Higher Surveying
Dr. Ajay Dashora
Department of Civil Engineering
Indian Institute of Technology, Guwahati

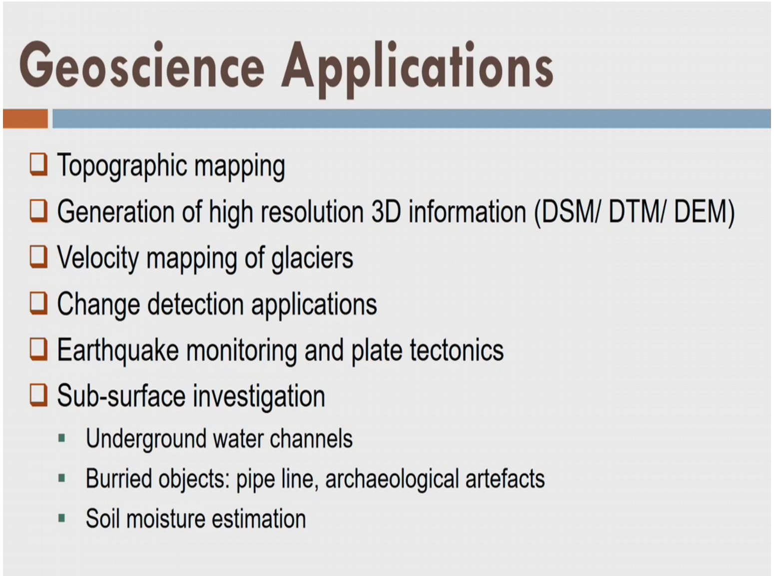
Module – 8
Radar (RADARgrammetry)
Lecture - 31
Geoscience perspective for RADAR applications

Hello everyone, welcome back in the course of Higher Surveying. So, today we are in the last lecture of the module 8 that is the RADAR. And we also wrote it like RADARgrammetry because we want to do the 3D mapping of the terrain using the RADAR.

So, in spite of explaining the earlier lectures based on the geometric aspect, a radiometric aspect, RADARgrammetry and the interferometry, after that we are going to understand all these aspects together today in one. And that is we want to use all this knowledge of interferometry RADARgrammetry, geometric aspect, radiometric aspect to address some of the geoscience perspective; that means, if I use the RADAR for the geoscience perspective or geoscience applications what are the things I should first understand about the RADAR. And then I should use the RADAR to understand what are the advantages as well as what are the limitations right.

So, today's lecture is geoscience perspective for RADAR applications. So, we are looking only at the perspective not the major applications; applications are tremendous, numerous, various applications are possible. However, we are only looking for their perspective to develop how one should develop an understanding. So, as to use those perspective in order to utilize the potential of the RADAR data.

(Refer Slide Time: 01:56)



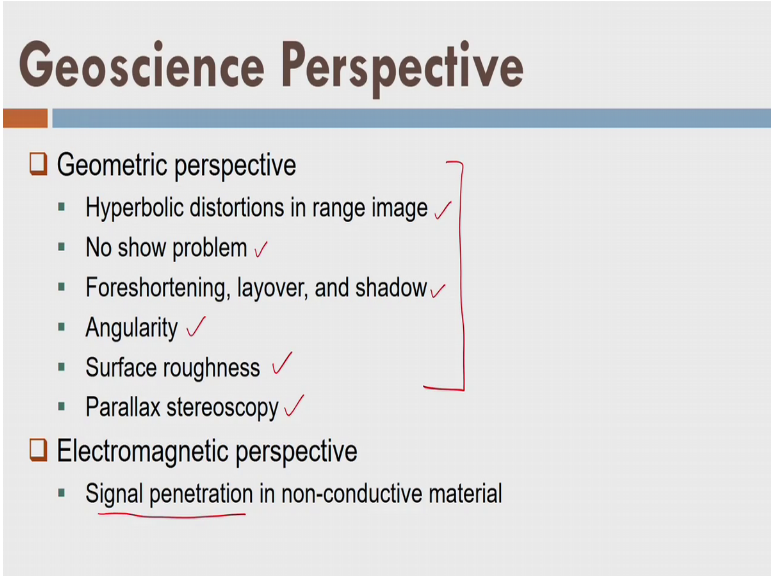
Now, these are the books and these are the Geoscience Applications ok. The first is a Topographic mapping ok, then we generate high resolution 3D information that is DSM, DTM or DEM. Then we want to do the velocity mapping of glaciers that is possible with the help of RADAR; then change detection studies, earthquake monitoring and plate tectonics and subsurface investigation which means; below the surface of the Earth if I want to find out some burried objects like, pipeline archaeological artefacts, some cultures for example, right then soil moisture content and so on, right.

And the underwater channels which are burried right; so all these thing we can find out from the RADAR applications. So, these are my basic geoscience application. However, as we said that we are going to you know consider only what are the perspective that are required to understand these applications.

So, in this lecture we are going to cover only the perspective or the some kind of reason, we need to have in order to address these applications. So, we have fundamentally 2 perspective for the RADAR applications, one is the geometric perspective and another is the electromagnetic perspective.

If you remember that the microwaves are not only sensitive to the material, but they also provides some capability of geometric data recording right? And hence we have developed 2 perspective.

(Refer Slide Time: 03:23)

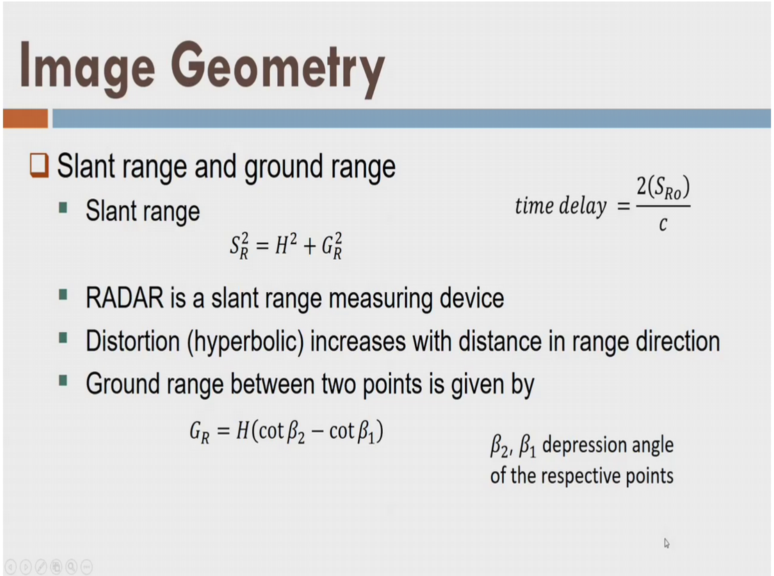


In case of a geometric perspective we will today look into the Hyperbolic distortion in the range image, No show problem, Foreshortening, layover and shadow, Angularity, Surface roughness and Parallax stereoscopy. So, in all these properties are basically geometric properties of the terrain surface or the terrain surface features.

On the other hand, if we consider the electromagnetic property of the material with which RADAR signal is interacting. We can also explore some of the characteristics or the geometric characteristics of that terrain. And that is why we have written a electromagnetic perspective fine. So, basically the signal the microwave signal of RADAR can penetrate through surface provided surface has some certain some particular characteristics or some particular electromagnetic characteristics of the material ok.

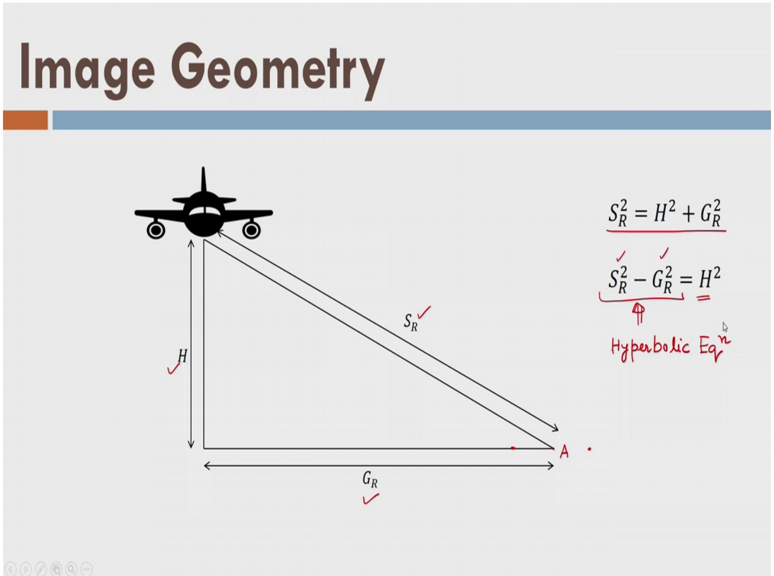
So now we are going to look into this perspective today. In this lecture let us start with the geometric perspective first ok.

(Refer Slide Time: 04:19)



So, we want to consider the relationship between the slant range and the ground range ok. So, this is the slant range, which is standard function of flying height and the ground range. Well, I can show you this thing here in this slide.

(Refer Slide Time: 04:32)

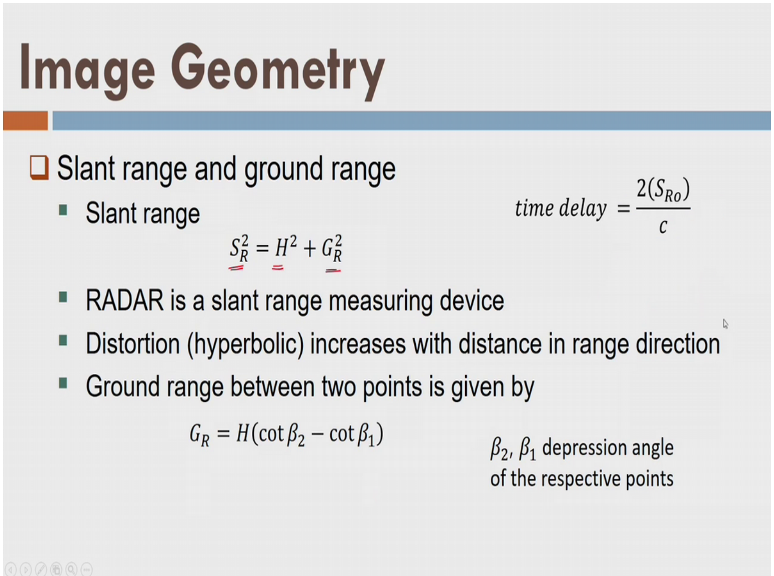


This is my slant range and by Pythagoras theorem I can write the relationship between ground range and the flying height with slant range. So, this is the relationship from this triangle.

So, let us say this point A, and for point A I can rewrite the same equation like this if my flying height is H is constant right for all since the flying height H is constant for all the points, at A at B or whatever right. So, point is here or here H is going to be constant right; that means, in order to keep the H constant slant range S R and G R will be varying.

