Radio Astronomy

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Demonstration of Antenna Design & Simulation - Part 3

Hello everyone. Welcome to the third demonstration video in regards to antenna design and simulation. I am Hasha Avinav Tanti and I am your course TA for this radio astronomy course. I am a PhD scholar under the supervision of Professor Abhirubdatta who is also the course instructor. So let us begin this video. So if you recall last time what we did, we did how we learnt how to design wire antenna using 4-NHC-II software.

Now there is a better version of that, not better version, actually a different software but it is actually better than that and much easier to use which is also known as CST StudioSuit which is also a proprietary software. So if you want to use a full version you have to buy it but student version or learning version is there to get a hang of it. So what we will do using CST StudioSuit specifically the learner software version, we will design, try to design dipole antenna, YAGI antenna, also reflector antenna. Remember in the last lecture what I said that reflector antenna in 4-NHC-II is with cumbersome and next to impossible to make.

So let us go through once again a bit what is dipole antenna and what are its design parameters. So for this also we will take dipole antenna, dipole antenna at the frequency range of GMRT band 2 which is 125 to 250 MHz. So center frequency of 187.5 MHz. Also in this so we get dipole length around from 0.

736 to 8 meter max, radius we kept at 0.003 and if you remember correctly I quoted in the last lecture that the radius of the antenna governs the bandwidth of operation for a dipole antenna which we were kind of able to see in 4-NHC-II but we will be more promptly and comparatively be able to see in your CST simulation software. And let us move on to another thing which is the YAGI UDA. So YAGI UDA the standard formulas are given over here. You can see that, see here.

So and based on this the last time we calculated for 5 elements that is 3 directors, 1 reflector and 1 field that is 5 elements. So for 5 elements these are the means the design lengths, the standard lengths what we are getting and we will see what the final fine-tuned version is. Now and also reflector antenna. So actually here we have to just revise a bit that there are different kind of reflector antenna. So there are different kind of feeding mechanism one is axial or front feed where the feed or the active element in this or the you can say driven element is kept at the focal of the parabolic dish or spherical dish.

And there is offset feed where it is the curve is a bit displaced such that the focal has to be at an angle to get whatever the rays are coming just like this and there is Casseguiran feed where there is a convex reflector at the focal of the parabolic dish such that it will again converge into another means the actual field, the actual element which is at the center of the parabolic dish. And the focal length of this will be this distance over here. So then there is Gregorian feed instead of convex you have a concave structure here. So kind of there is kind of variations. So we will just for this simulation sake we will take the axial front feed because this is the most simpler one to make and you can always make a complex structure.

And one thing you add is that we will be using the student version or the learner version of CST it will have many limitations. So we cannot have much more complex structures in this. So for this what we will have we will have D of 5 meter means the dish diameter of 5 meter and the focus will be at 0.6 into D. This is at the distance of 0.

6 into D. And we will for feeding element we will use a simple dipole having a reflector on back. So dipole we will get from the first dipole simulation and we will put a reflector normal reflector at the back which we will get from the early order simulations. So this is the layout for these are the basic theories for today's simulation. We will go a bit back and forth if needed. So let us begin the demonstration or the demonstrations of the how to make dipole antenna or some antenna structures in CST.

So if you can see that I have CST studio suite 2022. Actually what happened I told you how to install I showed you how to install 2023 version but for somehow my PC was not supporting that but 2022 version was supporting so I installed 2023 version. So there is no actually difference between the versions. There are few updates but the design procedure design means things will be are same only. So no need to worry about it about your versions.

So I have already simulated few of the antennas. So what you have to do you have when you open it you will not get these things. So what you have to do choose project template here. So when you choose project template you will get quite a few options. So you have to select on microwave and RF opticals.

