Computational Electromagentics and Applications
Professor Krish Sankaran
Indian Institute of Technology Bombay
Lab Tour 5

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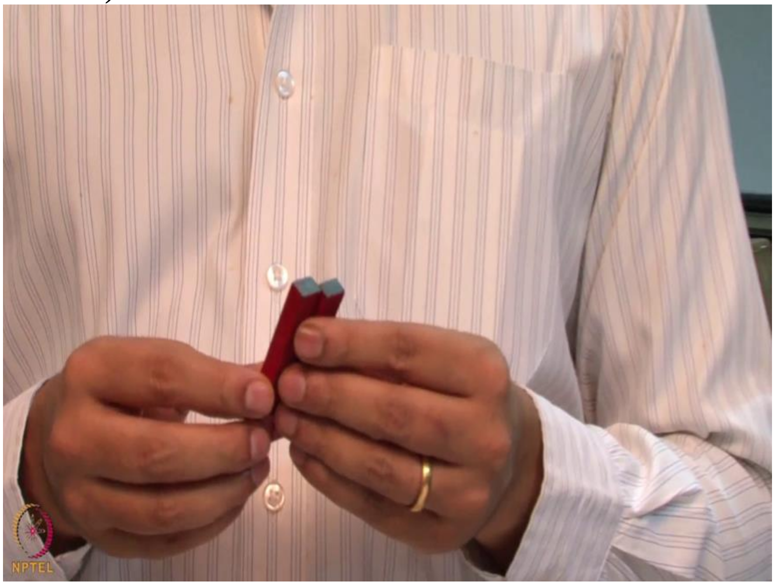

We are now going to simulate the different kind of material which is a permanent magnet and this is a material called as an eco made of aluminium Nickel and Cobalt. So what you are going to do is we are going to use finite element method and I am going to ask a student of mine to simulate this using finite element method to see the magnetic field in this case we are going to do D field. So we are going to simulate what the D field is going to be. Not only that if you are going to have a iron rod which is going to be next to it what is going to be the force of this magnetic field. So we are taking only one magnet we are not going to take two magnets so we are going to see and simulate the force exerted by this particular magnet on an iron rod so that is going to be the first experiment.

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So the next experiment what we are going to do is monopole antenna so this is a monopole antenna and this is designed by IIT Bombay so we are going to simulate this antenna this antenna is going to operate at 1.25 gigahertz. And as you can see it has a coaxial feed and it's going to have a kind of a ground plane. And we are going to simulate this particular antenna also using finite element method so let's go and see what student of mine is going to do and how he is doing this particular model on finite element method.

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Student teacher conversation starts

Aviraj so you have been working on a finite element method so could you please explain how you have modelled is permanent magnet using the finite element simulation and later on also we would like to see how you have done this monopole antenna. So let us start with the permanent magnet example.

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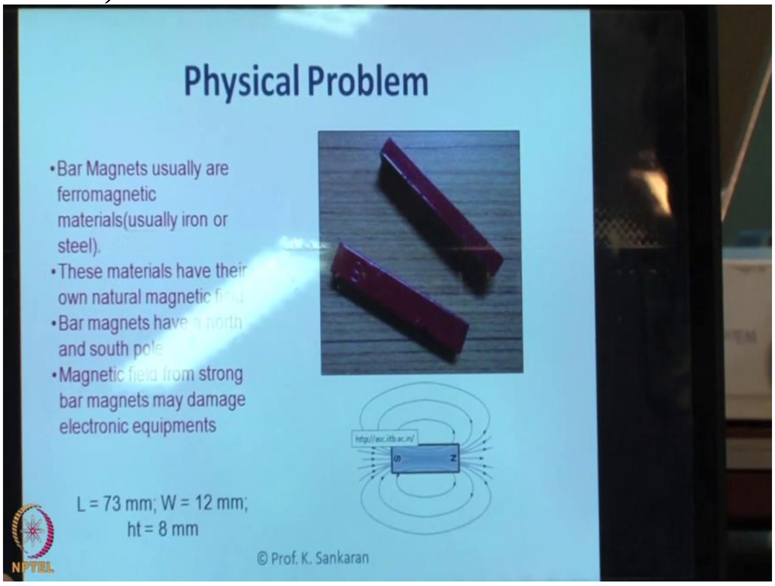

So what permanent magnets are like physically they are like field magnetic materials of iron or steel usually and they also have basically what we have learn in our physics(())(02:15) so we have one north pole and South Pole which have those flux lines from north to south pole so what magnets we have here is electromagnets who have length of some 73 mm width of 12 mm and height of 8 mm. So this is basically for this particular magnet you have taken the length actual length 73 mm and width is the 12 mm and then the height is 8 mm. Ok!

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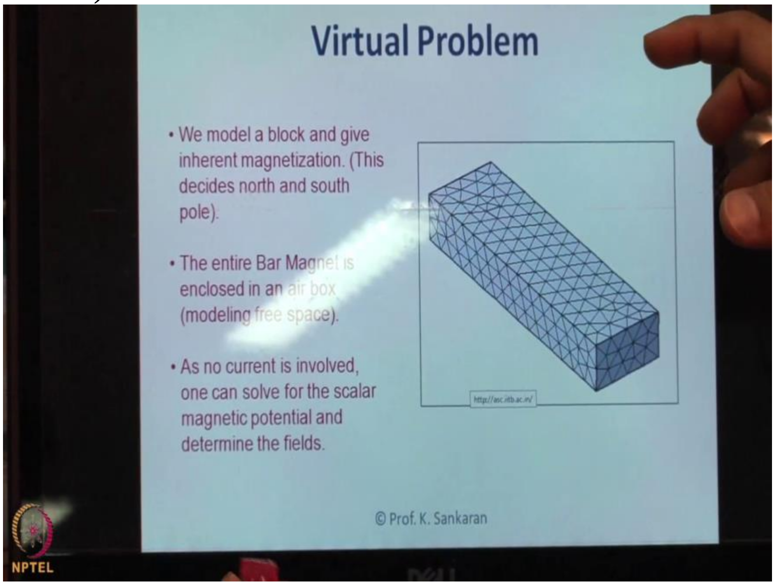

So to basically model this physical problem into the software(())(02:47) what we will need is first the block, we will make a block Model a block of this magnet of this exact size and we will give an inherent magnetization to it. So basically you take the equation D equal to Mu H Plus N so you are giving an inherent magnetization to the problem so the entire physically what we have is this magnetic surrounded by air so that infinite space we cannot model in the software so what will be doing is we will be closing it in a bounded box affair and as there is no current involved in it so the magnet itself is giving the magnetic field. So what the solver will be doing is actually solving the scalar magnetic potential. So basically you will be doing with the case of scalar magnetic potential so the solution to this you know.

