Radio Astronomy

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Demonstration Of Antenna Design & Simulation - Part 2

Hello everyone, I am Hashim Naasthati and I am your course TA for this Radio Astronomy course. I am currently a Research Scholar at Department of Astronomy and Strategic Space Engineering at IIT, Indore and I am pursuing my PhD under the supervision of Professor Abhirubita who is also the course instructor. So, in the last session what I said is we will demonstrate how to design an antenna using few softwares namely 4NHC-2 as well as CST. So, in this session what we will do, we will again revisit what is dipole antenna, YALUDA antenna and also we will see how to design those antennas in 4NHC-2. Taking an example, so let us revisit, so the design parameter for the dipole antenna as we discussed last time is that ideally the length of the dipole antenna should be 0.5 of lambda whereas due to practical limitations the length varies from 0.

45 to 0.48 of lambda and radius of the wire which will affect, that affects also the bandwidth of the antenna, bandwidth of the frequency. So this way we will see practically how it is happening. And in YALUDA antenna we have one radiating element which is also called feeder or which is simply a dipole and followed by, followed by directors which will focus the gain forward and there is a reflector on the back which will invert the beam to one direction.

So, the length parameters, whatever parameters you need for that length, radius and all is provided, is given here. Now let us go to how to design in 4NHC-2. So let us first quickly calculate it. We will take center frequency of 187.5 megahertz which is typically a band, center frequency of the band 2 of GMRT.

GMRT is one of the radio observatory facility which is very famous and located in India near, near Pune. So it operates in different bands. There is no, not one particular antenna which is for every band. So they are, it operates in different bands. So band 2 is from 125 megahertz to 250 megahertz.

So the center frequency is coming, is around 187.5 megahertz. So we will design for that. So the 187.5 megahertz corresponds to 1.

6 meter of lambda. So dipole length will be point, half of that ideally, that is 0.8 meter. So we will take from, the range will be like 0.72 to 0.8 means kind of the entire range. However we will take it from 0.46 to 0.8 that is 0.736 to 8 maximum and we will keep radius of wire 0.003 times of lambda. Just a random value, we took 0.003 to lambda, but we will see what, how the radius effects on the, on the radiation or the resonance of the antenna. Okay. So that will come around 0.0048 meter. Okay. So let's move how to design it. So on the desktop, first what you have to do, you have to go to your folders and click on the file extension name. You have to say that show the file extension name.

  Okay. Now here I will again, I have already created two things. So what you have to do? You have to first right click and right click and then create a new file here. Okay. A text document, normal text document.

  Okay. So, and also say, I will give it name dipole, 187. Okay. And edit the extension to NEC. Okay. So you have to do this thing.

  This is a very important step. Be careful. You have to do this for Yagi also to create another thing, another document, you have to rename it and edit the extension also. Okay. Then, then right click, right click.

  And you should open, always click open with notepad. Okay. So for foreign EC2, you have to reinitialize it and you have to create a file and kind of initialize it. Okay. Then I will have your CM.

  CM stands for comment command. So I will comment like dipole at 187.5 megahertz. Okay. And then I will type CE that is command means comment end.

  Okay. And then EN. I will close the file. Means close the entire routine. So this, if somebody is from electronics background, they might understand the pspice. Pspice also you have to write some code.

  Okay. So like similar in that way, you have to configure the file and after this few step, what you can, after this few step, what you can do, you can just go to, you can just open the software and from that you can load the file and do everything. Okay. So just save it. We will just save it and close it. And now, now we will open the software.

  Okay. So when you open the software, it will open the previously loaded file. So you do not have to take any, do not have to worry about it. Just click on here this folder icon.

Okay. This is for open. Okay. This folder icon, then open your current, this say dipole 187 NEC. I will open it. Okay.

So here everything is empty. You do not have any design in here. So to design it, what you have to do, you have to click on this red, red notebook sign here. Okay. When you open the red, red notebook sign, what you can do, you can go to symbol and see the scaling is in meters.

