Computational Electromagnetics and Applications
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Lecture No. 12
Boundary Conditions

So we have looked in the earlier modules both the absorbing boundary conditions for one and two dimensions and we also introduced one of the most important absorbing body conditions which is the perfectly matched layer and we said that the perfectly matched layer is a very important technique that you will not only used in the finite difference algorithm but also in other algorithm. Later on when we discuss other advanced methods and alternative methods for example finite volume method will discuss more about the perfectly matched layer itself but now we are going to look into some examples for modelling practical electromagnetical problems using both the absorbing boundary conditions and using perfectly matched layer.

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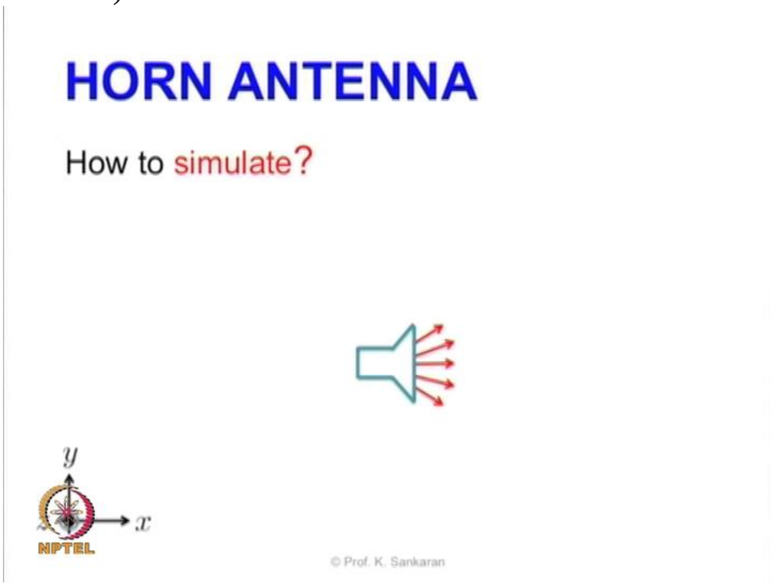

So let's now look into the first problem that we are interested in is basically simulating a horn antenna for example you can have horn antenna with radiation pattern and when you want to simulate it two dimensional space

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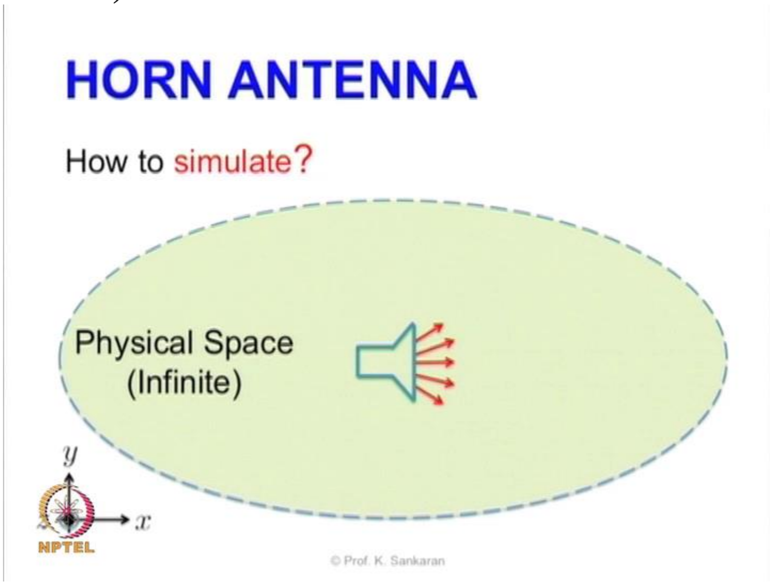

You have a physical space which is infinite and obviously we cannot simulate them for infinite space,

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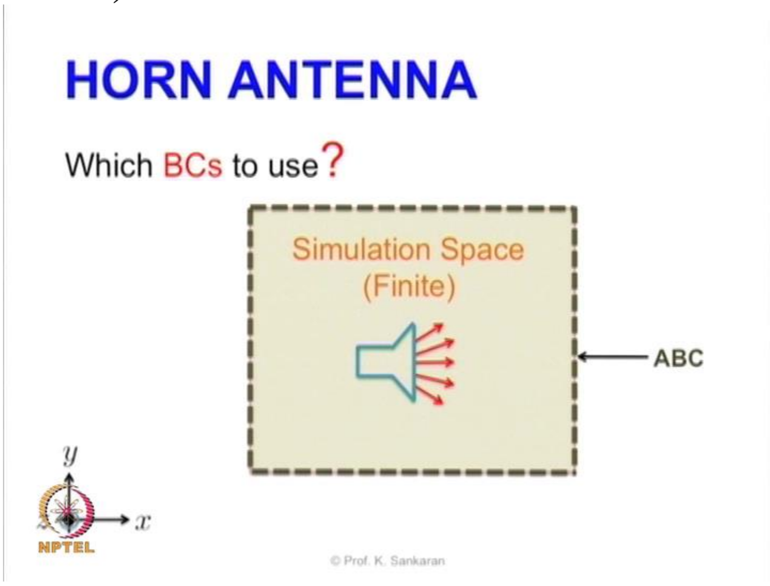

We have to have a finite simulation space and when we talk about a finite simulations space the question is what kind of boundary condition we are going to use so in this case we can have a choice of using an absorbing boundary condition

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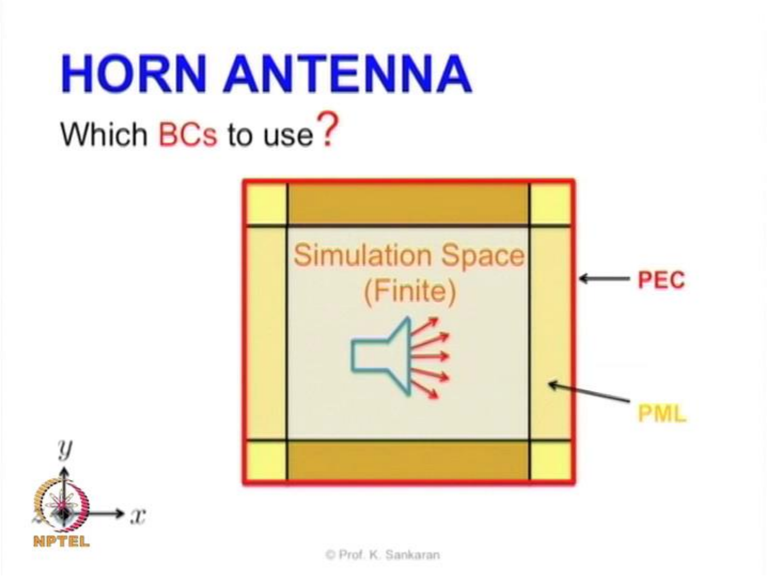

or using a perfectly matched layer

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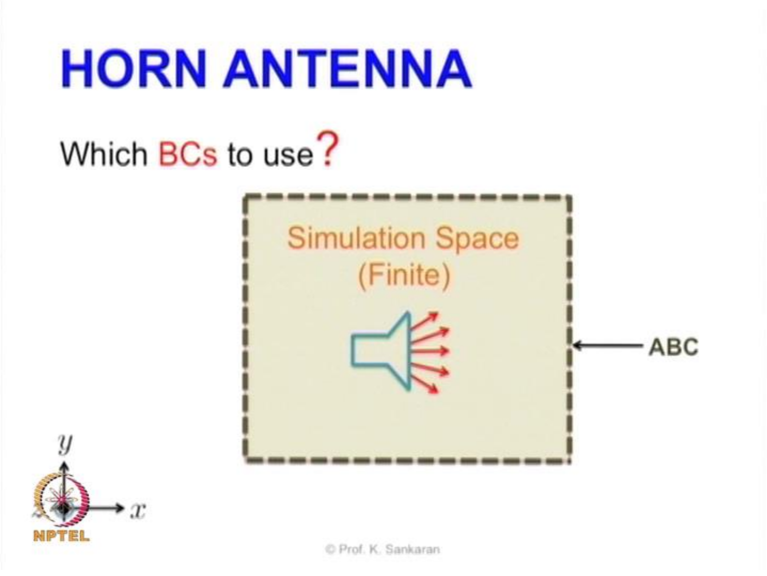