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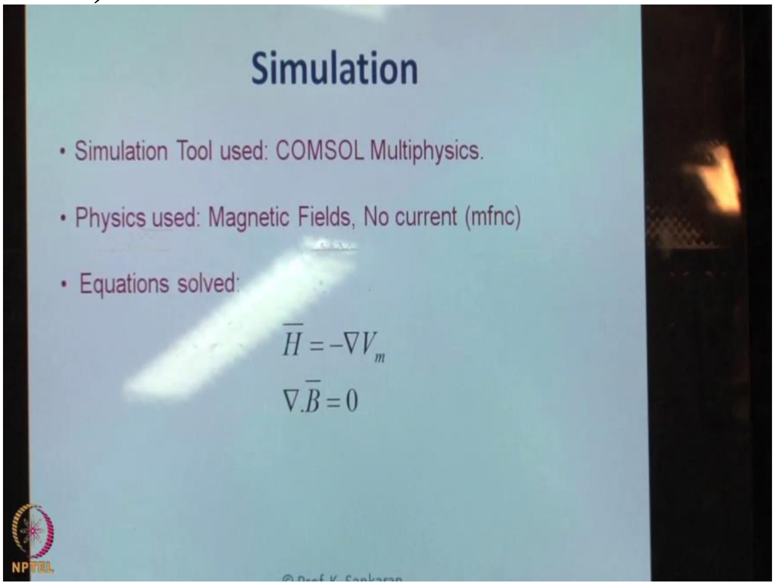

So basically you are starting to do the entire problem finite element solver. And you are modelling the thing with the scalar magnetic field. Ok! So H bar is basically the gradient of scalar magnetic equation J bar plus B bar and del dot B bar is 0. So these are the main equations which we will be plotting the magnetic fields.

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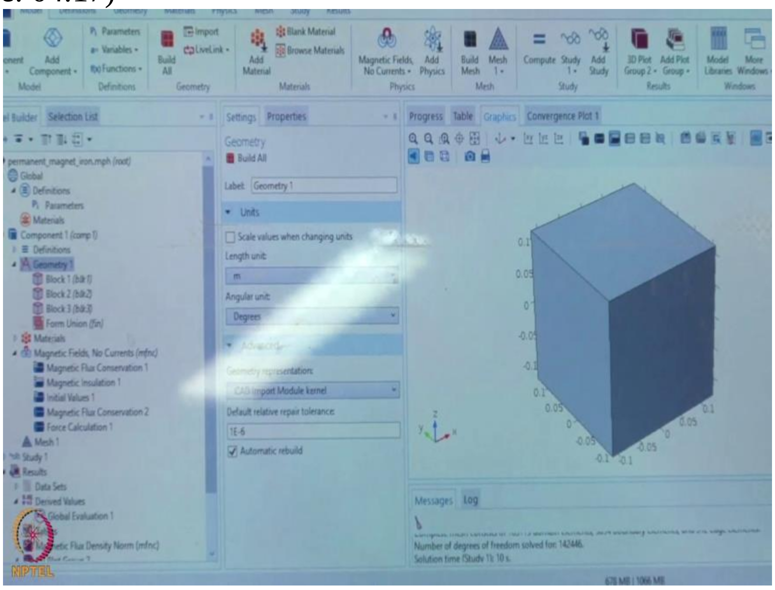

So starting with the building geometry first we build the geometry this is a magnet.

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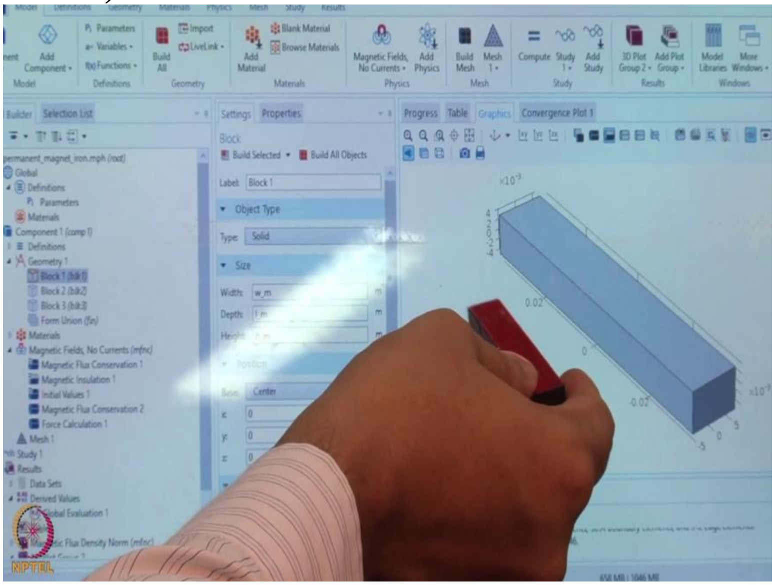

So this is the basic geometry you are using and the finite element solver you are using basically gives you the kind of geometry that you have modelled and you have taken basically the same dimension from the physical magnet you have and now you are going to mesh it, before that we will be enclosing it in a airbox.