Okay. We, we calculate everything in meters. We stayed in SI unit. Okay. So we have to see that is in meter.
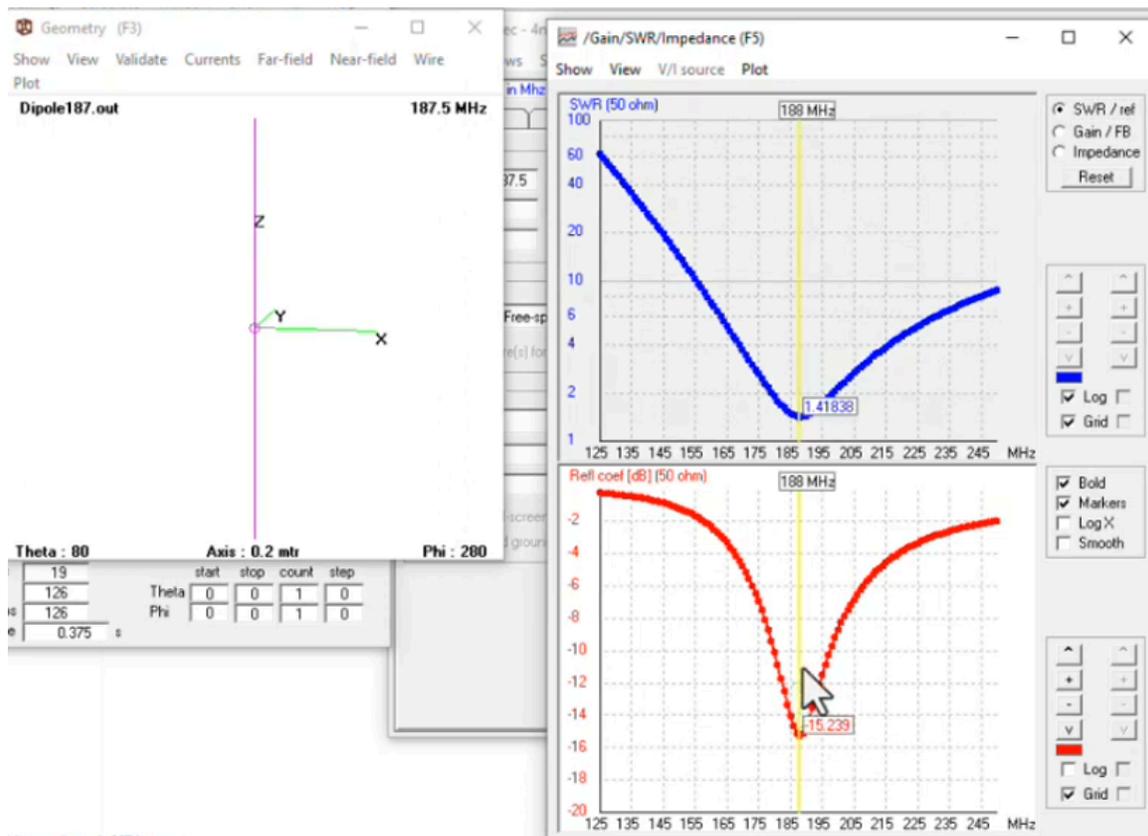
If it is a meter, all good. You're okay to go. So you have to first create a geometry. Okay. If you click here directly, it will come as a wire.

Okay. You have multiple options. Wire, helix, arc means you can, you can simulate any type of antenna. This is also called helical antenna, which is like a solenoid. Okay. You can learn more about in reading books. So say you have to give a tag number, means whatever the tag number will go from 1, 2, 3, 4, 5, 6.

Okay. So tag number to the antenna by which that antenna is specified. Okay. So you

have 1. Then there is, you have to divide the antenna in number of segments.

Okay. So that means, as I stated in the last lecture that the, any, any simulation software divides a certain antenna into small, small grids. And after that it calculates the based on boundary condition and electromagnetic equations. This is the, whatever the radiation or what, whatever the resonance is, whatever the antenna is resonant at. Okay. Keep in mind here, you have to always give an odd number of segments.