As I said before the idea of using a perfectly matched layer is to bring the boundary closer to the object of our interest itself so with that in mind as we can see in this example what we have done is we have we have brought the perfectly matched layer closer to the domain of our interest.

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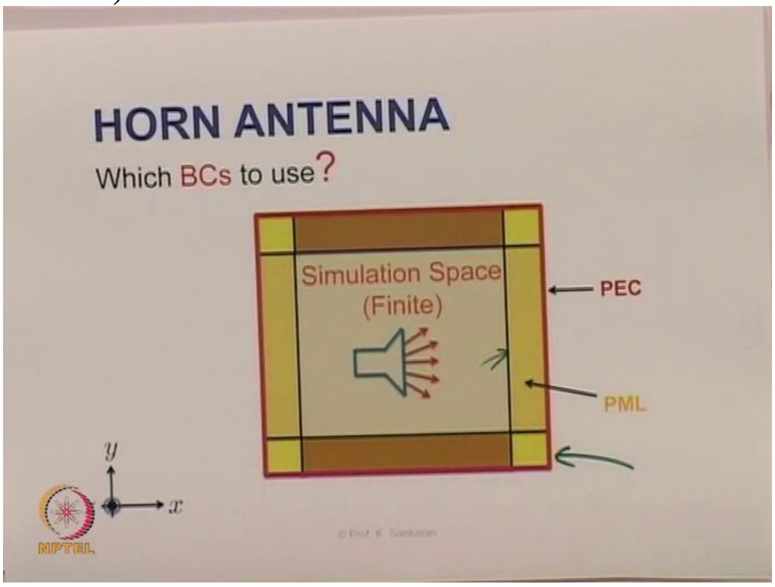

For example in this slide you see the previous example what we had is if we are using only and absorbing boundary condition we will place the absorbing boundary condition at the point where we have the PEC where is when we are using aPML we are bringing the PML inside and closer to the object of interest and that was the motivation for using the PML we can bring the boundary closer and closer in fact the boundary what this simulated space is going to look is this particular boundary here and obviously what we are going to do is we have to truncate also the PML what we are doing is we are truncating and using a PEC boundary condition and we looked at PEC boundary condition also before when we dealt with special interface condition show the motivation for using aPML is to bring the boundary from a faraway distance to closer and closer distance in order to make the simulation domain smaller and also the accuracy better.

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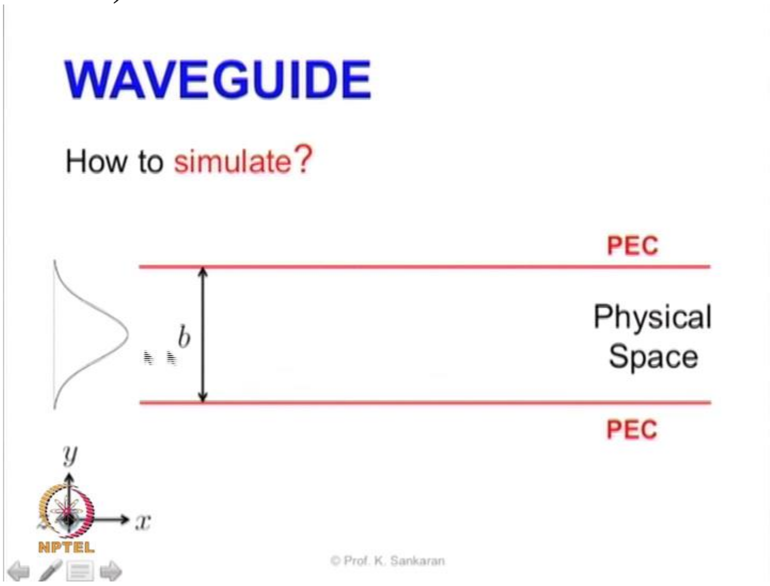

So we can also see a similar example when we are modelling a particular problem for a waveguide truncation so in this case when you are interested in truncating a waveguide so assume that we are interested in an infinitely long in X direction and infinitely long in Y direction in a finite dimension in Y and we are simulating this particular waveguide and obviously we cannot use the particularly large physical space we have to truncate this and this waveguide is going to be excited by a port so this is a source direction and When the source is in a particular direction we have to truncate this waveguide using a boundary condition.

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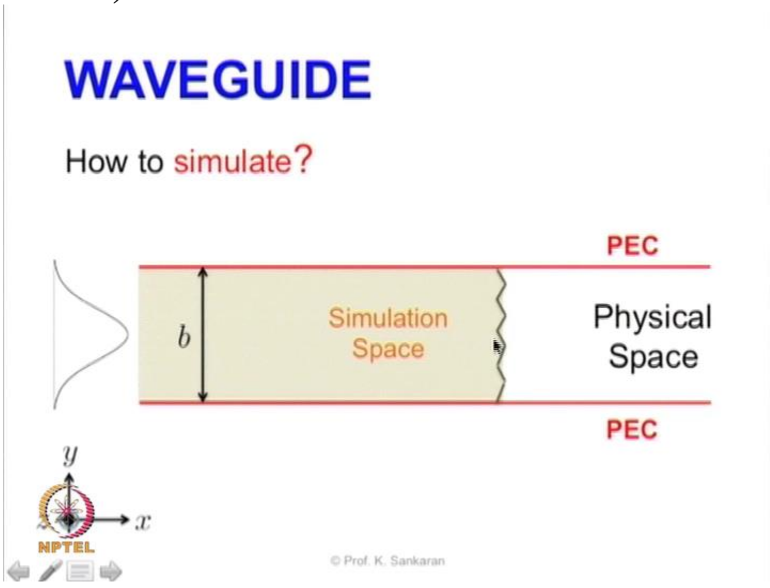

So what we are going to do is we are going to reduce the infinite space into a finite simulations space and the question is what we are going to put at the end of this simulation space.