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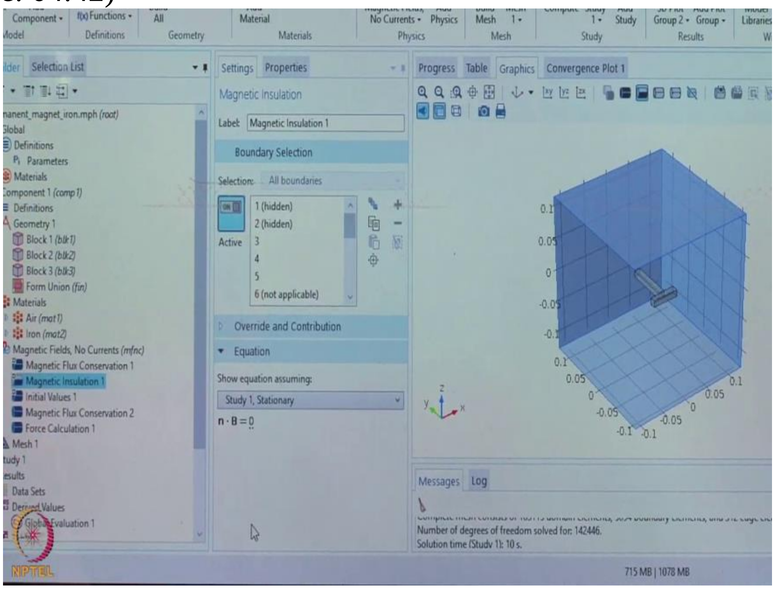

So a big airbox, Ok! So this is my magnet(())(04:45) So can you zoom it a little bit for us to see how the entire thing is looking.

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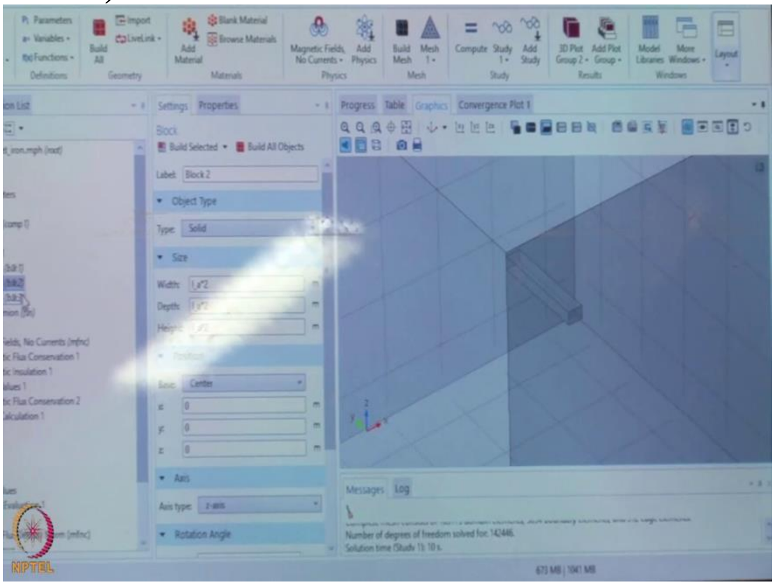

So this is a magnet that is there and then the air box is surrounding the magnet. Also we are putting an iron rod to see what the force will be applied to that iron rod. This if you can see. So this the iron rod you are having.

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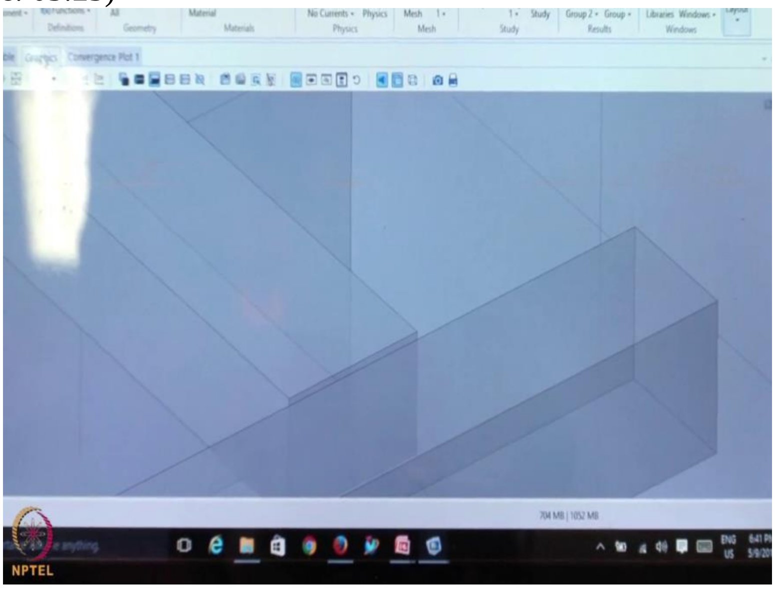

So if you can show this one so basically what you have is the magnet which is here and then you have a perpendicular iron rod in this case it is just another magnet but we can imagine that if this is an iron rod this is perpendicular to sitting here yeah exactly ok. Now we are seeing force of this particular magnetic field on this particular iron rod. so are assigning the material so will assign Air for surrounding space and also the magnet because what you are doing is we are giving some equations for magnetization in the Physics itself of the software.

