Computational Electromagentics and Applications
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Lecture No 33
Finite Volume Time Domain Method-III

Now we will go forward with the some of the applications. Now we will go forward with the sum of the applications before we begin let's recap on one important thing to notice. We said that we are getting uniaxial PML which is pretty generalise for all directions as you can see in the slide.

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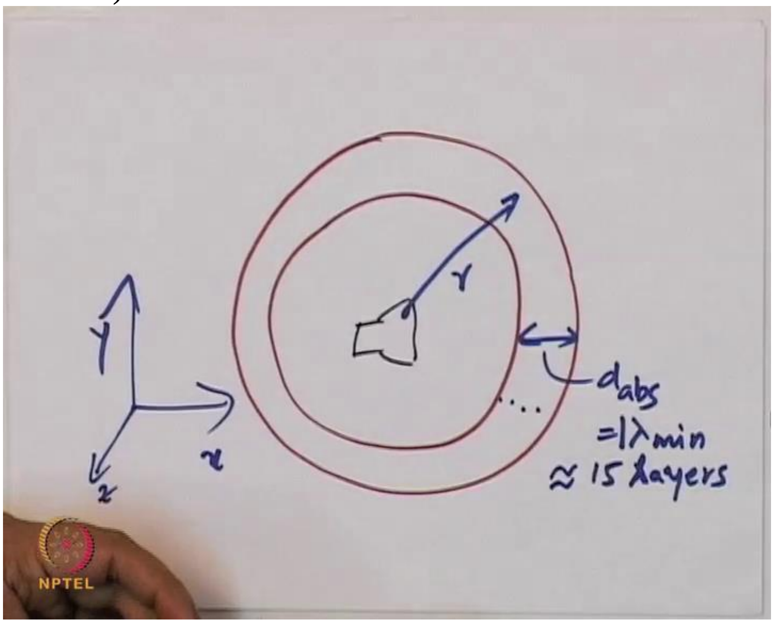

For most of the practical application will keep the thickness of the absorber as one Lambda which is roughly As a rule of thumb 15 layers of triangles settings and we are not worried about any direction like x or y. So we are able to get generalized formulation that will enable us to model any particular thing so if you wanted to do an antenna which is sitting here this is perfect so this is what we are going to see in the next flights as an application.

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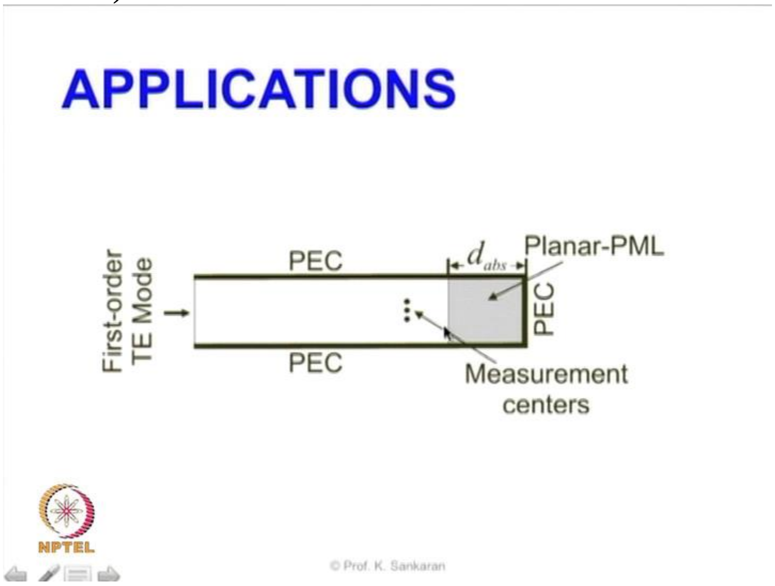

to begin with we will start with waveguide problem send a waveguide problem we are using simple PML truncation and the measurement points are here the measurement points are basically a points to evaluate what is the reflection how we are doing that is something important to know so what we are doing is for reference solution you are making this very large waveguide so we are not seeing any reflections coming back so it's a very large waveguide and we are able to subtract the reflection is coming from here from a very large waveguide to get the reflection feel that is getting reflected we are using a first order Te mode the boundary conditions for the waveguide are PEC on the either side we are truncating the PML using also PEC and as we said we have Dab x which is the thickness of the absorber.