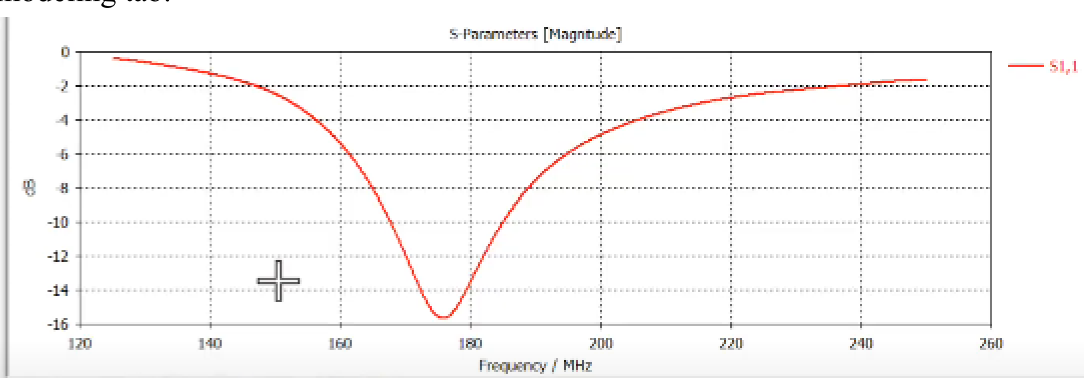
So here you will find antennas then press next. Actually you are creating an environment for the antenna simulation. So what kind of antenna we are designing first? The first two antennas are Yagi, Yagi Uda and Dipole. So that is a kind of wire antennas. So we will select wire antenna then next.

So we will choose time domain analysis solver. So this is for thick antenna wires. Thin antenna wires is virtually having no diameter. So for that we have to use an integral equation method. So those are different kind of methods to solve for the radiation pattern as parameters for dipole and other antenna dipole or different kind of antennas.

So you don't have to worry about that. So time domain solver is the most used solver and so after that you have to select dimension as meters, frequency in megahertz, time in nanoseconds is okay, heat temperature in Kelvin. Now go to next. So in settings you have to say 125 to 250 megahertz and you will select E1 to see E field, H field, far field pattern, power flow, power loss. These are kind of means field monitors.

What can you monitor? You can see the E field, how E field is oriented, H field is oriented, far field is oriented and how is power flowing and how much power loss is there. And this is on top of whatever S parameter means like your reflection parameters, matching impedances of the antenna and all those things you get. These are addition to that you will get. And this is you will get in only one compact screen. So that's the beauty of this software or this kind of simulation software instead of having multiple screen like 4NZ2.

So if you click next I will say here, I can give it a name band2-gmrt. So finish, as soon as I finish a file will open in that template only. Whatever parameters are selected, frequency range are selected, in that only a file will open. So when the file is open, what you have to do, you have to create a model or the structure of the antenna if you remember correctly I said. So what you have to do, you have to go to here you can see a modeling tab.



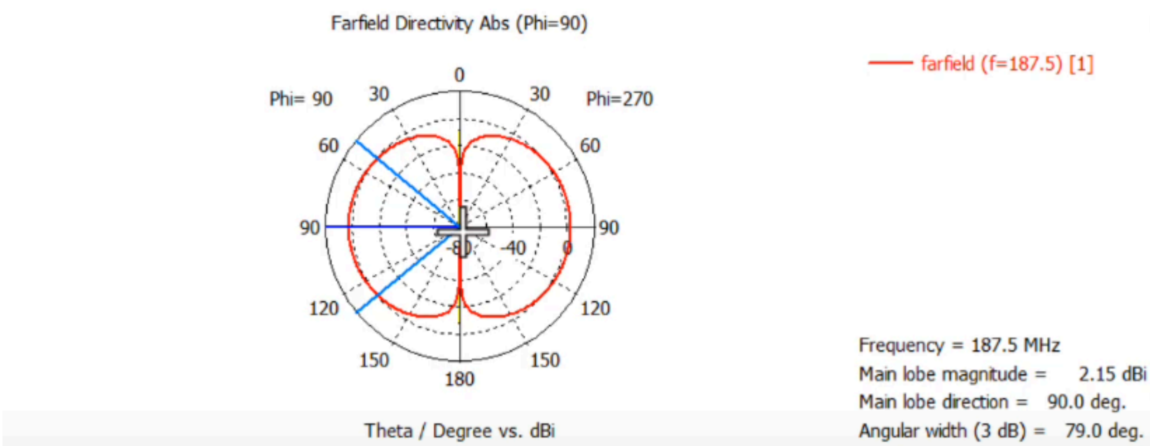
You have to click here. So you will get into modeling. So a wire you can represent in typically as a cylindrical structure, as a cylinder. So you can select this cylinder and see here double click on the center or something press escape. So you just press escape. So what you will get, you will get this kind of dialog here.