So we don't need to put some material Alnico we will put it as air only but the equation which will be solved that we will be putting as something in the Physics that I will show you in the next thing. so this is the iron which is material that you have and for the magnet itself you are going to do it in a different way so this is the Physics magnetic field so if we go in this and enter all the domains we can see two equations which are not so

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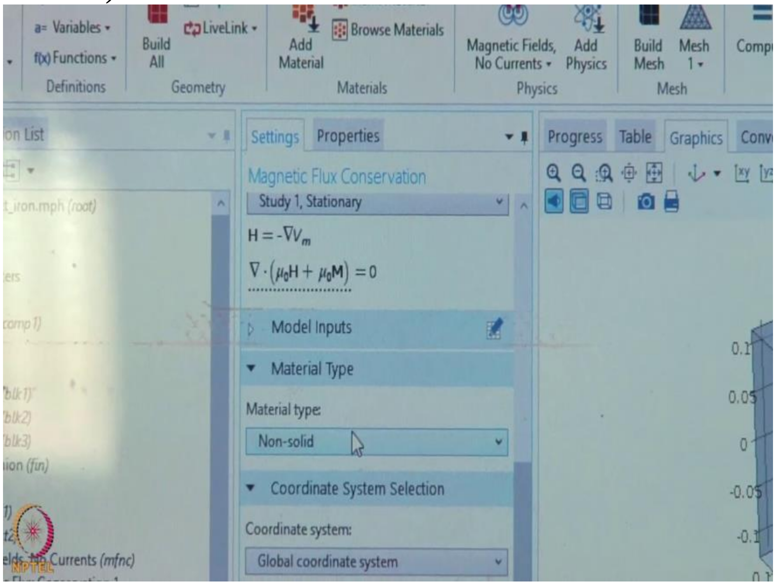

So you have the h field that is equal to minus gradient of a scalar magnetic field and then the dad divergence of the be equal to 0. ok so now will go in magnetic flux conservation so you are taking the conservation of the magnetic flux in the air box so whatever flux is going out comes back so that is idea what you are putting in so and the all the(())(06:54) magnetic insulator flux will escape so it is a bounded medium so and dot v is equal to zero(())(07:03) so basically what you are forcing is normal component of the D field is equal to zero so that means to normal component of the d field no flux is going out so initial values in the entire magnetic scalar potential is zero in the entire domain and here we are modelling the magnet the magnetic flux conservation to go you can see b is replaced by Mu 0 h plus Mu 0 n ok and that n i can used here.

So basically what you do is you and the value that your computing h is equal to minus gradient of scalar inter potential scalar magnetic potential and then you have the divergence of B or which you are substituting new not h + 9 or 10 is equal to zero and then your computing the value of m from there and then you are substituting the mean value here.

So this I will substitute here and if we substitute this will (())(08:04) here so like this single equation will get the value of Mu n ok at each point and by that you can get h in the older one ok so this is for permanent magnets if this constituted the relation if there is another materials suppose there is some linear materials so we can relative permeability(())(08:24). So its relative permeability (())(08:27) is equal to Mu 0 h. In this case we have taken at so we are not talking about the the relative permeability so we have many other options ok then I have to calculate the force exerted on the particular iron rod using this magnet I have included or not in this calculation in that I have included this domain this iron domain so the first equation itself is the integral of surface tensor so by that the integration in that domain we get the force in the inter domain.

So this is possible within the solver to get the value of h so these are all the settings. So what this solver does is in built physics control machines so it is different options finer and finer So what is the thumb rule is that (())(09:24) or iteratively we can do is I can go finer and finer till the results of two settings comes in. Ok And the larger setting we can ok that is the conversion aspect what you are looking. So can we see the results. So this is giving you the magnetic field B So at different place I have just got it (())(09:48)

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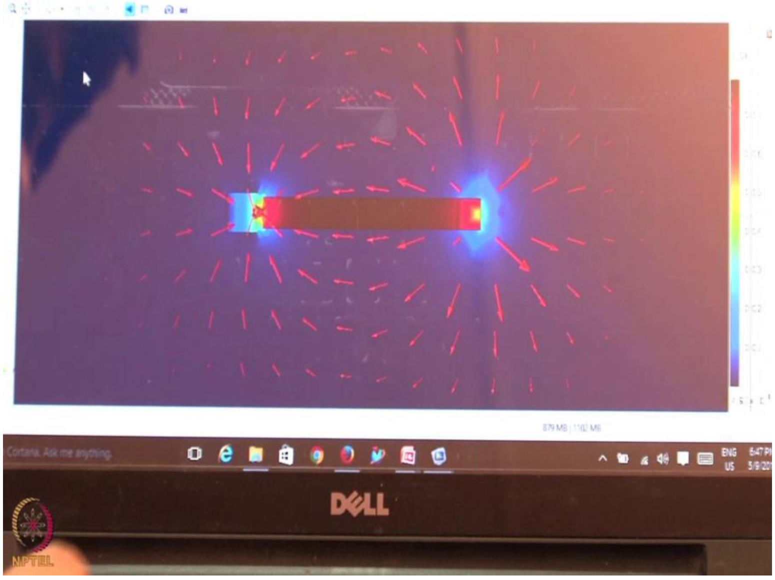

So this is basically one plane which is basically sitting on this particular surface. Yeah this surface so basically then get this surface here and then you have calculated the magnetic flux so it goes from the north to south. So basically (())(10:10) and it is coming here.

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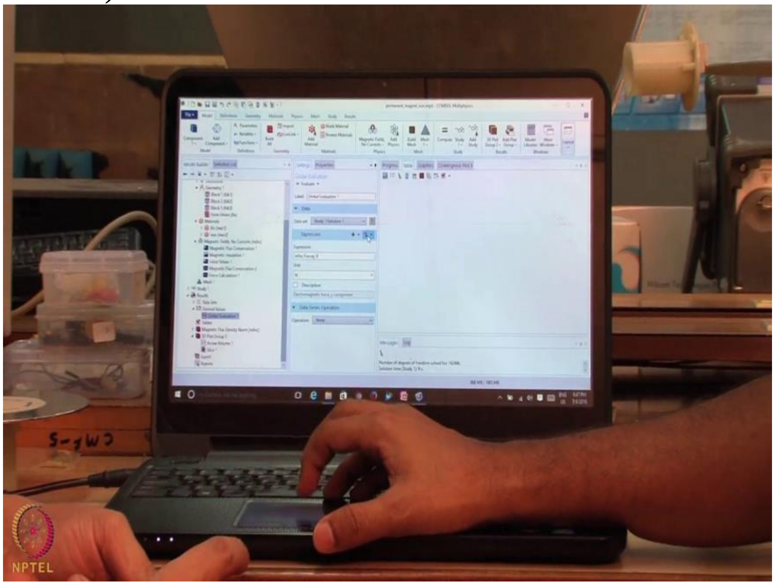