Okay. Why? That I will also tell in a little bit. Say I will always give odd number. Okay.

Odd number. Odd number, say I will give 19. 19 is a odd number, I will give 19. So and x center 0, y center I will give 0. I will have along z axis. So z1 will be your minus number.

So I will give minus what I have calculated. We have calculated 0.736, right? 0.736 correct.

So we will have here half of that. So 0.736 equivalent, half of that is 368. Okay. 368 in negative side.

Then again x2 will be 0, y2 will be 0 and 0.368. Okay. And radius was what? 0.0048. 0.0048. Done. So, so we have given all the thing. Now if you are designing an antenna, what you will have to connect? You have to connect a source to it, right? So you have to go to source. Now if you see, I will choose a voltage source.

- Designing for center frequency of band-2 of GMRT (125-250MHz) $f = 187.5 MHz$
- Let's have 3 directors
- Dipole length – 0.736 to 0.8 m(max)
- Reflector length – 0.8 to 0.848 m
- Director length – 0.608 to 0.72 m
- Reflector spacing – 0.32 to 0.4 m
- Director spacing – 0.48 to 0.672 m
- Radius – 0.003*wavelength = 0.0048 m

This is current source also. Current source you have to give to what? To a loop antenna, which is a magnetic antenna. Okay. So you have to give voltage source. So to which element in your structure you are providing current.

So there is only one antenna which tag is 1. So I will provide tag 1 and the segment number where you have to provide, say I quoted that you have to give odd number. Okay. Why odd number? Because if you divide even into two equal parts, even number into two equal parts, what you will get? You will get two middle points.

Okay. Two middle points. So say if I have 16, if I divide it by 2, I will get 7 and 8, both as middle point. If I have 19, okay, I have 19 and I will divide it by 2. So if I divide it by 2, then I will get what? 9.5. However, if I start from above to 9 and then again 9, so I have a middle point at 9.

Okay. I will have a middle point at, so above 9 and below 9, we have there, right? And 1. So, sorry, so 1 to 9, then 10, then again 9, 9 points. So we will have 10 as a center point. So divide by 2, you have to do means like 2n plus 1 divided by 2, if you have odd number.

So center point will be 10. Sorry for that. So center point will be 10. So option, what you have to select, 0, 0, because you are not providing any kind of polarization to it. So real part will be say I will take 1 volt.

Okay. Imaginary will be 0. Okay. And nothing else. Okay. Now you have to go to frequency, you have to set frequency. Okay.

So frequency for the antenna what you are desiring is 187.5. Okay. So this is done. So now you just click here save, every parameter is saved. Okay. Now environment is your free space, we are trying to simulate in free space. Now if you see the geometry here, you will see, now you will see there is an antenna and there is a small circle here.
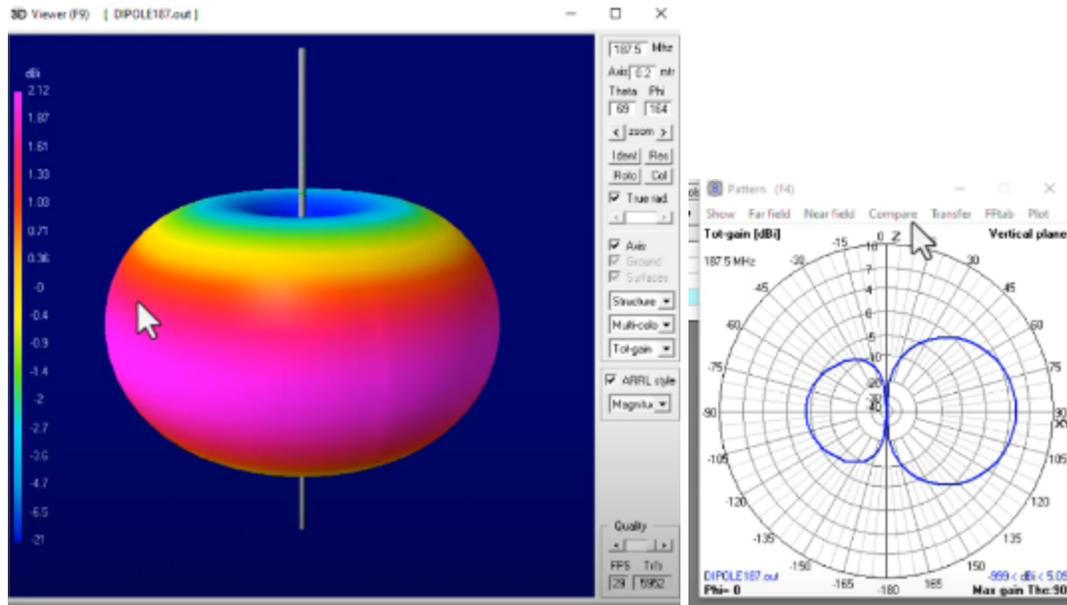
Okay. That shows where you are feeding an antenna. Okay. So now here there is a calculator sign, click on that. Okay. Now to calculate the reflection coefficient, how much your antenna is reflecting back the power you are providing to it. That is what it means. You will provide some power to the antenna and because of the mismatch of the antenna, some power will be reflected back.

