Computational Electromagentics and Applications
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Lecture No 34
Finite Volume Time Domain Method-III

Will now focus on the applications related to Antennas and we will show some examples of simple Antennas and then will also do some more complicated Antennas in this case what we are doing now is we will start with a simple horn antenna

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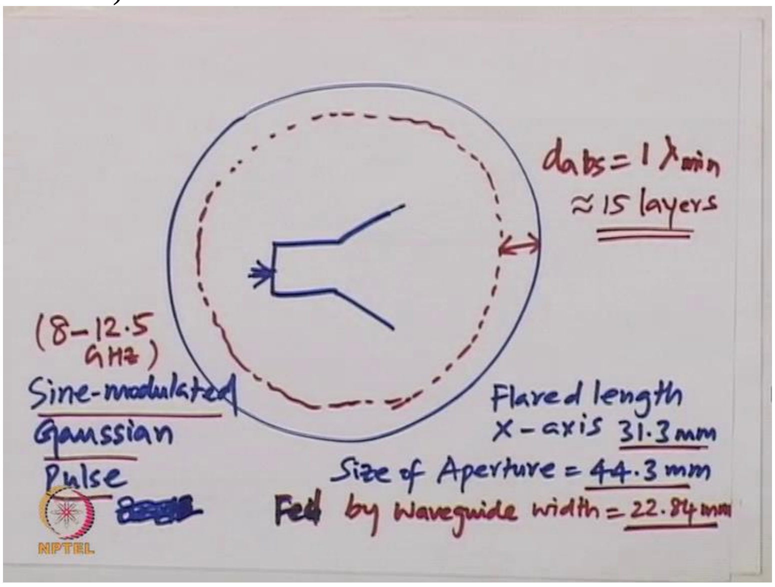

Which is going to be truncated in a radial manner so the important thing is the Antennas flair direction is roughly in the x-axis show the along x axis is roughly 31.3 mm and we are talking about the aperture this one the aperture size so size of aperture is 44.3 mm so the antenna is going to be fat in this direction so this is a source direction it’s going to be fed by a waveguide so it is going to be fed by a waveguide and the waveguide with this 22.84 mm so these are the important things in terms of the cases so the floor length along the x-axis is 31.3 mm now we are talking about an antenna aperture size roughly 44.3 mm and it’s fed by a waveguide with which is 22.84 mm.

So what we are using is we are using our kind of a sign modulated so sign modulated Gaussian pulse and whose bandwidth is roughly between 8 to 12.5 gigahertz so this is the weight of the band it’s going to be a sign modulated Gaussian pulse we are talking about various dimensions year as we discussed in most cases in fact in all cases our thickness of the absorber which is basically so we are talking about this thickness is equal to one Lambda minimum so these are in most of the cases will be roughly 15 layers.

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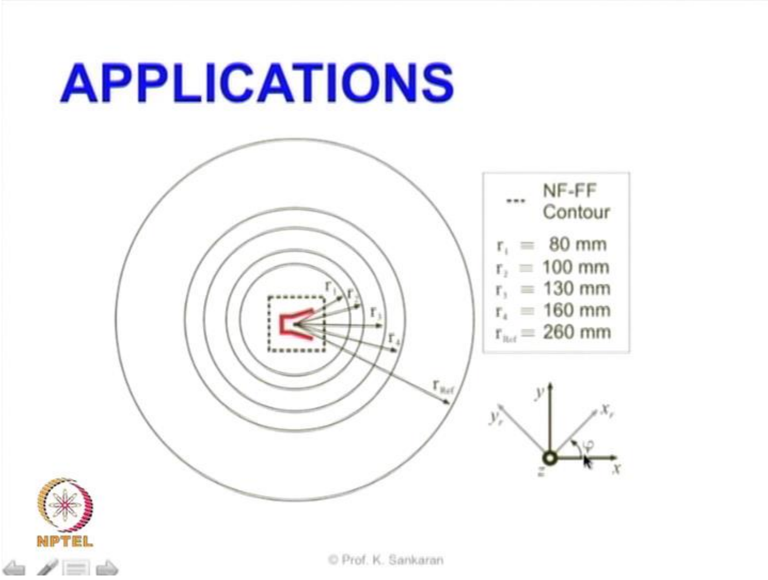

So what I have described here is basic geometry of the problem with this we are able to see what will be the various radius we are talking about and the property of this particular antenna and it's here in red because along the edges we can force certain boundary conditions whether it's pic or we want to be very specific we can also putcertain material parameters but I kept it very simple so so it is basically a kind of waveguide but with the opening here and this thickness I have already said will be the waveguide thickness and aperture area which is also given for some of the practical applications this is accurate.