And the force value it gives another global imagination here we can give some expression there are some in built expressions where lots of things we can calculate. So what I mean is magnetic field low current force yeah. So 0.06 newtons is the force exerted on that bar iron. Do the what is the force that is exerted by this particular magnet on the bar of iron what we have? And this is 0.06 newtons. So it is going to depend on the magnetic field of the material itself. And also the distance between them. Excellent! So this is a good example for us to see how you can use the finite element to understand model a permanent magnet. So I know that I asked you to also look at the monopole antenna which is operating at one point to 5 giga hertz. So if you can explain us how you have modelled this monopole antenna in the Finite element solver will help us to get a sense of what the things that we know about modelling such antennas on finite element pacemakers.

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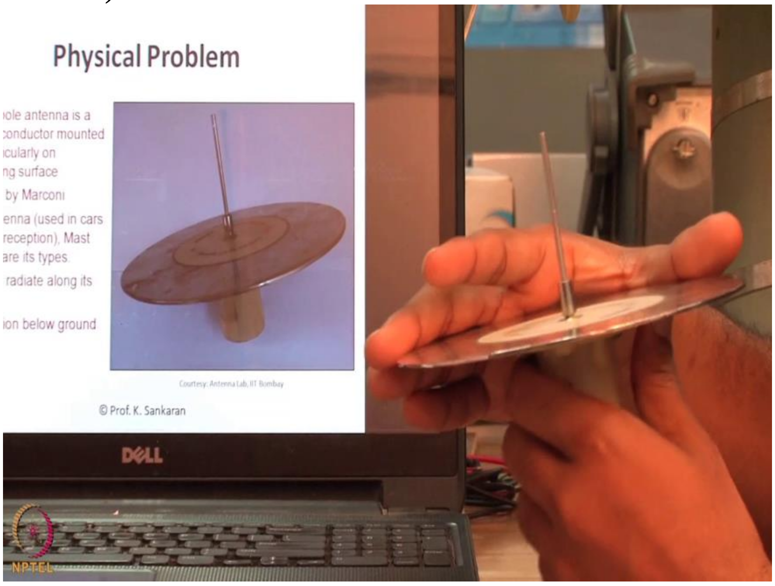

So this is simulation for monopole antenna ok and you are starting with umm the basic model that we have in our hand ok and so explain us little bit about this antenna. So this is a basic monopole antenna which is of length lambda by 4. So whatever frequency this is designed at 1.5 giga hertz. So the lambda at 1.5 Giga hertz we basically divide by 4 and take the length ok and this is the reflector plate ok. So ideally what people do is ideally the monopole antenna should have an infinite length. That is not possible practically so its like a finite length.

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So it acts as a reflector plane as in this is also having certain role in directing the beam of the antenna. ok. So it is a very similar case in the case of the patch antenna where you have a ground plane which also acts as a reflector so in this case you have you dont have any dielectric in between but you have a reflected layer which acts as a ground plane. ok. So explain us how you have gone from this physical model to the next step.

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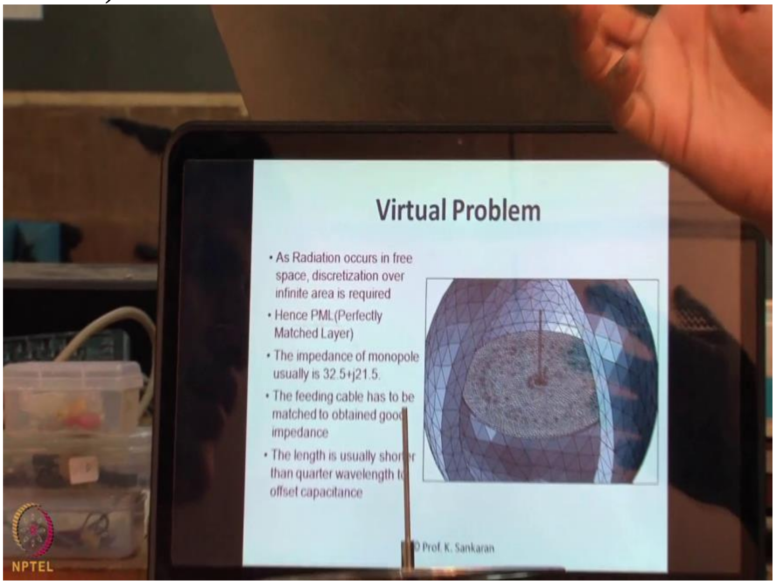

So basically this was the antenna and virtually what will happen is again this will be an issue of physically it has air surrounding it and we have to confine it with something. So here we have used the perfectly matched layers. What is the discretisation you are using? Discretisation is again in this particular frequency of problems its like the (())(13:02) lambda by 5. Ok . So the (())(13:04) should be lambda by 5. And what I also see that there is the input impedance on this particular antenna is 32.5 plus j 21.5. Ok. So it is a complex impedance where you have 32.5 as the real part and then the its imaginary part is 21.5. So that is what the issue that the feeding cable which we use coaxial cable has some real impedance of 50 ohms , 75 ohms. So there is an inherent mismatch in the antennas. So the feeding cable is normally in the range of 50 ohms. ok.