Just say we want to make a dipole, dipole dipole. Now I want this to be oriented at Z axis. So the outer radius what it will be. So as we put a numerical values in 4NZ2 if you remember but here we won't do that. We will put like radius R, then y center, x center will be 0.

Then in positive Z I will put as minus L by 2 and here plus capital L by 2. So L I took a variable where I will define the length of the dipole. Now also this is PEC, perfect electric conductor but I don't want perfect electric conductor. I want to design it with something more practical. Mostly dipole antenna are made of aluminum.

So I will select load from material library where I will select aluminum or lossy metal and then I will load it. So now your dipole structure will be in aluminum. I will press OK. So it will ask for missing parameters.

I have to define a parameter. So R is radius. Radius is 0.0048 if you remember correctly. I will comment as radius of dipole.



Now L is what length of the dipole. Length of dipole if you remember the minimum value was 0.736 and the maximum was 0.8. So what we will take? We will take somewhere near to the maximum 0.

78. I will explain this in a bit also why I took as 0.78. So and this is length of the dipole. So you are not able to see the structure if I guess. So what you have to do? You have to click this.

Now you are able to see the structure. So you can click and rotate. See this is the rotate sign. This is pan sign. You can drag your thing here and there.

This is zoom. Zoom can be, if you are using a laptop you can pinch or pinch out for zoom or you can use a scroll for zoom if you are using a PC. OK. So this is the thing. Now we have to feed it right? There we have created a, in Poloncito we defined into segments right and we gave the center location of the segment as feeding point.

But here that's not the case. Here you have to be more realistic. Means if you see a dipole antenna you will see two disjoint monopoles which there will be a gap in between from where you pull out a wire and you feed it. OK. So what you have to do? You have to again draw a cylinder. So I will select cylinder and press escape button.

So yeah here. So we will define a gap OK and this shape will be subtracted from the original one. I will show you how. So gap. So outer radius will be same as R. Center will be same and this will be minus g by 2 and capital G by 2.

OK. A material can be anything. No issue. You press OK. So g you are being asked what is g. OK. So we have to define g here.

Now g is what? G is gap. Gap we can put it anything. We can see what happens due to if we increase gap or something like that. Now let us see.

We will put the gap same as R 0.0048. OK. And description will be R 0.

0048. OK. Now we will put the gap same as R 0.0048. OK. And this will be just gap.

OK. So we defined as gap. Done. OK. Now if you see here there is a component section here. If you open it and if you open it you will see dipole and gap. So what you have to do? You have to click on dipole. Then you have to click on boolean and subtract. So if you click subtract so it is saying component 1 is dipole.

So from dipole what you want to subtract? You have to click on then gap and press enter. So there will be a gap created. OK. If you zoom in you see.

Now you have to have a, you want to have a gap. So you have to have a gap. You will need to have a wire here. OK. Or some kind of current flowing through this. So that how you will define? You will select here and say select pick circle center.

So you will select a center over here. Double click. One. And again we want to connect the second end. Right? You want to connect the second end. So we will pick again circle center and then put it here.

OK. Done. If you see it is done. Now what you can do? You have to create a link between these two. So you have to go to simulation, discrete port. OK.

You have to click on discrete port. So you will get this thing. So impedance of this port will be 15. Why 50 ohm? Because the RF is, there is a RF standard which is standardized at 50 ohm. So RF standards are, if you remember correctly, the RF standards are at 50 ohm. So everything is defined, is standardized at 50 ohm.

So that maximum power transfer can happen. And so you need to design antenna accordingly.

OK. So you have to press OK here. So everything is set. OK. Now what you have to do? You have to set up solver. Here what you can do? You can have at, means accuracy at 40, minus 40 degree. That is OK.