Because we have taken simple horn antenna geometry and we have tried to do the entire computation so what we are interested is we are able to compute for various radius of curvature and in order to compute the antenna radiation pattern we do a near field too far field Finance phone tour so this is a points along which this is the contour of the Highlands play where we do the near field to far field transformation so this will give us the kind of radiation pattern we are looking for to compare it with the experimental value as well and we can compare various radius of curvature and its impact and we are going to truncate it using the radial bml and the radius of curvature is is given along the radius axis and the angle in which we are doing the transformation is given by the p h i value so locally along each of the cells we might be able to compute what will be the p h i so locally it will be oriented along the x-axis but globally you can have certain transformation as we discussed earlier

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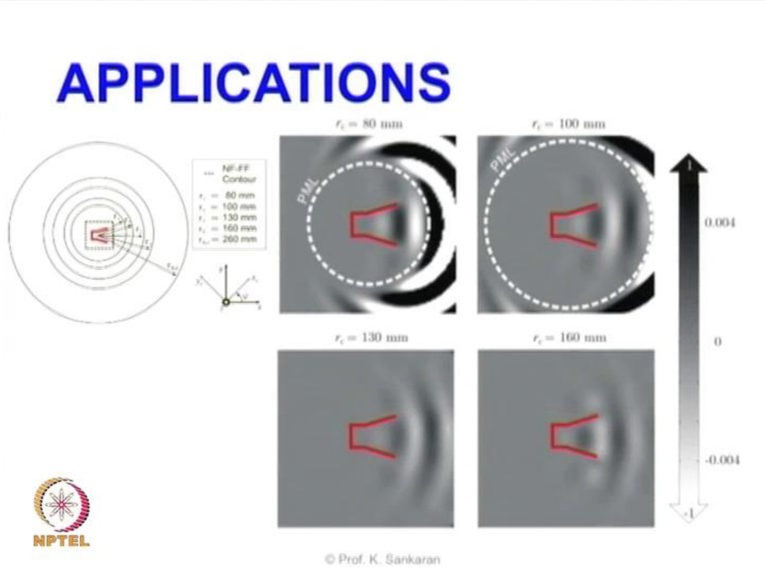

With this we will see what will be the reflected electric field so what your computing here is the reflected electric field the PML layer is starting from here as we discussed and what you see here is is the observed field values so here it is dark circle because the fields are getting absorbed these are the lies in which the losses are there and as I increase the radius of curvature going larger and larger so here the PML starts slightly far away you see again the corners and the outside areas there is an absorbed of field useless absorb feel back side compared to front side because the antenna is oriented in this direction when you increase the radius of curvature you will see that the reflection so you see that these are the reflected fields so here it is very very strong compared to here come back to here and compared to here so what is the meaning of this when we compute the radiation pattern this is what you are going to see here.

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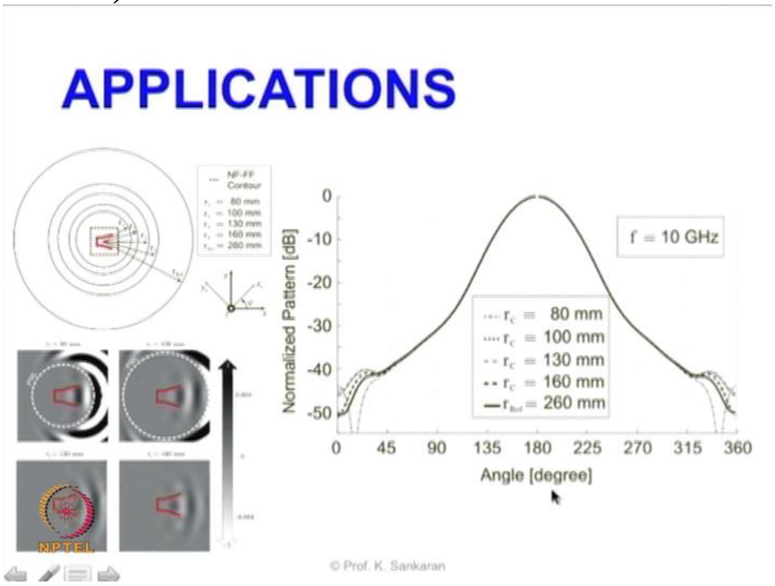