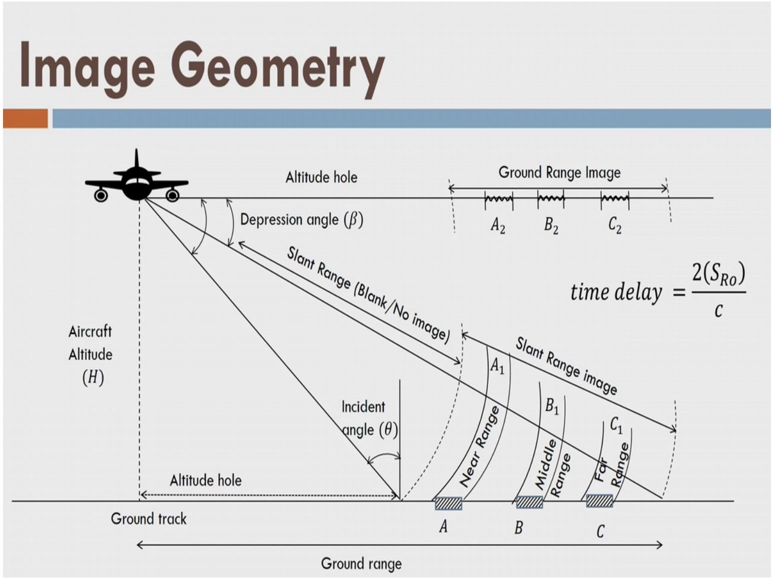
So, my S R and G R are the variables right. So, what happens here is this equation is nothing but equation of hyperbola. So, this is my hyperbolic equation or the variations in the slant range and ground range are according to be hyperbolic equation alright.

(Refer Slide Time: 05:25)



Now, you can see here that distortions will be hyperbolic as it increases with the distance in the range direction, and the ground range which is given by this here ok. So, they are beta 2 and beta 1 are the depression angle of the respective points; so that is my beta angle here.

(Refer Slide Time: 05:47)



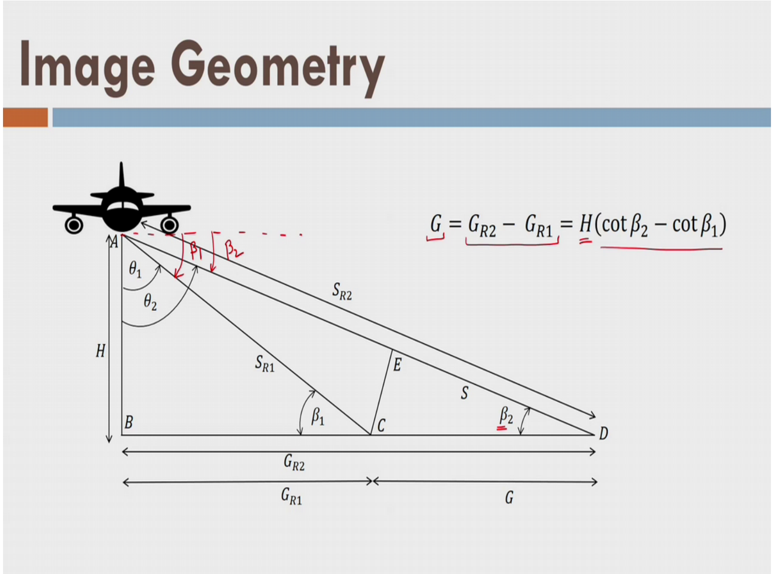
Now you see that this is my depression angle beta, and now I can see here that effect of what is the effect of image geometry. Let us see there are 3 objects A B and C which are at the datum or we can say at the same level of the ground surface, or the elevation of 3 points A B and C are same, or I should say that point A there is no point A there is a some feature A, feature A and feature A. They are of same length, but they are basically displaced along the azimuth direction or across that direction ok.

Now, this is my incidence angle which is same for all 3, but since A is at near range; what will happen? This is the range for this point here. Similarly this is the range for this point here and so on. Now we can see here that the near range will have less distortion. That means, for this point whatever distortions are there because this point is imaged instead of here it is imaged at A 1 alright ok.

As a result, what happens that feature A is appearing as A 1 with this distance ok. You might be feeling that the distance is same yes that is true, but the coordinates of point left and right point of the feature A will be having some distortions. Similarly, we have the distortion from point B area as well as feature C also all right.

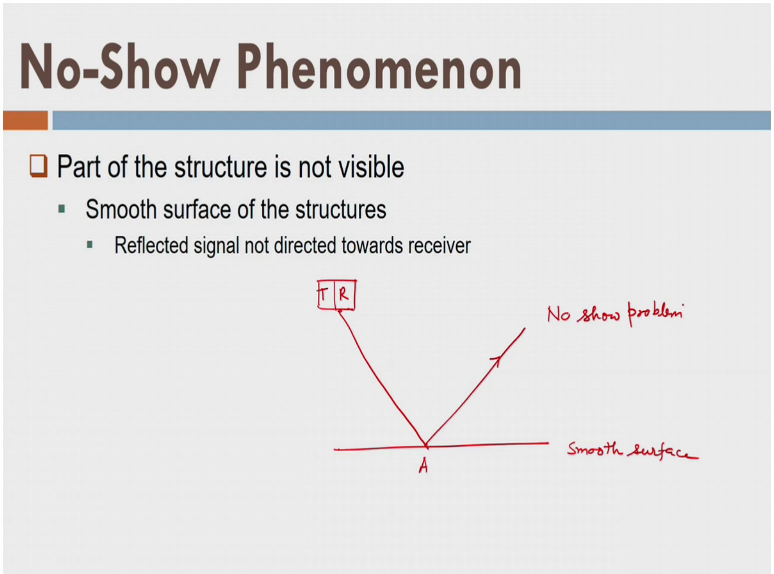
Now what happens is what is the amount of distortion; definitely as amount of distortion will be higher for C and minimum for A among these 3 features all right. So, that is the aspect we want to highlight here ok.

(Refer Slide Time: 07:22)



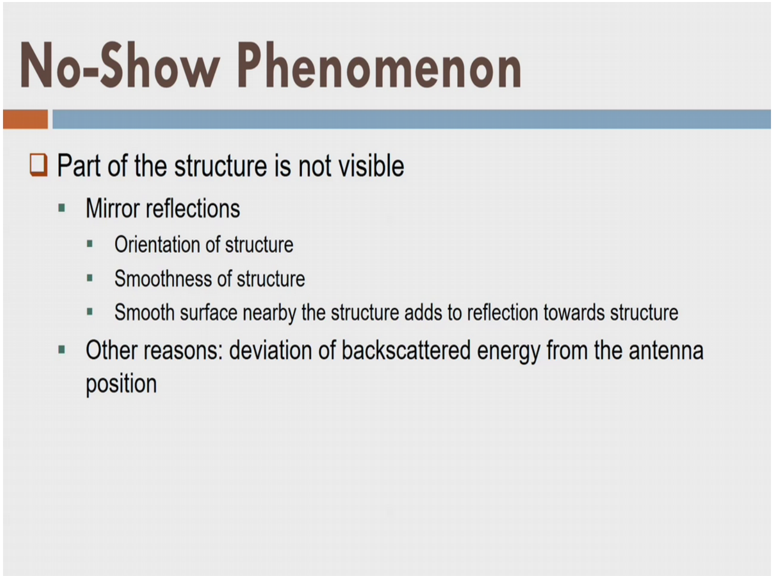
Now, if I consider the only 2 objects so this is the difference of ground range GR 2 minus GR 1. And it is given by this formula where beta 2 and beta 1 my depression angles and which are indicated here and which is nothing but you can measure it from here. So, they are basically this beta 2 will be this beta 2 and beta 1 will be this beta 1 alright. So, these things one should understand from the image geometry perspective right ok.

(Refer Slide Time: 07:54)



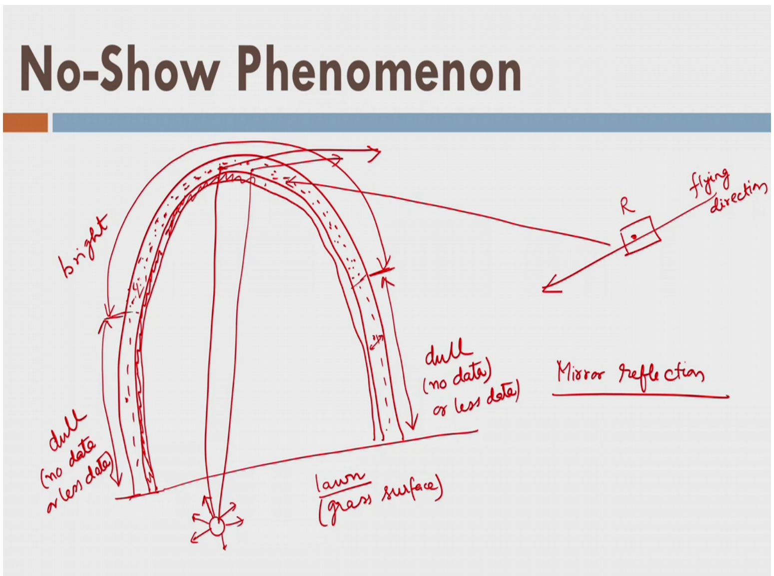
There is a another phenomena which is called the no show problem, what is no show problem? Let us imagine a situation so let us say this is a smooth surfaces here, and now this RADAR sensor here which is having transmitter and receiver assembly ok. Let us say it transmits a signal it is comes like this and because of the smooth surface it will be reflecting like this. And what happens is the receiver will not receive any signals from this point A. And so, the point A will not be image and that is called the no show problem, so this first kind of no show problem here ok. This is another type here.

(Refer Slide Time: 08:41)



There is a something called the mirror reflection, what is the mirror reflection? Let us look into the things.

(Refer Slide Time: 08:47)



Now let us imagine that there is a one ground surface here and on the ground surface we have an arch like this ok, and sensor is flying like this is the flying direction of the sensor, and let us say sensor is somewhere here situated. And because of the waves or the pulses sent by the sensor what happens is the structure of this arch which is reflecting the; so let us say this is a thickness here so this is thickness here.

So, the structure of the arch is basically reflecting the signals, incoming signal. Now the orientation of the sensor or the line of sight is like that; that means, it is perfectly coming here alright, and it is reflecting back here again ok. On the other hand, what about this places? There is no signal is coming because, these surfaces are basically parallel to the line of sight of the sensor, at certain position you can imagine that if at certain position these walls become parallel.

However, this surface is still reflecting this one what will happen. I can see here that this portion which is upper portion here to here let us say right? It will be image or it will be up reflecting the signal and this is the lower portion on the 2 sides will not reflect any signal rather it is not receiving any signal this portion from here to here. Similarly, from here to here, at the same time it has lot of reflections. So, that structure will be appearing like this one more problem is there generally these, such arches are basically situated in lawn.

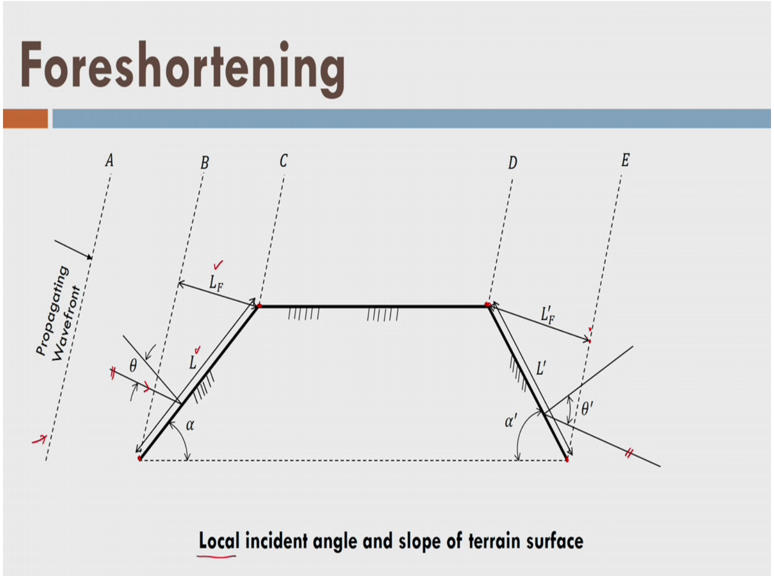
So, let us say this is a ground surface called lawn, having the smooth surface or a grass surface right. Now let us say because of this grass what will happen some of the incident signals will be reflected towards this also, again this will be reflecting in all the sides being a diffuse surface. And what will happen again the signal which is reaching again back here that will be reflected towards the receiver or the RADAR sensor.