Now after that, what you have to just start the simulation. OK. So let us start. It will take a bit of time.

So let us start. So let us start. So let us start. So let us start. So let us start. Can you see? So let us start.

So let us start.

So let us start. So let us start. . . . . So, after your simulation is done, what can see going to S11 that your frequency has shift in a quite a bit. So, that means your dipole length will be above 0.72, may be around 0.736 perhaps. So, we will, you can by yourself fine tune it, so that center will come around here.

So, if you see there is two tabs, parameter list and result navigator. In parameter list you can see R, L, G where you can change the variables what we have defined. And whereas in result navigator what you can see, there is, you can see the previous result and the current result. Okay, you can see how is the difference here. So, now what we will do the next thing is see what is the radiation pattern of course. And after that we will see, the comment I blabbered out in previous as well as this lecture that the radius of the antenna governs the bandwidth right.

It or the decides the bandwidth of the operation. Okay, so that is very interesting thing. So, first let us finish seeing the what, how the power field pattern looks like.

Here you see, I mean sparkle option. What you have to see at 17.5, 187.5 megahertz, what is the power field. So, here you will see something red, red, red. Just click on this. Okay, so see since your antenna is oriented along Z, you will see, you are seeing this kind of pattern.

So, here there is a power field tab. If you click that, so you can also say that show structure. Click on show structure. Okay, if you go like this, till here, you can see there is no radiation at the poles of the dipole. Okay, and normal Mendo order pattern.

But here, see here you are not getting the 2D pattern. How you will get the 2D pattern? Simply click here 1D. Okay, 2D is something different here. 2D means there will be a contour. Okay, let us see what is 2D also.

Now, in 2D, there is another thing which is equirectangle projection. This is UV projection. Okay, this is equirectangle projection where you have theta and phi. How it is varying in theta and how it is varying in phi. And if you click on 1D, you will get the famous pattern of 8.

If you see here, you are not able to see pattern of 8 instead of something like this. However, if you see closely the limit, okay, minus 80 dB to somewhere above 0. It is actually an impractical range to be observing because minus 80 dB means 10 to the power minus 8 of loss or kind of gain. Which is almost negligible when we are inspecting any signal in that value.

So, what we will do, we will just right click, plot properties. Here auto range is there. We will remove auto range. As we know that gain of the dipole antenna is somewhere between 0 dB to 5 dB. So, we will give it max as 5 and this is minus 20 will work.

Okay, 10 to the power minus 2 is okay. So, see figure of 8 we are getting. Okay, and also it is also calculating simultaneously what is the 3 dB beamwidth or the half power beamwidth which is 79 degrees near about 80 degrees. Okay, so main lobe direction, it is in 90 degree and gain given is 2.15 dBi. Okay, which is very near to the theoretical value which if you calculate it.

Okay, so this is how you do it. Now, I said that, again I will say it again, that I said that the bandwidth is governed by the radius of the dipole. Okay, bandwidth of operation. So, what we can do, we can change the radius, means your radius r. Okay, as well as we will change g also, gap g and see what effect it has on the radii, means S11 characteristics.

Okay, so what we will do, we will create a pair sweep here. Okay, we will click on pair sweep. This means parameter sweep. We will add up a new sequence here where we will input a new parameter called one is say r. Okay, we will provide a linear sweep from here to say we will go to 0.01 and we will take two samples in between.

Okay, and similarly we will create a new pair called g as we said 0.01 but in we will go in three samples. Okay, now by clicking okay, if we start this, in total it will create in total of how much combination? Two for radius and three for this. So, it will create three, three six six combination, means for one r it will generate three g, three combinations of gap and for the second r value it will create three combination of again g. Okay, so the parameter sweep will take a little bit of time.

So, do not worry, you should start it and just wait for it, wait for it. Okay. So, once your parametric analysis is complete, what you can do, you can go to S11 file here. Okay, and you can go to result navigator and select all the run id. Okay, given here. So, you can go to S parameter and you can select all the run id here.

So, if you see clearly, you will see r, l, g variation. Now, if you see, as g is increasing, okay, as g is increasing, your run id is your this 123. Okay, as g is increasing, your frequency is shifting towards the left. Means, frequency is lowering down.