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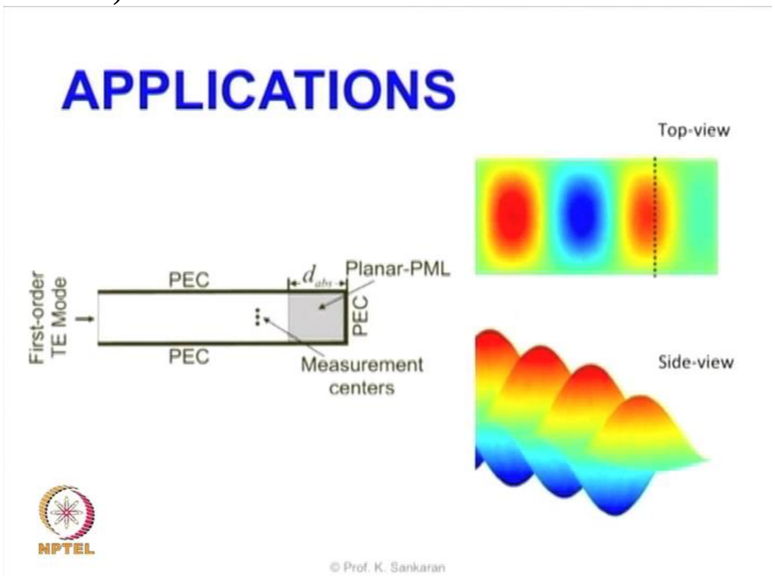

so this will with this geometry you can see this is how the wave truncation looks for practical waveguide simulation so this is the top view and you can see the PML Layer is starting from here and you are able to see what is happening in the PML layer and this is a side view the operation is very much as I expected when you see there is not much reflection from the PEC condition because sometimes when you have PEC wrongly coded you might see the most will not be going in this Manna you might have certain errors curious errors either numerical errors so you know when the boundary conditions are given properly and you can see how the waveguide is being truncated using a simple PML case

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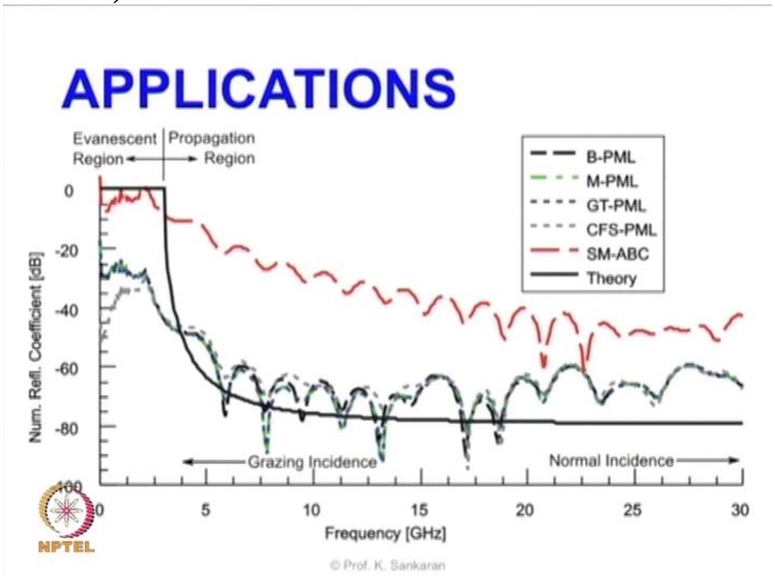

what we are seeing here is the result of this truncation something particular about this it’s a graph that tells us quite a lot of information these information are very important for many scientist or engineers who are using numerical method because this tells what is a computational cost aspect how much trade off we have to do what are the reflections in things of that sort I’m going to explain I am going to take time to explain the meaning of this particular graph using the case of the truncation what is or no so what is happening here as you can see there is on the x-axis you see that the frequency is increasing so when the frequency is increasing the value of Lambda is going to decrease.

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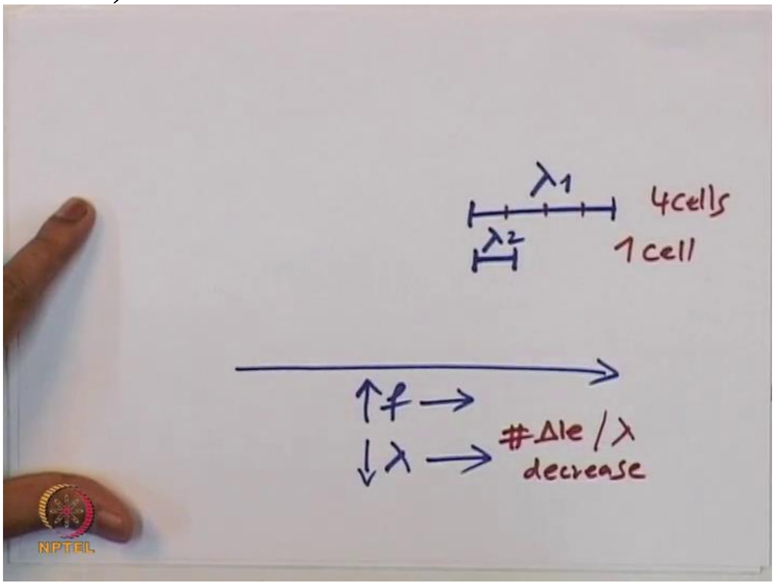