Now as a result also this surface will have very high reflection compared to these remaining lower surfaces. And as a result only this part which is dotted here shown that will be appearing in the image and the lower part will be appearing little dull.

So, I can (Refer Time: 11:41) write here so dull here and here is the bright and here it is dull again, this phenomena is called the mirror reflection. So, it is also one of the example of no show because there is no data here or very less data here ok. I can write here that no data or less data here. So, this is another no show problem alright.

So, I hope that you understand so once suppose if you are having such kind of structures, you should be careful enough in order to interpret your image ok.

(Refer Slide Time: 12:20)



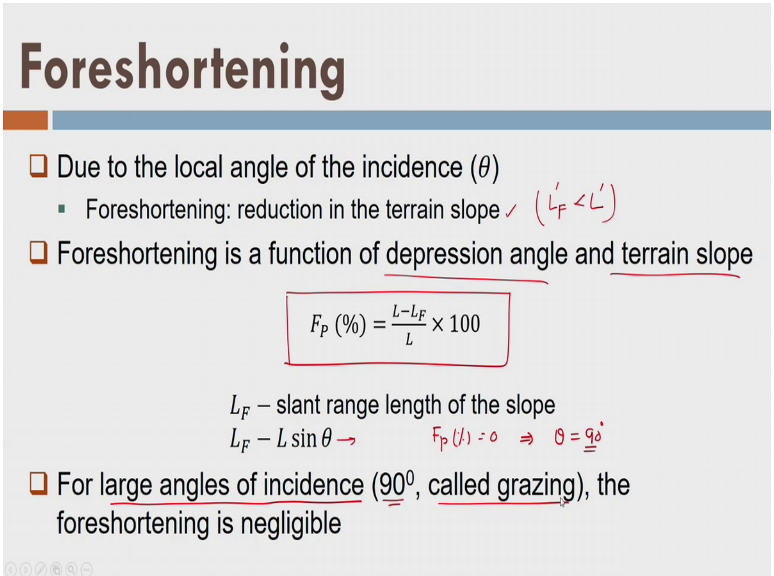
One more phenomena comes here that is called foreshortening; what is foreshortening? Now you can see that we already know from RADARgrammetry that the orientation of the local surface and the incident angle of the RADAR signal makes a lot of a difference all right. So, let us see this is the terrain here shown which is having slope at 2 sides and the flat at the center side. So, let us say this is slope alpha and angle alpha dash here now this is the normal to this surface and this is the normal to this surface.

Now, there is a wavefront that is approaching the surface from the RADAR sensor. So, this is the direction of my pulse or the wavefront alright. So, this is angle is theta what you call it is incidence angle or local incidence angle alright. So, similarly theta dash is my another angle; so this is also parallel to this and this directions are basically parallel ok.

Now because of this geometry of the local surface as well as the wavefront what will happen; this point will be imaged at B and this point will be imaged at C alright. So, along the wavefront this is the length indicated by the slant range right; the real length is this is so this phenomena is called foreshortening; that means, the length L is represented by LF which is quite a short, which is comparatively less than L and as a result this phenomena is called foreshortening. Similarly, if we talk about another surface which is inclined by alpha dash angle; so this is the 2 points here and here and now you can imagine that the perpendicular distance between the 2 wavefronts here and here all right like this.

So, this is my LF dash which will need a distance of slant range for these 2 point all right and as a result we can see that the real length is the inclined length and that is my L dash. So, L dash is represented by L dash, so these 2 are examples of the foreshortening, but what about this surface that will be represent is between the this point and this point, they will be represented as it is because they are flat ok. So, basically now we are saying that: what is the effect of a local incident angle and slope of the terrain surface. I hope what is the idea of foreshortening ok.

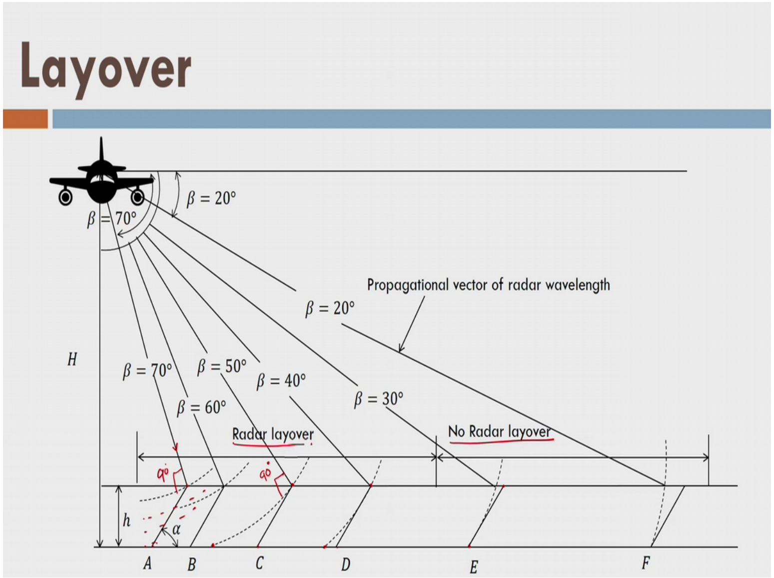
(Refer Slide Time: 17:44)



So, foreshortening happen because of the local angle of the incidence or it is nothing but the reduction in the terrain slope ok. So, foreshortening is a basically a function of a depression angle and the terrain slope here ok. So, it will reduce the terrain slope because the length L is represented by LF, L dash F for LF and it is less than l dash all right. So, as a result what will happen the slope of the terrain will be reducing?

Now let us look into the foreshortening it is a function of depression angle and the terrain slope here ok. So this is my foreshortening percentage ok. If I say that foreshortening is 0, which means my theta here should be equal to 90 degree. So, that it is possible all right which means that large angles of incidence close to 90 degree. And this phenomena is called a grazing; that means, ok. So, this is my RADAR pulse and this is surface, and this phenomena. If it is the RADAR pulses is pulse or the wavefront is glazing over the surface it is called grazing all right. So, this is my 90 degree of the incidence angle because this is my vertical and this is my 90-degree angle of a incidence.

(Refer Slide Time: 16:01)



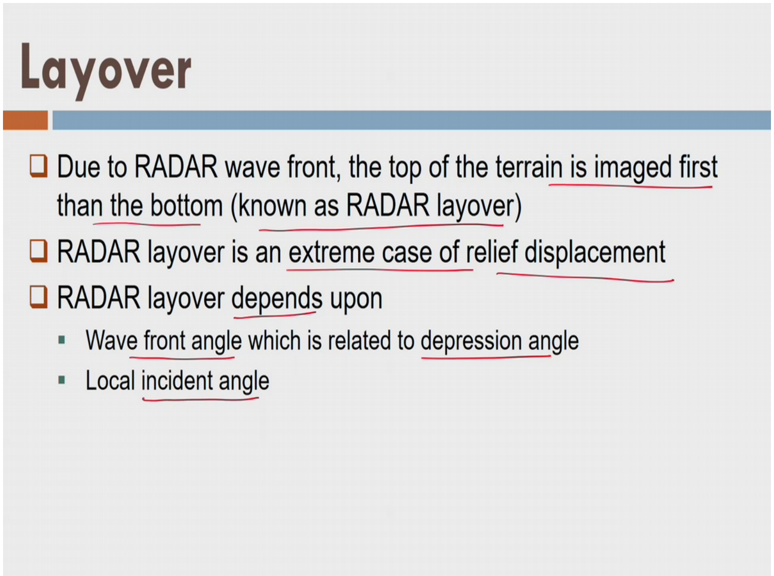
Now, coming to the next phenomena called layover ok. Layover is just like a relief distortion in photogrammetry, but here the relief distortion is completely different aspect and we should understand it first. So, let us see that all some surfaces are there which are shown here, let us say point A, point B, point C some features are there all features are inclined at angle alpha. Now so here you can see that the wavefront is coming and so this angle is my 90 degree alright.

So, this is my line of sight here and this is wavefront. So, wavefront will first touch here this feature, and then later on it will reach here like this. So, what happens here this point is image first in the slant range. And so, it will be somewhere represented on this side which are we are not saying. Similarly, it will happen with point B and let us say point C also ok. Now in case of point C you can see that this is the wavefront at 90 degree of line of sight. And the point C which is here or this point will be image here on the slant range or because it is interacting force with the wavefront and later on this point will be interacting.

So, that shift of the slant range of the 2 points because of the relief difference between the time is called the layover. Similarly, same thing will happen with D, D will be this point will be image here this point will be image here further. Now from point E, it will not happen because this point which is at the datum or some surface it is imaged first or the bottom point is first image by the or first touch by the wavefront. So, it will appear first and then this point will appear.

But in case of point D C or B the top points are appearing first and the bottom point is appearing afterwards and that is the called the phenomena of layover. So, for point E and F there is no layover. So, we are writing no RADAR layover and we are writing RADAR layover, alright.

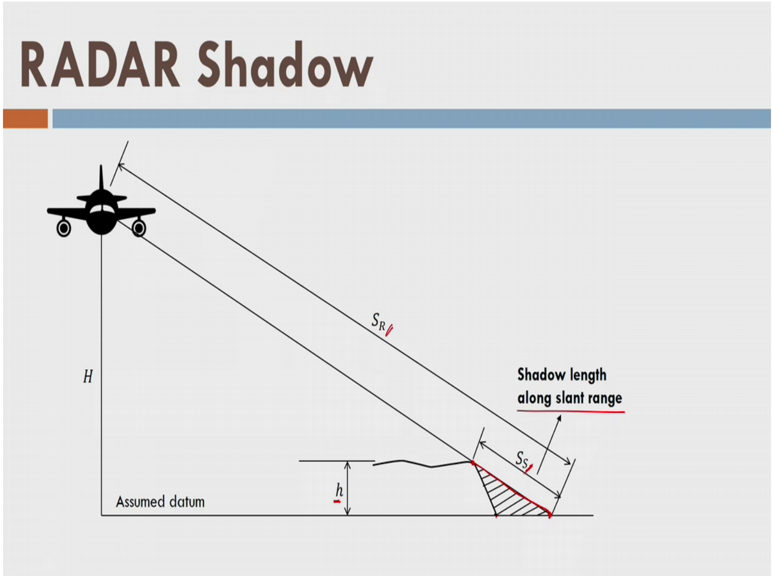
(Refer Slide Time: 18:04)



So, due to the RADAR wavefront the top of the terrain is image first then the bottom and this is known as RADAR layover ok. So, RADAR layover is an extreme case of relief displacement alright, but the relief displacement is different from the photogrammetry. In case of photogrammetry if you recall that if this is the line of sight what will happen, relief displacement would have happened on the right hand side not only left hand side well.

So, it depends upon the wavefront angle; that means, the line of sight; that means, this is decided by a depression angle and what is the local incident angle with the surface ok.