Here you are seeing the normalised radiation pattern represented in decimals you will see the main loop for practical application with are equal to 80 mm you are able to get for the main loop pretty much very accurate calculation you see the influence of the radius of curvature is only noticeable in the side loops you are able to see the influence of various radius of curvature this is expected because the radial absorber as reflections coming from the corners and below 40 DB – 40 DB

So we can see that we are able to see then we are talking about a particular frequency 10 gigahertz we are able to get the mail look pretty accurate compared to the theoretical value so here the theoretical value is basically value of the radius of curvature which is very very large again I should not use the word theoretical value maybe I should say this is for the case where reflection is quite low very low so this is almost like a plane wave normal incidence so you can see that it is confirming very well so we used this as a way because what happens is the numerical results for larger model is used instead of directly using the antenna chamber measurement because due to the limitations of the measurements of the Chambers The low-level back radiations of the horn antenna I not accurately resolved.

So what happens is the low level back radiation in the case of measuring directly from the Chambers is not very good so we are using a numerical result as theoretical value or a value which we have to compute in other words the performance of this radial truncation or radial PML is quite good for most of the practical applications we need and this idea we are still working it on a two dimensional plane where we have taken Z direction as a kind of asymmetrical direction but what you can think of is you can expand this idea 2 a 3 dimensional case so instead of saying it’s a radial only in the xy plane it can be radial in all the Planes so in that case we are going to go into a spherical radial absorber so spherical in the sense it’s going to be 3 dimension so I is the straight forward expansion or extension from a 2D case with certain additional mathematical complexities the mathematical complexities come because we have no longer the Z Axis symmetry we have to compute not only one angle but two angles so this is what we will see in the next slide

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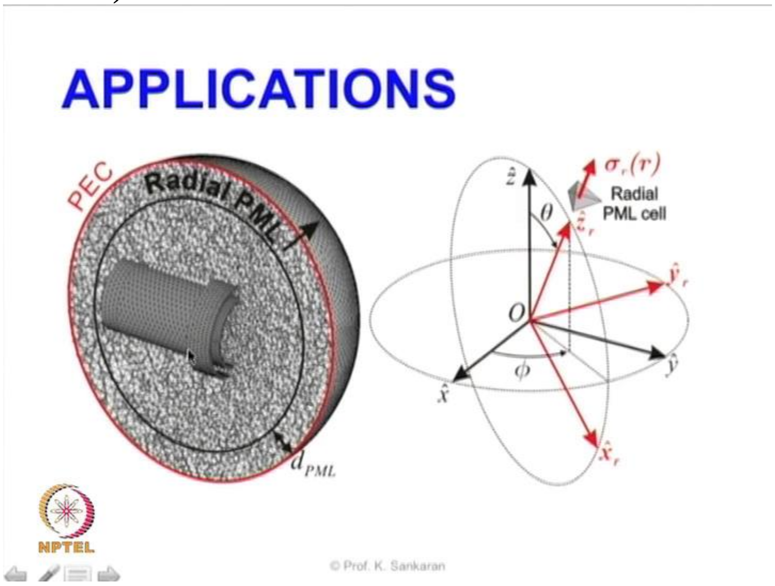

In the case of today we only focus on a particular angle of rotation which is a P H I axis but here I also have the theta so this these two things will give you unique definition of the radial PML because when using these two angles and the radius you can compute what will be the loss function so the loss function is this Sigma function as you can see this example is quite helpful for modelling quite Complex Antennas which are in 3 dimension this example is very simple but we are going to talk about a case here.