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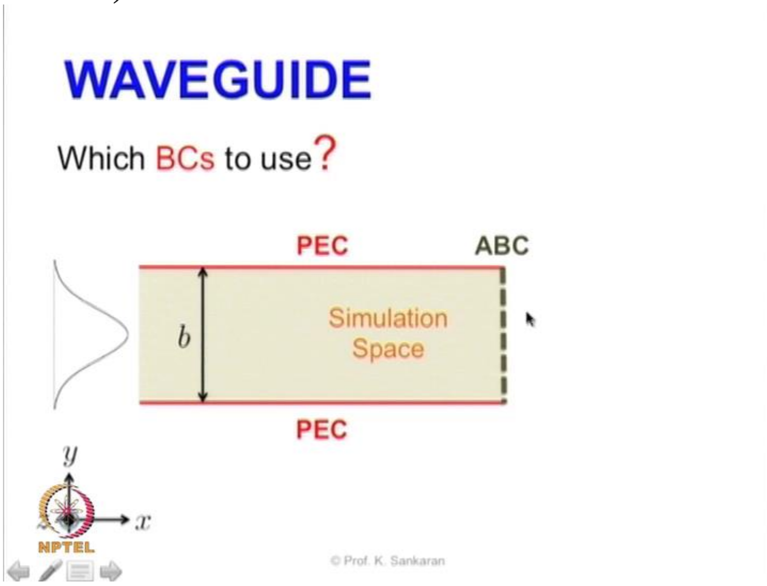

One choice is to use a simple boundary condition from Enguist Majta or Silver Muller boundary condition this is the case of a b c

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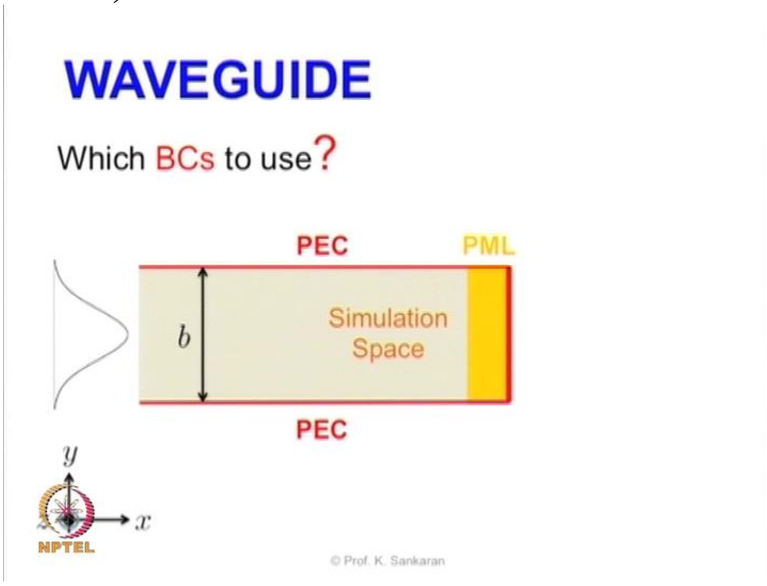

And as I said before in the case of a p m l interested in bringing the boundary closer and closer to the actual domain itself that is what you see the end point of the abc will be domain truncation itself and we will put the PML closer to the domain of interest itself so we are going to come closer to the domain since the actual interface is going to be closer to the simulation object of our interest so if we are interested in what is going to happen at this point we are coming closer this might be easier to explain using the example on the paper.

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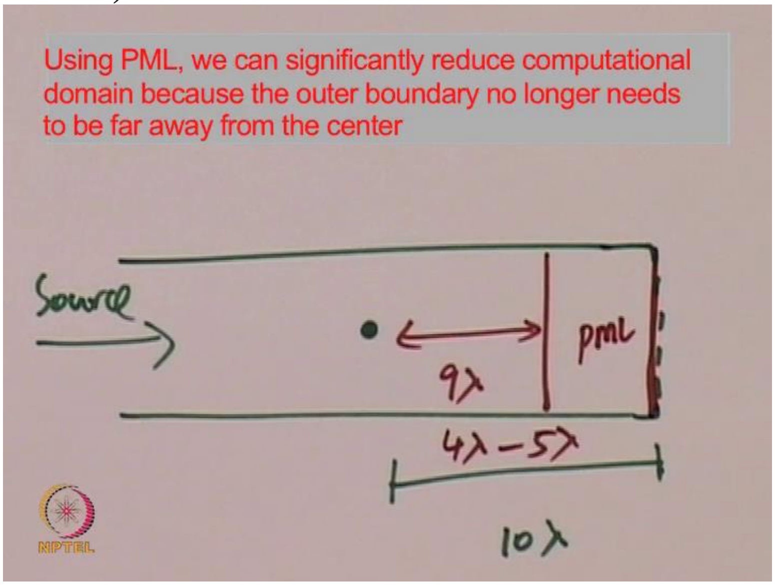

So what I am doing is I have a infinitely long waveguide and let's say I am measuring what is happening at this point the source is coming on this angle so if I have to put an ABC I am putting the abc at this point so let's say this has certain distance for example 10 Lambda so what I can do is with the PML I can come closer to this particular point let's say a thickness and this distance is 9 Lambda so I am able to reduce the computation domain a little bit and even for most of the practical problem we can come even closer to the order of 4 to 5 Lambda.

In some cases this Lambda value will change but the idea here is the computational cost that we are going to incur because of the PML should be justified by the reduction in the computational phase itself .

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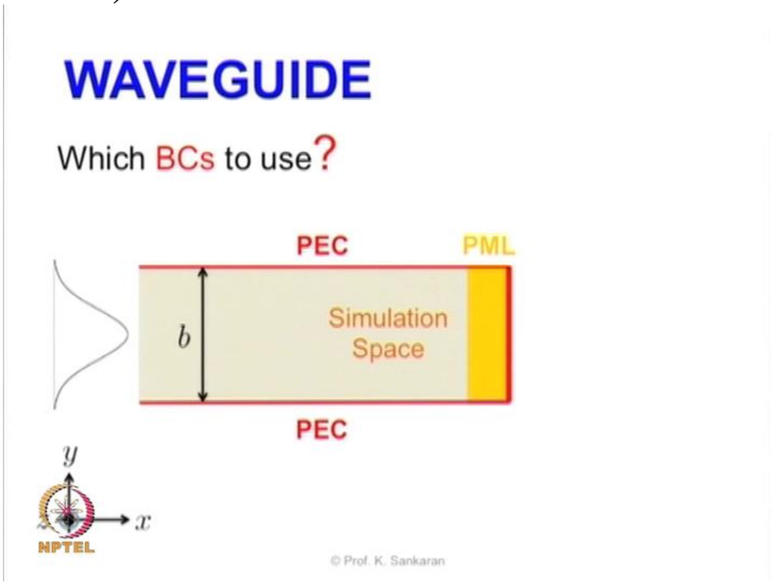

So that's what we are seeing here in the waveguide problem our PML is going to reduce the actual simulation space to certain level.