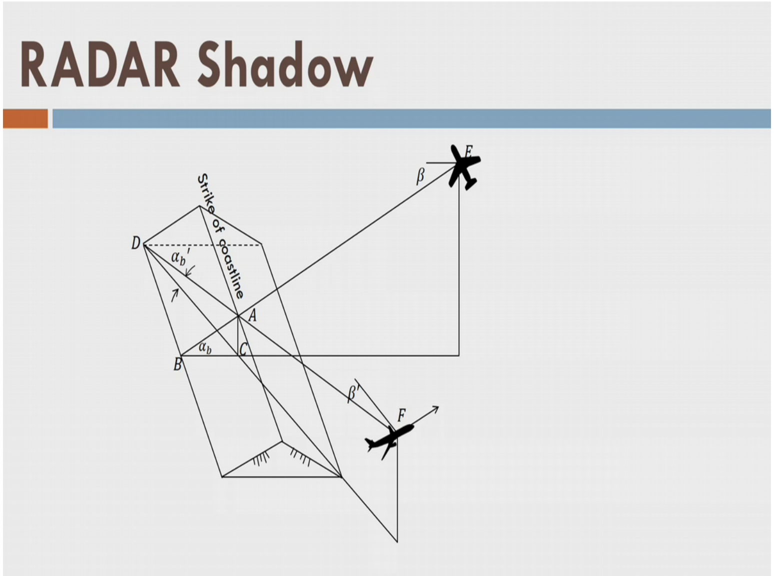
(Refer Slide Time: 18:42)



Next phenomena is my RADAR shadow, what is the RADAR shadow? A simple figures show that let us see this is the point here and that has elevation H with respect to some datum because of interaction of the wavefront at this point, this complete length here to here up to this point. This area or we can say this volume will be of the terrain will be under shadow right. There will not be any data from this point to this point on the surface of terrain.

And as a result this is called the shadow or the shadow length along this slant range is my SS here all right so this is the slant range fine ok

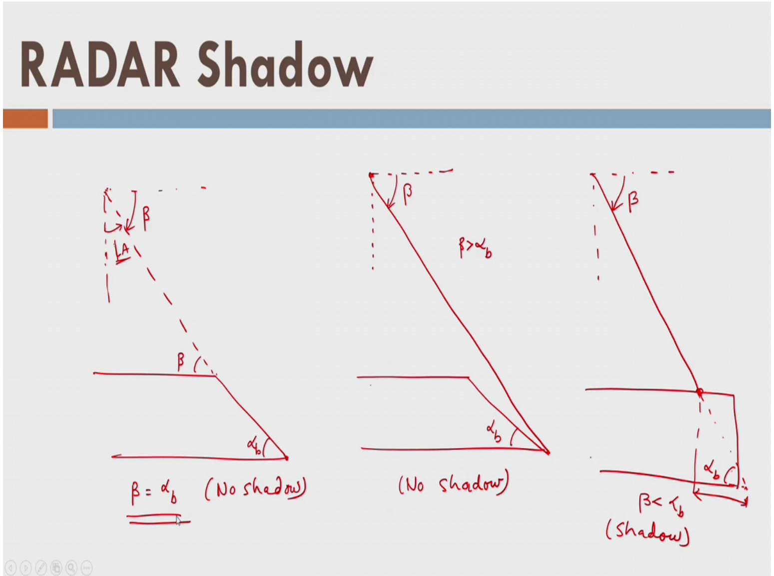
(Refer Slide Time: 19:21)



Now, we can just imagine that there is a surface which is like that which is elevating up and again going down all right. Now let us say this is the height of my it is triangular surface. For example, now at a sensor at E what will happen? This will be the point A will create a shadow up to point B. So, this C B will be under the shadow on the other hand for this position F of the sensor point a will create shadow up to point D. So, the complete D or C length will be of the ground surface will be under shadow.

And now we can see that this is my alpha B dash angle and alpha B angle here and that as the angle of the created with the geometry of the sensor and the terrain alright. So, that is another example of shadow, now we can see here that what is the relationship between the alpha B dash and alpha B; as well as what is the relationship between the beta or the here I can say the depression angle ok.

(Refer Slide Time: 20:22)



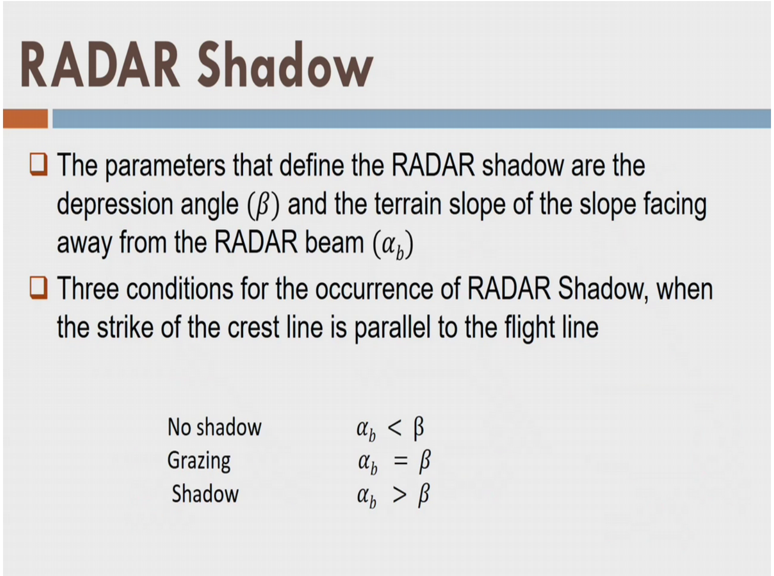
Just think now I am just explaining you couple of situations, let us take the first situation where there is sensor and there is another position here so this is a horizontal plane. And then this is the terrain like this and let us say this alpha angle of terrain or what you call alpha B. Now let us say that there is a 1 wavefront coming in this line of sight. And so, this angle is my beta here. So, this was my look angle I write it la. So, this is my depression angle beta. Now you can see this is my beta and here beta is equal to alpha B and as a result there is no shadow at all ok. So, I write it no shadow ok.

Let us take the second incidence this is again the horizon plane here and this is sensor position here. And now let us think that this is the wavefront and this is the case here. So, this is my angle here. So in this case I can say here, let us say there is a one line of sight falling here.

So, this is the line of sight here. So, let us makes my alpha B here and this is my beta here. So, in this case beta is more than alpha b. And so, there is still no shadow ok. Let us take the third case which is the sensor is here somewhere, and this is the let us say a line of sight here and now the terrain is somehow like this or I can say terrain is like this.

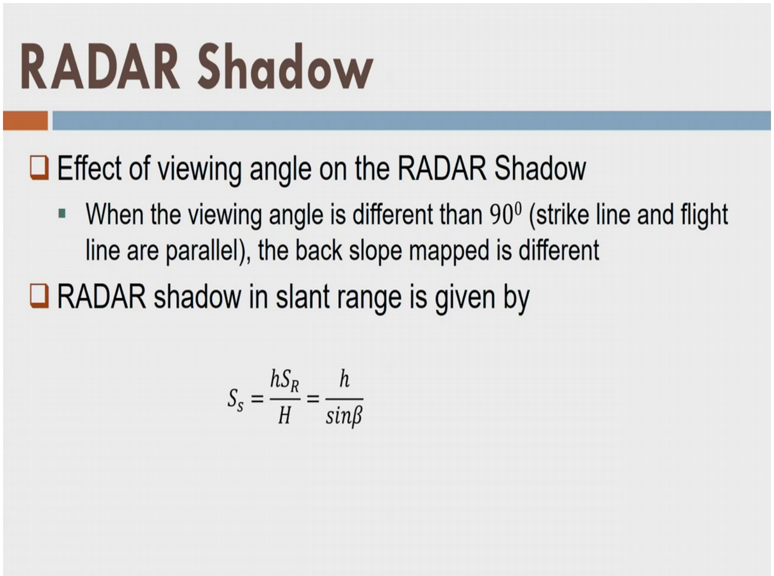
So, terrain is like this and this is my angle alpha B here and this is the depression angle beta all right, now we can see that beta is less than alpha B ok. So, here shadow is created; that means, this beyond this point let us complete up to this point there will be shadow. So, no data up to here to here this complete shadow here alright, now you can see that this case when beta is equal to A B it is called the grazing also.

(Refer Slide Time: 22:52)



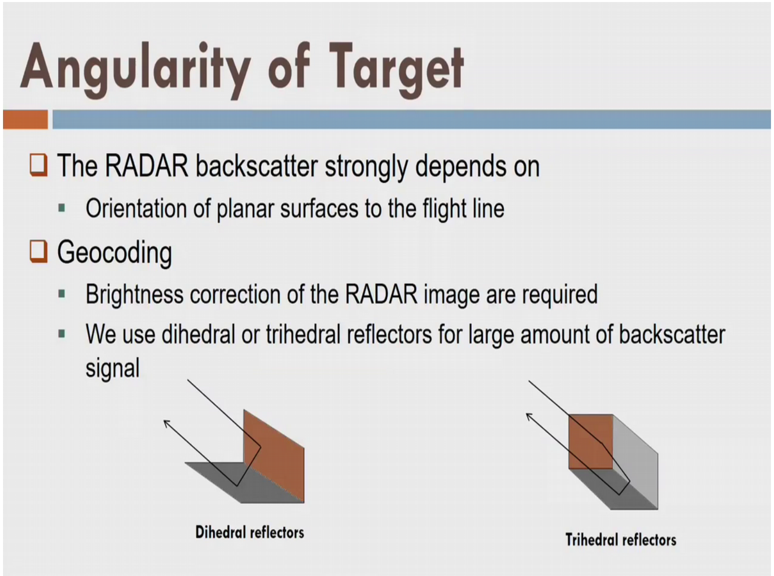
So now, we have explained here what is the grazing when alpha B equal to beta, shadow is my alpha B is more than beta and no shadow means alpha B is this one ok. So, these are the 3 conditions we generally have the RADAR shadow and no shadows idea right.

(Refer Slide Time: 23:08)



So, what about the shadow length shadow, length is given by like this as a function of slant range, and the height of the object or the feature above the datum and this is the flying height alright. So, this is my beta nothing but depression angle ok. So, you can measure the if you observe the shadow you can also measure what is the slant range along the SR, that is what is the length of the shadow along the line of sight.

(Refer Slide Time: 23:35)

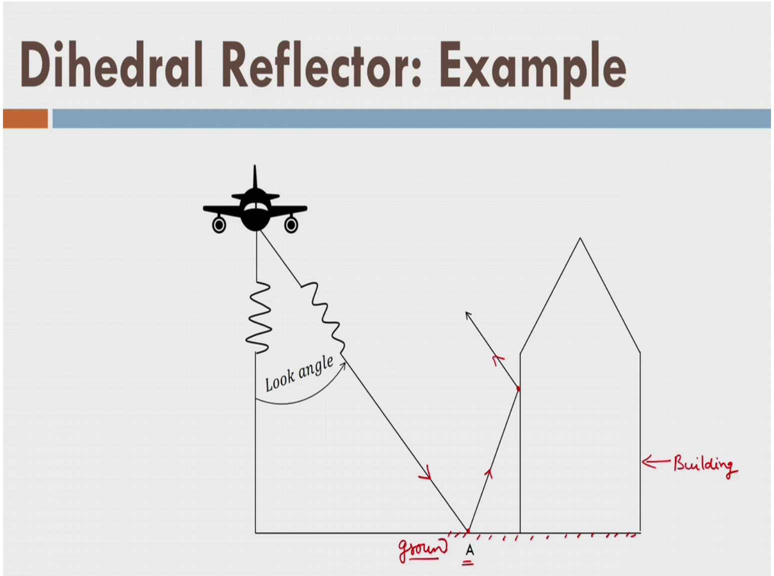


Now, one more aspect is there that is again important from the geometric perspective or the geoscience perspective that is the Angularity of the target, what is the meaning of Angularity right. So, let us see it is orientation of the planar surface to this flight line all right. Now you can see here that in case of geocoding; that means, when the geo reference the RADAR image or we reference the RADAR image in the some kind of object coordinate system or some kind of terrain reference frame.

We need to have some kind of brightness and this brightness if they are higher in value, we will have better opportunity for the correction and that is why we need higher brightness values.