So to calculate that, you have to click on frequency sweep. Okay. And then go to click expert settings and average gain. Okay. So, average gain will mean, okay. So here averaging means you do not, you will not bother for complex quantities.

Okay. Now here start frequency will be 125 because you are designing for band 2. So it will be 125 to 250. Okay. So 125 to 250 in how many steps? You have to provide step value means how many steps.

Step value means how much of megahertz you will change. The step value will be one. Okay. Then I will generate. Okay. So for each megahertz I got, see here, here, see at one around one 8 gigahertz or one means we have the maximum dip.

So what we saw that if the lambda is 0.46, we initially took 0.46, right? And for that we got the maximum resonance. So because I am not doing 0.

5, 0.5, right? The step size was one megahertz. So at one 8 we are getting. So where we got the resonance, right? That is coming minus 15 dB. This is a reflection coefficient which is called also called S11 which is minus 15 dB.

What does this mean? Minus 15 dB is 10 to the power minus 1.5. Okay. So 10 to the power minus 1.

5 which is nearly about point, I think, 0.066, right? 0.06 around. Okay. Around 0.06. So this means 6 percent of your power is only getting reflected back and other than 94, about 94 percent is getting transmitted. Okay. And that is what means, okay, your antenna is radiating.

So at first shot we got the right answer, right answer, okay, means right resonance. But if you didn't get, if you say if we start from the 0.8, this lambda is equal to 0.8, what will happen? Your frequency would have been on the lower side.

See if lambda is increasing, frequency will shift to lower. Okay. If lambda is decreasing, frequency will shift to higher. So then what you have to do, you have to give multiple values, feed multiple values here in the geometry. It means do a trial and error, trial and error and you will get the desired values.

Okay. That is correct. Got it. Now I said one thing that the diameter of the antenna will decide the bandwidth. Say we have taken 0.

0048 meter radius. Okay. Now what I will do, I will do here is I will give 0.005 meter. So this is very high, 0.

01 meter. Okay. Okay. I will save it and then again I will try to run this thing. See what happened? Your frequency got shifted as well as if you compare the previous bandwidth. Okay. The previous bandwidth, if you compare, that would have been increased by a margin. Okay. Now to effectively show you that, So, to effectively see that, what you have to do, you have to print out the results.