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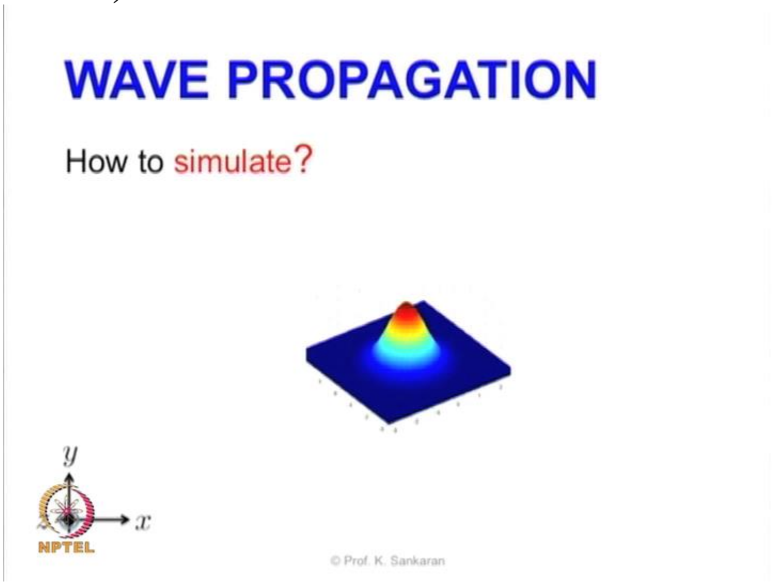

So another problem that we can look into is the problem of simulating a space with apportion wave.

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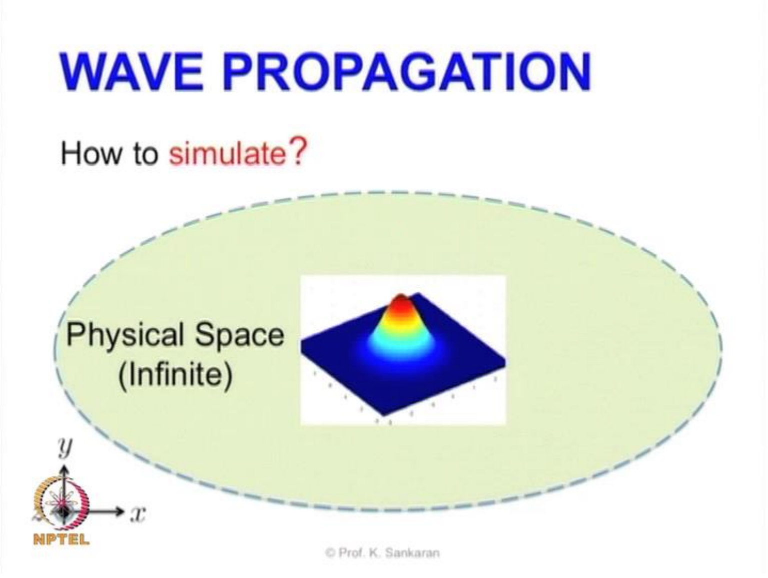

For example I am interested in a physical space and I am simulating the space with a Gaussian wave and instead of simulating this in an infinite space;

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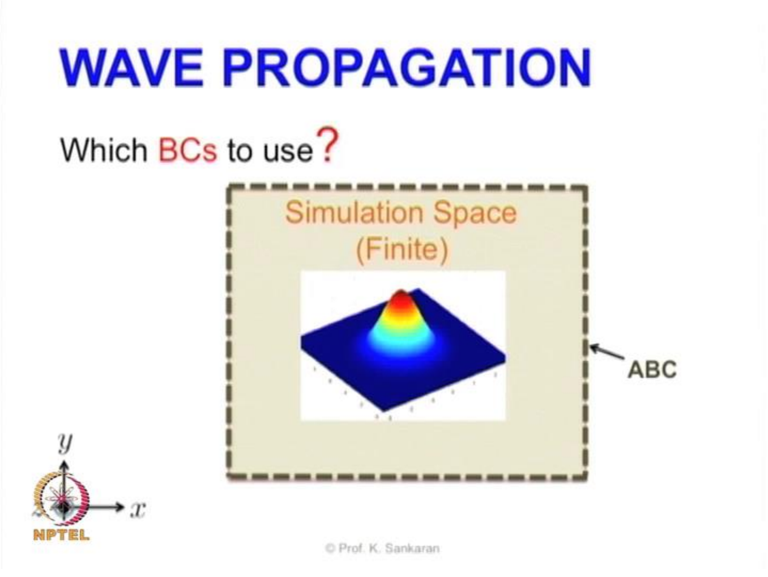

I can simulate this in a finite space and I can reduce the space in such a manner that I can truncate it using certain boundary condition one way of doing it is to put a b c and we will see this in our examples we will truncate it using the radiation boundary condition and we will see how this radiation boundary condition is implemented in the matlab and like in the case before we can also put perfectly matched layer.

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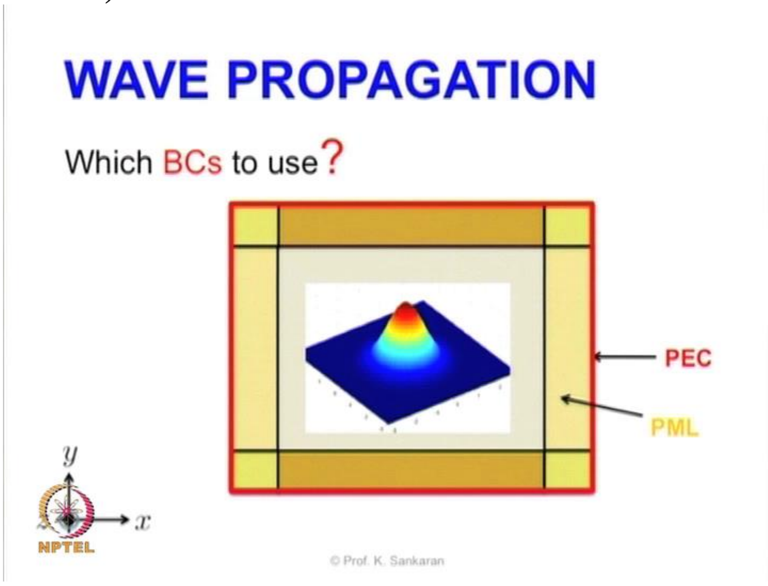

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And that is what you see here instead of ABC you can come and truncate the domain even closer than the abc condition itself so that will be a PML condition so what we are going to show in a simulation is both the case of truncating using a absorbing boundary condition radiating absorbing boundary condition and using a perfectly matched layer the one which we described in the previous module.

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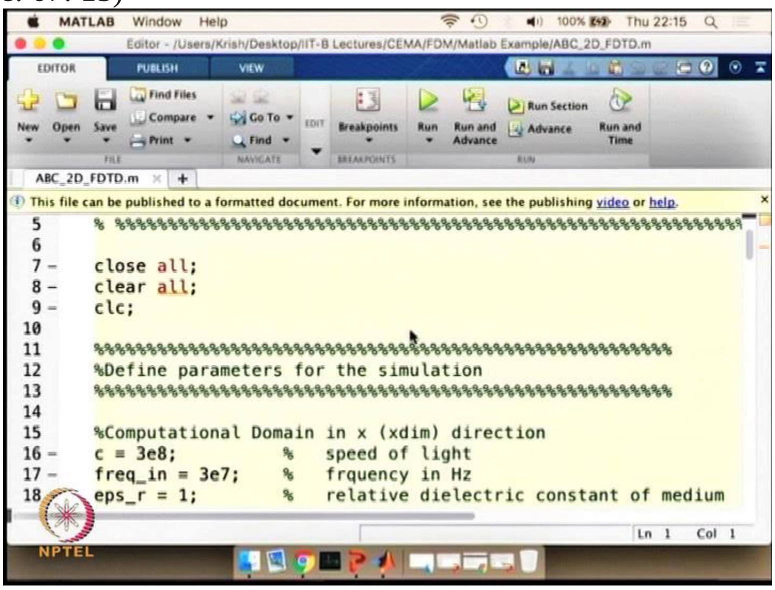

So let's start looking at the MATLAB program here so what we are doing here is we are initialising certain simulation parameter.