And that is why we use the dihedral or we prefer the trihedral reflectors ok, what is the example here we have already given one example. So, let us assume that there is a some angle here on the wall right. So, what will happen this is my incident signal and it is reflected back like this. And that is called the dihedral reflector similarly we have trihedral reflectors. So, such kind of bodies or such kinds of terrain features are preferred in order to understand the angularity of the target.

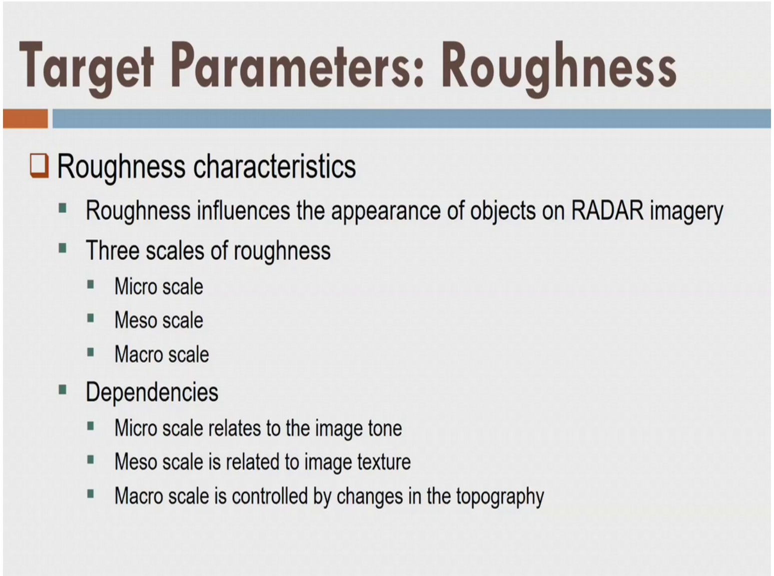
(Refer Slide Time: 24:46)



So, here I am showing that one practical example and this is the building here and this is the ground surface here.

So, what happens is because of the building that incident signal at point A will be reflected here, and again it will be reflected towards the sensor. And so, for point A we are having more energy reflected and as a result a point will be appearing brighter or the area around the A will be appearing brighter. And that is needed and that is why these kinds of features are very important or rather we look for such features when we do the image RADAR image geo coding alright.

(Refer Slide Time: 25:30)



Now, next is the Roughness, we have already explained the roughness is nothing but the special arrangement of the features. That means, the irregularities of the special arrangement of the features right.

That means, what is the spacing and what is their height of the feature for example, if I have some kind of troughs and the peaks and lows and so on, and then what is the spacing. So, what is a wavelength of those things right of the undulations? So, wavelength will decide me horizontal expands of the undulations and the peaks will decide the vertical change with respect to the remaining data points.

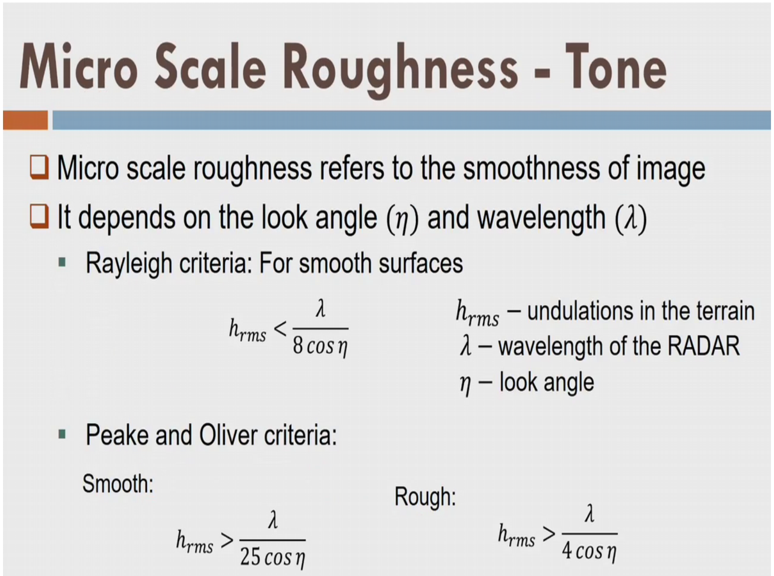
So, that is what is called roughness now my surface can be smooth my surface can be rough. So, what are the criterias right and that is why we define the roughness. Fundamentally roughness basically decides the appearance of the object on the RADAR image and 3 types of roughness are defined Micro scale, Meso scale and Macro scale. So, micro scale depends on the image tone that is nothing but image tone in case of photogrammetry is represented by the color remember. And here since the microwave region does not have any color or the color, we do not perceive it in the micro reason that is why we apply this false color.

So, higher the reflection: higher the intensity or higher the tone alright. So now, we can see here that micro scale depends on the image tone, meso scale depends on the image texture, what is do what do you mean by the texture? Texture is nothing but repetition of certain element ok; for example, I sometimes we feel that the cloth is a fine texture what does it mean cloth consist of elements called thread.

So, when threads are spaced very closely because each thickness of each thread is very, very small. And as a result if I you know try to feel the cloth it will appear very smooth or it appears very fine textured, because the repetition of the elements that is threads right it is very closely spaced.

However, when thread is thicker what will happen for example, jute I feel that it is very coarse texture all right. So, that is the meaning here. So, that texture is nothing but the repetition of certain element in an image. So, the meso scale depends on the image texture. Finally, macro scale is controlled by the change in the topography or rather is a basically larger scale phenomenon.

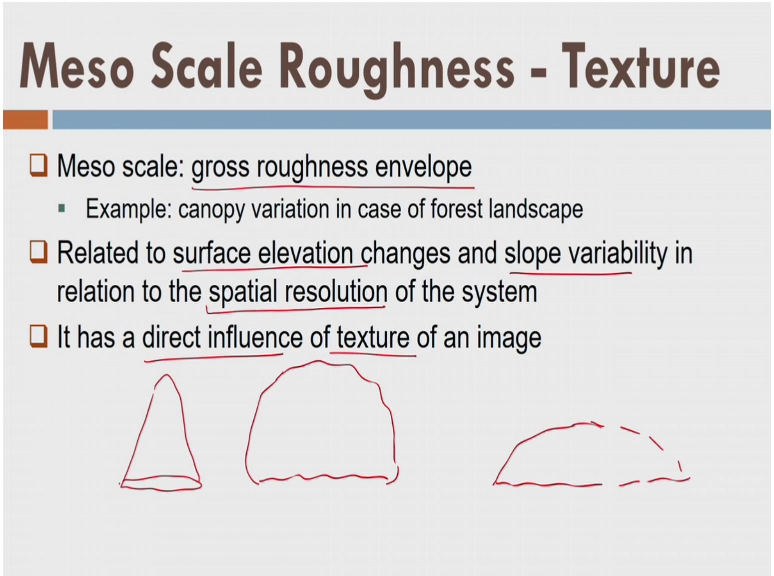
(Refer Slide Time: 27:54)



Now let us go into the Micro scale it is referring to the smoothness of the image and it depends on the look angle eta and the wavelength lambda, and it is given by this one remember h rms is nothing but the root mean square value of the terrain variation all right.

So, we are writing this rms value here, and this is my look angle here and these criteria we have already learned that is the Rayleigh criteria all right. Now there is a another criteria Peake and Oliver criteria which says that; it is surface is smooth then we should follow this criteria, but if surface is rough we should have this criteria. So, somewhere they give the range of smooth and rough. So, Rayleigh criteria is somewhere in between the Peake and Oliver criterias for smoothness all right.

(Refer Slide Time: 28:43)

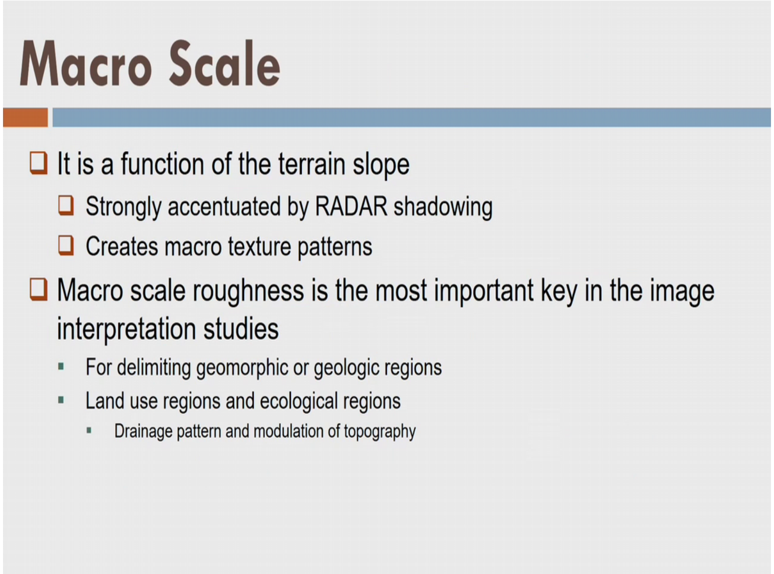


Coming to the Meso scale, meso scale is nothing but the gross roughness envelope defined by the gross roughness envelope what is that for example, ok. Let us say there is a canopy ok, what happens is in case of canopy the canopy will be appearing like a volume ok. Over that volume lot of change will be there in the slope and in a given resolution we can find out what is the changes happening in the slope of the surface represented by the canopies alright.

So, that will decide the meso scale roughness of the and right we can say here that there is some repetition in the image texture because of the certain depiction in the element of the tree, that is canopy elements maybe leaves because they have certain structure.

So, I will have different type of canopies here like this. So, I will have canopy like this or I can have canopies like this all right. This is one type of canopy another type of canopy like this right. So, all these will be having a different-different slopes on the surface and then. So, my surface elevation changes and the slope varies and accordingly according to the special relation of the system, we will have the direct influence of the meso scales on the texture of an image alright. So, this is the way we define the meso scale roughness.

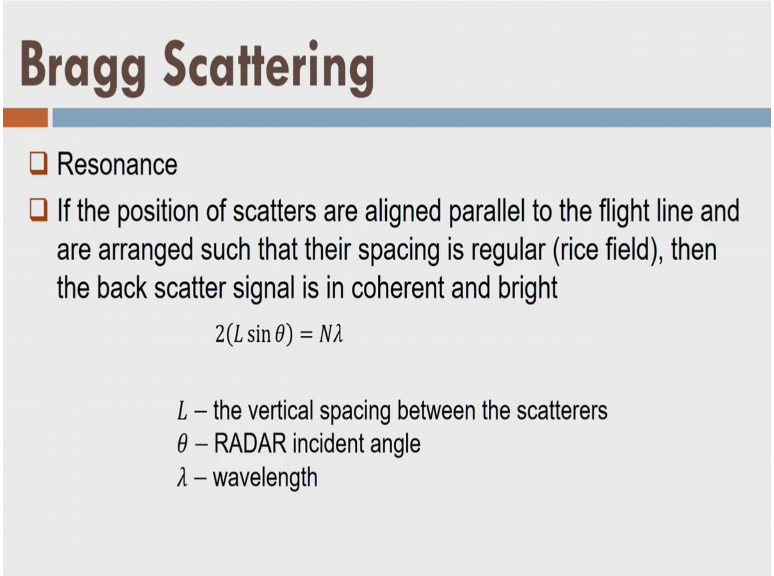
(Refer Slide Time: 30:03)



So, meso scale is very important if you want to study the texture of a surface. Now Macro scale it is a basically function of the terrains loop. And we know that it is basically signal is strongly attempted by the RADAR shadowing. And hence in case of shadowing it creates a macro texture pattern; that means, if there is some shadow here. We can find out some kind of macros level of structure or the pattern of the structure. So, macro level pattern we can find out.