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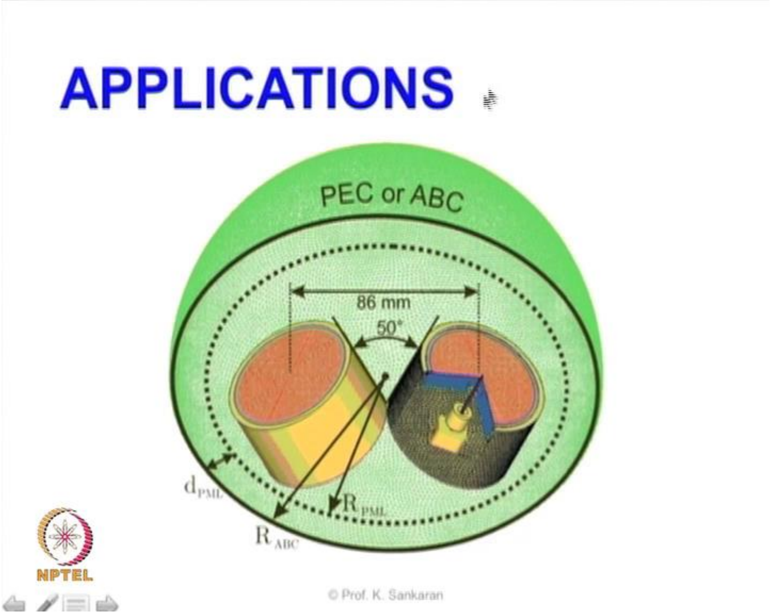

And this case is very very complicated geometry because we have totally two pairs of 26 bindings and these bindings point to 5 mm in thickness so it's very very very very fine bindings and these are archimedean spiral antenna and what we are interested here is we are interested in finding out the coupling between two spiral Antennas 1 antenna will be a radiating antenna and the other antenna will be the reception antenna we are interested in seeing what is a coupling between these two Antennas for scattering problems it's very similar case of the low level coupling you are interested in the reflections because the reflection should be very very low because once the reflection become higher they become dominant source of error for finding out the coupling because the coupling is quite low.

So what we need is an absorbing boundary which is quite good for practical applications until today this has become quite a way to go ahead before having radial PML or a spherical PML what we might do is we might keep the direction or we might keep the direction radial but we will keep the boundary condition quite far away so it means that you are doing too much computation too many cells in between and these cells are kept only because you wanted to reduce the reflection there is no any other reason why you have to have too many cells.

If we keep the boundary condition closer you get so many reflection and this is quite difficult problem to compute because you are interested in coupling which is very very low in terms of a decimal value so any source of reflection coming from the boundary should be avoided to the minimum so in other words you keep them far away so with the help of the radial boundary condition you can bring the boundary closer and closer and what is happening here is we are able to make sure that the reflection is quite low for practical application and what we are interested here is as you can see the value of the reflection is low that is one aspect.

And the other aspect is the geometry itself is too complicated for you to do it on a finite difference or any structured methodologies finite element will do but the commercial Solvers are finite element at the time are when we were trying to solve such problems they were not good enough so we have to go for a one in house coding so that is how we got it but today maybe the computational solvers are good enough but still for any commercial solver a problem of this sort is a challenge because we are talking about the spirals which are quite fine we are talking of 26 windings.

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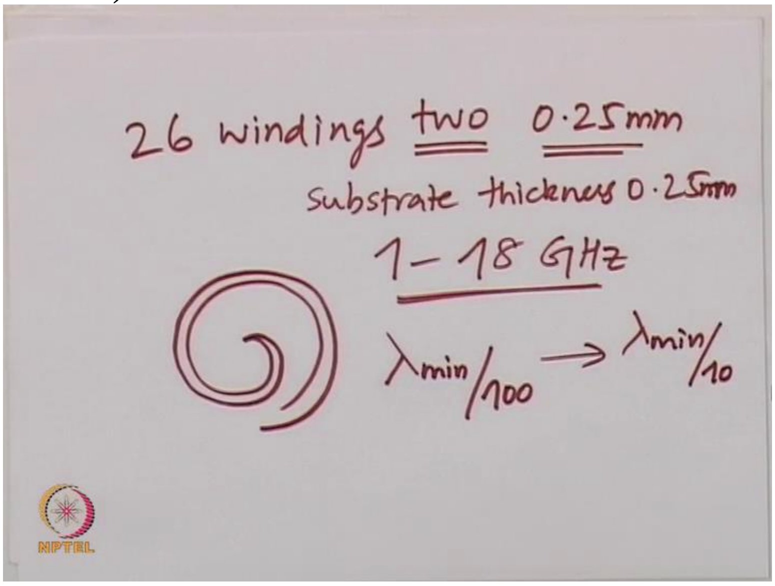

So let me write it down for you to have an idea so we have totally 26 windings so to set of windings and each of the windings the the width is 0.2 5 mm there are 26 bindings but two arms are rotating so these are like something of this sort and thickness of this windings 0.25 mm second thing is the substrate thickness is also 0.25 mm and we are talking about a kind of range of frequency which is operating frequency which is 1 to 18 gigahertz and for most of the applications of this sort we need to go for multi scaling if you remember we discuss about multi scaling in the earlier part so in the case of the Balloons the feed is quite small when we talked about Lambda minimum 100 cells for Lambda 2 so this is what is happening.