And the main thing which we can observe is if you increase the r here, see the point one. Okay, fifth one. So, pink one and the black one all are point one. So, if you see the black one and compare it to this one, okay, or the blue one here, this curve, it will seem broader. Right? So, broader means more bandwidth. Okay, so what I commented earlier that the radius of a dipole can increase the bandwidth if we increase the radius. So, by simulation, you can see it, it is actually happening and this kind of dipole which has a very large bandwidth are also called fat dipoles.

Okay, there is entirely a section of dipoles for which a theory is developed called fat dipoles. Okay, now what we will do, we will build it from here to Yagi antenna. So, for Yagi antenna, what you have to do, you have to again go to, you can create a new file and do it again, but I will do it in this one only.

So, what I will do, I will go here, revert these parameters from 0.0048, let it be 0.72. Okay? And this one will, gap will be also, I will keep as 0.004. Okay? Now, I will press F7, see here it is written press F7 for parametric update, I will press F7. So, parameter is updated.

Okay? So, if you can see here, you can see that the axis of this dipole is along Z axis. Okay? So, I want to place a reflector along X axis. So, what I will do, I will go to modeling. Okay? Then select a cylinder here, then press escape.

Now, this is a reflector. Okay? The radius will be same as R, X center will be minus of R, F spacing. Okay? Reflector spacing. Now, Z will be minus reflector value length by R, F length by R, F length by 2. Take same material as aluminium, if you press okay, okay, now R, F spacing is asking.

So, maximum of R, F spacing what was that? 0.4. Okay? 0.4. That is 2.25 lambda. Lambda is your 1.6. So, 0.4. So, reflector spacing.

Okay? Now, it will ask for R, F variable. R, F was what? Zero point maximum value 0.048. Reflector length. Okay? If you remember that we have only here X center. Okay? Not X1, Y1 like in 4NSE2. So, here what it does, if you are oriented, I mean, if you see, I will again add a director. Okay? So, if you see here, and press escape, if you see here, it is saying orientation along X or Y. So, if you change the orientation, it will ask for Y min, Y max and X min, X max and you will say where is the center of X, Y and Z is at.

Okay? So, you are putting each X1, Y1, Y2, X1, X2 values like in 4NSE2. Okay? So, for director, what you will have, you will have same radius. You can say director 1 is equals to, I will give positive side.

Okay? D1 underscore spacing. Okay? Now, Z min will be, the minimum value was 0.0608. Okay? So, minus say D1, we can vary each director's length. So, D1 by 2, D1 by 2, same material aluminum, press okay. So, spacing was what? If you remember correctly, the spacing was 0.

48 meters. Okay? There about that, the minimum value was that 0.48 meters. So, director 1 spacing.

Okay? Now, it will ask for D1. D1 was 0.608. Okay? So, you will press okay. So, there is a director here. So, its name, the default name is solid1. What I will do, I will change the name, right click it, and there will be a rename option or just triple click it or press F2.

Click and press F2. That way you can rename it. So, you will press director 1. Okay? Now, I have to put director 2. So, what I will do, I will press again cylinder, escape. We will get here. So, director 2 will be the name and radius will be what? R.

Then x center will be D1, sorry, D2 underscore spacing. Okay? Z minimum will be minus D2 by 2, D2 by 2. Okay? Now, D2 spacing will be what? D1 underscore spacing plus the value you are putting that is 0.

48. So, director 2 spacing. Okay? D2 is your length. So, we will keep it as same. You can change it and play with it and see what happens.

So, director 2 length. Okay? So, similarly we will put a third director also here. Press escape. So, director 3. So, R, D3 spacing minus D3 by 2, D3 by 2. So, okay? D3 spacing will be D2 spacing plus 0.

48. Remember, it would not be D1 plus D2 because D2 already has D1 spacing. Okay? So, it will be D2 plus spacing. D2 plus the spacing. Okay? So, director 3 spacing. So, D1 is we will keep it as same. You can always play and check. Director 3 length. Okay? So, now when you are done with this, what you can do again, go to simulation, then simulate and see the S-parameter as well as the radiation pattern.