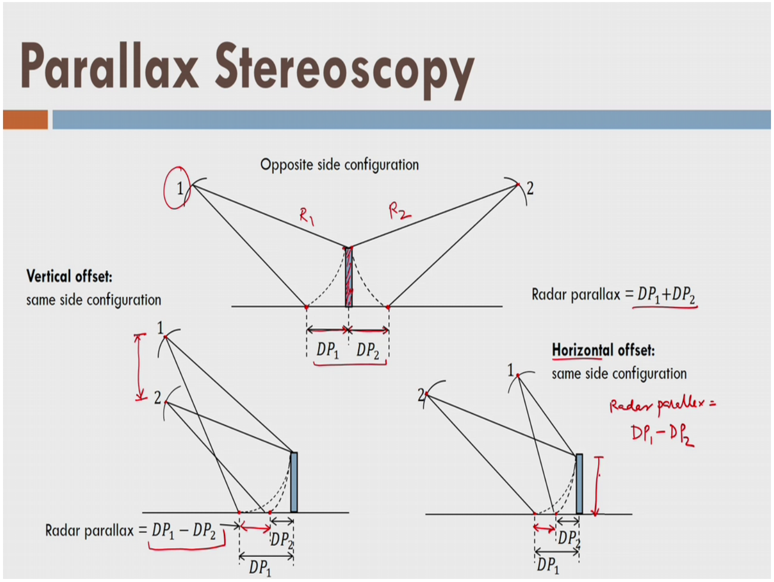
So, this basically is very very useful for large scale study for example, some kind of a geological feature study you want to do, or you want to do some kind of regional drainage network study; where these things are very useful that is macro scale roughness is very very useful. Now the macro scale roughness is function of terrain slope.

(Refer Slide Time: 30:53)



One more concept comes here Bragg scattering. I think we have already discussed about the Bragg scattering well ok. The Bragg scattering is also called resonance and again you can reread this thing from the previous lecture. So, but in order to introduce here the word resonance we brought it here alright.

(Refer Slide Time: 31:13)



Now, there is a another aspect of that; so we have learned all the possible distortions and all the possible effect of the geometry of terrain, and the sensor, and the line of sight, and the depression angle and so on. Now let us say we want to develop a 3 D from the

RADARgrammetry. So, we use this stereoscopy concept what is the stereoscopy here ok. Let us say there is an object it is shown here right and it has some height here that I want to measure.

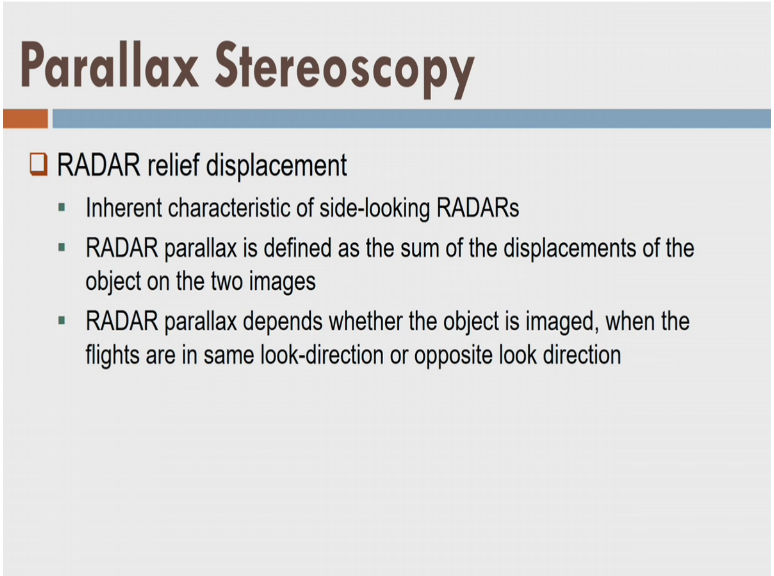
Now, from the sensor one here what will happen this is my range R 1 it is another sensor 2. So, I have raised R 2. This point will be image here and this point in another image will be image here. So, this is the 2 images and we have 2 presence of the same point. Now if I measure the steel of parallax according to the photogrammetry, this is the parallax in one image and I can say that total parallax of the 2 images is nothing but DP 1 plus DP 2 written here alright ok.

Let us look at another arrangement of the sensors. The sensors are arranged in a way that they are at more or less same position of the in the vertical, but sorry in the horizontal. So, there is no horizontal difference between the sensor 1 and 2 their horizontal position are same. However, they are vertically separated. So, I get some offset here in the image 2 images right. So, this is my offset and which is nothing but the difference of parallax in the 2 images all right.

So, I can write here that RADAR parallax is the DP 1 minus DP 2 here all right you can see this is the distance what we call DP 1 minus DP 2. Similarly, now we consider the horizontal offset which means the sensors are separated horizontally and not the vertically, alright. So, again we will have and both sensor one and 2 in case of horizontal offset and vertical offset they are on one side of the object, alright.

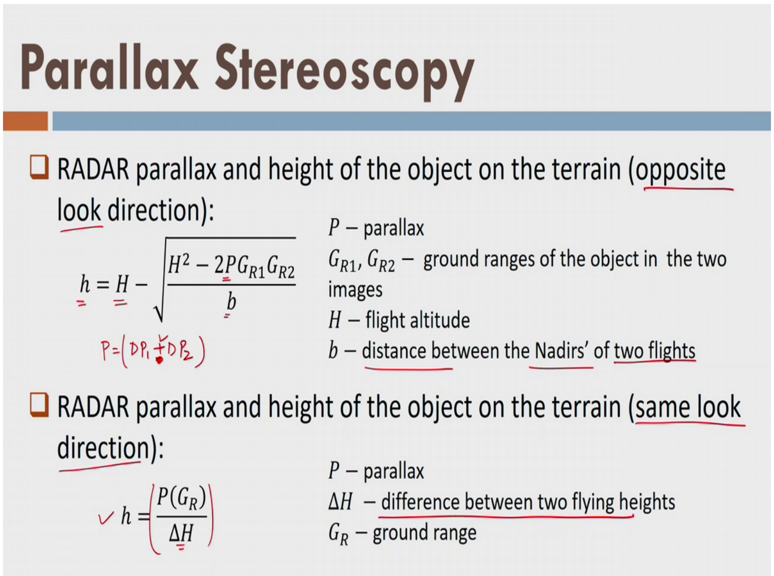
So, what happens here is you can see here that this is the parallax, integrated by the red line here red arrow here, alright. So, that is called the horizontal offset and again it is given by DP 1 minus DP 2, alright. So, using these parallax I can measure the height of the object let us say the height of the object is H ok.

(Refer Slide Time: 33:42)



So, it is nothing but the relief displacement as we have discussed before now you can see that it is RADAR relief displacement is an inherent characteristics of the side looking RADARs. So, RADAR parallax is defined as the sum of the displacement it is an algebraic sum of the appearance or the image of the same object in 2 images. So, it depends whether the object is image in the same look direction or opposite look direction alright

(Refer Slide Time: 34:12)



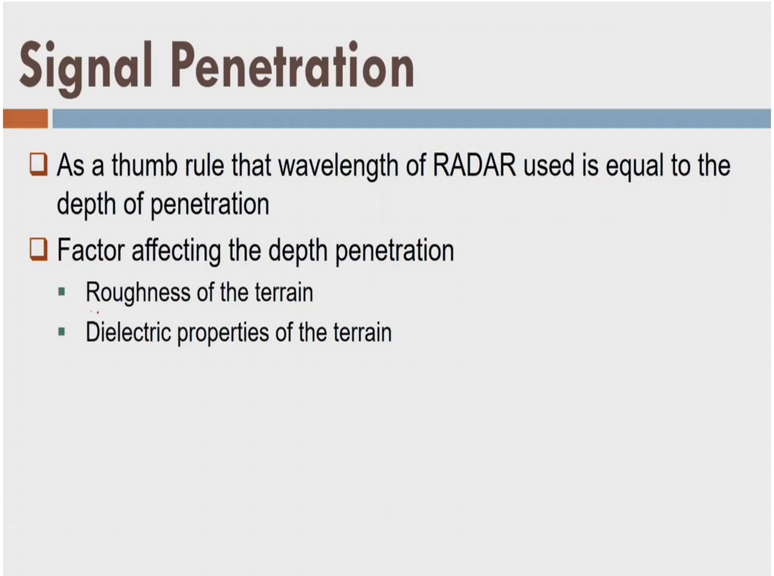
So, the height of the point is given in case of opposite look direction you can note it here by this formula, where H is my flying height, P is my parallax or what we call RADAR parallax. So, algebraic sum here right? So, I can write plus months depending on. So, it in this case plus only so then B is my distance between the nadirs of 2 flights all right. So, GR 1 and GR 2 are my ground edges of the object in the 2 images fine. Similarly, if the object if you have the same look direction of the 2 sensors, then we gave the formula by this.

And there my delta H is nothing but the difference between the 2 flying heights we come to the though another aspect and that is the electromagnetic aspect or electromagnetic perspective of my RADAR signal ok, what is that? We know that there is some electromagnetic property of the material. And accordingly we define the material is non conductive or more reflective, because the material is non conductive. That means, it will not absorb it will not transmit, but rather it reflects more energy towards the RADAR receiver ok. So, that is the highly reflecting or low conductive material.

On the other hand, we have some contradictory terms for example: the highly conductive material will be least reflecting material, alright. So, that is a idea here so in orders that signal should penetrate through the material what should happen? First of all, it should interact with the signal moreover it should allow signal to reflect from different-different layers of the material within itself ok. So, and that is capability of the RADAR signal is termed as signal penetration, alright.

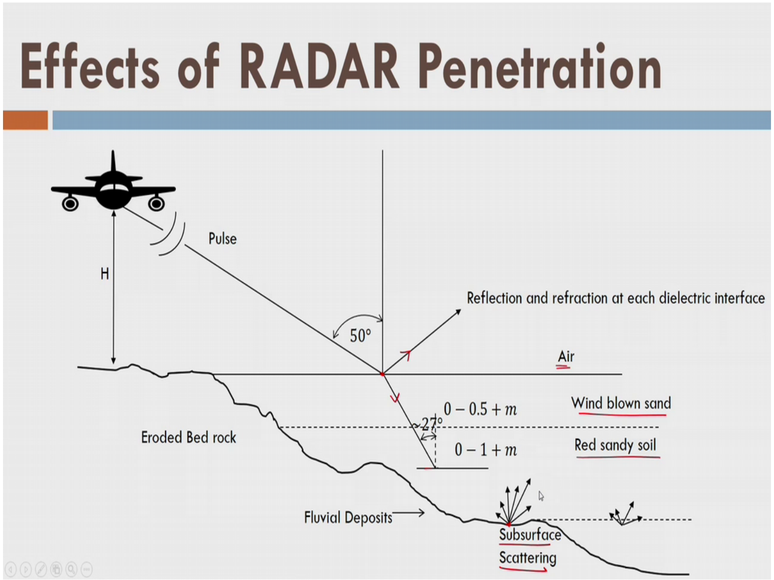
So, the thumb rule here is that generally we get the depth penetration up to a maximum level of lambda all right so what are the factors that affects it.

(Refer Slide Time: 36:20)



So, first is the roughness and another is the dielectric property alright. So, the rule of thumb is very simple that the wavelength the depth of penetration is generally limited to the maximum 1 lambda or the 1 wavelength of the signal.