so let’s discuss this using the slide here so what we see is when we have the frequency is increasing on point axis so frequency is increasing so we also see that the Lambda value so frequency is going to increase in this direction and I’m the value is going to decrease in this direction so that means let’s say we have a Lambda is equal to a particular length when we are increasing the frequency the Lambda values are going to be lesser and lesser so this is the value of Lambda so that means for a particular increase what is happening is the number of cells that are going to sit with in this Lambda so let’s take a simple example where we say so this is Lambda 1 this is Lambda 2.

Let’s say that we are having in the first case 1,2,3 there are 4 cells for this Lambda but in the case of Lambda equal to 2 there is only one cell approximately for the same discretisation for this Lambda it will see send this case there are 4 cells and here there is only one cell so from the discussion point of you from the special discretisation point of view increasing the frequency is going to create a poor performance because the lambdas are going to become smaller and smaller accordingly the number of cells so triangles in a case of a 2D is number of cells 10 Lambda is going to decrease so you expect as you increase the frequency the performance should deteriorate so that is one thing

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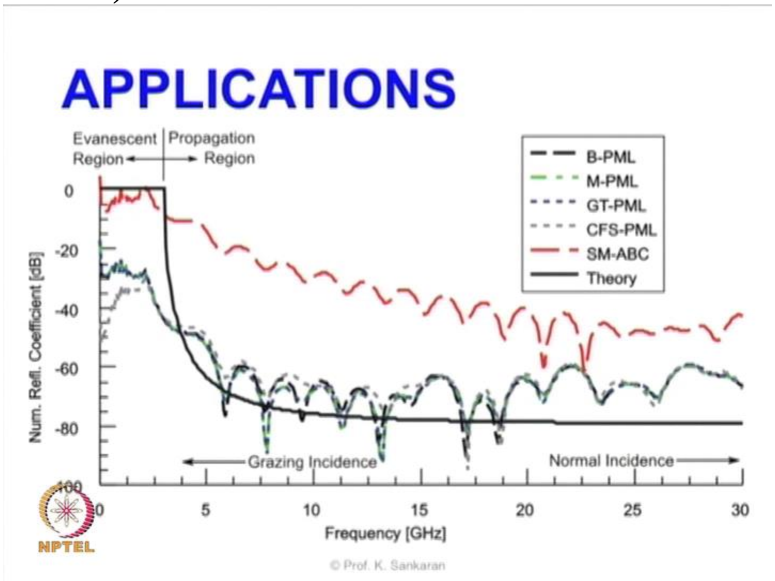

But if you seen the slide again we are increasing the frequency what we are computing here is a numerical reflection invisible so we're taking log a natural logarithm and where computing it in DB what you are saying here is when we are increasing the frequency the black line is a line for theory so theoretically you should see how the reflection should decrease and this is the performance of the Silver Muller boundary condition which is one of the state of the art before PML was used this is the boundary condition that they used and there are quite a lot of PML Benergen PML Maxwellian PML.

And all these are the types which we discussed before what you are saying here is as we increase the frequency the performance of the boundary condition whether it is a Benergen PML or whether it is a uniaxial PML whatever it is the performance is improving and also for the case of silver Muller boundary condition the performance is improving which is contrary to the case of Silver Muller as a number of discretisation becoming Coarser and coarser there should be more numerical error but something else is happening what is that that is something we need to know what is happening here is when we are increasing the frequency when we are talking about a mode ;mode is basically superposition of two wave that are going in opposite direction and meeting them so let me explain here in the slide.

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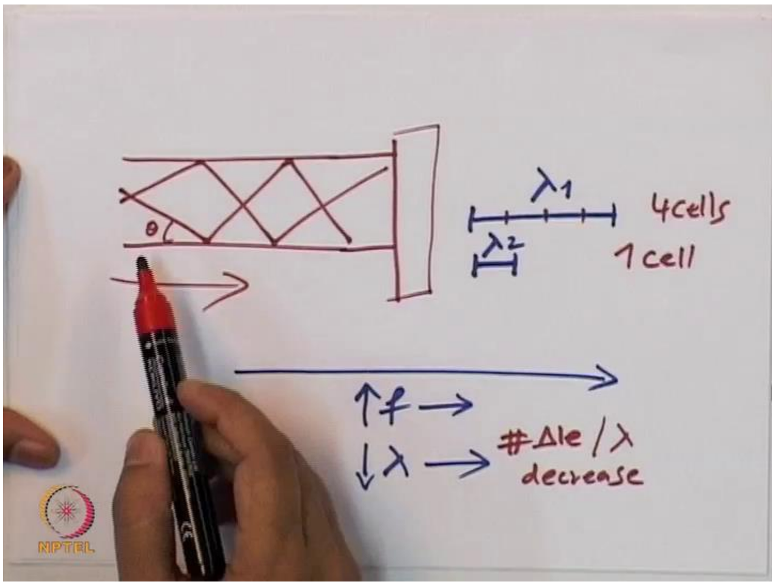