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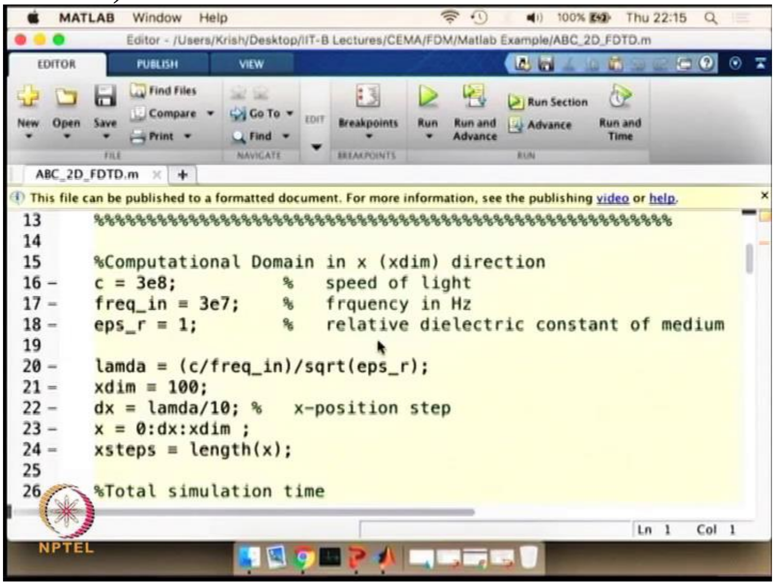

For example the speed of propagation the frequency of excitation relative permittivity and permeability so on and so forth.

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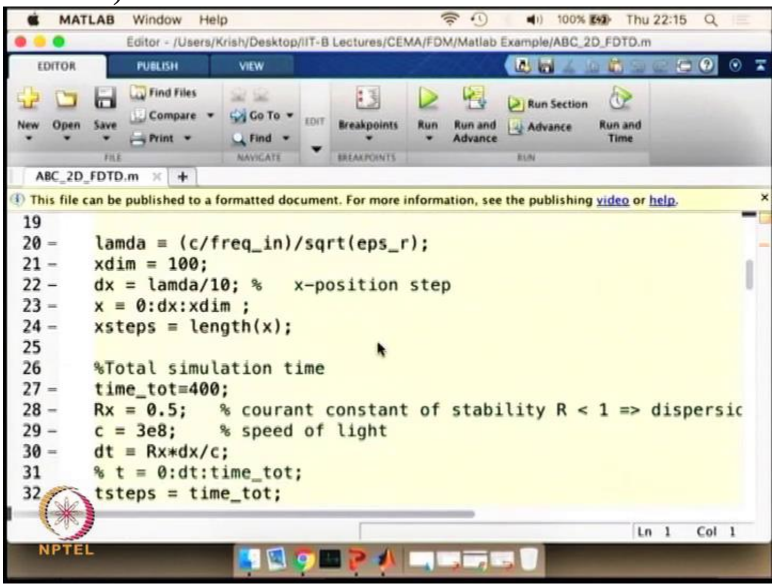

And we're setting the simulation time here and we are also setting the Courant limit for simulating this problem we have set it into 0.5 because we are in explicit method here.

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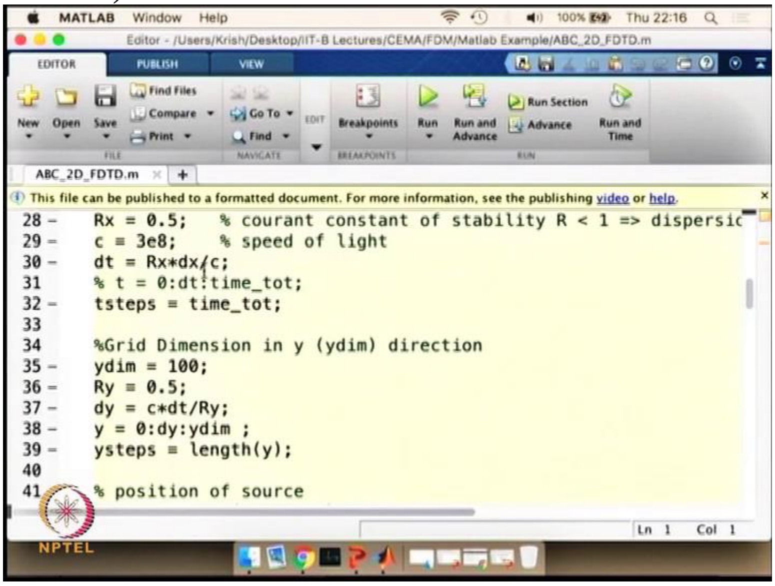

And we have set the value of Delta T based on the Courant condition And The Delta X that we have computed or which we have assigned and we are going to set also the grid parameters in X direction and Y direction.

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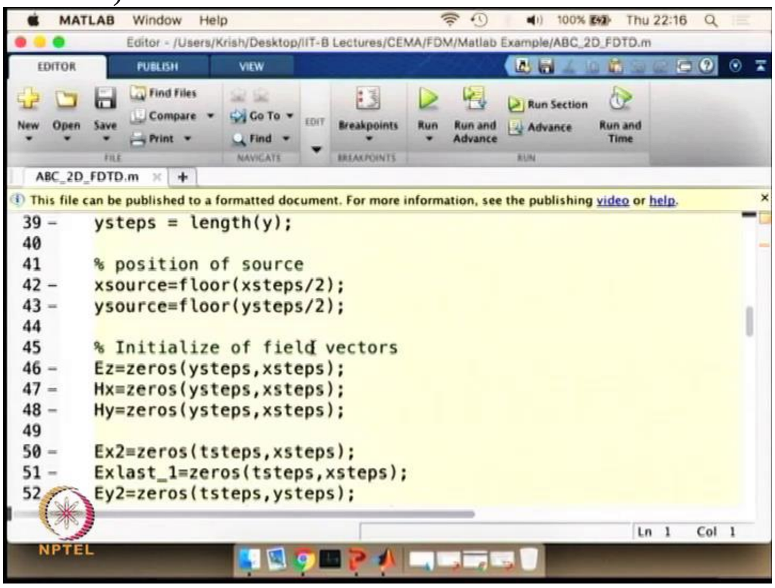

And the position of the source itself; and we are initialising the speed value remember we have to give both the initial and the boundary condition so this is the initial condition for E z H x and H y fields.