Okay. Print out the results and compare it with that. See increasing the radius will have two kind of effect. Okay. One, you will see slight change in the bandwidth.
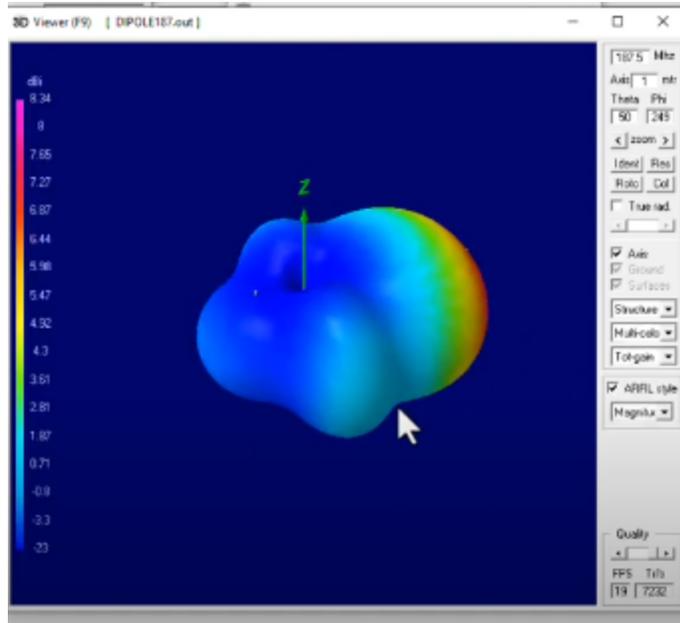
Also what we saw that there will be a frequency shift also. Okay. So there will be a few, there will be a change if you change any parameter in the antenna. Okay. So for having a good wire antenna, it is said that you should have at least of, means radius of the wire at least 0.

0003 times of lambda. Okay. So, this is kind of a thumb rule in anterior design. So that gives you a very good response. If you decrease it, that will also give you a good response, but your bandwidth will become narrower and the thing will become sharper. Okay. So, you can experiment this and also you can get back to this on discussion forums.

I will be glad to answer any of your doubts. Okay. Now, what we saw, we had a very good result on 0.

048. Right? I will, 0.048. So at this we got the perfect result. So we will save this and we will remember these values.

Okay. Okay. Correct. Now, we will move on to the next part. Okay. Next part means we will design a bit of complicated antenna, a bit complicated antenna, that is the argued antenna for the same band. Okay. So, let us see what is the design parameters for that.

Okay. So, let us see what is the design numbers, whatever the meter length, spacing and all. Okay. Let us view that. So let us discuss first a bit about what are the different values we need to remember to design the detectors and reflectors for the Yagiura antenna. So from the previous experiment of dipole antenna, what we got to know that

0.736 lambda is giving out perfect antenna resonance, means like the resonance of the dipole is as we want.

Okay. Now, we will see how a Yagiura can be made for the same frequency. Okay. So, dipole length we already got from our previous experiment.

Okay. So, the reflector length is typically from 0.2 to 0.25 lambda.

Okay. So, that is we can have from 0.8 to 0.848. Okay. So, and director length can vary from 0.608 to 0.72 and reflector spacing can, reflector spacing varies from 0.

32 to 0.4. And director spacing varies from 0.48 to 0.672. So for this example, what we will do, we do not take too many of directors, we will take only 3 directors and 1 reflector that means total of 4 passive elements and 1 active element which is the dipole. So, total of 5 elements.

Okay. Now, here what we will take, we know the dipole length, how it will be.

Now, let us see. Dipole length we know, reflector we will take as 0.848. Okay. So, 0.525 lambda 0.848 we will take and the director length we will take point at the starting only, it is 0.

608. Okay. And then we will try to change and see what will happen and reflector spacing we will take as 0.4 first. Okay. And then director spacing we will take 0.48 and change accordingly.

Okay. So, what the design strategy will be are, are will be like first we will have a dipole antenna. Okay. Then we will simulate it which already we did. The one thing is remaining which is to show you the 3D patterns.

Okay. That we will see in a bit. And then after that we will move forward to your Yagyu antenna. So and after that the design strategy first we will have a dipole, we will see all the characteristics of it. Then all the characteristics means reflection coefficient, VSWR and radiation pattern how it radiates.