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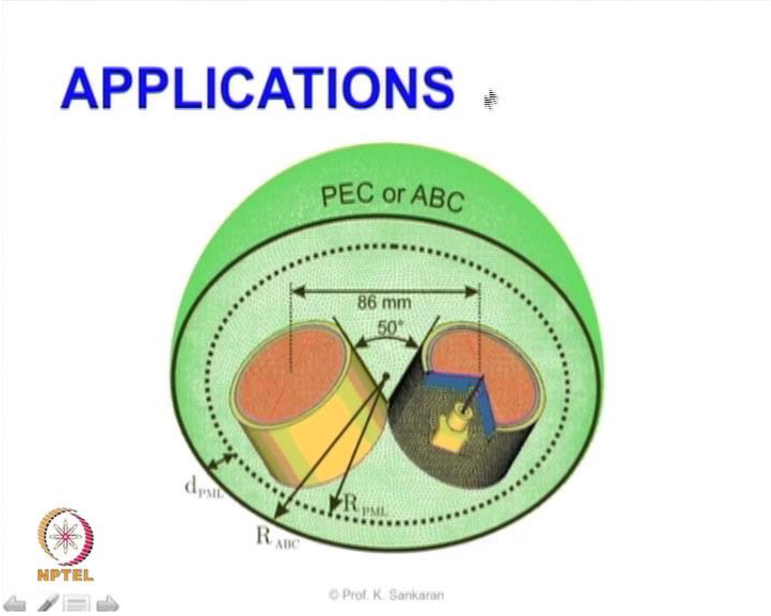

So in the case of the balloon where the feed is there we are talking about very very very fine refinement so we are having 100 cells for Lambda but in outer areas in those Areas where we are just computing for the sake of having the truncation domain far away we can go for Lambda by 10 and with this what you are interested is we are computing the S 21 parameter one of the antenna is excited with the white band pulse of the range with pearls what we have discussed and we are interested in coupling parameter s21 parameters to the second antenna so this is what we are computing and with this problem definition we will see what is happening in the case of the practical simulation

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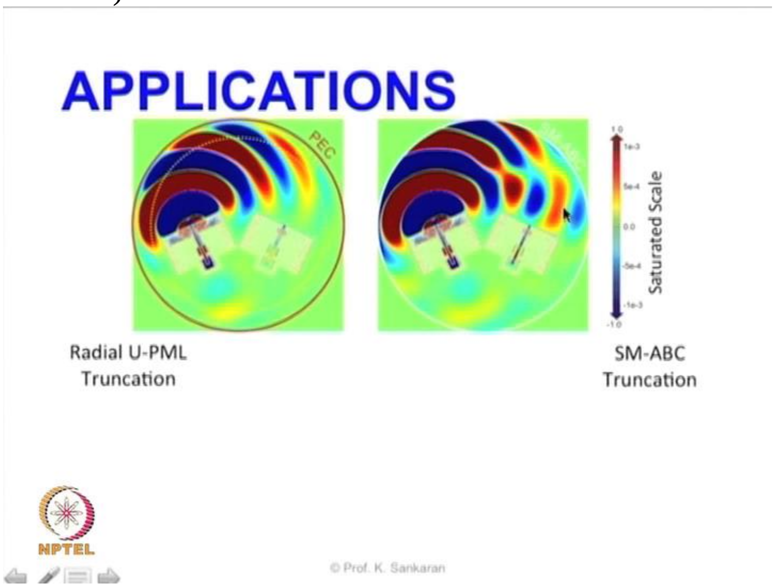

So you see that one of the antenna is excited and other antenna is kind of being coupling is getting coupled here so what we here is basically a silver Muller boundary condition so instead of having a PML I am just using silver Muller boundary condition to show what is a kind of reflection what we see if you want to compute the coupling parameter are the coupling coefficient as 1 anything of this reflection is practically a disaster so you can't computed accurately because there is so much reflection coming from the Silver Muller boundary condition so we need to either put this boundary condition really far away so that the reflection is low or do something using the PML condition so this is where the spherical radial PML come into play.