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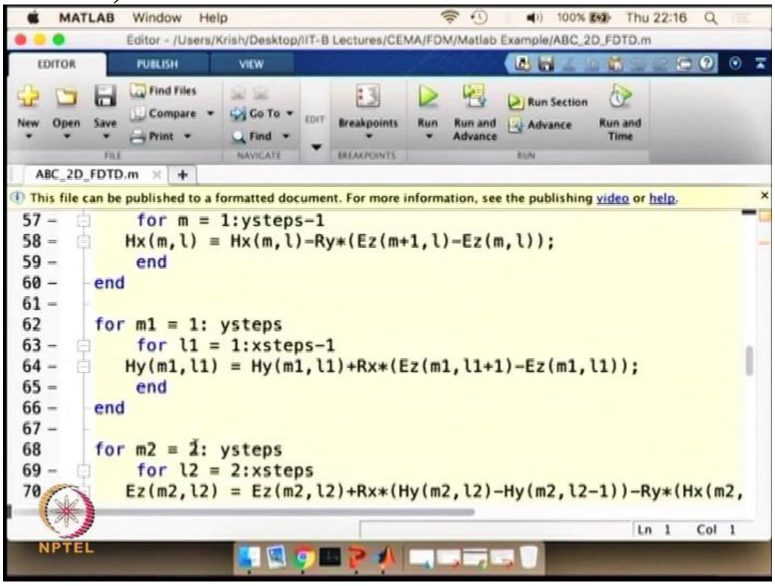

And we are setting the equation into a loop us to compute the value of H x H y and E z so these are the three values we are computing based on the Maxwell equation.

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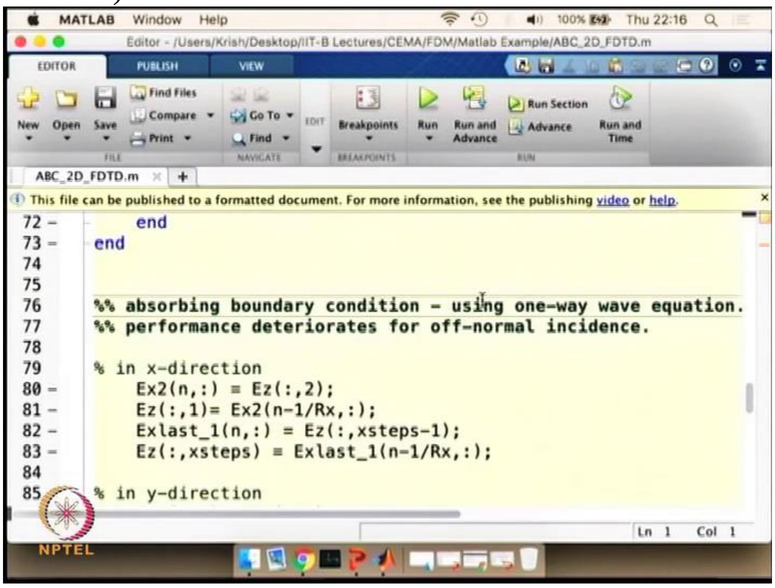

And we are setting the absorbing boundary condition which is here a one way wave equation similar to the Enguished Majta equation that we saw before.

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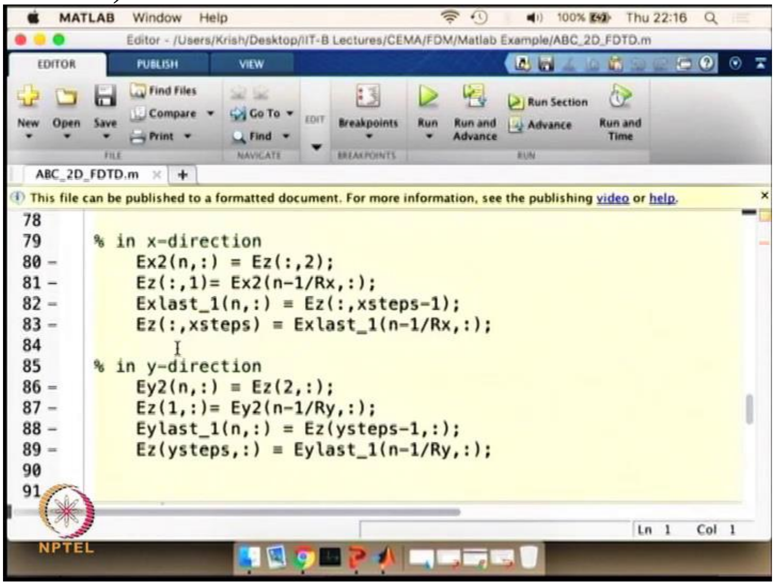

And it is going to be assigned the value E z like the way we computed before.

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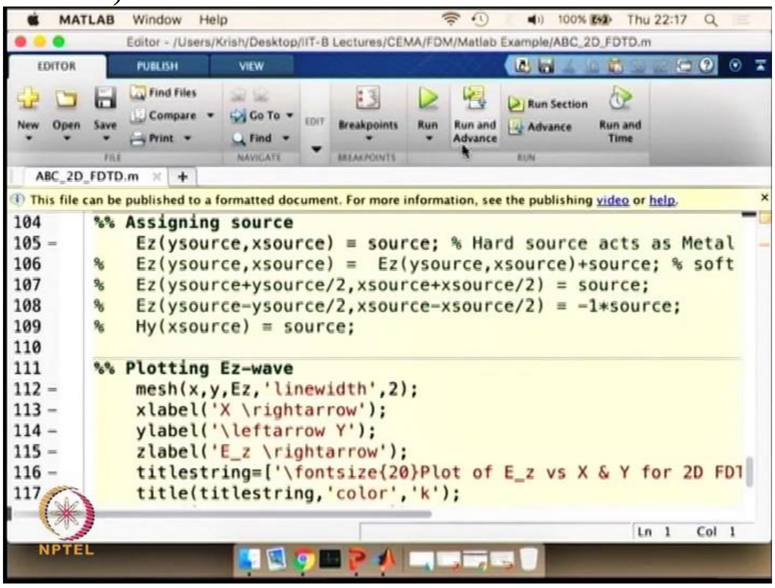

And we are going to see what is going to be the value of the field by plotting it here so we are plotting here the E z wave.

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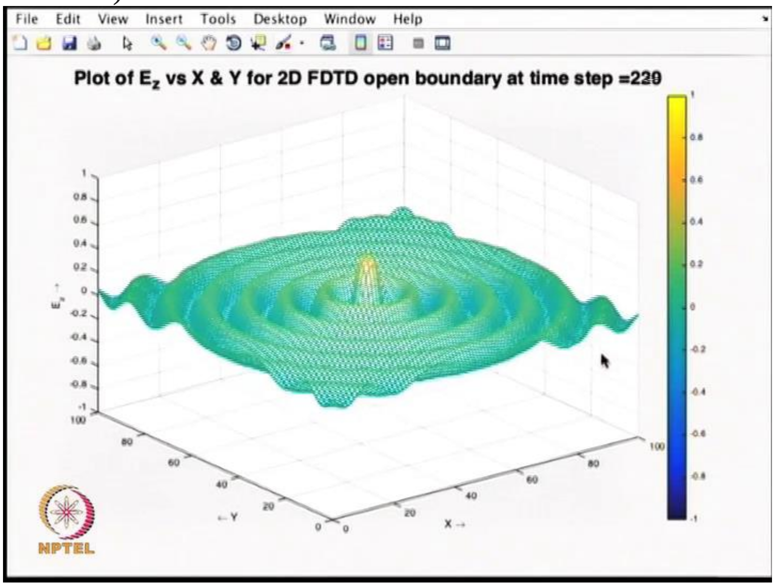

So Let’s run this program; so what you are seeing is Gaussian wave excited exactly at the centre and this domain is a square domain like the way we saw before what you see is as the wave is coming towards the boundary it’s going to just go without any reflection theoretically but there are going to be some reflection and this reflection is going to depend on the angle at which particular boundary is going to see the incoming wave so what you see is a classical example for the boundary equation and the value of the E z field at the boundary is also going to change with respect to time and we see that the wave is going without any problem and the the simulation runs without any instability issue.

