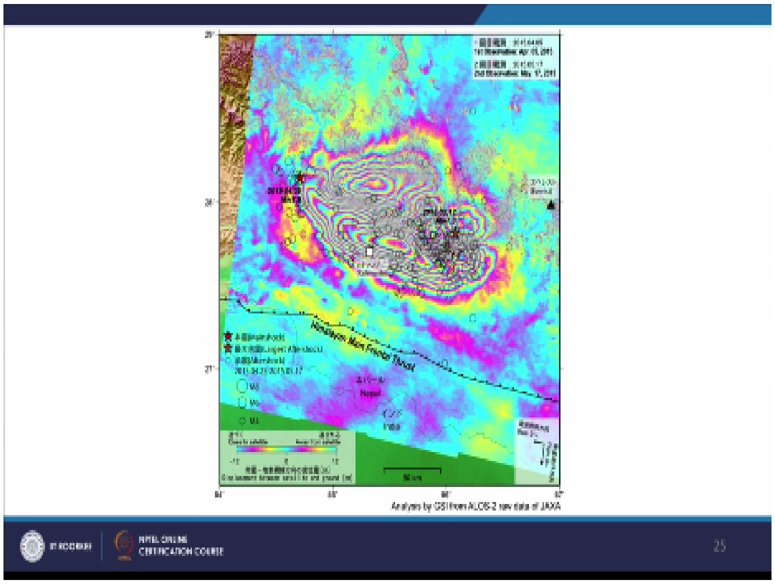

Another example of ground deformation in which quite reason in 2015 in Nepal as you can see that in this carton do valley, there where lot of ground formation all fringes can be seen. And there were two major earthquakes on occurred on 25th April 2015, and then 12th may 2015. And in between these are the ground formation which has taking place.

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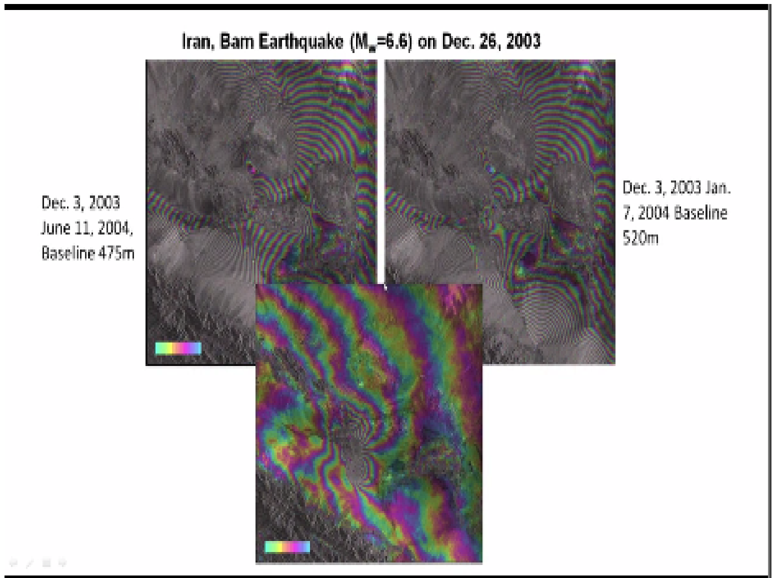

Now again there are more ways of analyzing, so this the same example but different dates month can enroll and again one can analyze the digital elevation model is also there. In case of balm earthquake one can also imply the two pass differential interfere programs or model in this is side we are seen in the model network.

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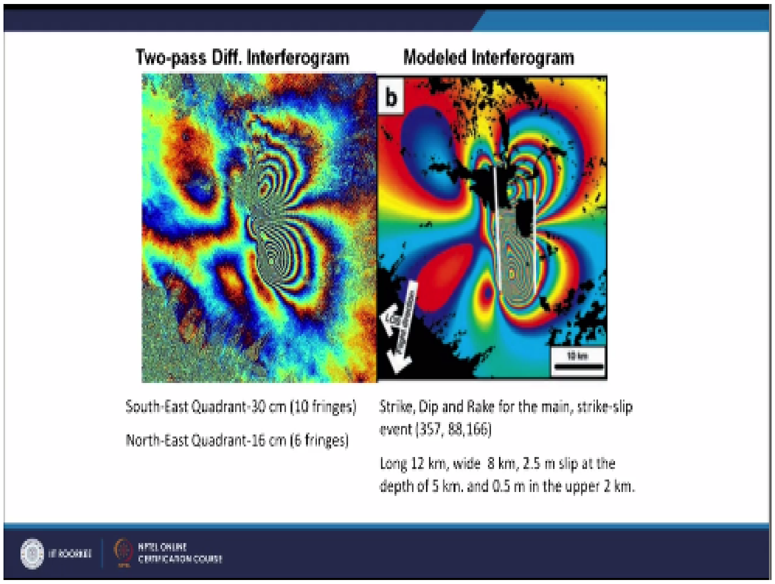

It was the real the core size may deformation is taking place in case of balm earthquake was very close to the model interfere program. And these model interfere program we creativity in before and if we have been know that how be the earthquake. Therefore the ground deformations can also be accordingly. So this that advantage of the interfere if the more example earthquake of 2000 date according china Sichuan earthquake.

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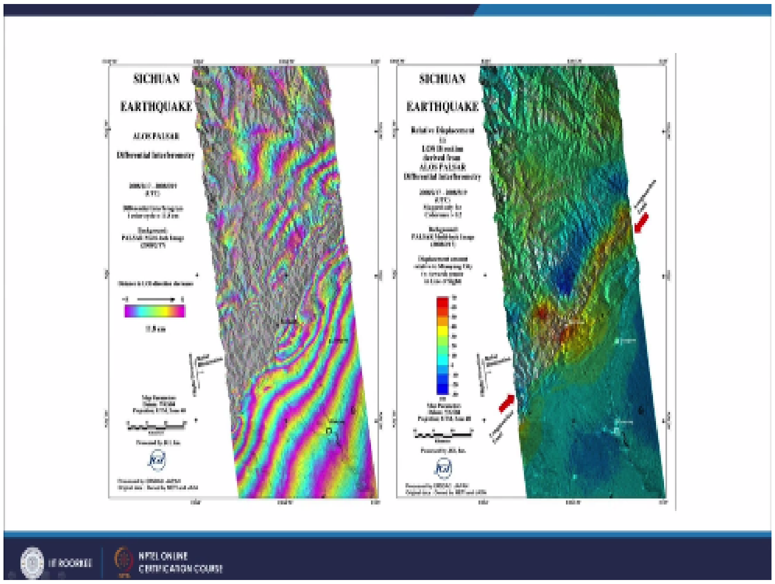

And that two waves cause lot of ground deformation and that could be measured very accurately as you can see the are here a ground reformation map is also here so this brings to the end microwave remote sensing I have mainly talked about active microwave remote sensing not passive wave microwave remote sensing and I have also discuss in length about the SAR interferometry which is as which in recent years as become really very popular and very useful to measure the ground deformations which might be causing because of an earthy quake key band or may be because of over withdrawal of ground water may be in landside and so on thank you very much.

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