So we are talking about more that is propagating in this direction what is happening is your basically having so these are the two ways you can think of them as plane waves going in this direction and then they are going in this direction This Is The theta so this is the angle of incidence so when you computing what is happening here so this is a theta this is angle which it is going to in pinch the PML Layer so here is where the PM is sitting so what you are talking about his as we increase the frequency we are coming closer and closer 2 normal incidence.

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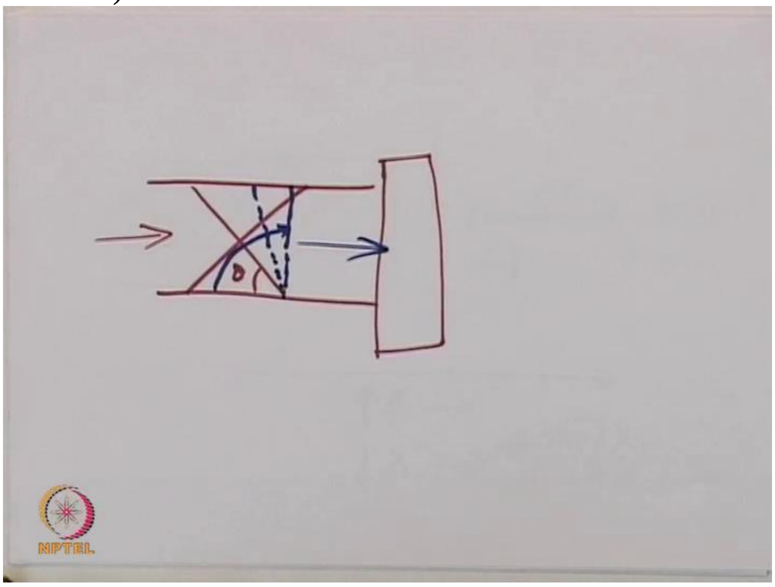

So what we see is when theta is becoming 90 so we said that this is a value of theta and we said this is theta this is a direction in which we are succeed in it this is the direction in which we are truncating it so when theta becomes closer and closer 1 frequency is increasing theta becomes closer and closer two plane wave so what is happening here is when frequency is increasing this theta values going to change so theta is going to increase and when frequency is very very high you are coming almost like a plane wave so in this case theta will be 90 and the direction will be a normal incidence so this you can see also in the previous slide

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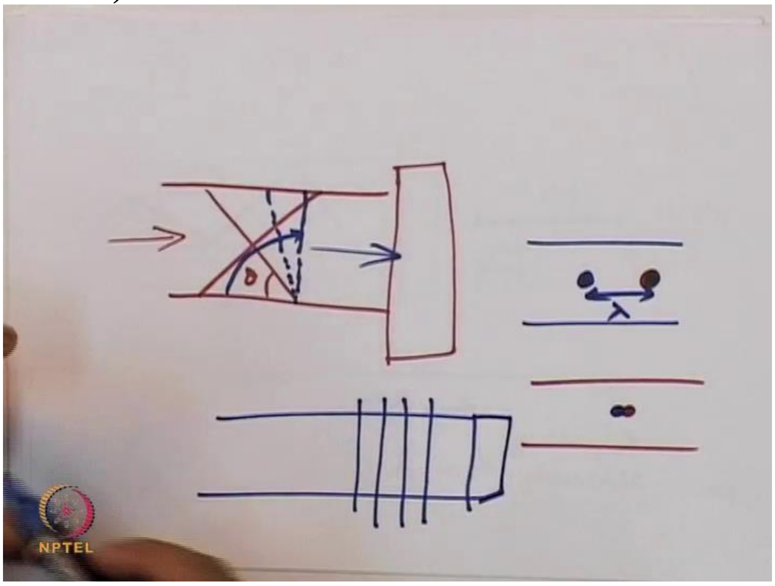

When theta is increasing the distance between the red and the blue will become narrower and narrower let's say for now so this is the distance between blue and red say this is red this is blue so what is happening is when theta is increasing this one will be coming closer and closer so this will be the definition of Lambda and is Lambda is going to go smaller and smaller so what you see is when frequency is quite high you will almost see them like a plane wave there will be like a plane wave going and hitting the PML surface.