(Refer Slide Time: 36:37)

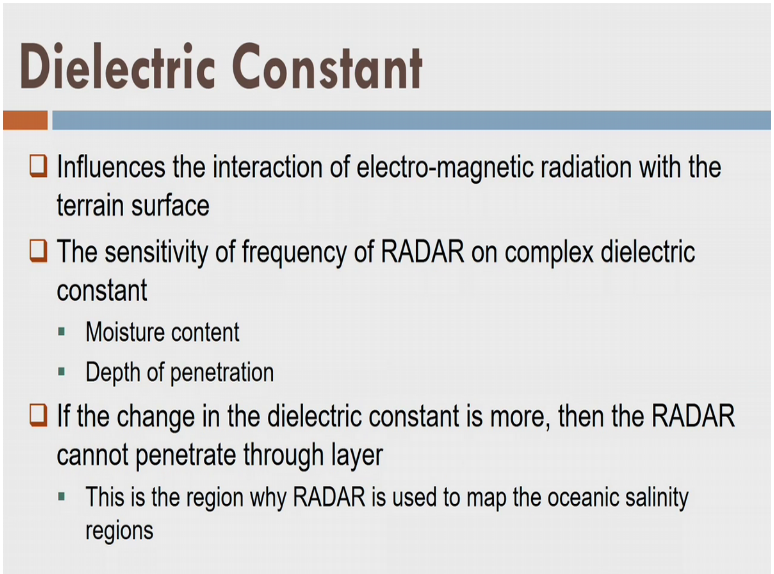


Now, you can see that there is a RADAR pulse and it is interacting or it is transmitting through air and it is interacting here with the surface ok. And it is nothing but the wind blown sand and here this is the red sandy soil here.

So, what happens is it will be refracting here like this as well as reflecting here like this all right. From this level again we can see it is reflected back and finally, at this point it is reflected in all the directions. So, this is what we call surface scattering here ok. So, this is we are showing the effect of RADAR penetration.

So, RADAR is penetrating from here up to this layer and so on up to this layer. This layer is non permeable or we can say for the microwave this surface is very very hard or least or it does not allow the signal to pass through, and as a result it is reflecting it back.

(Refer Slide Time: 37:33)

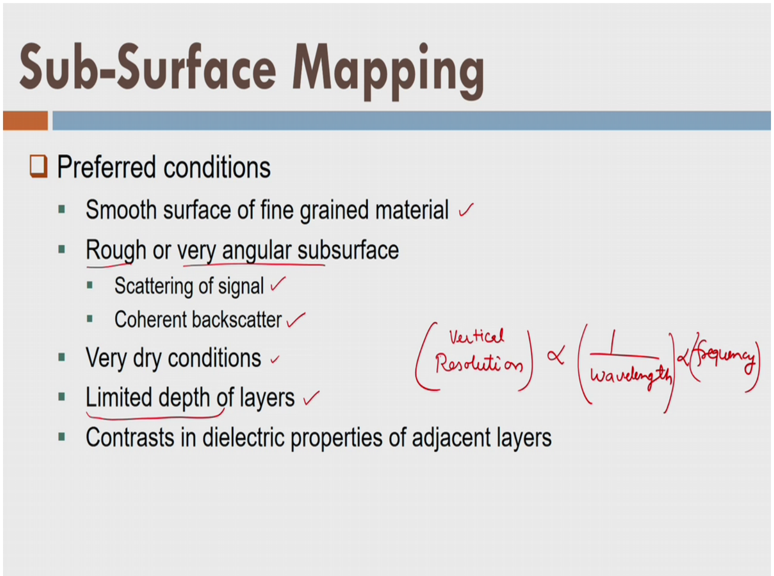


Now, let us come to the dielectric constant it; basically the signal penetration is influenced by the dielectric constant or basically it decides the interaction of the electromagnetic radiation with the terrain surface the sensitivity of the frequency of RADAR on complex dielectric constant is it depends on the moisture content of the surface as well as the depth of penetration. So, if the change in their dielectric constant is more than what happens RADAR cannot penetrate through the layer or if there are layers arranged or stacked vertically, what happens is when signal comes, and it start interacting it will start penetrating into the layers.

However, if the change in the dielectric constant is very high what will happen the RADAR signal will not penetrate through the surface and that is the key here ok. So, there are 2 perspective we should consider. Now, one is let us say there is some very highly conducting material and below that material there is a non conducting material, what will happen? Through that conducting material RADAR signal will pass and from highly non conductive material it will be reflected back.

So, surface which is lying below the highly conductive material can be mapped; that means, sea surface can be mapped easily because the sea water is saline and it allows the penetration of the signal through it alright. But the sea surface which is very hard and non conductive it does not allow, and as a result we can map the sea surface which is quite below or which is much below than much lower than the top sea surface, alright. That is the worst first application because of the dielectric property of the material.

(Refer Slide Time: 39:12)



Now another criteria we can understand or another aspect you can understand that let us say there are some layers which are stacked and these layers are low conductive layer no doubt they will be highly reflecting, but the change in the dielectric constant is also not there. That means, change is not very more alright. What happens is RADAR signal will penetrate and it will be reflected it will further penetrate and it will be reflected back according to the dialectic characteristics of different-different layers all right.

So, this is another application so what are the preferred conditions? Now the surface should consist of the smooth as well as fine grained material ok. Where the rough surface is surfaces should be very very angular; that means, highly reflecting.

So, that is scattering of signals should happen and coherent backscatter should also happen alright. One more condition we need here that the material should be dry; that means, there should not be any moisture content ok, but we have some limitation here as we told that the depth of penetration is basically decided or rathers maximum equal to 1 lambda or 1 value of the lambda.

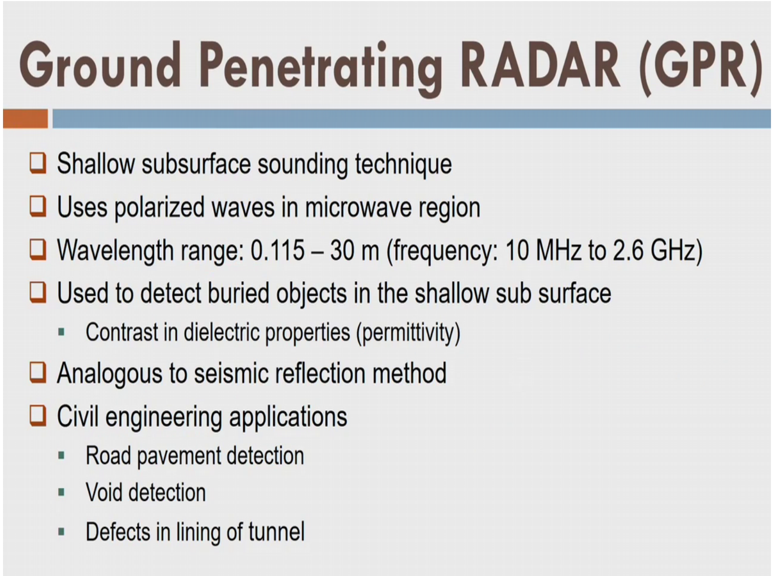
So, that we can penetrate through the limited depth, one more aspect I would like to tell you that the resolution is or the vertical resolution is inversely proportional to the wavelength, or proportional to the frequency. So, what is the mean, what does it mean? The meaning is very simple that if I take the higher frequency of my signal it will penetrate less, but at the same time it will give you very high this resolution vertical resolution.

Now, if I want the deep penetration I should take higher wavelength, but I should not expect higher resolution. So, what is the consequence of that ok; the consequence is very simple let us say there is some artificial or let us say there is some archaeological artifacts under some buried layers, what will happen? Because of that if the artifacts are let us some palace big palace of let us say 200 years old or 2000 years old. We need to have the depth penetration; that means we want to know up to what depth the palace is there or glide. So, once we determine the depth of the palace which is quite some couple of feets.

Now, what happens is in that case we need some wavelength of higher value. So, that it can penetrate through the ground surface alright. Later on once we determine what is the extent of the this archaeological site you want to know what are the small small features for example, earthen pots or some stone pots, what they used to do or the earlier cultures what kind of pots or jewelries or some kind of features were used by the those cultures. In order to determine such small features, I need to use some frequency or the higher frequency or lower wavelength.

In that case what will happen, you will be able to we will be able to detect the small features also right. So, in that case we do not expect that to detect the features at very large depth. However, we try to detect the features with high resolution all right. Finally, the layers should also have these some changes or the variation in the dielectric properties. That means adjacent layers which was tacked one below another should have some variation in the dielectric property alright.

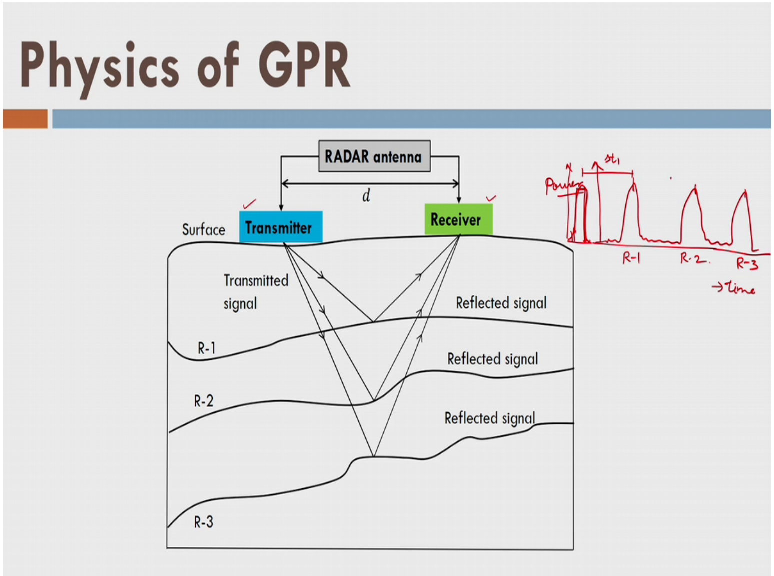
(Refer Slide Time: 42:46)



Now, the application of this thing is my GPR what we call ground penetrating RADAR and that is very important and very popular one and that is why we have included here ok. So, it is used for the shallow subsurface sounding it is it uses the basically polarized waves in the microwave reason and the range is this much in the frequency in the wavelength. And in the frequency it is 10 megahertz to 2.6 gigahertz ok, what next? It is used to detect the buried objects in the shallow subsurface zone. When there is a contrast in the dielectric properties or what you call this is a permittivity is there.

It is just like seismic reflection method and what are the fundamental applications in civil engineering. We want to detect my road pavement we want to detect the voids and we want to detect and the voids in the lining of the tunnel alright. So, I can use the subsurface investigation by the GPR.

(Refer Slide Time: 43:45)



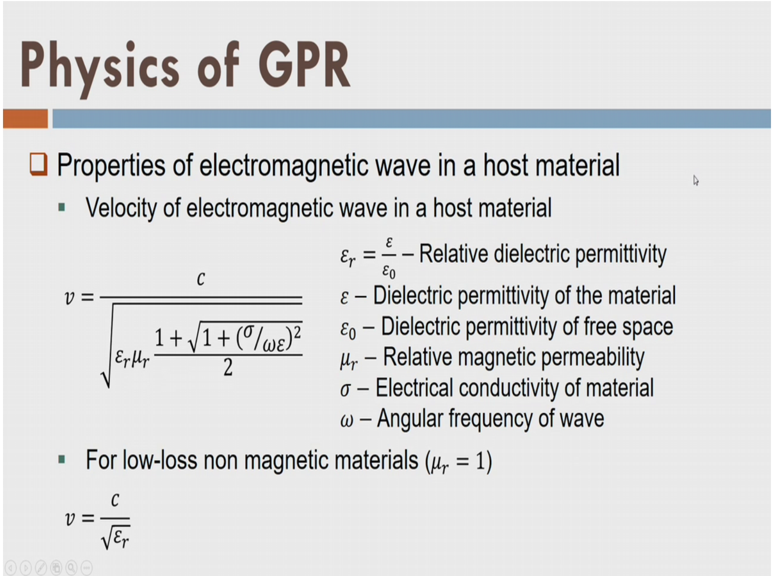
So, let us see what is the simple principle of GPR, GPR here is let us say there are 3 reflecting surfaces R 1 R 2 R 3, which means all 3 layers are low conductive material as well as they are highly reflecting, they do not have the any moisture so I assume all ideal conditions.