Then we will add a director to it. Okay. We will add, sorry not director, add a reflector to it. Okay. Then see what the radiation pattern looks like, whether we are getting full beam inversion or not. We will see all those things and then we will add one director, then we will check again, then we will add another director, then we will check again and then we will add another director. This is the design strategy of any Yagyu antenna

what you will, if you are designing one.

Okay. So, let us move, move on to the, okay. So, we have dipole antenna. So, what I will do, I will edit the previous file only. I will not create another new file. But if you want, you can follow the steps like before and do the new file. So, what I said, I said that we will have, see already the previous file results.

So, what we will do, we will have here, we will go to design sheet. Okay. So, we will run this design and see what we are getting.

Frequency sweep, expert setting. So here, so one and generate. Okay. So, we got at 180 megahertz. Correct. Now, there is one more, then we will add one more wire.

Okay. However, I skipped one thing that is the radiation. So we have here this and there is a 3D icon here mentioned. Okay. We will click on that 3D icon. We will click on true radiation, then, oh, sorry, we didn't generated a pattern here.

So that's why we are not seeing the pattern. So we will click on this again. Sorry, got, I think, some issue. Let us reopen it. Let's reopen it. So, okay, so we have all the 3D structure over here, then we will click on this, this icon, the calculator icon, then we will see powerful pattern.

We want to see full pattern. Okay. So, expert settings and we will see average gain. Okay. Now, we will generate. Okay. So, this is the radiation pattern we got. See from the theory, what we saw, it will be like 8 pattern.

Now, we will see the 3D pattern how it looks like. It will look like a donut shape or Indian way is Mendu Wada shape.

Okay. So here, hide pattern is there. So, we will see multicolor pattern. Okay. So, okay. So, see, this is a donut shape, we are getting. This is getting. So, do not bother about the antenna is too long than that. It is just a way to say that that antenna is there and this is there.

Actually the far field will be much further away than the poles. It will be like we studied right 2D square by lambda distance away. So, the far fields will start from a bit far away, but to show that there is an antenna and how the radiation pattern will be, it is like this.

Okay. See, the radiation is maximum around this which is 2.12 dB dBi. Okay. So, this

is an omnidirectional antenna with having maximum radiation or maximum gain perpendicular to the antenna axis. This is the antenna axis Z perpendicular to that you will have the maximum gain.

Okay. So, this is the radiation we got. Now what we will do? We will close this and then again click on book sign. Okay. Now, we will add reflector to it. Okay. So, I will tag it to, okay. Again I will have, you can have any number of section for this one, no issue, but I will have same number of section.

Now I have to place reflector, I have to place reflector. So along x axis I will try to place reflector.

Okay. So, along x axis is what is the reflector spacing? If you recall what is the reflector spacing? Reflector spacing is 0.32 to 0.4. Okay. So, 0.4 and that too on the negative side, on the positive side we will keep the vectors. So I will keep minus 0.4. Correct. So, then tab here 0 and after that what was the, if you remember correctly, what we said, how much, how much long we will take the reflector size, we will take at 0.

848 and half of that will be minus 0.424, then x2 will be what? x2 will be also minus 0.4. Okay. Then y2 will be your 0 and z will be 0.424 and radius will be same as the previous one. Okay. So then I will save this and then again we will do a field pattern sweep first.

Let us see what is coming. See you got a beam inversion, right? You got a kind of beam inversion. Okay. Now, if you, this is what is the beauty of the simulation is. So, what you expect that there will be some kind of beam inversion you will be getting.

Okay. And what we can see, we can reduce the distance and we can see what is happening. Okay. Reduce the distance between the reflector and the antenna and we can see what is happening where we are getting in this back loop.

This is called back loop, minimum back loop. Okay. So, what we will do, we will again go to this and we will reduce the distance say to 0.