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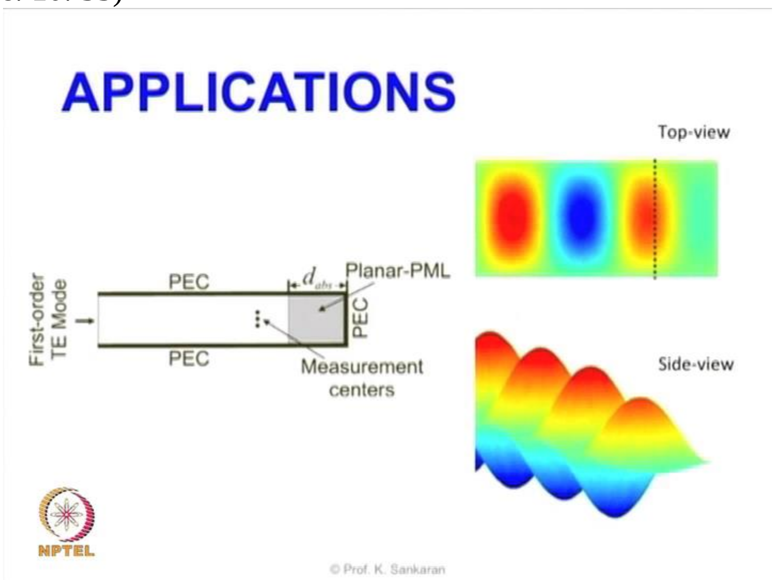

And that is what is happening in the case of this example when I am going to increase the the frequency what I will have is pretty much like a plane wave

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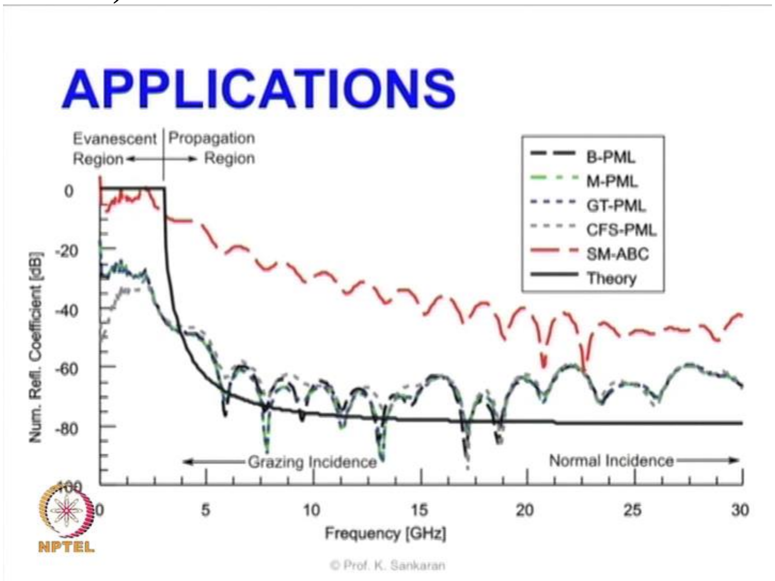

And this is the reason why although the Lambda is decreasing and special discretisation is going to be poor when I say poor we are having less number of layers at lamda minimum still the PML and silver Muller boundary condition is performing better because we are coming towards the normal incidence as a frequency is increasing the exact opposite is going to happen at the lower frequencies so the frequency is becoming less and less irrespective of the fact that there is going to be more number of cells per wavelength we see a poor performance of the PML and also the Silver Muller boundary conditions.

So we see that as we increase in Lambda or as we decrease in frequency the performance is deteriorating and this is the importance and also the uniqueness of this particular graph as you can see this is a propagating mod where we are talking about there is some I'm innocent region which we are not very much interested we are interested in the propagation region and we see that this is very much going as per the expectation of theoretical value so with this we are able to see couple of important factors and we will go into direct application factor number one is the PML is working fine as expected and we are able to see what is a trade off as as a scientist or an engineer you have to do to make sure that your computational cost versus accuracy is maintained so with this we can also see for any of the plane wave or waveguide truncation Lambda minimum as the thickness of the PML and roughly 10 to 15 cells is quite good and this is what we have seen also in the example we have shown here.