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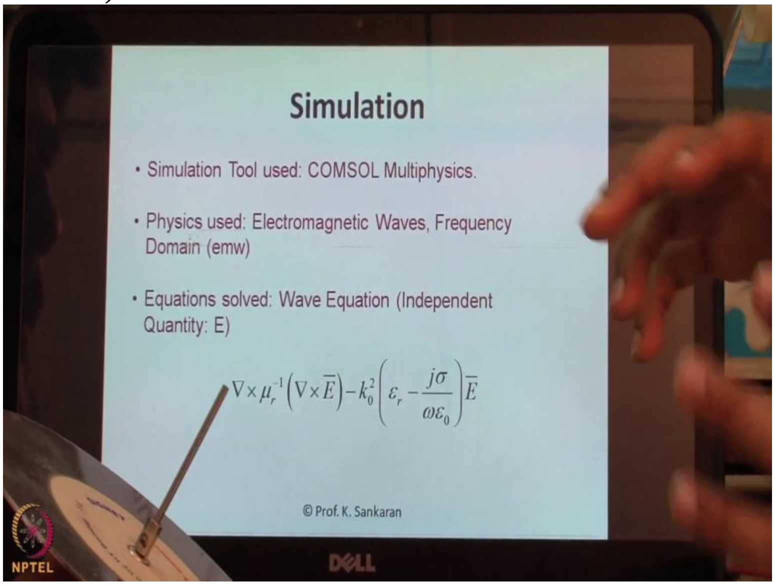

So in this type of simulation we saw a wave equation. ok and this equation we find the electirc fields all the points. Yeah So basically what you have is the wave equation as a curl formulation and its totally in terms of E. And what we have is the relative permeability and you have the sigma which is the conductance and then the omega and epsilon 0 . ok. And came out is a wave number free space wave number. ok

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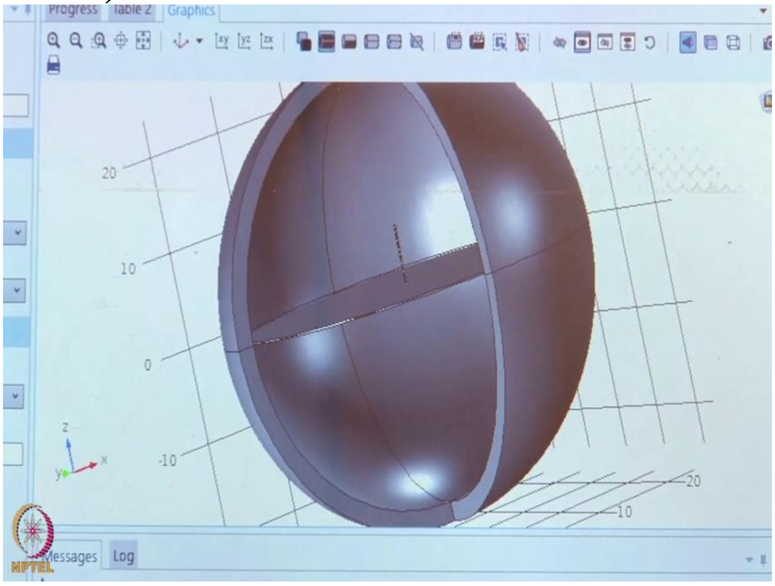

So you are basically modelling the particular geometry using the finite element solver. So this domain entirely enclosed in this PML. So I have hidden this things just to show you. ok. So what you have got here is basically the domain and its internal geometry what we see here is reflector plate, yes, and we have a lambda by 4 monopole which is say. So practically to compensate with for the capacitance there is an inherent capacitance in the designs or practically what we do is we reduce it slightly by lambda 4. Its not exactly lambda by 4. ok.

Its like small length is reduced by (())(15:00) lambda by 4. So after building geometry what to do is assing materials. ok. So here inside is air and then all the things are metallic. So you used copper as the base material. Yeah. And then you have teflon for the field. So the field area here so where you are using teflon material so as insulate between the reflector plane and the actual monopole. ok.

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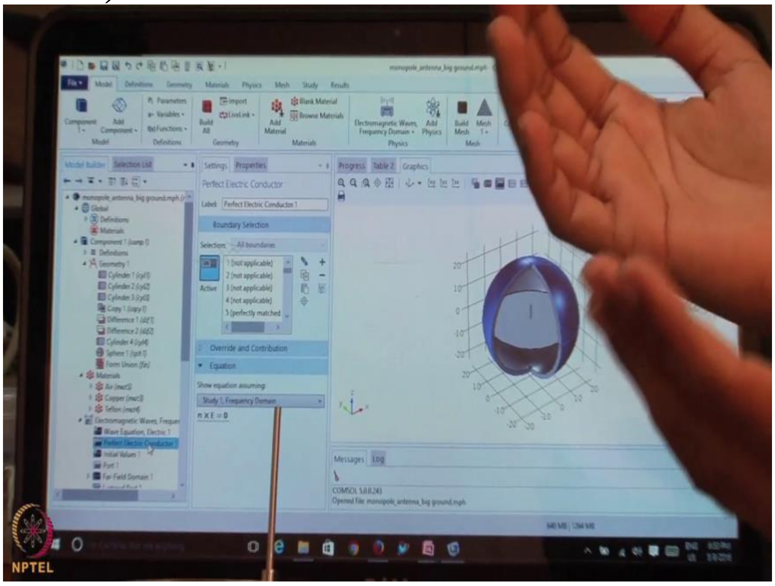

So here what we are using is electromagnetic waves physics so in this what I have shown in the slide this is the equation which we (())(15:42). So we have a curl curl foundation and we get a wave equation in terms of E. So in this electric waves of physics what happens is by default PEC is used as the boundary in the (())(16:01). Yeah So which gives N cross E (())(16:04)So the tangential component of the electric field is set to 0. ok. And this is again you have done frequency domain you are solving this in frequency domain. What is the frequency of operating its 7.25 giga hertz. So let us see the end of initial values (())(16:18) Yeah And then what we include here is? we include far face and domain because I want to calculate the far face of the antenna. Now how to feed here is the coaxial code the lump code.