So this is a classical example for an absorbing boundary condition. I will give you these quotes for you to try for yourself and simulate the problem for various Delta x and Delta y values and also for various time stepping so that you can see the accuracy of the one way Wave Equation for absorbing boundary conditions so what we will do next is we will simulate the same problem using a PML condition and we will see instead of the wave propagating as if the domain is infinite the wave will start to decay inside the medium that is important for you to know because the wave is going to see the losses inside the medium as we have explained it in the previous module.

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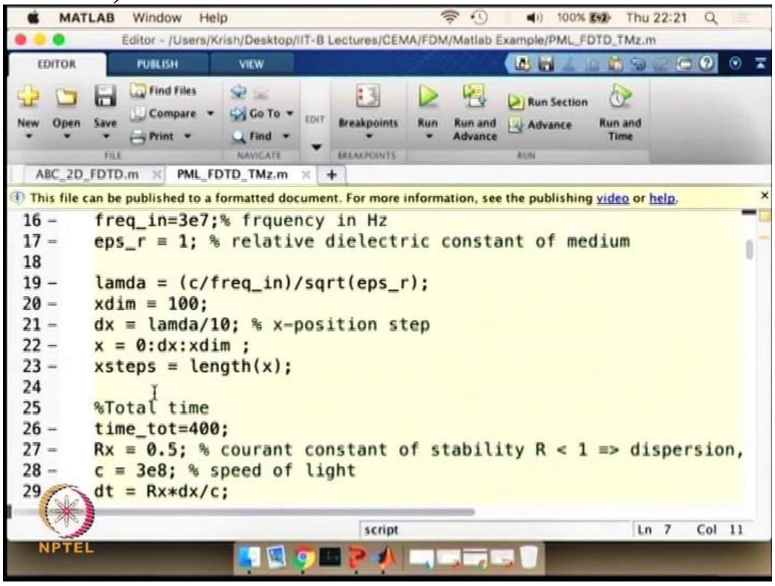

Let’s now simulate the example for the perfectly matched layer let us start running this program so we are defining the grid like the way we did before we have the Lambda value which is the frequency value we have to know this for us to set the thickness of the perfectly matched layer

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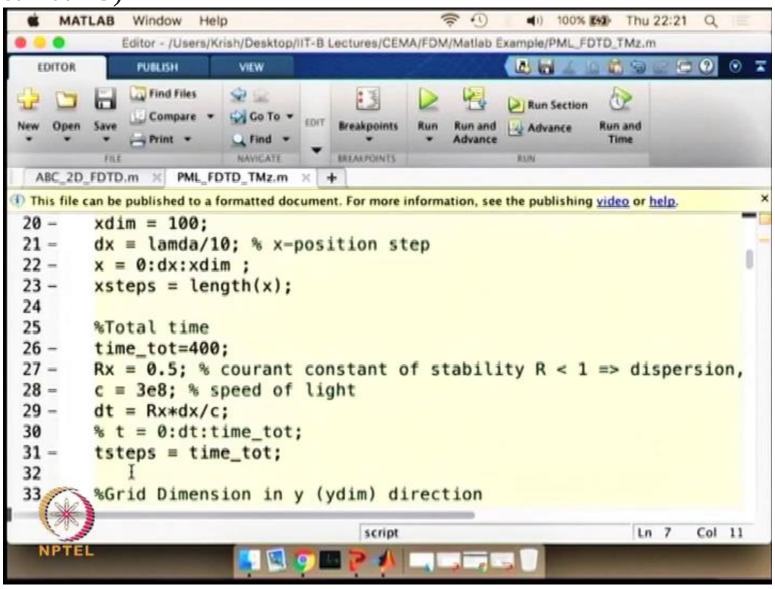

And we have set the time and Delta T and so on and so forth like the way we did before we have set the X and Y direction the source is going to be in the same place.

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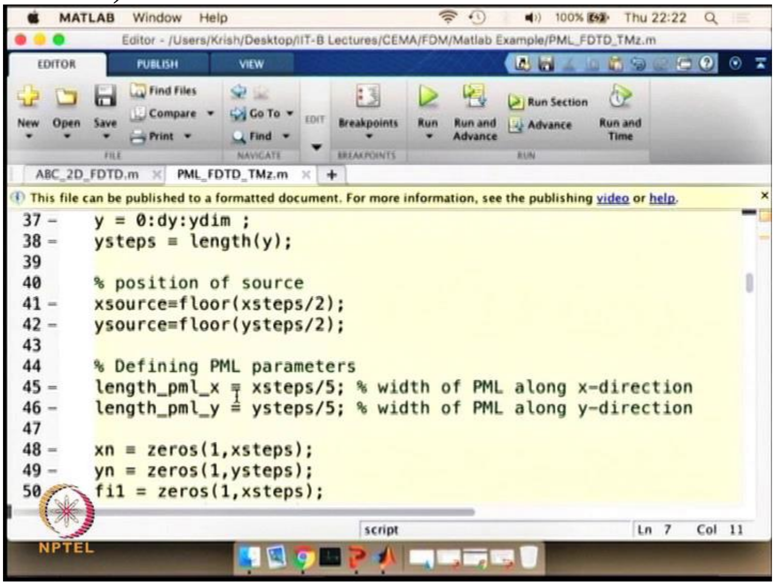

The PML parameters are defined here so we are going to increase the thickness of the PML in 5 steps.

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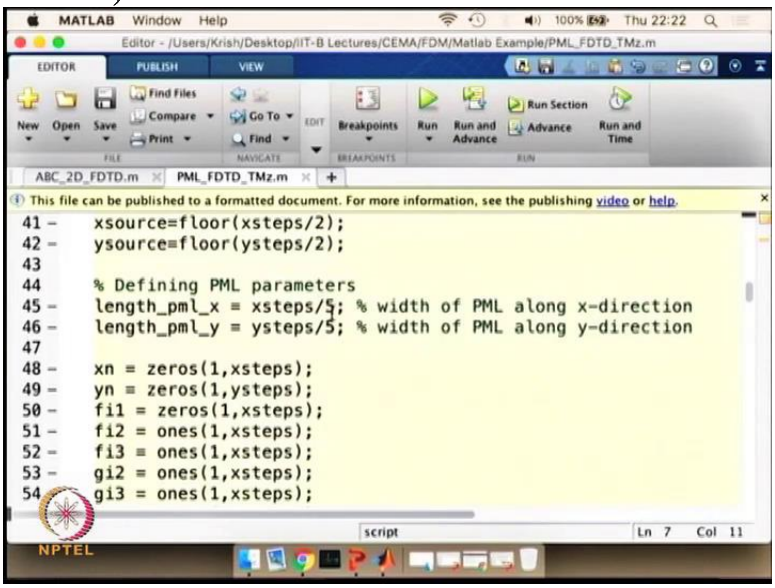

We can also increase it in a parabolic way so on and so forth here we have done it in 5 steps.