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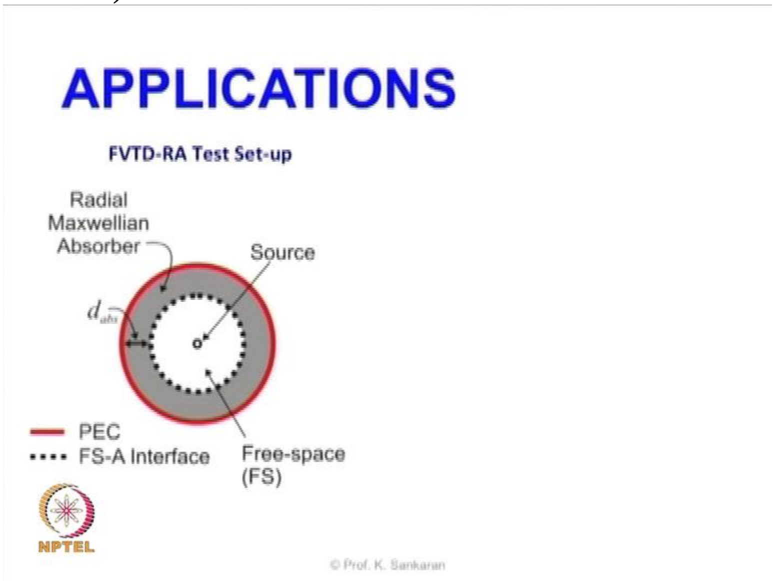

So with this we will go into the next application which is the radial application I discuss the radial application in the previous module where we say that the direction of anisotropy is in the radial application and we are going to see what is the impact of location of source r a scatter so I assume that this point is a source it can very well be a scatter where your plane waves coming in one direction you are kind of truncating in the manner which is shown so again.

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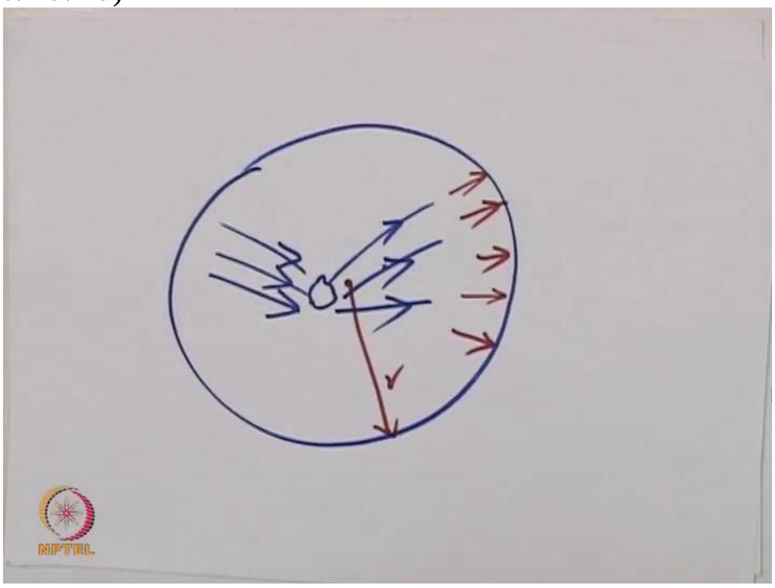

So this particular can be a source or so let's say you have plane wave coming show the position of the source or the scatter is going to be very critical because it is going to change the way in which the radial PML is going to see incoming waves so ideally you want them to be in normal direction which is not possible on most of the application because we can't keep always the source at the middle we can't predict the way in which the wave is coming but we tried to make sure that we are able to have the good compromise in terms of the radius of curvature so this is a radius of curvature we are making the radius of curvature as small as possible all the case of numerical computation and as large as possible so that we can reduce the number of numerical error or the value of the numerical error

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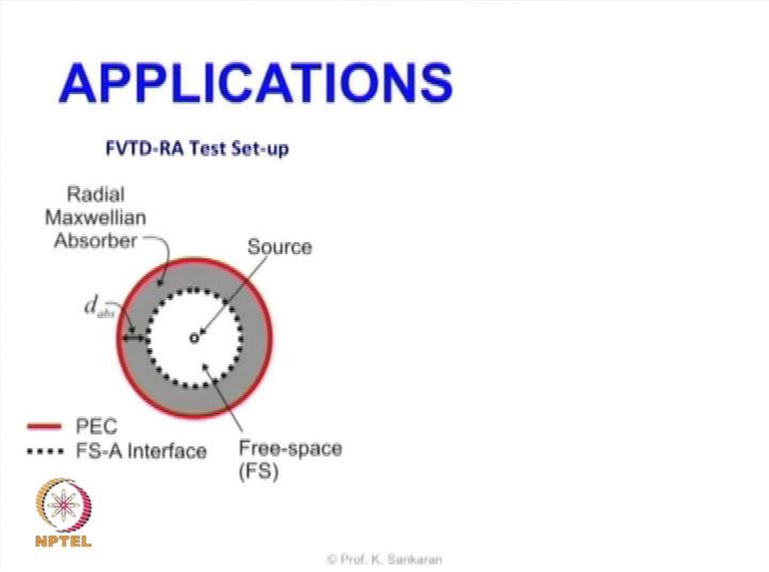