And now we have a RADAR antenna which consists of transmitter here and the receiver here. So, we place the transmitter and receiver at distance D on the ground surface. Now let us say this is my distance D ok. From the transmitter we send we transmit some energy at the same time. So, all these 3 signals are now propagating towards the different layers ok, what happens is they will be reflected back at different-different time like this. And by moving the time of flight or the time from transmitter to receiver all right I can measure the depth alright.

So, how to do that, right? I hope that you got the principle because different layers that are at different depth as a result a different layer has different characters of the material, and so they will take different time to reflect back, but a general idea is the lower the layer it will take more time to reflect back. And as a result receiver will have some kind of multiple response after transmission. So, at my receiver I will have some kind of response like this, like this, like this for 3 layers; let us say R 1 R 2 and R 3 on the timescale. This is my time here and as well this is the power of the signal here.

So now I can find out these times or if this is my somewhere transmitted signal which could be like this alright. Now I can say that this is my time delta t 1 delta t 2 and so on.

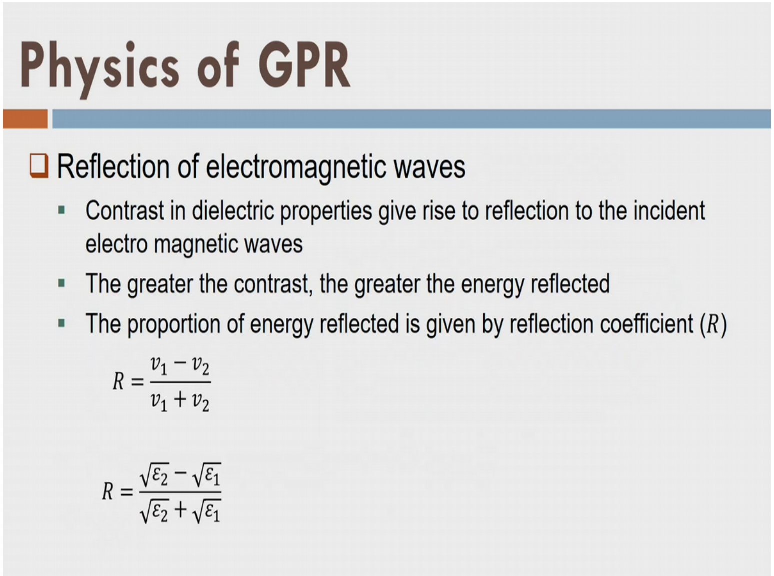
(Refer Slide Time: 45:45)



Now how do you use the electromagnetic property of the material or what we call host material ok? The velocity throughout the material of the microwave pulse is given by c is my speed of the light and these are the electromagnetic properties all right, but in case of low conductive material this factor is 0, all right and permittivity is equal to 1 here fine.

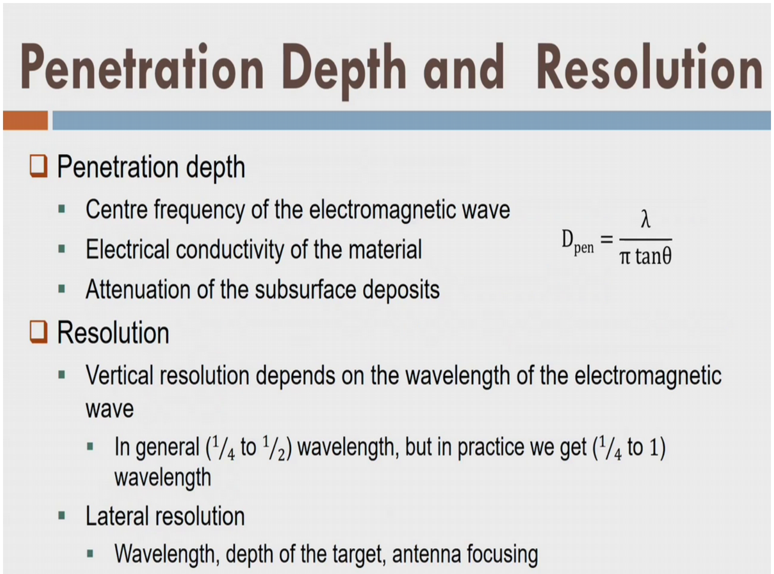
So, I say that in case of low loss and non magnetic material in case of non magnetic materials mu is equal to 1 and low loss material this quantity is equal to 0 fine. What happens is ultimately we remain with this term where is my relative dielectric permittivity and where epsilon and epsilon 0 are the dielectric permittivity of the free space and the material alright. So now, we have a very small formula for the speed of the microwave throughout the material ok.

(Refer Slide Time: 46:47)



So, with this speed the microwave pulse width travel and it will be reflected back alright. So now what happens is because of the contrast I will have different-different speeds. So, we can define a reflection coefficient R like this; that means, if there are 2 layers one layer has v 1 speed and another has v 2 speed. So, I can define this R here and that will tell me the electromagnetic property of the material which is underlying in the surface.

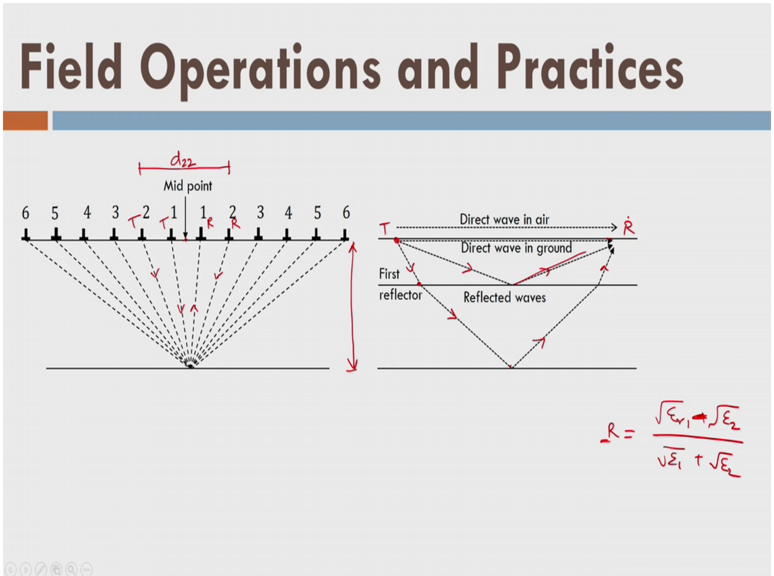
(Refer Slide Time: 47:21)



Now, we need to understand what is the penetration depth remember; we said that the maximum we get the lambda depth penetration depth repetition up to lambda. However, it is given like this all right fine.

So, in general we observe that we get one 4th to 1 wavelength, but in practice we get up to 1 4th to 1 ok. So, what is my vertical resolution here basically it depends on the wavelength and the vertical resolution is my up to 1 4th to 1 half wavelength, what is the lateral resolution it is depends on the wavelength, depth of the target and the antenna focusing all right.

(Refer Slide Time: 48:00)



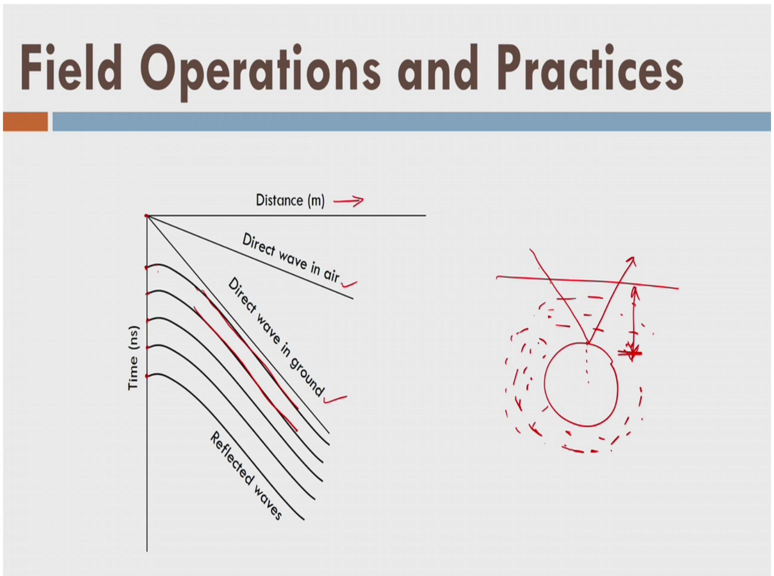
Now, let us see a simple field operation how to conduct this thing, because question is that how to find out this factor right? We have given like say this one, this one divided by this 1 plus this one is my reflective conduct coefficient like this ok.

Now, you can see there is something called common midpoint method wherein the midpoint around the midpoint we first put our transmitter here and receiver here. And we perform some operation where through this layer energy transmitted and deflect is like that. Similarly, then we shift our transmitter to point 2 and reflector to point 2. And again we perform the same operation and we repeat this operation for many many points as we go away from the midpoint.

Now, from the field we know this distance between the receiver and the let us say D 2 2, it is my distance between the transmitter and the receiver when they are at position 2 alright. So, by measuring these distances we know; what is the horizontal distance between the 2 points, transmitter and receiver. And we also know that this material is same. So, when we have performing multiple observations what will happen we will write this equation multiple times and so we first receive the direct wave in the air every time.

The second will receive direct wave in the ground; that means, wave is from transmitter to receiver it is coming along the ground. And then we will receive the reflected waves from here to here. And these waves will be reflecting here a refracting first going here and again reflecting back here. So, we will then we get the written response at different-different times alright.

(Refer Slide Time: 49:44)



We can see here this thing that as we grow in the distance the between the transmitter and receiver, what happens? First we receive the direct waves and as we are increasing the distance the direct wave also taking the time and that is why this curve is there all right.

Now, in the ground it is taking more time and the more slope, but if you look here carefully. If there is no distance, but; that means, my transmitter and receiver both are at the same point what, will happen? Each wave will take minimum times from different-

different it will take will take more time at the same. So, it depends on which layer it is touching. So, this particular curve where it is touching or from which layer it is coming similarly like that.

Now, as we show that as we see that if I increase the distance between the transmitter and receiver what will happen? So, distance will keep on increasing with time all right and using this information of the slope of these lines which is nothing but the speed ok. I can find out the magnetic the material property alright.

And using those, so I basically I do I correlate these curves or the velocity curves with the material property and I can find out the what are the characteristics of the material or for example, if there is any conflict or is there any the an anomaly, what will happen? Let us say there is a buried pipe inside a layer here like this ok.

What will happen when: this is the same property here, this material but the moment it comes here it will be reflected back, and it will have different behavior here. And immediately in the image we can find out the change in the speed, and we can immediately say that at this depth the there is some pipeline is there alright, because this material is completely same here.

And now we can also find out is there any flaw in the pipeline structure. So, we can detect the location of the flaw in the pipeline also. So, this is the application of the ground penetrating RADAR which is purely based on the dialectic or the electromagnetic material property ok.

So, with this thing we finish this lecture, and this is the last lecture of this module. And so, we completed our module 8 on the RADAR.

Thank you.