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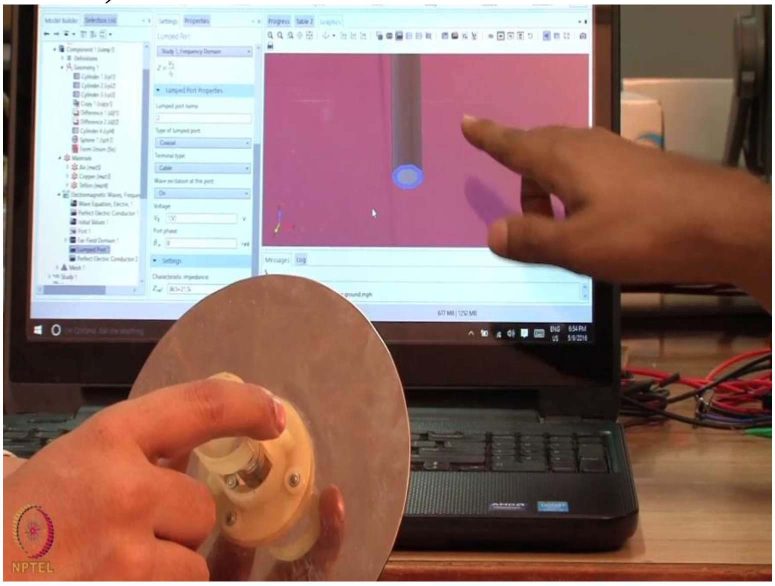

Can you zoom this once to show us how the coaxial (())(16:37). So this is basically this part where we have the coaxial feed coming. So this is the inner conductor and that is the outer conductor. And between that is the teflon and we have just given the excitation to that part. So the waves will travel in that signal will travel in that part. ok. So this is the coaxial feed what you are having. Yes So (())(17:00) is the coaxial field to this part and you have excited it. The excitation and this port is on. So the next step is meshing. So again we use the physics control mesh. And again what I told it can go finer finer. ok. So you are talking about roughly 5 cells per lambda exactly ok. So this frequency domain studies I have given the 1.25 Giga hertz ok and after simulating what we get is such kind of (())(17:36).So basically what you see here is the reflector plane is here and this kind of reflecting the entire things.

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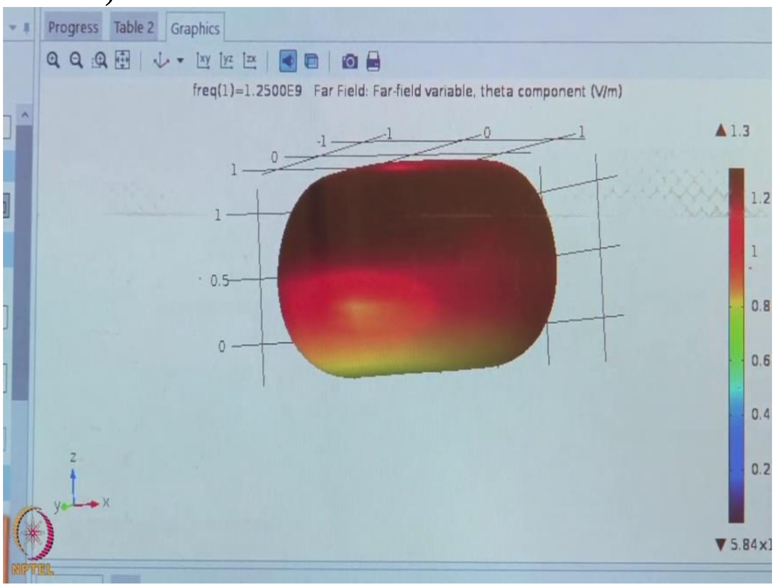

So what you are plotting here is the E field and then the reflector plane is pushing everything on the upside. Like (())(17:50) So the (())(17:56) is a bit shifted. ok So here the 0 is there there is a ground plane maximum is shifted here so what we can see is on the axis there is no (())(18:06).So this is classically like in (())(18:09). So this is the far field value of this particular antenna.

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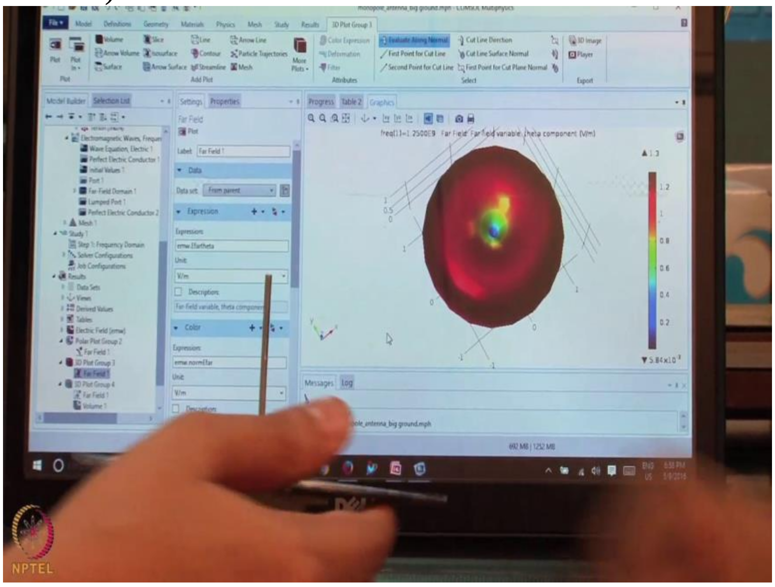

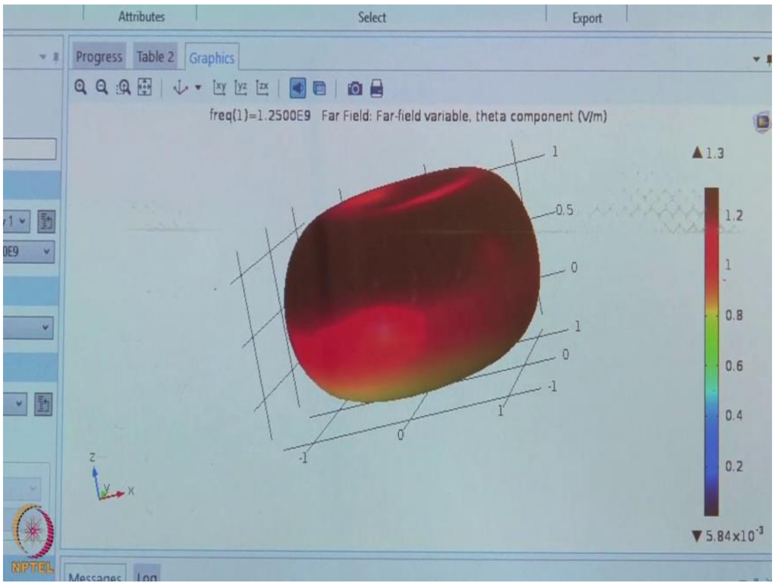

So could you please show us the far field value that you have been showing.So this is the electric field basically the far field value for this particular ok. And the theta component here is being shown. And could you please also show us the plot what you had before the power plot.