So this we will see here when I keep the source exactly at the centre as you can see in the slides what is going to happen so when the sources exactly at the centre all the points are going to be more or less in the normal incidence

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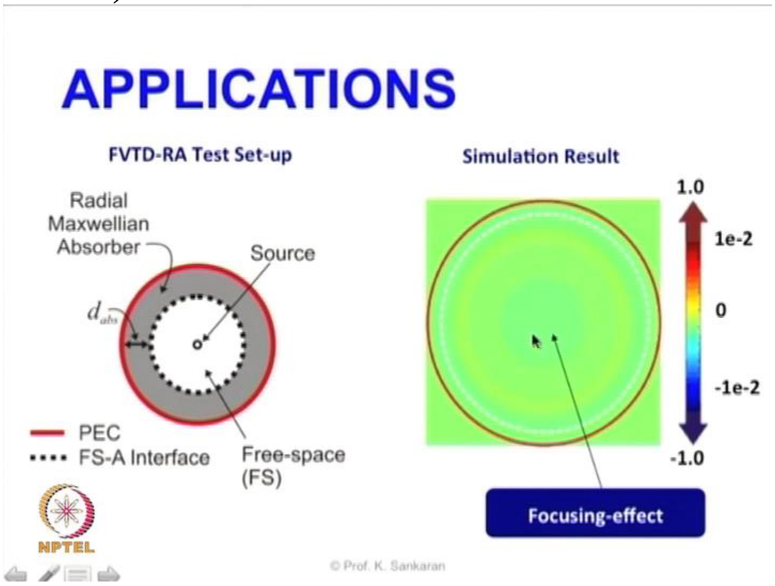

So it should be the best case scenario where we will see we are having aPML radial PML sitting here and we are truncating using PEC so the red line is a PEC and the source is let's say a kind of a sine modulated co axial flux what you see here is the pearls is going and you see that some amount of reflection is coming and then its focusing exactly at the centre and this is us as expected because this is like a radial mirror which is putting all the reflected is exactly at the centre.

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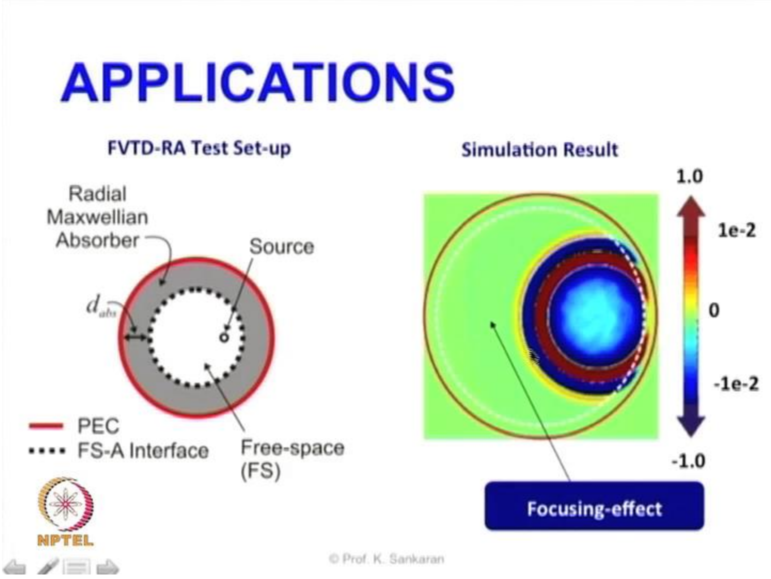

And let's see if I can change this source position elsewhere so instead of putting it at the centre I am making it go on the point as it is shown here so for most of the points which are exactly at the opposite it will be still normal incidence but you we'll see this. And this. It is no longer normal incidence it is kind of a grazing incidence so accordingly we will see the performance of the PML will be slightly worse then the initial case but still good enough for most of the practical application and you will see the focusing effect has moved from the centre as expected to the exact mirror. Which is on the other side so with this we are able to see how the radial PML is functioning