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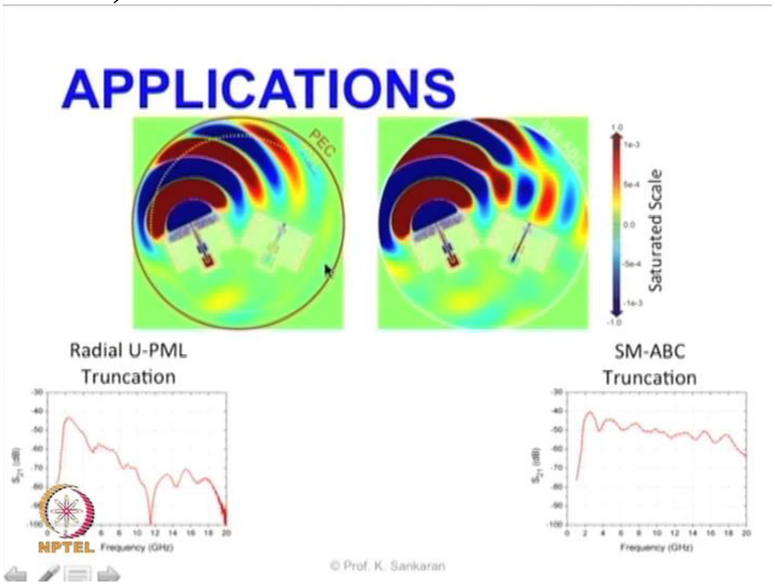

So what we are doing now is your computing the value of the PML so on the left hand side what you see is the domain truncated using a uniaxial spherical PML so as you can see the wave reflection here is different what is happening in the case of silver Muller boundary condition so in the Silver Muller boundary condition we don't have any PML you just have a silver mirror boundary condition and the waves are getting reflected in the case of the uniaxial sperical PML you have a PML sitting right from the point here so you can see slightly a dotted white lines is a starting point of the PML and this is roughly one Lambda roughly 15 cells which we said for the lowest frequency and we're talking about truncating it truncating PML using a PEC there is still reflection coming but we need to know what is this reflection so you can see in the case of the radial PML the s21 parameter is quite different compared to what you can see here in a silver Muller boundary condition those zeros are quite missing here because there is so much reflection here so there is hardly any way you can compute the the s21 parameter but in the case of uniaxial PML you are getting it but still you don't know what is the actual reflection.

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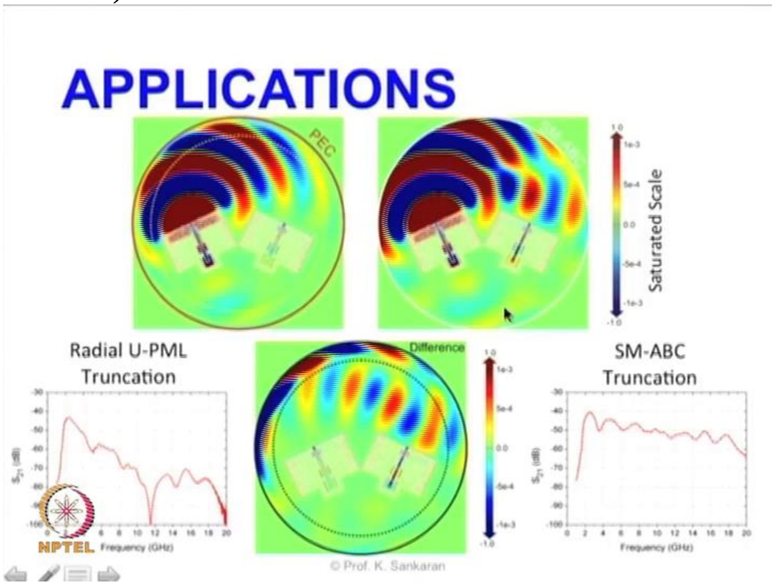

So what I am doing here is I am showing you the reflection from the uniaxial PML I am not worried about silver Muller boundary condition because it is clearly not a good thing so let's focus only on the case of the uniaxial PML and I am trying to show you is what will be the difference so in the case of a difference I am computing like before I take a bigger space so let me explain this using a slide here