I already simulated this. So, I will just open it. I actually did some parametric analysis and found a very good spot. So, I will open that file and show you what are the results, but you should, so read by yourself and play with it and see what optimum results you are getting. Your result might differ. It is totally possible based on the radius, the director spacing, the reflector spacing, but from my parametric analysis, I got the following results.

Okay? Let it load for a moment. So, here it is. So, along X, same as that. So, if you see the parameter list here, it is still loading. Okay? So, I got best results for where L is 7, radius is 0.

048, gap is same, RF spacing is 0.4, RF length, reflector length is 0.82, D1 spacing is 0.48 and reflector length is 0.6. Your each is same. So, what I got, the 1D result which I got is the following. This is what I got as a 1D result. So, if you can see, I have done for many, many, many iterations.

So the best result which I got is at this value, see. If I put an axis marker here, 187.5, see, I got the best results here. Maybe you can improve more, but for this case, this is the best result. Now, if you can see the radiation pattern and particle curves, see, you will see angular width of 57.5 degree, beam width of around 58 degree, whereas if you remember for dipole, it was around 80 degree.

Okay? Now, it's a bit more directive. Okay? Now, if you see, the main lobe gain is 0.822 dBi. Okay? So, this is very directive antenna. Now, if you want to see the powerful pattern in 3D, you just can go to 3D. Okay? And then similar to your 4NAC2, you will find similar kind of radiation pattern which is like this.

Sorry for that, because system is hanging, I do not know why. However, you will get this kind of pattern. See the main beam is formed this way. Okay? So till now what we have learned, we have learned about two types of wire antenna, dipole and also Yagi-Uda and the, I said we will learn about one more type of antenna which is reflector antenna and we will make this on CST.

Okay? So, what will be reflected dish diameter will be 5 meter. Okay? So, the circle will be 0.6 times D. Okay? That will be at 0.6 into D is what? Your 3 meter. 3 meter will be the focal length and there we will place active field as dipole within reflector. Means Yagi-Uda only, but we will, we will not have any directors.

Okay? Okay? So, we will have this as simulation. So here what we have to do, so I will just, we will save the designs first. So now for this we need to create a new template. Okay? So in new template what we have to do, if you remember correctly, reflector antenna is a aperture antenna. Okay? It is a kind of aperture antenna. So we have to select horn waveguide type of system.

Okay? So, if we click here and then antennas, we have to go next and then waveguide horn cone, this one. Okay? Now we have to choose time domain, then meter, megahertz and Kelvin, nanosecond and Kelvin, same frequency range 125 to 250. We need EHF power flow, power loss. Okay? So here waveguide 1. Okay? As you finish it, you will get to the screen.

So now here what I will do, I have already, prior to this I have already simulated a reflector antenna. Okay? I will show you how to make a reflector plate and also show you how to place an antenna over there. Okay? However, I won't try to simulate it. I will show you what are the results I got. Okay? And also tell you about the limitations of those results, means those results are very constrained.

Okay? Because this learning addition provides you to simulate till only 1 lakh mesh. Okay? About 1 lakh mesh, meshing. And we will see what is meshing also. So but it provides only till that. And that is a very huge constraint because if you design a parabolic dish, the number of meshes are actually more. And that will affect the simulation. Okay? So for simulating, you will see that I have reduced the mesh which has led to system, led the system to take an approximation of few things and I will tell also why.

So let's just first see how to create a dish. So go to macros, macros then there is a construct, then go to parts, there is a reflected dish. Okay click on that. So here you will get reflected dish diameter.

What is the focal length? So focal length I will keep it as 0.6 into D and D is I said is 5 meters say 5. Okay now I will give a thickness to this.

So to enable the thickness of dish, you have to press 1. Just click 1 and the thickness is 0.2. Okay that's okay. Now I will press okay. So a dish is created here. If you see the parameter list here, already there is three parameters which is created which is focus and thickness true or not.

So that is already created. So if you see there is a dish here. And if I zoom it for a bit. Now I was talking about mesh thing. So if you click here mesh view, now see there will be a number of how many number of mesh cells are there.