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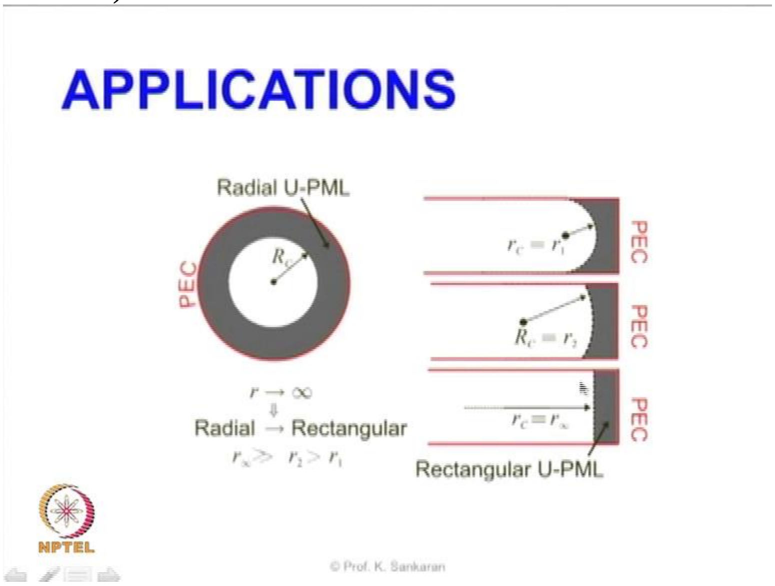

and we will also see now what is the role of the radius of curvature as I told you has a radius of curvature is going towards infinity we will be able to go more or less like a plane rectangular PML but in the case of a real truncation also on the spherical truncation it will be not Infinity it will be finite value R1 and R2 so what you are interested is what is going to be the impact what is going to be the ideal or rule of thumb value for choosing what should be the radius of curvature and we will see how this is going to impact with this example I have shown here

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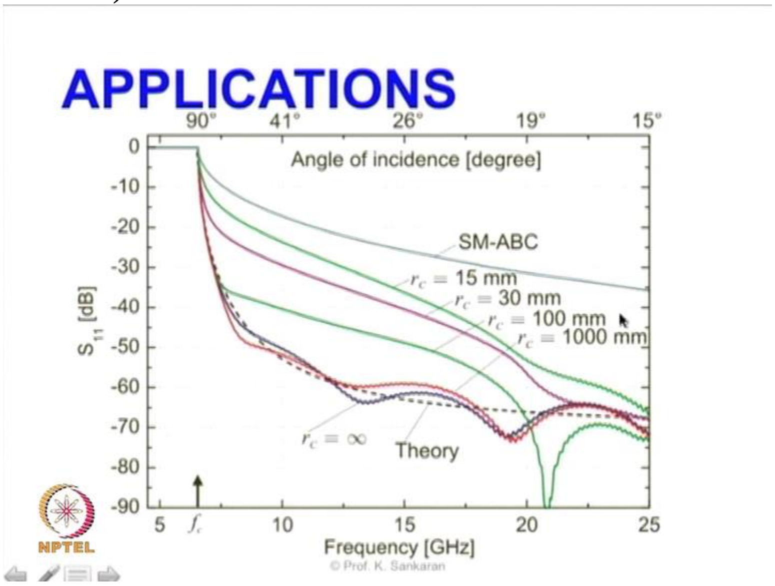

So this is the example where we are able to compute the scattering parameter the s 11 of example and we are able to see as the frequency is increasing we are able to see that so this is example of waveguide truncation where I have kept the measurement points as I have mentioned in the previous case and I am truncating with different radius of curvature show the Silver Muller boundary condition is behaving as expected what are then the other possible cases of radial truncation radial PML.

As you can see for any case the radial PML is better than the Silver Muller boundary condition the question is can be go closer and closer to theoretical value yes we can as we increase the radius of curvature bigger and bigger we see that our pm l performance is becoming better and better you might ask what are the ripples these ripples are coming because of the reflected field and they are pretty much in a periodic manner as you can see as a radius of curvature is changing the ripple position is also going to change or the kind of effect that is coming from resonance is also going to change.

When I have RC the radius of curvature equal to 100 you can see that the resonance is somewhere in the 2021 gigahertz region and I am increasing it to are equal to 1000 you see that it’s moving away and are equal to infinity is pretty much the planar truncation and you can see that the resonance is also are the kind of the dips you can see is also moving away so this shows that the PML is functioning as expected and it also shows that we are able to make a good informed decision on what should be our radius of curvature.

If you are saying that what we are having is minus 40 DB and we are interested in let’s say 20 gigahertz application you can pretty much go with that RC equal to 15 mm as you can see here but if you are saying that you want to have measurements accuracy of minus 60 DB and then you have to probably go for RC equal to 100 and you are interested in frequencies let’s say 10,11 or 12 gigahertz so this is a way in which you can understand the performance of the PML and the numerical accuracy or the numerical error that you can expect from the PML and make an informed decision based on that so with this we will stop here and dinner next slides we will discuss about examples related to horn antenna and also other more advanced antennas, Thank you!