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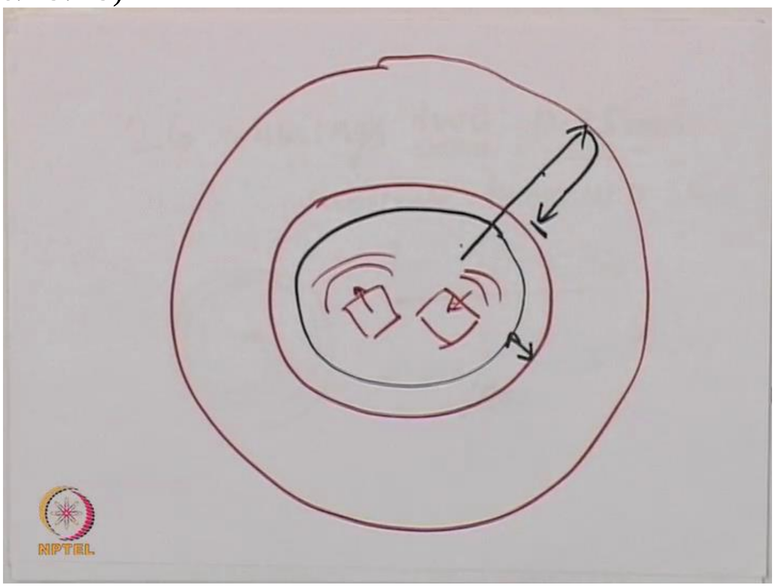

So I will have a very big domain so this domain is a reference solution and I have those two Antennas here so this is exciting antenna Indian dish antenna where the coupling is happening so what happening here is I keep the reference solution as big so in the case of practical thing I am computing using aPML that is shorter in terms of the radius let's say the thickness of the PML is here so I use this one as a reference solution such that I make sure that the wave is going from here and then there is some reflection that is coming back I stop the simulation before the reflection is coming back so in other words I make sure that I am only seeing propagating wave but the reflection is going to be practical is zero so I stop the simulation before the wave reaches the main computation what are the main computation what we are interested in so in that sense I can use this bigger model as a reference model and I can compute the reflection based on the difference between what is happening here – what is happening here so that is what I have shown here

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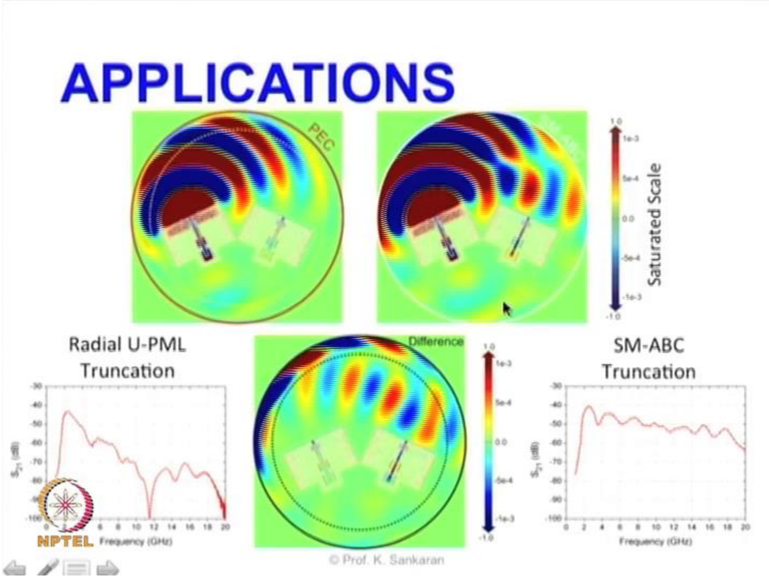

So in the example what you are seeing here in the slide. So this is the difference between the bigger model and the smaller model and I am also getting some kind of reflection but there is a very good way in which you can see the performance of the PML is and how much amount of the wave is going to be reflected and things of that sort.