36. Okay. So, 0.36, say 0.4 and right, 0.38, we will go to 0.38 first. Okay. And this also 0.38. Now, one more thing is that, so x1 and x2 both I have, I took as 0.38 because you have, this says that this has two points. Okay. From z positive to z negative, what will be on the positive side? What will be on the negative side? Means there will be two z points you will have, right? Means whenever you are designing say, you will go from this point to this point.

Okay. In whatever axis, this point to this point. So, that is how x1, y1 is there, x2, y2 is there, from which point to which point? If both points are, you say same, so it will be there at that position. Okay. If you put some other value, it will say that design error or you will find another wire stretching out and connecting to, connecting till the 0 point.

Okay. Now, 0, 0 and we will save it and we will see what is the far field pattern. So we will press ok. See if you see from the previous one, this got increased, a bit increased. Say the total gain in DBI touching 5, last time we did not took any, means we did not, we were not careful that, careful.

So we will, this time we will see. See the back lobe is above minus 5 and the front lobe, this is called the main lobe. Main lobe or main beam is at 5 DBI. Okay. Now, what we will do, we will go again to back, go back to 4, 4.

Save it and then again we will run it. See, so pardon me, there was no difference. So there was no difference if we go from 0.38 to 0.4. So from this we got to know there was no difference. Okay. So we saw some, I thought we saw some kind of difference but there is no difference here.

Now we will go much more closer to the antenna which is 0.36 and see whether we are getting any difference or not. Okay. So save it and then again generate. Now this is the best reading, this is not the best reading we got because this is not the best reading. Why I am saying so? If you see, pardon, let me revisit this. This is minus 5, right? This is the best reading we got.

We got the gain, okay, between above, I think, above 4 dB line, between 4 to 7 line, that is, it is more than 5 dB gain, what we got earlier. Okay. The backlobe remains same but the gain is higher, a bit higher.

So we can point it, I see, point it 5.09 dB. Okay. So it might be a bit higher, that is why the ticks, that auto ticking, auto ticks changed.

Okay. So this is a bit higher. So let us see what was the gain in. So let us fix this at 0.36. Okay. So there might be a minor difference, earlier it was almost 5 dB when 0.

09 was added and that is why the minor tick difference came. Let it be like that. So we will add, now see we have wire, we will add a director here. Okay. So we will tag it 3.

Okay. Same number of things. Now what is the director spacing? So here error was

coming.

So what is the director spacing? Director spacing is 0.48, we will take as 0.48. Okay. 0.48 to 0.672, so we will take as 0.48 and the length we will take as 0.61.

Okay. Trial error 0.61, we will vary it and see what is the best reading we are getting.

So what we told, we will take 0.48 director spacing and so director spacing 0.48, so 0 here 0.48. Okay. Then here 0, z will be 0.61. Right? So minus 0.30, what? 5 to 0.480 and 0.305. And radius same. Okay. Okay save it. Then we will, let us now we will, now let us see what is the frequency sweep.

Does our frequency change at all? Did our frequency change at all? If it changed, then we have to revisit the design also of the length and the things which we are considering. We have to take that also, consideration.

So see, so adding any passive element changed your resonant frequency also. Okay. It changed your resonant frequency and see the reflection coefficient improved. Okay. Improvement in this means that your much more power is getting delivered as a radiation.

Okay. So what, see now to, this del is for delete. So since the frequency changed, what we can do? We can check once that what will happen if I change the reflector length to 0.

42. Okay. So then again, we will try to run. See. Nothing changed. So that means it does not have effect on the frequency. Okay. So we need to change the length of the radiating element itself. But before doing that, what we will find? We will find out what are the proper, what are the proper spacing between the detectors so that we will get a proper field means directive beam, proper directive beam.

Okay. Before that, we will see that and then we will revisit to tune the antenna using that means by changing the length of the radiating element.

Okay. Now let's see, let's delete this extra file. Okay. This one also delete. So we have the director already here.

So we will see the far field pattern. So radiation, radiation efficiency, no average gain. And I want to check. Okay. See, now the gain is touching almost 70, 0.

69, almost 70V it is touching. Now let's change the, change the distance between them.