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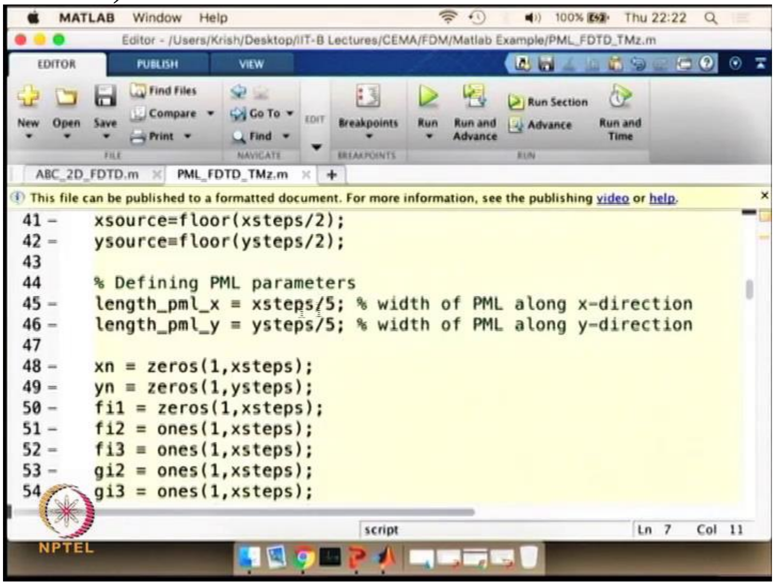

And we have set the values for various fields initially to zero.

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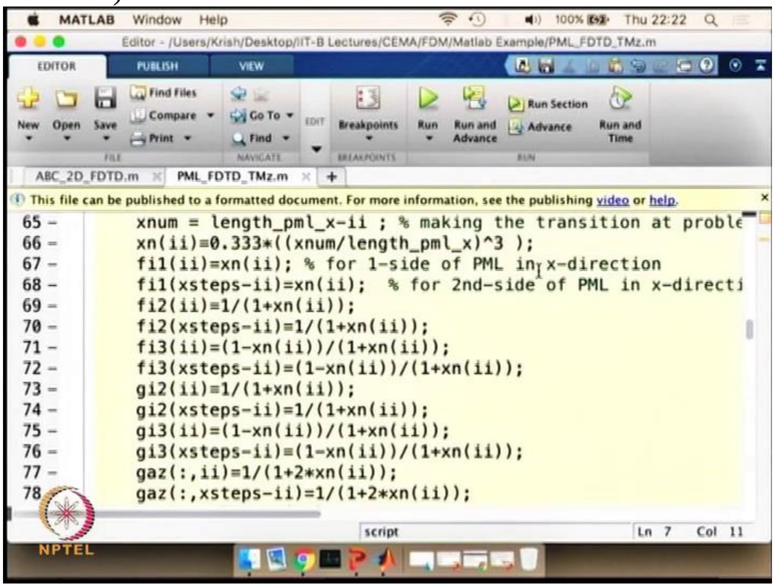

And we are computing the value of the of the PML fluxes that we need for one side PML in X direction the second side PML in X direction so on and so forth.

And we have done that also for the Y direction

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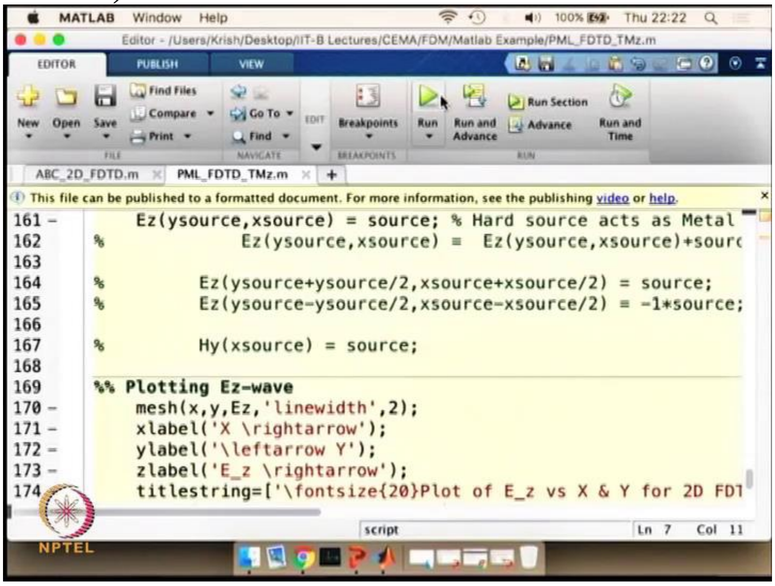

And we are substituting the value accordingly into the field and we are updating the E z H x and H y field so now we are also simulating the problem like the way we did for the EZ field and we are going to plot it and see how does EZ field is getting absorbed.

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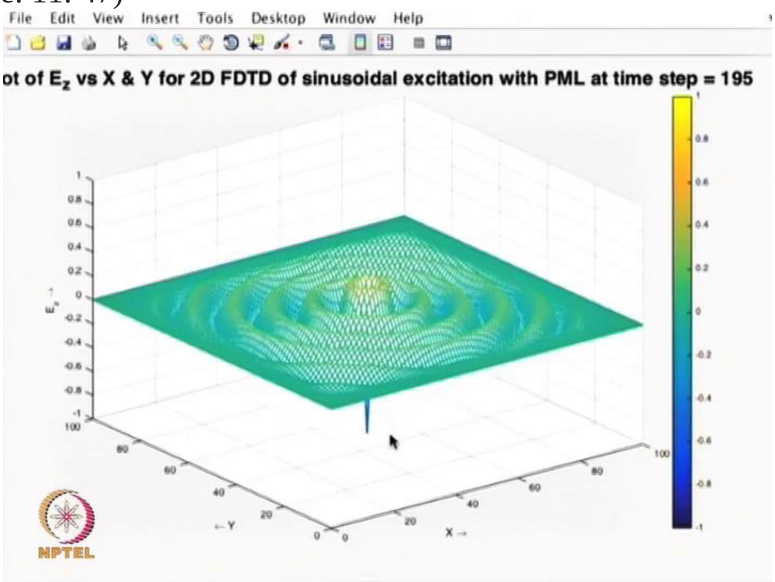

So let's simulate this problem in this case the wave should be decay where at the edge where the conductivity of the losses are going to be maximum the wave should not be seen at the end of the boundary itself as we excite the wave is coming inside is not reflecting out and we see that it is also getting absorbed as it should be and we don't see any wave almost at the boundaries it's a good sign for the perfectly matched layer and we also see that the wave is not seeing any reflection and there is no instability as it should be.

So I encourage you to also simulate this and test for yourself how the PML is working and also see what are the parameters we can change and adapt and how this PML will behave for various parameters in this case we did the step by step increase of the losses you can also increase as a parabolic as we discussed in the previous module with that being said we have seen various applications for using the absorbing boundary condition and also the perfectly matched layer. I encourage you and also request you to really look into the different types of boundary conditions because we will be using them for various applications not only in the finite different problem but also for finite element finite volume and algebraic problems so for you to be fully comfortable with modelling problems for electromagnetic application absorbing boundary conditions are key tools for you to master so I encourage you to test it and try it for yourself.