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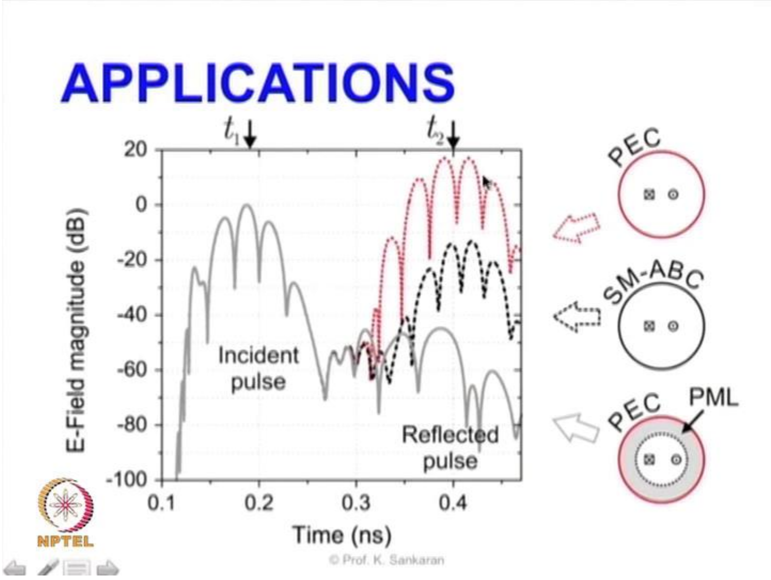

So what we are seeing here is 2 3 things one is you have an incident pulse and his pulse is getting reflected over a period of time and we have to make sure that our computation is such that we are able to stop the simulation before the reflected pearls comes back second thing is we see that the clearly the E field magnitude in terms of decibel in case of this is a reflected field what you see here is quite high in the case of silver Muller boundary condition but in the case of PEC we are seeing it as an kind of a test case where everything that is coming is getting reflected you can see that the magnitude is slightly larger because there is a superposition and the also there is a numerical error and you are able to see that where is getting reflected whatever is going in is getting reflected and here what we are saying is in the case of silver Muller boundary condition this reflection is low because some amount where is getting absorb but still not good enough in the case of the uniaxial spherical PML we see that the reflected pulses even lower than the case.

So these are the three cases when is that everything is getting reflected which is a red case in the absorbing boundary condition you see that there is amount of thing is getting reflected still there is state of an absorption but this absorption is still in the range of – 20 decibel what we need is in the range of minus 50 minus 60 decibel and this is what we are able to get using the uniaxial spherical PML.

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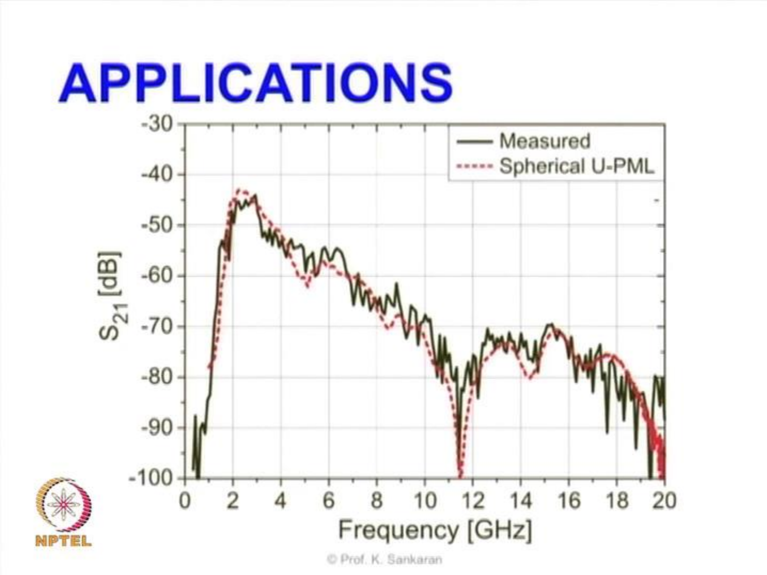

And we are able to see also the s21 parameter the scattering parameter what we are computing and we are using that using two cases one is a spherical radial PML and we are comparing it using the measurement results from the antenna chamber. So what you see here as a frequency is increasing the performance is improving or the similar reason that we discuss before and you see that the results of spherical PML is quite close to the measurement result. So which is a great relief because you don't want a big disparity between a measurement and the value it is one of the biggest advantage of spherical uniaxial PML which we have done but this is one of the very good results what we have got which matches with measurement results and not only that it is able to get those dips the local zeros what we are interested in which we are able to compute also very accurately.

So with this we are coming to the end of this module we have discussed simple applications like waveguide truncations and things of that sort and we also discuss some complicated problems using very very difficult geometry where the multi scaling factor is very important and also the PML performance is quite satisfactory compared to the measurement result with this we have come almost to the end of the finite volume time domain method we will discuss in the next module the challenges and limitations of this technique and also we will discuss about the potential for future research and also the direction to go forward thank you.