Distance between antenna and director.

Okay. So we took as 0.48, the distance between that. So we will, what we will do? We won't come close. We will go a bit farther away. So take 0.5, it is 0.

5, save it and then generate. So, gain decreased.

See earlier we got 0.69. If we increase the distance between director, the gain decreased. So that means let's do the other way around to the back.

Okay. So we are going to 0.5. Let's go to 0.45. Okay. So, gain improved. Gain improved. So, let's go to 0.42 and see what happens. If you go beyond, very less than 0.42, what will become? You will come in the quarter wavelength range.

Then what will happen? The beam inversion on the other side will happen and the beam will become some mess kind of thing.

So we will see that also. Okay. Go to 0.42. See, gain again started decreasing. We got 0.93, right? 6.

93 if you remember correctly and 0.6.92. Now again, got decreasing. So we got an ambient point around 0.45. We got an ambient value around 0.

45, right? So let's again do a test.

Yep. Around 0.5 we got a good value. Now using this only, what you can do, you can add one more director.

Okay. Fourth one. 19. Again we will take 0.45 plus 0.45. 0.9. Okay. 0 minus 0.305. 0.90 and 0.305 and 0.0048.

So see. Now let's see. Okay. Oh, sorry, sorry. There was a mistake here. I think no, there wasn't a mistake. There was a token. Yeah. So there was a mistake here.

Instead of, instead of decimal, I gave a comma value. Okay. So instead of that, it's that was showing that error.

So you need to be careful about what you are typing. Okay. So this is a common mistake which can happen. So just, okay. Let's see. What is the gain value here? Let's see. 0.745. So gain further increased. Okay. So what's happening? Gain is getting

increased if you are adding more and more directors.

So if you increase and decrease the space of the spacing of these directors, that will also affect the game. Say instead of 0.9, I will go 0.85. 0.85. I will save it. And again, generate.

Okay. So, 0.37. Earlier it was 0.45 and gain decreased. So same number of spacing improves the gain. Okay. So we saw that the spacing is equidistant.

For this particular system of arrangement, the gain is increasing.

So now again, we will add one more. As we said, we will have four elements. So one more 5. Then 19. Then 9 plus 4, 5 is equal to 1.35.

Then 0. Then minus 0.305. 1.35. 0.305. And 0.0048. Okay. So, now, if you see, generate. See 0.834. So we got a very directive antenna, which is, and 3 dB down will be your beam width. So 0.84 and 3 dB down will be your 5, 4 around. So 60 degree to, I think this one, 60 to 120. That is around, means roughly around 60 degree beam width you got. Right? So this is how you make a Yagi Uda antenna.

Okay. Now you can play with it, change the diameter, change the distance between the directors, change the director lens, change the reflector lens, then you will get what is the, how you are getting the beam and all.

So let us, for the completeness, we will see how the beam looks like. So height pattern, you will show, so multicolor pattern. See this is how the beam of a Yagi Uda looks like. Okay. This is how a 3D beam looks like, Yagi Uda.

So mostly the gain is in front direction and the back, there is very little, little on the back, that is the back scatter also you can say. This is what is called back scatter. Okay. Back scatter or back loop. Okay. Something like that. So with this, now also if I code, this is your 3D design.

See this is the directors we are getting. Now one thing you should have, you might have noticed that whenever I am trying to simulate say far field pattern, this pop-up is coming. Wire, ground lossless are set to 0 for AGD test. Okay. So it is saying that loss due to ground and wire is being set to 0. Because we didn't provide any kind of material to it. What kind of material? It is taking perfect conductor material and all.

So in fact, you can set up the environment also, like what is the, whether your

environment is free space or you have a ground at particular distance. If you want to connect wire to the ground, secondary ground, something like that.

Okay. And there is a different kind of options you can put. Okay. So you have to just play around. If you have some doubts, you can ask in the discussion forum. I will be glad, I am glad to answer, I will be glad to answer it. So with this, I will say thank you to all. Thank you.