It's above 6 lakh. So this won't simulate. You need to change the meshing. That's why going to global properties I will show that how. First we will have a dipole and a reflector there.

So for having that we have to go to modeling. Then just click on this escape. So for dipole you will have dipole. Then radius R. Your X center. You have to change the orientation because the dish is on XY plane. So you have to change, you have to be on your say I will put at Y the orientation of your dipole at Y means it will be along Y.

So I will put outer radius 1, the X center is 0. Whereas Z center will be your focus. So we will build it at focus. Now Y minimum will be your minus 0.73 by 2. So for now I will take it as PAC but you can take as Aluminium or Copper whatever you feel like.

So Aluminium and Copper are two materials which is used very frequently for making antennas. So radius is 0.0048. I will press ok. So if you see the component list here you will have an antenna at here.

If you see clearly you can see one line here. I will just try to zoom in here. See here you are getting a line. Now you have to create a gap. Gap will be also along Y and that will be your along focus. So Z center will be at focus.

So similarly we will subtract the thing like we did in the first simulation. So gap it will be along Y outer radius your R, Z center focus Y minimum say minus 0.

0048 to 0.0048. One by two and here also by two. So press ok. Now what you have to do. Dipole minus gap enter. So you will get a gap here. So you can just click here to zoom in the region you select. So I will select this region. Now I will just click circle center and again click circle center and then go to simulation and create a discrete port here.

So I have created a discrete port here but I said we will have a reflector antenna. So reflector antenna with a field having a dipole thing, dipole with a reflector thing. So go to modeling again, click here and press escape.

So reflector along Y we will have that. So reflector radius will be keep it as R, Z center will be what? Your focus plus 0.4 minus 0.848 by 2, 0.848 by 2. Actually you can give variable to this. You can increase and decrease the variable amount to get a proper thing but still you have to approximate mesh it will lead to faulty readings. But you will get an idea about how the reflector antenna works even with this faulty readings also.

So after doing that you can see there is a reflector antenna over here. Now if you go to simulation home or simulation you can go to mesh view. You can see above, it is above 1 crore mesh. You will not be able to do it anyway.

So what you can do, you can go to global properties. You can see the near model. You can, near model say 5 mesh you will have and apply the mesh salaries will reduce. So if you press okay then okay. So if you see clearly what is happening, what should ideally be that the gap of the dipole should have one mesh cell inside it such that it will treat it as a gap there.

The feed line is there. But you can see the mesh cell is like this. So it will say that this entire mesh cell is a feeding point. Because we did not created a fine mesh cell so that the feeding point will be separate from the radiating elements that is the both poles of the dipole. So this will lead to some kind of approximation which will be not suitable for this kind of simulation but you will get an idea about how the reflector antenna radiates or means how the radiation pattern look like.

So let us go to home then start, set up a solver and then we will start the simulation. Everything looks okay. So we will start the simulation. So once the simulation ends you can go to your S-parameter results. You can see how the S-parameter looks like. It will not look like the expected thing because I said that there is approximation going on because you reduce the mesh size.

Do not care about that just you can go to your power patterns. You can go to any of the pattern. So all the pattern will be near up means the shape will be near about same even if you click here or here. So what you can see here is see how the shape looks like. See is it looking like it is focused towards one direction.

There is lots of minor loops also but you can see that this is like this. And there is also backscatter because the reflector antenna also means there is something called dish utilization. If say the feeds pattern is bigger than your dish, what will happen? You will get backside or means radiation towards backside also which is shown by this. So then you are seeing some radiation on the backside of it. So it is not much but you can see the maximum beam is towards outward which is 15.4 dBi but this is not valid because we have approximated most of the feed things and you try to stretch bigger simulation into the smaller one.

So you are not getting a proper thing but you are actually able to see how the reflective antenna radiates in a focused direction. So here you can see the directivity, total directivity, efficiency and all. And if you go to 1D pattern plot, you can see the angular beam width of 20.9 degree. Although there is a lot of approximations you have considered but you are getting very sharp beam and if you increase the diameter of the beam, this will further reduce.

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