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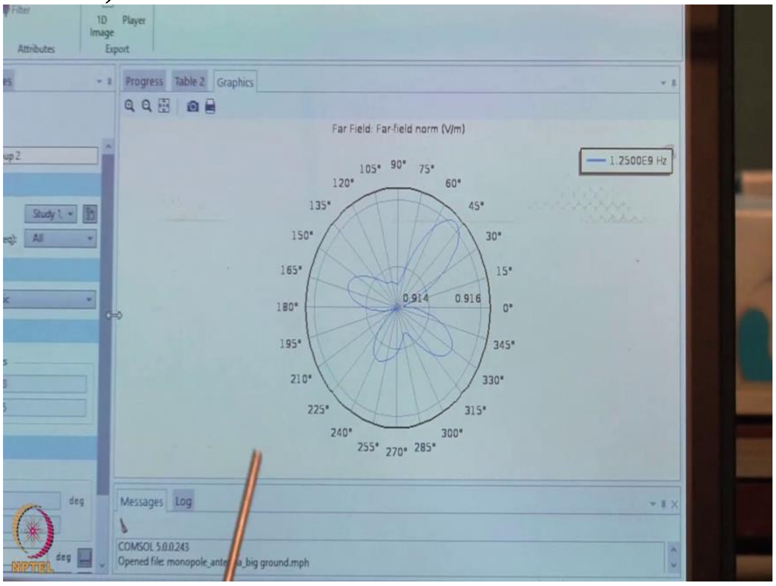

So the power plot is basically is a far field value and normalized value and then you see that it is interacted on the upside so this is a ground plane area.

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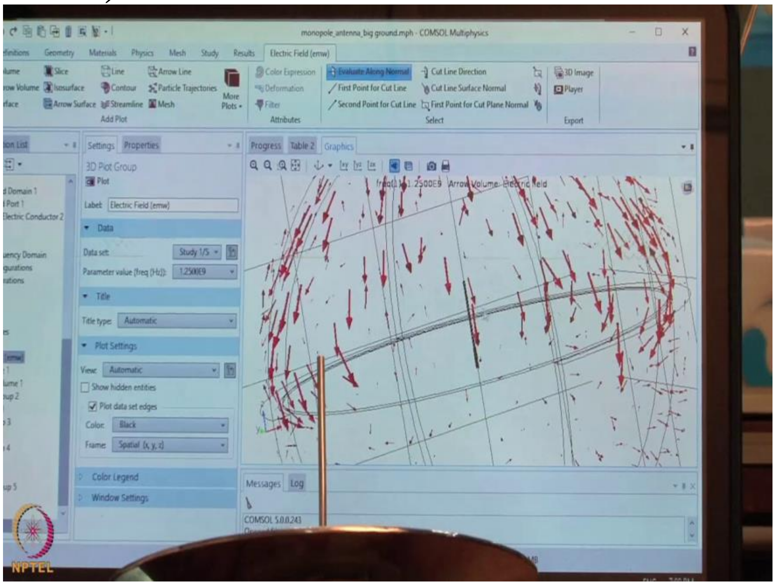

And this is the electirc wire used so these are electric field directions. So basically what you see can you explain us so what you can see here is like the electric fields are going outwards around the antenna and it is getting pushed up by the reflector plane. So there are less electric field vectors below the plane and more above the plane. And that is the main purpose of this particular kind of reflector plane is to push the radiation more less in the upside.

So how long did you take to simulate it properly modelling these kind of antennas is for a design Engineering point of view once we have the dimension and once we have the right aspect of the frequency that we are interested in modelling this since its a frequency domain it does not take a long time But what if I am interested in going in broadband simulation.

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So for broadband simulation I think the geometry itself has to be a bit modified so that is like a different topic so this is kind of a focus for (())(12:58) engineer you think from numerical point of view so can you also do the similar design using Finite element time domain method where you can basically send in Gaussian pulse and then you can see broadband aspect.So that is something that you should try in the next example but I think for now its a good thing to know how we can simulate a any kind of antennas using finite element method particularly we looked at the monopole antenna where we see how the radiation pattern is going to look like what are the ways in which one can model it. So we also looked at much of the important aspect of modelling itself because one thing is to have a physical antenna the other one is to make them you know model them in a virtual platform so there the question of how you are truncating the thing is coming and the things are there. So what are the other methods you normally do in modelling these kind of antennas?

umm what we can do is we can do this similar thing in CST which uses , so basically you can also model it using finite intelligent technique or finite difference technique then it will be a time domain broad band effect so what if you send Gaussian pulse excitation and all (())(21:20) and also one other thing we can say is we can also apply the scattering boundary condition this solver. The scattering boundary condition is need the normal incidance of the wave. so that gives bit high reflection than perfectly matched layer. Ok. So perfeclty matched layer solves the problem of reflection issues. ok

So Excellent! So thanks a lot Avinash for showing us two problems one is using a permanent magnet and the other one is using a monopole antenna so both of them we are trying to look at kind of finite element solver where we can model such practical problems and then get certain practical results so that we can either improve design of certain antennas through the connectivity of the antennas also looking at magnets what are the strengths and pole strength and things of that sort. So thanks a lot!